Great Basin Ecological Site Development Project:

State and Transition Models for Major Land Resource Area 29 Nevada

Black Rock Lava Flow, Lunar Crater Volcanic Field, MLRA 29, Nevada. T.K. Stringham 2024

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Executive Summary

This report was completed in January 2026 in fulfillment of Agreement L21AC10513 with the Bureau of Land Management. It contains state-and-transition models (STMs) for 112 ecological sites within Major Land Resource Area 29 in the state of Nevada. STMs were developed in accordance with the National Ecological Site Handbook (NRCS 2017) and the Interagency Ecological Site Handbook for Rangelands (Caudle et al. 2013). A team of scientists, professional land managers, and interested stakeholders, led by Dr. Tamzen Stringham, developed these products. The team examined local knowledge, soil mapping data, and published literature on soils, plant ecology, plant response to various disturbances, disturbance history of the area, and many other important attributes necessary to document the ecology of MLRA 29 by ecological site. Pre-existing ecological sites were sorted into groups based on their responses to natural or human-induced disturbances. These groups are referred to as Disturbance Response Groups (DRGs). DRGs simplify the landscape into ecologically significant units for management and were utilized during the STM-building process. DRGs can also be used to map ecological sites. This report is organized by DRG, with one generalized STM narrative for the group, followed by individualized STMs for each ecological site within the group. Fieldwork reports including site visit locations and field note reports are included as appendices.

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Introduction

Ecological Site Descriptions (ESD) synthesize information concerning soils, hydrology, ecology, and management into a user-friendly document. A crucial component of an ESD is the state-and-transition model (STM) that identifies the different vegetation states, describes the disturbances that caused vegetation change, and suggests restoration activities needed to restore plant communities. State-and-transition models are powerful tools that utilize professional knowledge, data, and literature to describe the resistance and resilience of an ecological site. The STM then captures various disturbances, triggers leading to ecological thresholds, feedback mechanisms maintaining ecological states, and the restoration techniques required for moving from one ecological state to another (Stringham et al. 2003, Briske et al. 2008).

Many ecological sites are similar in their plant composition and other important physical attributes such as soils, but may differ in total production or landscape setting. Thus, often these similar ecological sites will respond to the same disturbance in a similar manner. The rate of response to disturbance may be different but the endpoint of the change will be very similar. In order to expedite development of STMs, a process developed by Dr. Stringham, referred to as Disturbance Response Grouping was utilized in this project. The Disturbance Response Group process is conducted at the Major Land Resource Area (MLRA) scale, making it a highly efficient method for STM development. The process requires a team of experts with years of experience working in the area of interest.

The core team for this project consisted of:

- Tamzen K. Stringham is a Professor with the University of Nevada, Reno
- William C. Richardson is a Postdoctoral Researcher with the University of Nevada, Reno
- Lucas Phipps is a Professor with the University of Nevada, Reno
- Wade Lieurance is a Rangeland Ecologist with University of Nevada, Reno
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Additional support members of the team:

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Initial office meetings were conducted with all Core Team members present to group sites into preliminary Disturbance Response Groups (DRGs) (Stringham et al. 2016). During the DRG office exercise, the Core Team examines characteristics of each existing range site, including but not limited to the following:

- Dominant Vegetation
- Soils: depth, texture, parent material, diagnostic horizons, chemical properties, soil temperature and moisture regimes
- Precipitation
- Slope and Elevation
- Plant productivity
- Response to various disturbances based on all the above characteristics, plus management history

The Core Team spends an extensive amount of time on the topic of response to disturbance. Discussions on different disturbances such as fire, grazing, long-term drought, insects, flooding or ponding, invasive species, and combinations of disturbances are recorded. The Core Team makes a determination as to which DRG each ecological site or range site will be assigned to for modeling purposes. After the initial DRG is finalized, the "modal" ecological site for the DRG is chosen. This ecological site typically represents the site in each DRG with the most mapped acres in the NRCS soil survey. Dr. Stringham then develops a "Tier I" state-and-transition model for the modal ecological site for each DRG. This generalized STM represents each ecological site within the DRG until field validation is complete, and changes to the STM are deemed necessary based on field observations.

Field validation occurs primarily with the Core Team and at times with assistance from others interested in the process. To facilitate the field component, the GIS specialist builds a geodatabase with relevant data. These include NRCS soil survey data (i.e. ecological site type locations, soil map units, ecological site polygons, soil pit sampling locations), historical wildfires dating back at least 30 years, BLM land treatment layers, land ownership, roads, any available vegetation monitoring data, NAIP imagery, and USGS Digital Raster topography. The GIS specialist or the soil scientist utilizes this geodatabase while in the field to inform the team of recent fires, multiple fires, or mechanical treatments performed on the site. The Core Team attempts to visit every ecological site at least once, and visits the modal ecological site for each DRG multiple times in different locations, and in different conditions. At each site visit the following information was recorded:

- GPS coordinates
- Photos
- Elevation
- Slope and aspect
- Landform
- Soil description to 20 in. depth, or to restrictive horizon
- Soil is identified to series if possible
- Known disturbances: fire, drought, insects, management practices, and others
- Plant species composition by weight, estimated ocularly and sometimes clipped
- Shrub and tree cover
- Rangeland Health
- State-and-transition model state and community phase, including any relevant notes on ecological dynamics

Dr. Stringham modifies the STM if needed based on field notes, this then becomes the “Tier II” model. The Core Team reconvenes in the office and reviews the Tier II state-and-transition models. Members of the interested public are invited to the meetings to provide input and critical review. Models are modified if warranted. STMs are built using Microsoft Visio, and a shorthand “key” is written for each Community Pathway and Transition. Dr. Stringham, along with her staff, complete the STMs by developing the “STM narrative,” which explains the ecological dynamics associated with the various States, Community Phases, Community Pathways and Transitions. An extensive literature review is conducted and added to the knowledge gained from the field investigations. The Core Team and interested agency partners peer review and provide critical feedback for the ecological dynamics section and the STM.

This project produced 335 field notes over the course of five field seasons and 20 weeks of field work. The Final Report contains the Disturbance Response Group list for MLRA 29, a robust literature review and Ecological Dynamics section for the modal ecological site of each DRG, State-and-Transition Model diagrams for each ecological site contained within a DRG, and supplemental information with field notes for all site visits.

Definitions and Standardized STM Concepts for this Report

This report aims to adhere to the ecological site standards for ecological dynamics outlined in The Interagency Ecological Site Handbook (hereafter "Handbook", Caudle et al. 2013). This section defines concepts and terms used throughout this report, many of which come from the Handbook or associated literature (Stringham et al. 2019).

Definitions:

Disturbance Response Group (DRG):
DRGs are defined as groups of ecological sites that respond similarly to natural or human-caused disturbance, reaching the same state or endpoint, although the rate of adjustment may vary by site.

State:
A state is a suite of community phases and their inherent soil properties that interact with the abiotic and biotic environment to produce persistent functional and structural attributes associated with a characteristic range of variability (Briske et al. 2008, Caudle et al. 2013). Alternative states differ in the operation of one or more primary ecological processes including the hydrologic (water) cycle, nutrient cycle, the process of energy capture and transformation (energy flow). In this report, States are given a number and a title, i.e. Reference State 1.0.

Phase:
A vegetative community within a state, capable of self-repair and resilience in the face of disturbances. In this report, Phases are given a decimal number within their respective State, i.e. Phase 1 in Reference State 1.0 is Phase 1.1.

Community Phase Pathway:
Community pathways describe the causes of shifts between community phases. Community pathways can include the concepts of episodic plant community changes as well as succession and seral stages. Community pathways can represent both linear and non-linear plant community changes. A community pathway is reversible, attributable to succession, natural disturbances, short-term climatic variation, and facilitating practices such as grazing management (Caudle et al. 2013). These pathways generally, though not always, flow in both directions, and are visualized by directional arrows. Arrows are numbered based on the state and phase from which the pathway arrow originates, followed by a lower-case letter (a, b, c, etc.) uniquely identifying the arrow (i.e. 1.1a is the first pathway that originates from Phase 1.1 in State 1.0).

"At-Risk" Phase:
These phases are at risk of transitioning to another state. Careful management is necessary to prevent a transition.

Threshold:
A boundary in space and time at which one or more of the primary ecological processes responsible for maintaining the sustained equilibrium of the state degrades beyond the point of self-repair. These processes must be actively restored before the return to the previous state is possible.

Transition:
The point in space and/or time at which a vegetative community crosses a threshold. Transitions are not reversible without external inputs of energy or resources to restore to a previous state. These are numbered based on the state from which the transition arrow originates, followed by an upper-case letter (A, B, C, etc.) uniquely identifying the arrow (i.e. T4A is the first Transition that originates from State 4.0).

Restoration Pathway:
Restoration pathways describe the environmental conditions and management practices that are required to recover a state that has undergone a transition. These are numbered based on the state from which the Restoration Pathway arrow originates, followed by an upper-case letter (A, B, C, etc.) uniquely identifying the arrow (i.e. R4A is the first Restoration Pathway that originates from State 4.0).

General descriptions of State concepts used in this report:

Reference state:
The reference state has seen little unnatural disturbances and is thought of as pre-settlement condition. Only native species are present in this state. The reference state and reference community phase (below) formed as a result of interacting environmental gradients, natural disturbance regimes, and physiological characteristics of species comprising the community.

In this report, <u>Phase 1.1</u> is designated as the “reference community phase,” which most closely represents the ecological site concept of the modal site for the DRG. The reference community phase may or may not represent a late successional community, because the natural disturbance regime may have maintained early-seral species (i.e. tall grass prairie maintained by frequent wildfire) (Briske et al. 2008, Caudle et al. 2013).

Current potential state:
This state is similar to the Reference state, but with the presence of non-native species. All plant functional groups from the Reference State are still dominant. Non-native species are present in small numbers, but threaten site resilience through competition and by exacerbating effects of disturbances (i.e. increasing fire frequency by creating drier fuels).

Phase 2.4 in the Current Potential State does not occur in every DRG. It is primarily used to capture the phenomenon of non-native annual grass flushes after particularly favorable annual weather patterns. Native bunchgrasses and forbs still comprise 50% or more of the understory annual production, however non-native annual grasses are nearly codominant. This phase is temporary, and weather patterns that are unfavorable to annual grasses may reduce the high cover and production of the annual grass component. This phase is considered "At Risk" because fire could lead to perennial bunchgrass mortality, which may shift the site to an Annual State.

Shrub state:
This state is characterized by a loss of deep-rooted native perennial grasses. Shrubs are usually dominant, but after fire the dominant plants are usually Sandberg bluegrass or low-growing, mat-forming forbs. This state is a product of decades of inappropriate grazing management.

Annual state:
In this state, non-native annual species dominate. The species may include cheatgrass, medusahead, Russian thistle, annual mustards. Annual species dominate site resources; soil function and disturbance frequency and severity are altered.

Tree state:
The Tree state is written for shrub-grass ecological sites that currently have Phase II or Phase III trees encroachment (Miller et al. 2008b). The shrub-grass understory on these sites has begun to decline in vigor, and significant shrub mortality may be occurring.

Infilled tree state:
The Infilled tree state is like the Tree State, but written for woodland ecological sites. This state has old growth trees present, but because of lack of disturbance, an overabundance of young trees exists. The health of the old growth trees may be impacted, and the risk of stand-replacing crown fire is significantly increased.

Eroded state:
This state is characterized by active soil movement, which inhibits establishment of new plants. This site occurs in late-state conifer encroachment, after severe fires, or after long term inappropriate grazing management resulting in a loss of understory vegetation.

Forb state:
This state is characterized by a dominance of forbs like mule ears. It is a product of long-term overgrazing by sheep and usually occurs on clayey soils. This state is less common, but may occur in small areas that have had concentrated use in the past (i.e. sheep bedding grounds)

Major Land Resource Area 29

MLRA 29 (NRCS 2022).

Major Land Resource Area 29, known as Southern Nevada Basin and Range, is 25,883 mi^2 (16.6 M ac) in size. Most of MLRA 29 is located in Nevada, with the remainder along the middle of the southeastern border of California and in the southwestern corner of Utah. Elevation ranges from 1,950 to 5,600 ft in most of the area, with mountains as high as 9,400 ft. This MLRA consists of aggraded desert plains separating north-south trending mountain ranges. Uplifted fault blocks with steep side slopes create the mountains, which are not well dissected due to low rainfall. The Owens River and Owens Lake are in this MLRA, though most of the streams are small and intermittent. The valleys consist mostly of alluvial fill, with playa deposits at the lowest elevations in the closed basins. The mountains are dominated by andesite and basalt rocks, though very young tuffaceous sediments and older intrusive outcrops are found scattered in the western and eastern portions of the MLRA. The dominant soil orders are Aridisols and Entisols, though Mollisols occur at higher elevations. The soils are shallow to very deep, well drained or somewhat excessively drained, and loamy-skeletal or sandy-skeletal. The majority of soils in this area are mesic with an aridic or xeric moisture regime (NRCS 2022).

Average annual precipitation ranges from 5 to 12 in., increasing with elevation up to 29 in. This area experiences most of its rainfall from high-intensity, convective thunderstorms during the growing season with sporadic storms throughout July and August. The average annual temperature is 26–58°F, decreasing with elevation. The freeze-free period averages 205 days, but ranges from 80 to 335 days along an elevation gradient (NRCS 2022).

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Major Land Resource Area 29 Disturbance Response Groups

Ecological Sites and Associated Disturbance Response Groups

Ecological Site Name	*Status*	*Dominant Vegetation*	*Site ID*
Group 1: Loamy soils with shadscale and Indian ricegrass			
Loamy 5-8" P.Z.	***Modal***	***ATCO-PIDE4/ACHY***	***R029XY017NV***
Loamy Slope 5-8" P.Z.		*ATCO/ACHY*	*R029XY022NV*
Gravelly Loam 5-8" P.Z.		*SAVEB/ACHY*	*R029XY087NV*
Loamy Slope 3-5" P.Z.		*ATCO/ACHY*	*R029XY033NV*
Sodic Loam 3-5" P.Z.		*ATCO/ACHY*	*R029XY032NV*
Coarse Gravelly Loam 3-5" P.Z.		*ATCO-AMDU2-SAVEB/ACHY*	*R029XY039NV*
Shallow Silty 5-8" P.Z.		*ATCO*	*R029XY059NV*
Loamy 3-5" P.Z.		*ATCO-LYSH-PIDE4/ACHY*	*R029XY035NV*
Stony Slope 5-8" P.Z.		*ATCO-ARBI3/ACSP12*	*R029XY064NV*
Group 2: Alluvial soils with spiny menodora and Indian ricegrass			
Cobbly Loam 5-8" P.Z.	***Modal***	***MESP2/ACHY***	***R029XY036NV***
Cobbly Slope 5-8" P.Z.		*MESP2/ACSP12-PLJA*	*R029XY037NV*
Shallow Cobbly Loam 8-10" P.Z.		*MESP2-EPNE/ACHY*	*R029XY161NV*
Granitic Cobbly Loam 5-8" P.Z.		*MESP2/ACSP12*	*R029XY107NV*
Eroded Slope 8-10" P.Z.		*PSPO-ERNAN/ACHY*	*R029XY162NV*
Shallow Loam 5-8" P.Z.		*MESP2/ATCO/ACHY-ACSP12*	*R029XY074NV*
Cobbly Loam 8-10" P.Z.		*MESP2-ARTRW8/ACHY*	*R029XY038NV*
Group 3: Sandy sites dominated by saltbush and Indian ricegrass			
Sandy Loam 5-8" P.Z.	***Modal***	***ATCA2-KRLA2/ACHY***	***R029XY046NV***
Sandy 5-8" P.Z.		*ATCA2/ACHY*	*R029XY012NV*
Sandy 3-5" P.Z.		*ATCA2/ACHY*	*R029XY034NV*
Shallow Sandy Loam 5-8" P.Z.		*ATCA2-MESP2/ACHY*	*R029XY080NV*
Group 4: Silty soils with winterfat and Indian ricegrass			
Coarse Silty 5-8" P.Z.	***Modal***	***KRLA2/ACHY***	***R029XY042NV***
Silty 5-8" P.Z. P.Z.		*KRLA2/ACHY-ELEL5*	*R029XY020NV*
Group 5: Seasonally flooded areas with basin wildrye			
Saline Bottom	***Modal***	***SAVE4/LECI4-SPAI***	***R029XY004NV***
Sodic Terrace 8-10" P.Z.		*ARTR2-SAVE4-ATTO/LECI4*	*R029XY091NV*
Deep Sodic Fan		*ATTO/LECI4-SPAI*	*R029XY093NV*
Dry Floodplain		*ARTR2/LECI4*	*R029XY156NV*
Group 6: Salty soils with shadscale and black greasewood			
Sodic Terrace 5-8" P.Z.	***Modal***	***ATCO-SAVE4/ACHY***	***R029XY024NV***
Dry Sodic Terrace		*ATCO/ACHY*	*R029XY063NV*
Saline Terrace 5-8" P.Z.		*BAAM4-ATCO/ACHY*	*R029XY120NV*

Group 7: Salt-affected soils with greasewood, iodinebush, and warm-season grasses

Sodic Flat	***Modal***	***SAVE4/DISP***	***R029XY076NV***
Sodic Floodplain		*ALOC2/SPAI*	*R029XY094NV*

Group 8: Sandy soils dominated by black greasewood and salt-desert shrubs

Sodic Dune	***Modal***	***SAVE4/ACHY***	***R029XY018NV***

Group 9: Sites associated with ephemeral streams

Dry Wash	***Modal***	***ERNAN5-ATCA2/ACHY***	***R029XY041NV***
Upland Wash		*ARTR2-PRFA/POSE-ACHY*	*R029XY009NV*
Valley Wash		*ATCA2-AMER/ACHY*	*R029XY072NV*

Group 10: Loamy soils with basin big sagebrush and basin wildrye

Loamy Bottom 8-12" P.Z.	***Modal***	***ARTRT/LECI4***	***R029XY003NV***

Group 11: Calcareous soils with black sagebrush and needlegrasses

Shallow Calcareous Loam 8-12" P.Z.	***Modal***	***ARNO4/ACHY***	***R029XY008NV***
Shallow Calcareous Slope 8-12" P.Z.		*ARNO4/ACHY*	*R029XY014NV*
Shallow Calcareous Hill 10-14" P.Z.		*JUOS/ARNO4/ACHY*	*R029XY081NV*
Shallow Clay Loam 8-12" P.Z.		*ARNO4/ACHY-ACTH7*	*R029XY104NV*
Shallow Calcareous Hill 8-10" P.Z.		*JUOS/PUST-ARNO4/ACHY*	*R029XY015NV*
Shallow Eroded Slope 8-10" P.Z.		*GUSA-ARNO4/PLJA*	*R029XY168NV*
Shallow Calcareous Loam 10-12" P.Z.		*ARNO4-PUST/ACHY*	*R029XY170NV*
Stony Calcareous Hill 8-12" P.Z.		*ARNO4-MAFR3/ACHY*	*R029XY099NV*
Stony Calcareous Slope 8-12" P.Z.		*ARNO4/ACSP12*	*R029XY045NV*
Limestone Slope 8-10" P.Z.		*PUST/ACSP12*	*R029XY160NV*
Travertine Bar		*MAFR3-ARNO4/ACHY*	*R029XY047NV*

Group 12: Calcareous soils at higher precipitation zone with black sagebrush and cool-season grasses

Shallow Calcareous Slope 12-14" P.Z.	***Modal***	***ARNO4/PSSPI***	***R029XY028NV***
Shallow Gravelly Fan 12-14" P.Z.			*R029XY173NV*

Group 13: Loamy soils with Wyoming big sagebrush and cool-season grasses

Loamy Slope 8-10" P.Z. P.Z.	***Modal***	***ARTRW8/ACHY-HECO26***	***R029XY010NV***
Loamy 8-10" P.Z. P.Z.		*ARTRW8/ACHY-HECO26*	*R029XY006NV*
Sandy Loam 8-12" P.Z.		*ARTRW8/ACHY*	*R029XY049NV*
Loamy 10-12" P.Z.		*ARTR2/HECO26-ACHY*	*R029XY029NV*
Loamy Slope 10-12" P.Z.		*ARTR2/HECO26-ACHY*	*R029XY075NV*
Gravelly Clay Slope 12-14" P.Z.		*ARTRV-AMUT/POFE*	*R029XY164NV*
Loamy Fan 8-12" P.Z.		*ARTRW8/LECI4-ACHY*	*R029XY114NV*
Gravelly Loam 8-10" P.Z.		*ARTRW8/BOGR2-PLJA*	*R029XY167NV*
Bouldery Slope 8-12" P.Z. P.Z.		*ARTR2/ACSP12*	*R029XY073NV*
Gravelly Clay Slope 10-12" P.Z.		*ARTR2/ACTH7-ACHY*	*R029XY106NV*
Loamy Slope 12-14" P.Z.		*ARTRV/PSSPI*	*R029XY057NV*
Coarse Loamy 8-10" P.Z.		*ARTRW8-ATCA2/ACHY*	*R029XY158NV*
Loamy 12-14" P.Z.		*ARTRV/PSSPI*	*R029XY030NV*
Fan Collar 12-16" P.Z.		*ARTRV-PUGL2/LECI4*	*R029XY061NV*

Group 14: Loamy soils with mountain big sagebrush and needlegrasses

Loamy Slope 16+" P.Z.	***Modal***	***ARTRV/ACHNA-POFE***	***R029XY051NV***

Mountain Slope 12-14" P.Z.		*ARTRV/POFE-BOGR2*	*R029XY138NV*
Loamy 16+" P.Z.		*ARTRV/ACHNA*	*R029XY050NV*

Group 15: Steep slopes with serviceberry and muttongrass

Eroded North Slope 12-14" P.Z.	***Modal***	***AMUT-PUTR2/POFE***	***R029XY165NV***
Stony Loam 12-16" P.Z.		*AMUT-ARTRV/POFE*	*R029XY098NV*
Eroded South Slope 12-14" P.Z.		*PUST-CEGR/PLJA*	*R029XY166NV*

Group 16: Clayey soils with low sagebrush and cool-season grasses

Cobbly Claypan 12-14" P.Z.	***Modal***	***ARAR8-AMUT/POFE***	***R029XY163NV***
Claypan 8-12" P.Z.		*ARAR8/ACSP12-ACHY*	*R029XY062NV*

Group 17: High precipitation zone low sagebrush with needlegrasses

Claypan 16+" P.Z.	***Modal***	***ARAR8/ACLE9-POFE***	***R029XY052NV***
Claypan 12-16" P.Z.		*ARAR8/ACTH7-POFE*	*R029XY055NV*
Mountain Ridge 16+" P.Z.		*ARAR8/ACHNA-POFE*	*R029XY053NV*
Mountain Ridge 12-16" P.Z.		*ARAR8-ARNO4/ACTH7*	*R029XY056NV*

Group 18: Fans with pygmy sagebrush and needlegrasses

Barren Fan 8-10" P.Z.	***Modal***	***ARPY2/ACHY-HECO26***	***R029XY092NV***

Group 19: Pinyon and juniper woodland with black sagebrush understory

PIMO-JUOS/ARNO4	***Modal***	***PIMO-JUOS/ARNO4-POFE***	***F029XY069NV***
JUOS/ARNO4/ACHY		*JUOS/ARNO4-PUST/ACHY*	*F029XY071NV*
PIMO-JUOS/ARAR8-AMUT		*PIMO-JUOS/ARAR8-AMUT/POFE*	*F029XY068NV*
PIMO-JUOS/ARNO4-QUGA		*PIMO-JUOS/ARNO4-QUGA/POFE*	*F029XY083NV*

Group 20: Pinyon and juniper woodland with mountain big sagebrush understory

PIMO-JUOS/ARTRV	***Modal***	***PIMO-JUOS/ARTRV/POFE-ACHNA***	***F029XY066NV***
PIMO-JUOS/ARTRV		*PIMO-JUOS/ARTRV/POFE*	*F029XY095NV*
PIMO-JUOS/PUST		*PIMO-JUOS/PUST/PYRRO-POFE*	*F029XY058NV*
PIMO/ARTRV/POFE		*PIMO/ARTRV/POFE*	*F029XY103NV*
PIMO/ARTRV/POFE		*PIMO/ARTRV/POFE*	*F029XY102NV*

Group 21: Pinyon and juniper woodland with fire-adapted shrub understory

PIMO-JUOS/QUERC-AMUT-ARTRV	***Modal***	***PIMO/JUOS/ARTRV-AMUT/POFE***	***F029XY078NV***
PIMO-JUOS/ARTRV-AMUT-QUGA		*PIMO-JUOS/ARTRV-AMUT/POFE-BOGR2*	*F029XY084NV*
PIMO/AMUT-ARTRV-QUTU2		*PIMO/AMUT-QUTU2/POFE*	*F029XY100NV*
PIMO-JUOS/ARTRV-AMUT-GAFL2		*PIMO-JUOS/ARTRV-AMUT/POFE*	*F029XY067NV*

Group 22: Silty soils with Bonneville saltbush and Indian ricegrass

Silty Plain	***Modal***	***ATBO/ACHY***	***R029XY117NV***
Deep Silty 5-8" P.Z.		*ATBO-ATCO/ACHY*	*R029XY159NV*
Outwash Plain		*ATCA2/LECI4*	*R029XY048NV*

Group 23: Sites on hills and mountain sideslopes dominated by littleleaf mountain mahogany.

Limestone Hill	***Modal***	***CEIN7-ARNO4/HECO26***	***R029XY040NV***

Group 24: Rocky soils with mountain mahogany, mountain big sagebrush, and needlegrass

Mahogany Thicket	***Modal***	***CELE3/ARTRV/ACHNA-LECI4***	***R029XY027NV***

Mahogany Savanna		*CELE3/ARTRV/ACHNA-POFE*	*R029XY043NV*

Group 25: Loamy soils with spiny hopsage and cool-season grasses

Droughty Loam 5-8" P.Z.	***Modal***	***GRSP-EPNE/ACHY-ACSP12***	***R029XY079NV***
Loamy Upland 5-8" P.Z.		*GRSP-ATCA2/ACHY*	*R029XY016NV*
Shallow Droughty Loam 5-8" P.Z.		*GRSP-MESP2/ACHY*	*R029XY031NV*
Loamy Hill 5-8" P.Z.		*GRSP-LYAN/ACHY-PLJA*	*R029XY021NV*
Joshua Upland		*YUBR/GRSP-EPNE-ATCA2/ACHY*	*R029XY007NV*

Group 26: Shallow soils with blackbrush and cool-season grasses

Shallow Gravelly Slope 8-10" P.Z.	***Modal***	***CORA/ACSP12-ACHY***	***R029XY019NV***
Shallow Gravelly Loam 8-10" P.Z.		*CORA/ACSP12*	*R029XY077NV*
Shallow Gravelly Loam 5-8" P.Z.		*CORA/ACHY*	*R029XY013NV*

Group 27: Bouldery slopes

Bouldery Slope 5-8" P.Z.	***Modal***	***EPVI/ACSP12***	***R029XY085NV***
Scree Slope 8-10" P.Z.		*EPVI-ARTRW8/ACSP12*	*R029XY169NV*

Group 28: Pinyon and juniper woodland with Wyoming big sagebrush understory

PIMO-JUOS/ARTRW8	***Modal***	***PIMO-JUOS/ARTRW8/POA***	***F029XY065NV***
JUOS/ARTRW8-PUGL2/ACHY		*JUOS/ARTRW8-PUGL2/ACHY*	*F029XY070NV*

Group 29: Well drained soils dominated by oak

North Slope 12-14" P.Z.	***Modal***	***QUTU2-AMUT/POFE***	***R029XY172NV***
Oak Thicket		*QUGA-AMUT/POFE*	*R029XY171NV*

Group 30: Singleleaf pinyon pine with white fir

PIMO-ABCOC/AMUT/POFE	***Modal***	***ABCO-PIMO/AMUT/POFE***	***F029XY096NV***

Group 31: Ponderosa pine and mixed chaparral shrubs

PIPOS/ARPA6-QUGA-AMUT	***Modal***	***PIPOS/ARPA6-QUGA/POFE***	***F029XY086NV***

Group 32: Riparian ponderosa pine forest

PIPOS/ARTRV/POFE	***Modal***	***PIPOS/ARTRV/POFE***	***F029XY097NV***

Ecological Sites Omitted from This Report

The following list of ecological sites were omitted from this final report for various reasons. Some ecological sites have been removed from the soil survey after being deemed redundant, so they no longer have any acres mapped in the USDA Soil Survey database (SSURGO). Other sites are minor inclusions in the MLRA and may only occur on a few hundred acres, and riparian sites were outside the scope of this project. For our purposes, we focused on providing ecological information for Ecological Sites that were extensive enough to be meaningful for management. A tentative Disturbance Response Group (DRG) number is given for some sites, in the event that mapping is updated in the future to include them on a larger scale.

Site Name	Reason	Dominant Vegetation	Site ID	DRG
Streambank 10-14" P.Z.	*Riparian*	*ARTRT/LECI4-ELLA3*	*R029XY025NV*	
Streambank 14+" P.Z.	*Riparian*	*ARTRV/LECI4-ELYMU-ACHNA*	*R029XY026NV*	
Wet Meadow 16+" P.Z.	*Riparian*	*CAREX-DECE*	*R029XY060NV*	
Wet Meadow 8-12" P.Z.	*Riparian*	*CAREX-JUNCU-POSE*	*R029XY001NV*	
Dry Meadow	*Riparian / zero acres*	*CAREX-POSE*	*R029XY054NV*	
Saline Meadow	*Riparian*	*SPAI-DISP-JUARL*	*R029XY002NV*	
Wetland	*Riparian*	*TYPHA-ELEOC*	*R029XY044NV*	
Gravelly Clay 8-10" P.Z.	*Zero acres*	*ARAR8/ACHY*	*R029XY128NV*	
Shallow Calcareous Loam 12-14" P.Z.	*Zero acres*	*ARNO4/ACTH7-BOGR2*	*R029XY115NV*	
Gravelly Clay 10-12" P.Z.	*Zero acres*	*ARTR2/ACTH7-ACHY*	*R029XY105NV*	
Mountain Shoulder	*Small acreage*	*ARTRV/ACLE9-POFE*	*R029XY150NV*	*14*
Loamy Plain	*Zero acres*	*ARTRW8/ACHY-PASM*	*R029XY116NV*	
Silt Flat	*Zero acres*	*ARTRW8/ELEL5-POSE*	*R029XY119NV*	
Shallow Limestone Hill 5-8" P.Z.	*Zero acres*	*CEIN7-PUST*	*R029XY151NV*	
Mahogany Pocket	*Zero acres*	*CELE3/ARTRV/ACHNA-POFE*	*R029XY139NV*	
Stony Mahogany Savanna	*Zero acres*	*CELE3/ARTRV/POFE-ACNED*	*R029XY122NV*	*24*
Shallow Limestone Slope 8-10" P.Z.	*Zero acres*	*CORA/ACAR14-ACSP12*	*R029XY127NV*	
Shallow Sandstone Hill 8-12" P.Z.	*Zero acres*	*CORA/ACPAD-ACHY-POFE*	*R029XY132NV*	
Shallow Granitic Slope 8-10" P.Z.	*MLRA 30*	*CORA/ACSP12*	*R029XY144NV*	
Gravelly Inset Fan 8-10" P.Z.	*MLRA 30 / small acreage*	*CORA-PRFA/ACSP12-POFE*	*R029XY143NV*	
Shallow Granitic Loam 8-10" P.Z.	*MLRA 30*	*CORA-QUTU2/ACSP12*	*R029XY129NV*	
JUOS WSG: 0R0405	*Zero acres*	*JUOS/CORA/BOER4-ACHNA*	*F029XY125NV*	
JUOS WSG: 0D0406	*Zero acres*	*JUOS/QUTU2-PUGL2-CEGR-ARTRW8*	*F029XY089NV*	
PIMO WSG: 0R0603	*Zero acres*	*PIMO/ARAR8/POFE-ACPI2*	*F029XY131NV*	*19*
PIMO WSG: 1R0601	*Zero acres*	*PIMO/ARTRV/POFE*	*F029XY101NV*	*20*

PIMO WSG: 1R0607	*Zero acres*	*PIMO/QUGA-ARTRV/POFE-ACOCO*	*F029XY109NV*	*21*
PIMO WSG: 0R0607	*Zero acres*	*PIMO/QUGA-SYLO-AMUT-ARNO4*	*F029XY136NV*	
PIMO WSG: 0R0607	*Zero acres*	*PIMO/QUGA-SYLO-AMUT-ARTRV*	*F029XY140NV*	
PIMO WSG: 0R0607	*MLRA 30*	*PIMO/QUGA-SYMPH-ARTRV/POFE*	*F029XY141NV*	
PIMO WSG: 0R0606	*Zero acres*	*PIMO/QUTU2-CORA/ACHNA-POFE*	*F029XY148NV*	
PIMO-JUOS WSG: 0R0507	*Zero acres*	*PIMO-JUOS/ARNO4-AMUT-GAFL2*	*F029XY135NV*	
Limestone Ridge	*Small acreage*	*PIMO-JUOS/ARNO4-ARPU5/ACAR14*	*F029XY137NV*	*19*
PIMO-JUOS WSG: 0R0504	*Zero acres*	*PIMO-JUOS/ARNO4-PERA4*	*F029XY124NV*	
PIMO-JUOS WSG: 0R0504	*Zero acres*	*PIMO-JUOS/ARNO4-PUST*	*F029XY145NV*	
PIMO JUOS WSG: 0R0507	*Zero acres*	*PIMO-JUOS/CEMO2-GAFL2/POFE*	*F029XY111NV*	
PIMO-JUOS WSG: 0R0505	*Zero acres*	*PIMO-JUOS/CORA-QUTU2*	*F029XY152NV*	
PIMO-JUOS WSG: 0R0507	*MLRA 30 / small acreage*	*PIMO-JUOS/PUST-CORA/BOGR2*	*F029XY126NV*	
PIMO-JUOS WSG: 0R0506	*Zero acres*	*PIMO-JUOS/QUTU2-ARNO4*	*F029XY149NV*	
POTR5 WSG: 1A1707	*Zero acres*	*POTR5/SYOR2/ELTR7*	*F029XY130NV*	
Bouldery Sandstone Slope 8-12” P.Z.	*Zero acres*	*QUTU2/ACHNA-ACHY-POFE*	*R029XY133NV*	
Shallow Sandstone Hill 12-14” P.Z.	*Zero acres*	*QUTU2-ARPU5-ARNO4/ACPAD*	*R029XY142NV*	
Granitic Slope 10-12" P.Z.	*MLRA 30*	*QUTU2-ERFAP/ACSP12*	*R029XY112NV*	
Granitic Hill 10-12" P.Z.	*Zero acres*	*QUTU2-ERFAP/ACSP12*	*R029XY113NV*	
Sodic Sands	*Zero acres*	*SAVE4/ACHY-SPAI*	*R029XY153NV*	
Sodic Loam 5-8" P.Z.	*Zero acres*	*SAVE4-ATCO/SPAI-ACHY*	*R029XY155NV*	
Dry Saline Meadow	*Zero acres*	*SPAI-DISP*	*R029XY154NV*	

Small acreage: Less than 200 ac. ***MLRA 30***: All mapped acres of that ecological site occur in MLRA 30 exclusively. **Zero acres***:* Ecosite is not associated with any map unit in the NRCS SSURGO soil database. ***Riparian***: Ecological site is riparian in nature and outside of the scope of the project.

MLRA 29 Group 1: Loamy soils with shadscale and Indian ricegrass

Description of MLRA 29 Disturbance Response Group 1

Disturbance Response Group (DRG) 1 consists of eight ecological sites. The precipitation ranges from 3 to 8 in. with slopes ranging from 0 to 75%. Elevations range from 3,000 to 6,500 ft. Soils are typically formed in alluvium from mixed sources and are typically alkaline, calcareous, or carbonatic. Soil textures are variable but soil profiles are skeletal and gravels or stones are common on the surface. Soils are well drained and shallow to very deep depending on landform. The soil temperature regime is mesic and the moisture regime is aridic. Production ranges from 50 to 450 lb/ac for a normal year, with an average of about 320 lb/ac. The potential native plant community for these sites is typically dominated by shadscale (*Atriplex confertifolia*) in the overstory. Bud sagebrush (*Picrothamnus desertorum*), winterfat (*Krascheninnikovia lanata*), Bailey's greasewood (*Sarcobatus baileyi*), Shockley's wolfberry (*Lycium shockleyi*), and white bursage (*Ambrosia dumosa)* are other important shrubs. The understory is dominated primarily by Indian ricegrass (*Achnatherum hymenoides*). Galleta grass (*Pleuraphis jamesii*), desert needlegrass (*Achnatherum speciosum*), and bottlebrush squirreltail (*Elymus elymoides*) are also important grasses on these sites.

Disturbance Response Group 1 Ecological Sites:

Loamy 5-8" P.Z. – Modal	R029XY017NV
Loamy Slope 5-8" P.Z.	R029XY022NV
Gravelly Loam 5-8" P.Z.	R029XY087NV
Loamy Slope 3-5" P.Z.	R029XY033NV
Sodic Loam 3-5" P.Z.	R029XY032NV
Coarse Gravelly Loam 3-5" P.Z.	R029XY039NV
Shallow Silty 5-8" P.Z.	R029XY059NV
Loamy 3-5" P.Z.	R029XY035NV
Stony Slope 5-8" P.Z.	R029XY064NV

Modal Site:

The Loamy 5-8" P.Z. ecological site is the modal site that represents this DRG, as it has the most acres mapped. This site occurs on piedmont slopes and alluvial plains on all exposures. Precipitation ranges from 5 to 8 in. Slopes range from 0 to 30%, but slope gradients of 2 to 8% are most typical. Elevation ranges from 4,400 to 6,500 ft. Soils of this site are moderately to strongly alkaline, non-saline to slightly saline, and non-sodic to slightly sodic. Permeability is moderate and runoff is medium. The available water holding capacity of the soil is very low to low. The soil temperature regime is mesic and the soil moisture regime is typic aridic. Production for a normal year is typically 450 lb/ac. The native plant community is dominated by shadscale (*Atriplex confertifolia*), bud sagebrush (*Picrothamnus desertorum*) and Indian ricegrass (*Achnatherum hymenoides*). Other important species are galleta (*Pleuraphis jamesii*), winterfat (*Krascheninnikovia lanata*), and bottlebrush squirreltail (*Elymus elymoides*).

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasives. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans across Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area, especially in eastern Nevada, when strong convection storms contribute significantly to annual precipitation. Moisture and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

Periodic drought regularly influences these ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West (Miller et al. 2008a). Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006).

The ecological sites in this DRG are dominated by deep-rooted, cool-season perennial bunchgrasses and drought tolerant shrubs with high root to shoot ratios. Native bunchgrasses generally have somewhat shallower root systems than the shrubs, but root densities are often as high as or higher than those of the shrubs in the upper 0.5 m (1.6 ft) of the soil profile. General differences in root depth distributions between grasses and shrubs results in resource partitioning in these shrub – grass systems. Although not dominant, warm-season grasses occur on all sites.

Shadscale, the dominant shrub in this group, is a densely clumped, rounded, compact native shrub. It generally attains heights of 8 to 32 in. and widths of 12 to 68 in. (Blaisdell and Holmgren 1984). Shadscale, a short-lived species, is considered an evergreen to partially deciduous shrub, since a small percentage of leaves are dropped in the winter (Smith and Nobel 1986, Harper et al. 1990). Shadscale possesses wider ecological amplitude than most *Atriplex* species (Crofts and Epps 1975), and shows ploidy levels from diploid (2x) to decaploid (10x). The extensive polyploidy of shadscale is an important consideration when implementing revegetation projects because ploidy levels are usually associated with distinct habitats (Sanderson et al. 1990). Diploid individuals are unlikely to perform as well in areas where tetraploids are more common. Diploid individuals generally occur above Pleistocene lake levels, whereas lake floors are usually occupied by autotetraploids. Overall, tetraploids are the most widespread throughout its range (Carlson 1984). Thus, the diploid most associated with these sites are a tetraploid.

Shadscale roots to the full depth of the winter-spring soil moisture recharge, which Fernandez and Caldwell (1975) reported as between 80 and 110 cm (31.5 in. to 43.3 in.). This species initiates root growth, in early April, a few days to a week prior to aerial plant parts and exhibits active root growth for several weeks after termination of shoot growth (Fernandez and Caldwell 1975). Continued root growth, even for established plants that are not exploring new areas of the soil, facilitates water absorption particularly in low soil moisture conditions (Gardner 1960). Fernandez and Caldwell (1975) concluded that the ability of shadscale to explore the soil volume at greater depths with a more profuse system of small branching lateral roots than winterfat or sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) may play a role in its ability to remain photosynthetically active longer into the summer season. Although shadscale exhibits the ability to withstand drought conditions on a short-term basis, the forty year photographic record (1951–1990) from the Raft River Valley of south-central Idaho visually demonstrates the impact of multiple years of drought on shadscale communities (Sharp et al. 1990). Scale insects have also been implicated in the death of shadscale (Sharp et al. 1990), however, the data on this subject remains inconclusive (Nelson et al. 1990a). Interestingly, periods of above normal springtime precipitation are also linked to shadscale die-off. (Nelson et al. 1990a) investigated areas of severe shadscale die-off that were, for the most part, located in low areas in valley bottoms or upland depressions that apparently incurred prolonged high soil moisture during a wet period. The high soil moisture appeared to be correlated with increased pythiaceous fungi leading to rootlet mortality and plant stress (Nelson et al. 1990a). The authors suggest that depending on the degree and duration of plant stress, injury could range from a sustained disease to rapid death. However, mass die-offs in shadscale stands have been witnessed to bounce back presumably through a persistent seed bank (Sharp et al. 1990, Meyer et al. 1998, Haubensak et al. 2009).

Bud sagebrush, a common shrub in this group, is a native, summer-deciduous shrub. It is low growing, spinescent and aromatic in nature with a height of 4 to 10 in. and a spread of 8 to 12 in. (Stubbendieck et al. 2017). Chambers and Norton (1993) found that the species does not break dormancy until fall precipitation penetrates the soil and reaches its deep, spreading root structure at 9.8 to 11.8 in. It will then produce new leaves, but not elongate its stems until spring and go dormant by early summer (Wood and Brotherson 1986). The bud sagebrush root system is able to penetrate deeper into the soil and branch out significantly more than shadscale (Chambers and Norton 1993). This allows the shrub to compete for valuable resources.

Bailey's greasewood is a small, densely spined, deciduous shrub that can grow up to 0.5 m (1.6 ft) tall. They grow on mounds of accumulated sand and silt. Unlike black greasewood, it is reliant on precipitation for moisture which is not abundant in their environment. In response to drought, it conserves energy by delaying flowering—and sometimes leaf emergence—for years at a time (Young and Clements 2006). It has been commonly found coexisting with shadscale in areas slightly south of cheatgrass (*Bromus tectorum*) zones. It is resilient against fire and is able to resprout after damage (Monsen and Kitchen 1994).

White bursage, a deciduous shrub commonly found in arroyos, bajadas, gentle slopes, valley floors, and sand dunes. White bursage can grow up to 23 in. tall with stiff branches and a hemispherical crown (Fonteyn and Mahall 1981). Roots grow and extend to a depth of 28 in. (Fonteyn and Mahall 1981). Vasek (1979) notes white bursage colonizes in large open spaces because of the large-scale seeding establishment. White bursage flowers around May and germination usually occurs during September (Beatley 1974).

Anderson wolfberry (*Lycium andersonii*) is a drought-deciduous, spiny, rounded and many branched shrub typically found on sandy or gravelly ashes, sandy or alkali flats, mesas and slopes from 1,500 to 6,000 ft in elevation throughout the southwestern United States (Tesky 1992). It possesses a relatively extensive, tough and fibrous root system extending 25 to 30 ft from the plant and enabling it to reach heights of 1 to 9 ft (Tesky 1992). Wolfberry is characterized by its spiny light-barked twigs that harbor fleshy red berries and thick, fleshy and flattened leaves. Germination either occurs late in the year following summer rains as a result of seed dispersal after ingestion by small mammals or through root sprouting from broken roots (Tesky 1992).

Indian ricegrass, the dominant understory species of this group, is a long-lived, cool-season perennial bunchgrass that grows from 4 to 24 in. in height (Blaisdell and Holmgren 1984). Primarily adapted to coarse textured soils, its deep, fibrous root system makes Indian ricegrass one of the most drought-tolerant native species (Booth et al. 1980). Unlike other cool-season species, Indian ricegrass does not require vernalization (exposure to cold) in order to produce flowers and flowering can continue into late fall with favorable environmental conditions. This allows the seeds in each panicle to ripen over a longer period of time than most other species thus providing a greater opportunity for successful seed production (Jones 1990).

Galleta is a mat-forming, rhizomatous, native grass that is 11 to 19 in. tall (Stubbendieck et al. 2003). This warm-season, perennial species is more water efficient than its cool-season counterparts. This allows galleta grass to survive in low precipitation zones where a significant portion of rainfall occurs during summer months (Banner et al. 2011). Everett et al. (1980) found that galleta grass initiated more than one phenological cycle with the presence of summer precipitation, allowing the species to grow and set seed more than once. This plant is typical of southern Nevada and the transition zone between the Great Basin and the Mojave Desert. It is most common on fine-textured soils (Stubbendieck et al. 2003).

The ecological sites in this DRG have low to moderate resilience to disturbance and resistance to invasion. Increased resilience increases with elevation, aspect, increased precipitation and increased nutrient availability. Five possible stable states have been identified for this DRG.

Annual Invasive Species:

The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and depressed competition or can increase resource pools by the decomposition of dead plant material following disturbance. Historically, shadscale dominant salt-desert shrub communities were free of exotic invaders; however, excessive grazing pressure during settlement and into the 20th century has increased the overall presence of cheatgrass, halogeton (*Halogeton glomeratus*), Russian thistle (*Salsola* spp.) and weedy mustard species (Brassicaceae family) (Peters and Bunting 1994). The presence of non-native annual plants within these ecosystems decreases ecosystem resilience and resistance to disturbance through competition for limited resources.

The species most likely to invade the ecological sites in this DRG is cheatgrass. Cheatgrass is a cool-season annual grass that maintains an advantage over native plants, in part, because it is a prolific seed producer, can germinate in the autumn or spring, tolerates grazing, and increases with frequent fire (Klemmedson and Smith 1964, Miller et al. 1999). Cheatgrass originated from Eurasia and was first reported in North America in the late 1800s (Furbush 1953, Mack and Pyke 1983). Bradley et al. (2018) found that cheatgrass has expanded to greater than 15% cover over 210,000 km^2 (130,488 mi^2), roughly 31% of the Intermountain West. In the Great Basin, cheatgrass is expanding at a rate of expansion of 3,700 km^2 (2,300 mi^2) annually and is a land management issue that will require creative solutions (Smith et al. 2022). Mapping potential or current invasion vectors is a management method designed to increase the cost-effectiveness of control methods. Recent modeling and empirical work by Lauenroth and Bradford (2006) suggest that seasonal patterns of precipitation input and temperature are also key factors determining regional variation in the growth, seed production, and spread of invasive annual grasses. The phenomenon of cheatgrass “die-off” provides opportunities for restoration of perennial native species (Baughman et al. 2016, Baughman et al. 2017). The causes of these events are not fully understood, but there is ongoing work to try to predict where they occur, in the hopes of aiding conservation planning (Weisberg et al. 2017, Brehm 2019).

Halogeton is a non-competitive plant that tends to invade areas that are susceptible to repeated disturbance such as; livestock trails, roadsides, trampled areas near watering holes or corrals and rangeland areas stripped of the natural vegetation by excessive grazing or other soil disturbing activities (Young 2002). It was first introduced into the western U.S. during the 20th century with the first collection being made near Wells, Nevada in 1934. Halogeton is highly toxic to sheep and has been responsible for thousands of sheep deaths throughout the western U.S., which triggered a massive effort to eradicate the introduced species in the late 1900s (Young 2002). Halogeton has two distinct seed forms; a black form which consists of the achene only and a brown form which consists of the achene and attached sepals (Tisdale and Zappetini 1953, Robocker et al. 1969). The black form of halogeton seed germinate readily under a wide range of pH and salt concentrations within the first year. The brown form of seed was found to be 100% viable at the end of two years and 15% viable at the end of 10 years, proving that halogeton seed may remain viable in the soil for up to 10 years (Robocker et al. 1969). Eradication of this species is problematic, therefore, appropriate range management practices focused on soil and rangeland integrity are necessary to control the species.

Fire Ecology:

The lack of continuous fuels to carry fires made fire rare to nonexistent in shadscale communities (Young and Tipton 1990), thus it is not surprising that shadscale and bud sagebrush are both fire intolerant (Banner 1992, West 1994). Shadscale does not readily recover from fire, except for establishment through seed (West 1994). The slow reestablishment allows for easy invasion by halogeton, cheatgrass and other non-native weedy species (Sanderson et al. 1990). The increased presence of exotic annual grasses has greatly altered fire regimes in areas of the Intermountain West where shadscale is a major vegetation component. Exotic annuals increase fire frequency under wet to near-normal summer moisture conditions and repeated, frequent fire has converted large expanses of shadscale rangeland to annual non-native plant communities (Knapp 1998). However, the shadscale communities in MLRA 29, to-date, have not experienced a reduced fire-return interval nor do they exhibit a conversion to annual grass dominance. However, the shadscale communities located in northern Nevada exhibit conversion to annual grass dominance following fire, suggesting the potential exists for the expansion of non-native annual species in the shadscale communities of MLRA 29.

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species' response. Thus, fire mortality is correlated to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant, and abundance of old growth (Wright 1971, Young 1983). Boyd et al. (2015) found soil color and depth of burn to be accurate predictors of bunchgrass mortality in post-fire landscapes. They also found that bunchgrasses in close proximity of shrubs had up to a five-fold higher mortality than bunchgrasses located in the interspaces (Boyd et al. 2015).

Indian ricegrass is fairly fire tolerant (Wright 1985), which is likely due to its low culm density and below-ground growing points. Vallentine (1989) cites several studies in the sagebrush zone that classified Indian ricegrass as being slightly damaged from late summer burning. Indian ricegrass has also been found to reestablish on burned sites through seeds dispersed from adjacent unburned areas (Young 1983, West 1994). Thus, the presence of surviving, seed-producing plants facilitates the reestablishment of Indian ricegrass. Grazing management following fire to promote seed production and establishment of seedlings is important. When properly managed, Indian ricegrass can be a key factor in a community recovering from disturbance because it can grow in rough, rocky, coarse, and otherwise unproductive soils (Booth et al. 1980).

Galleta grass, a significant component of these ecological sites, has been found to increase following fire likely due to its rhizomatous root structure and ability to resprout (Jameson 1962). This sod-forming grass species may retard reestablishment of deeper-rooted bunchgrasses. Fire in this community, although rare, will significantly reduce shadscale, bud sagebrush and winterfat while promoting establishment of an annual weed community with varying amounts of galleta, spiny hopsage (*Grayia spinosa*), ephedra (*Ephedra* spp.) and rabbitbrush (*Chrysothamnus* spp.).

Like many long-lived desert perennials, Anderson wolfberry (*Lycium andersonii*) isn't strongly adapted to fire. Wolfberry's ability to sprout after a fire depends on the fire's severity: with high-severity fire reducing most plants to ash with very high levels of mortality while moderate or low severity fires allowing intermittent sprouting to occur after disturbance (Tesky 1992). However, even with this possibility to may take many years to reach pre-burn densities on disturbed sites (Tesky 1992).

Rehabilitation on these sites following fire will have limited success as evidenced in similar communities in the West. Observations from one hundred and seven separate plantings within the shadscale zone in Utah and Nevada indicate a very low success rate (Bleak and Frischknecht 1965). Seed from 148 native and non-native grasses, forbs and shrubs were planted from 1937 to 1962 across 10 locations. Good seedling stands were obtained with introduced wheatgrasses, but most perished during the first summer. A few plantings of crested wheatgrass (*Agropyron cristatum*), fairway and Siberian wheatgrass (*Agropyron fragile*) along with Russian wildrye (*Psathyrostachys juncea*) maintained stands for 10 or more years but eventually declined to a very few plants (Bleak and Frischknecht 1965). The primary cause of seeding failures appeared to be the arid climate.

Livestock/Wildlife Grazing Interpretations:

Traditionally, shadscale plant communities provided good winter forage for the expanding sheep and cattle industry in the arid west. Shadscale is a valuable browse species for a wide variety of wildlife and livestock (Blaisdell and Holmgren 1984). The spinescent growth habit of shadscale lends to its browsing tolerance with no more than 15 to 20% utilization by sheep being reported (Blaisdell and Holmgren 1984) and significantly less utilization by cattle. Increased presence of shadscale within grazed versus ungrazed areas is generally a result of the decreased competition from more heavily browsed associates (Cibils et al. 1998). Reduced competition from more palatable species in heavily grazed areas may increase shadscale germination and establishment. Chambers and Norton (1993) found shadscale establishment higher under spring than winter browsing as well as heavy compared to light browsing. During years of below average precipitation, shadscale has been found to be very susceptible to grazing pressure regardless of season (Chambers and Norton 1993). Following fire, grazing exclusion for two or more years is beneficial for revegetation of shadscale communities as first year shadscale seedlings lack spines and are highly susceptible to browsing. Spines develop in the second year (Zielinski 1994).

Bud sagebrush is also a palatable, nutritious forage for upland game birds, small game, big game and domestic sheep in winter, particularly late winter (Johnson 1978); however it can be poisonous or fatal to calves when eaten in quantity (Stubbendieck et al. 1992). Bud sagebrush is highly susceptible to effects of browsing. It decreases under browsing due to year-long palatability of its buds and is particularly susceptible to browsing in the spring when it is physiologically most active (Harper et al. 1990, Chambers and Norton 1993). Heavy browsing (>50%) may kill bud sagebrush rapidly (Wood and Brotherson 1986). Winterfat, a highly nutritious winter feed, shows similar results to bud sagebrush with significant declines in density with late winter or early spring grazing (Harper et al. 1990). Interestingly, the same 54-year study also showed winterfat density decreasing in the ungrazed plots.

Anderson wolfberry plays a minor role as a browse species due to its fair to low palatability, resulting it in being used as forage by livestock and feral burros, only when more desirable species are unavailable (Tesky 1992). Its red berries provide a small percentage of the diet for some birds and small mammals that it uses for seed distribution (Tesky 1992).

Indian ricegrass is a preferred forage species for livestock and wildlife and cures well, providing nutritious winter feed (Cook 1962, Booth et al. 1980). It is also readily utilized in early spring, being a source of green feed before most other perennial grasses have produced new growth (Quinones 1981). Booth et al. (1980) note that the plant does well when utilized in winter and spring. In eastern Idaho, productivity of Indian ricegrass was at least 10 times greater in undisturbed plots than in heavily (60% utilization) grazed ones (Pearson 1965). Cook and Child (1971) found significant reduction in crown cover, plant vigor and herbage yield of Indian ricegrass when the species was utilized at 90% during any season. However, they found no reductions at 30% utilization during any season and no reductions at 60% utilization during winter and early spring grazing (Cook and Child 1971). The seed crop may be reduced where grazing is heavy (Bich et al. 1995). Tolerance to grazing increases after May, thus spring deferment may be necessary for stand enhancement (Pearson 1964, Cook and Child 1971); however, utilization of less than 60% is recommended. In summary, adaptive management is required to manage this bunchgrass well.

Galleta is a highly palatable forage species for cattle, sheep, deer (*Odocoileus* spp.), antelope (*Antilocapra americana*), and horses during late spring and summer while it is green (Stubbendieck et al. 2017). Due to its rhizomatous characteristics, galleta grass is particularly tolerant of heavy grazing and trampling (Pratt et al. 2002). This species will also initiate more than one phenological cycle if summer precipitation is present (Everett et al. 1980), allowing galleta to grow and propagate after defoliation.

Thus, overgrazing causes a decrease in Indian ricegrass along with bud sagebrush, while shadscale may initially increase. Spring grazing, year after year, can be detrimental to bud sagebrush and bunchgrasses. Continued abusive grazing leads to increased bare ground and invasion by annual weeds (e.g., cheatgrass, halogeton, and tansy mustard). Shadscale may become dominant with an annual understory. With further deterioration, shadscale declines, bare ground increases, soil redistribution accelerates and site productivity decreases. On some soils, erosion can result in increased surface salts and development of desert pavement. Reestablishment of perennials is limited in areas of extensive desert pavement.

State and Transition Model Narrative for Group 1:

This is a text description of the states, phases, transitions, and community pathways possible in the modal ecological site State and Transition model for the MLRA 29 Disturbance Response Group 1.

Reference State 1.0:

The Reference State 1.0 is a representative of the natural range of variability under pristine conditions. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community changes would be reflected in production response to long-term drought. Wet years will increase grass production, while drought years will reduce production. Shadscale is highly sensitive to drought, and will experience significant mortality during extended droughts; however, extreme growing season wet periods have also been shown to cause shadscale death.

Community Phase 1.1:
This community is dominated by shadscale and Indian ricegrass. Galleta and bottlebrush squirreltail are minor components along with bud sagebrush and winterfat. Potential vegetative composition by air-dry weight is 45% grasses, 5% forbs and 50% shrubs.

Approximate ground cover (basal and crown) is 15 to 25%. Total annual air-dry production ranges from 200 to 700 lb/ac.

Community phase changes are primarily a function of drought, insects and/or disease. Drought will favor all shrubs except shadscale over perennial bunchgrasses. However, long-term drought will result in an overall decline in plant community production, regardless of functional group. Extreme growing season wet periods may also reduce the shadscale component. Fire is very infrequent to non-existent.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
Long-term drought or an unusually wet spring which encourages the growth of a pythiaceous fungi, reduces the shadscale community. Drought and/or insect infestation will favor all shrubs except shadscale over perennial bunchgrasses, however, shadscale death allows for the reallocation of onsite resources to the remaining bunchgrasses and shrubs.

Community Phase 1.2:
Shadscale has been reduced in the community. Bud sagebrush, winterfat, and other shrubs dominate the overstory while perennial bunchgrasses dominate the understory with less competition from the shadscale community.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
Release from drought, insect infestation or disease will allow shadscale to reestablish from seed into the system.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0:

Trigger: This transition is caused by the introduction of non-native annual plants, such as halogeton, Russian thistle, mustards and cheatgrass.

Slow variables: Over time the annual non-native species will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

The Current Potential State 2.0 is similar to the Reference State 1.0 with the addition of a shrub dominated community phase in which deep-rooted perennial bunchgrasses have been reduced.

Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of invasive weeds. Non-natives may increase in abundance but will not become dominant within this State. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These feedbacks include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal.

Community Phase 2.1:
This community is compositionally similar to the Reference State Community Phase 1.1 with the presence of non-native species in trace amounts. This community is dominated by shadscale and Indian ricegrass. Galleta, bottlebrush squirreltail, bud sagebrush and winterfat are also important species on this site. Community phase changes are primarily a function of chronic drought or extreme wet periods. Fire is infrequent and patchy due to low fuel loads.

Loamy Slope 5-8" P.Z. (R029XY022NV), Current Potential 2.1, P. Novak-Echenique, May 2021

Loamy Slope 3-5" P.Z. (R029XY033NV), Current Potential 2.1, T. Stringham, May 2021

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
Long-term drought or an unusually wet spring makes shadscale more susceptible to insects and disease, reducing the shadscale community (Schultz and Ostler 1995; Weber et al. 1990). Drought will favor all shrubs except shadscale over perennial bunchgrasses, however, shadscale death allows for the reallocation of onsite resources to the remaining bunchgrasses and shrubs.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.3:
Inappropriate grazing management causes a decline in the deep-rooted perennial bunchgrass community.

Community Phase 2.2:
Shadscale has been reduced in the community. Bud sagebrush, winterfat, and other shrubs dominate the overstory while perennial bunchgrasses dominate the understory with less competition from the shadscale community. Annual non-native species are present.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Release from drought will allow shadscale to reestablish from the seed bank.

Community Phase Pathway 2.2b, from Phase 2.2 to 2.3:
Release from drought combined with inappropriate grazing management will significantly reduce deep-rooted perennial bunchgrasses, winterfat and bud sagebrush in favor of shadscale, rabbitbrush, and galleta.

Community Phase 2.3 (At Risk):
Shadscale and other unpalatable shrubs such as rabbitbrush dominate the overstory while deep-rooted perennial bunchgrasses, winterfat, and bud sagebrush are reduced

from inappropriate grazing during the growing season. Galleta may increase due to its rhizomatous growth habit. Annual non-native species may be stable or increasing due to a lack of completion with deep-rooted perennial bunchgrasses. Bare ground may be significant. This community is at risk of crossing a threshold to either Shrub State 3.0 or Annual State 4.0.

Loamy 5-8" P.Z. (R029XY017NV), Current Potential 2.3, T. Stringham, June 2021

Community Phase Pathway 2.3a, from Phase 2.3 to 2.2:
Release from inappropriate grazing management allows for bud sagebrush, winterfat and deep-rooted perennial grasses to increase. An unusually wet growing season may also reduce shadscale allowing other desirable species to increase.

T2A: Transition from Current Potential State 2.0 to Shrub State 3.0:

Trigger: Long-term inappropriate grazing and/or long-term drought will decrease or eliminate deep-rooted perennial bunchgrasses and favor shrub growth and establishment.

Slow variables: Long term decrease in deep-rooted perennial grass density.

Threshold: Loss of deep-rooted perennial bunchgrasses changes nutrient cycling, nutrient redistribution, and reduces soil organic matter.

T2B: Transition from Current Potential State 2.0 to Annual State 4.0:

Trigger: Long-term inappropriate grazing management including wild horse and burro use. An unusually wet spring may also facilitate the increased germination and production of exotic annual species leading to their dominance within the community.

Slow variables: Increased production and cover of non-native annual species.

Threshold: Loss of deep-rooted perennial bunchgrasses and shrubs truncates, spatially and temporally, nutrient capture and cycling within the community.

Shrub State 3.0:

The Shrub State 3.0 has two community phases. This state has crossed a biotic threshold where deep-rooted perennial bunchgrasses have been removed from the system and site resources are being controlled by shrubs. Shrub cover exceeds the site concept and may be decadent, reflecting stand maturity and lack of seedling establishment due to competition with mature plants. The shrub overstory dominates site resources such that soil water, nutrient capture, nutrient cycling and soil organic matter are temporally and spatially redistributed. Bare ground has increased.

Community Phase 3.1 (At-Risk):
Shadscale, bud sagebrush and/or winterfat dominate the overstory. Deep-rooted perennial bunchgrasses may be present in trace amounts or absent from the community, however, galleta may be the dominant understory grass species. Annual non-native species have increased and bare ground is significant.

Loamy 5-8" P.Z. (R029XY017NV), Shrub State 3.1, T. K. Stringham, May 2021

Gravelly Loam 5-8" P.Z. (R029XY087NV), Shrub State 3.1, D. Snyder, September 2020

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:
Inappropriate or excessive grazing, including wild horse and burros, reduces shadscale, bud sagebrush and/or winterfat cover and allows for sprouting shrubs to dominate the overstory. Brush treatments (not observed) with minimal soil disturbance could also facilitate this community phase pathway. Although brush treatments were not observed for these ecological sites, brush treatments were observed in MLRA 28B at similar sites.

Community Phase 3.2 (At Risk):
Rabbitbrush dominates the overstory. Annual non-native species may be increasing and bare ground is significant. Desirable species such as Indian ricegrass and/or shadscale may be present in trace amounts. This site is at risk for an increase in invasive annual weeds. This community phase is at risk of transitioning to an Annual State 4.0 or an Abiotic State 5.0.

Loamy 5-8" P.Z. (R029XY017NV), Shrub State 3.2, T. Stringham, June 2020

Community Phase Pathway 3.2a, from Phase 3.2 to 3.1:
Time and lack of disturbance and/or grazing, including wild horse and burro, management that favors the reestablishment and growth of shadscale and/or other non-sprouting shrubs.

T3A: Transition from Shrub State 3.0 to Annual State 4.0:

Trigger: Long-term inappropriate grazing, including wild horse and burros, an unusually wet spring, and/or long-term, chronic drought.

Slow variables: Increased production and cover of non-native annual species.

Threshold: Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and shrubs truncate energy capture spatially and temporally thus impacting nutrient cycling and distribution.

T3B: Transition from Shrub State 3.0 to Abiotic State 5.0:

Trigger**:** Long-term, inappropriate grazing and/or wild horse and burro management, severe drought and/or soil disturbing activities combined with significant soil loss and redistribution.

Slow variables: Long-term decrease in density of native, perennial vegetation combined with soil movement and loss.

Threshold: Increased wind or water erosion resulting in soil loss preventing the establishment of native perennials. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and shrubs truncate energy capture spatially and temporally thus impacting nutrient cycling and distribution.

Annual State 4.0:

This state has one community phase. In this state, a biotic threshold has been crossed and state dynamics are driven by the dominance and persistence of the exotic annual species. Halogeton, Russian thistle, tumble mustard and/or cheatgrass dominate the plant community. Bare ground may be abundant and desirable, native vegetation is trace or missing.

Community Phase 4.1:
This community is dominated by annual non-native species. Halogeton most commonly invades these sites. Trace amounts of shadscale and other desirable species may be present, but are not contributing to overall site function. Bare ground may be abundant, especially during low precipitation years.

Loamy 5-8" P.Z. (R029XY017NV), Annual State, T. Stringham, June 2023


Loamy 5-8" P.Z. (R029XY017NV), Annual State At Risk of Abiotic, T. Stringham, June 2023

T4A: Transition from Annual State 4.0 to Abiotic State 5.0:

Trigger: Long-term, extremely inappropriate grazing and/or wild horse and burro management, severe drought and/or soil disturbing activities combined with significant soil loss and redistribution.

Slow variables: Long term decrease in density of native, perennial vegetation combined with soil movement and loss.

Threshold: Increased wind or water erosion resulting in soil loss preventing the establishment of native perennials. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and shrubs truncate energy capture spatially and temporally thus impacting nutrient cycling and distribution.

Abiotic State 5.0:

This state consists of one community phase in which abiotic factors (i.e. wind or water erosion) have dramatically altered the site. It is characterized by the loss of vegetative cover along with the redistribution and loss of the soil surface. Feedbacks contributing to the stability of this state include soil loss, nutrient loss, soil surface degradation and increased area, distribution and connectivity between patches of bare soil.

Community Phase 5.1:
This community is the result of extreme soil loss and redistribution. The vegetative cover is minimal, but is dominated by introduced non-native grasses and/or forbs. Trace amounts of desirable species may be present and bare ground interspaces are large and

connected. Site function is controlled by soil erosion, wind and soil temperature. Rehabilitation of this community is unknown.

Loamy 5-8" P.Z. (R029XY017NV), Abiotic State 5.1, T. Stringham, May 2021

Potential Resilience Differences with Other Ecological Sites in this Group:

Loamy Slope 5-8" P.Z. R029XY022NV:

This site occurs on steeper slopes than the modal ecological site and the soils of this site are shallow or very shallow to bedrock and well drained. Surface textures are typically very gravelly, cobbly, or stony. Production is typically 225 lb/ac during a normal year. This site is at risk of forming desert pavement, however this site is not expected to develop an Abiotic State.

Gravelly Loam 5-8" P.Z. R029XY087NV:

The site occurs on piedmont slopes and inset fans with typical slopes from 4 to 15%. The plant community is dominated by Bailey's greasewood and Indian ricegrass. Shadscale, bud sagebrush and galleta are minor components. Production is typically 450 lb/ac during a normal year.

Loamy Slope 3-5" P.Z. R029XY033NV:

This site occurs on steeper slopes than the modal ecological site and the soils of this site are shallow or very shallow to bedrock and well drained. Surface textures are typically very gravelly, cobbly, or stony. Production is typically 50 lb/ac during a normal year. This site also receives less precipitation than the modal, making it less resilient to disturbances. An Abiotic State is not expected.

Sodic Loam 3-5" P.Z. R029XY032NV:

This site occurs on summits and sideslopes of lower fan piedmonts with typical slopes from 4 to 15%. This plant community is dominated by shadscale and other shrubs in the reference state and naturally does not carry as much grass as the modal ecological site. Production is typically 125 lb/ac during a normal year. This site also receives less precipitation than the modal, making it less resilient to disturbances. The Abiotic State is not expected.

Coarse Gravelly Loam 3-5" P.Z. R029XY039NV:

This site occurs on lower fan piedmonts with typical slopes from 2 to 8%. This plant community is dominated by shadscale and other shrubs in the reference state and naturally does not carry as much grass as the modal ecological site. Production is typically 350 lb/ac during a normal year. This site also receives less precipitation than the modal, making it less resilient to disturbances. An Abiotic State is not expected.

Shallow Silty 5-8" P.Z. R029XY059NV:

This site occurs on lake plains and lake plain terraces of basin floors. The plant community is dominated by shadscale and other shrubs in the reference state and naturally does not carry as much grass as the modal ecological site. This site is also occasionally flooded and is susceptible to rills and gullies. Production is typically 375 lb/ac during a normal year.

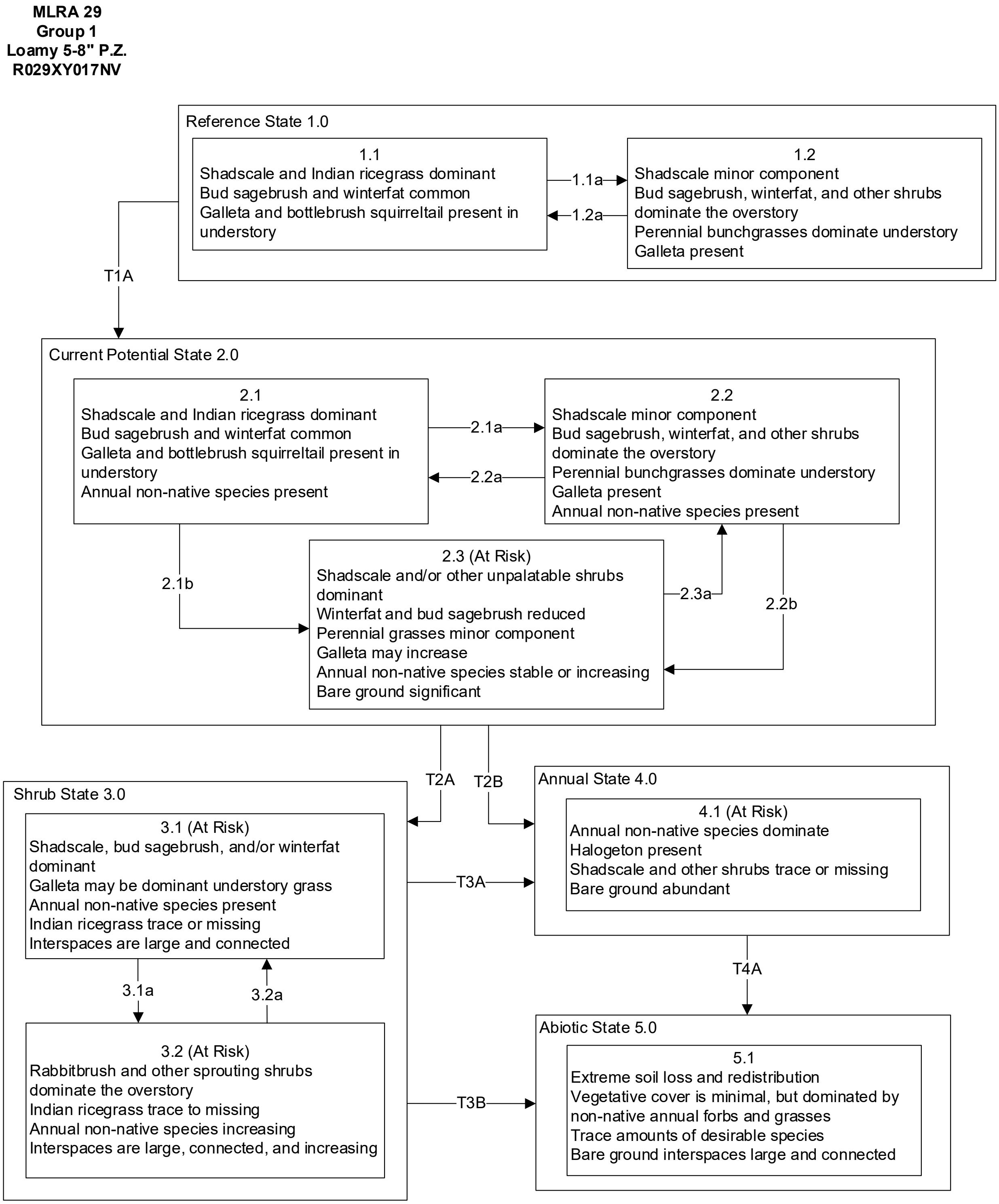
Loamy 3-5" P.Z. R029XY035NV:

This site occurs on alluvial flats of basin floors where slope gradients are flatter than the modal ecological site and precipitation is lower. The reference plant community is dominated by a mix of shrubs – shadscale, Shockley's wolfberry, and bud sagebrush. This site naturally does not carry as much grass as the modal ecological site. Production is typically 150 lb/ac during a normal year.

Stony Slope 5-8" P.Z. R029XY064NV:

This site occurs on summits and sideslopes of hills and lower mountains. The soils are shallow to moderately deep and are formed in residuum from dolomitic limestone. The plant community is dominated by shadscale, Bigelow's sagebrush, ephedra, and desert needlegrass, although the shrub component is variable due to the mosaic of rock outcrop and varying soil depths. Production is approximately 700 lb/ac in a normal year, but is less on shallower soils. Most of the decrease in production on the shallower soils is because of a reduction in desert needlegrass. An Abiotic State is not expected.

Modal State and Transition Model for Group 1 in MLRA 29:



MLRA 29
Group 1
Loamy 5-8" P.Z.
R029XY017NV

Reference State 1.0 Community Phase Pathways
1.1a: Prolonged drought or an unusually wet spring that promotes growth of a pythiaceous fungi reduces the shadscale community. Drought favors other shrubs over shadscale and reallocates resources for bunchgrasses.
1.2a: Absence of drought, insect infestation, and/or disease.

Transition T1A: Introduction of non-native annual species such as halogeton, Russian thistle, cheatgrass and annual mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Prolonged drought or an unusually wet spring makes shadscale more susceptible to insects and disease, reducing the shadscale community and favoring other shrubs and grasses.
2.1b: Inappropriate grazing management reduces deep-rooted perennial bunchgrass community.
2.2a: Release from drought.
2.2b: Release from drought combined with inappropriate grazing management that reduces deep-rooted perennial bunchgrass community.
2.3a: Absence of inappropriate grazing management allows deep-rooted perennial grasses and palatable shrubs to re-establish and/or an unusually wet spring reduces the shadscale community allowing for the reestablishment of desired species.

Transition T2A: Long-term inappropriate grazing management of cattle/horses/burros and/or long-term, chronic drought will reduce perennial bunchgrasses, favoring shrub growth.

Transition T2B: Long-term inappropriate grazing management and/or an unusually wet spring, increasing germination of invasive annual species.

Shrub State 3.0 Community Phase Pathways
3.1a: Long-term inappropriate grazing, brush treatments, or other disturbance reduces non-sprouting shrub community.
3.2a: Time and lack of disturbance that allows for shrub reestablishment.

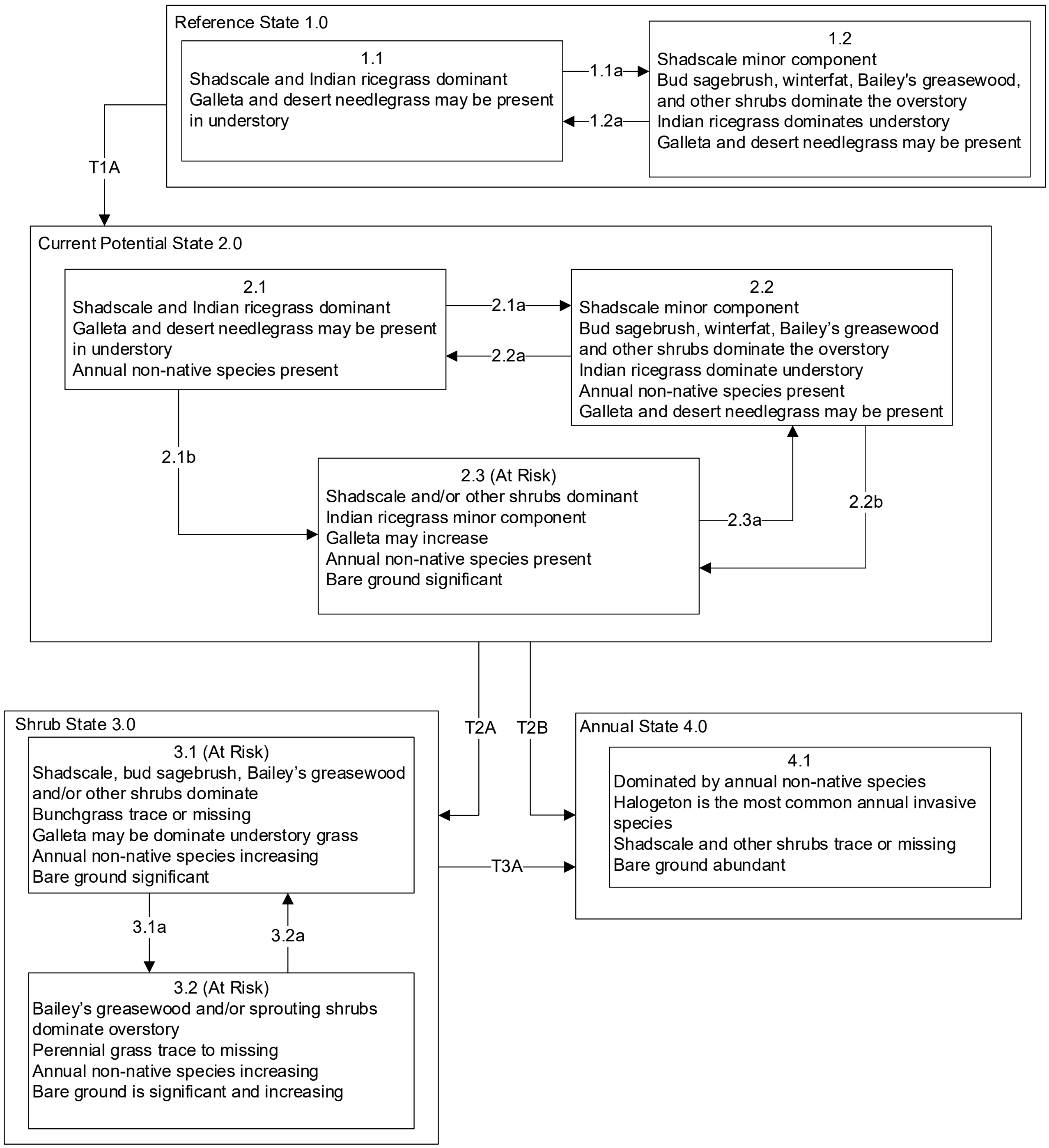
Transition T3A: Long-term inappropriate grazing management, long-term, chronic drought, or an unusually wet spring.

Transition T3B: Long-term, inappropriate grazing management, severe drought, and/or unsuccessful soil disturbing treatments (drill seeding, roller chopper, etc.) combined with significant soil loss and redistribution.

Transition T4A: Long-term, inappropriate grazing management, and/or severe drought, and/or unsuccessful soil disturbing treatments (drill seeding, roller chopper, etc.) combined with significant soil loss and redistribution.

Additional State and Transition Models for Group 1 in MLRA 29:

MLRA 29
Group 1
Loamy Slope 5-8" P.Z.
R029XY022NV



MLRA 29
Group 1
Loamy Slope 5-8" P.Z.
R029XY022NV

Reference State 1.0 Community Phase Pathways
1.1a: Prolonged drought or an unusually wet spring that promotes growth of a pythiaceous fungi reduces the shadscale community. Drought favors other shrubs over shadscale and perennial bunchgrasses.
1.2a: Release from drought, insect infestation, and/or disease.

Transition T1A: Introduction of non-native annual species such as halogeton, Russian thistle, cheatgrass and annual mustards.

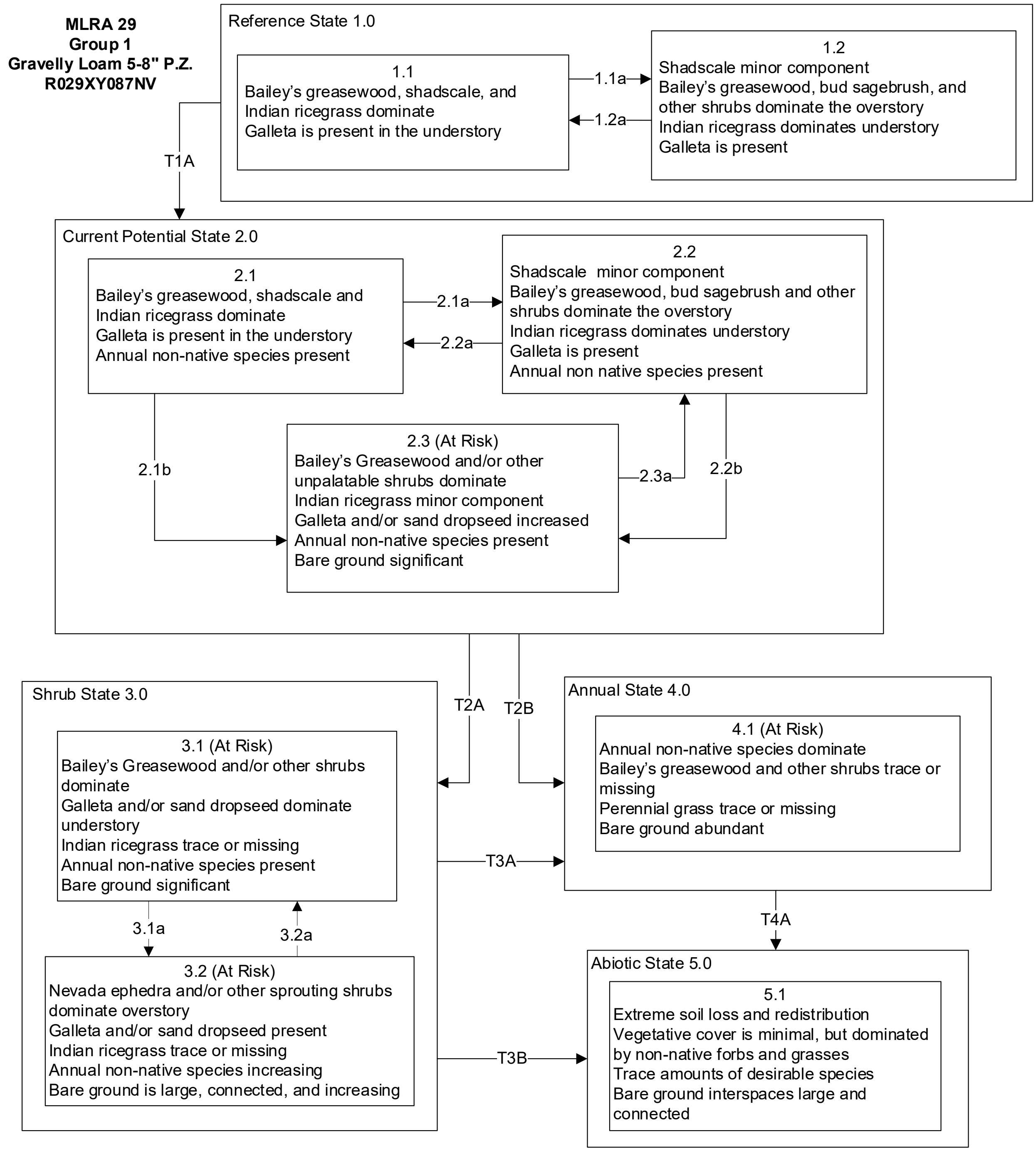
Current Potential State 2.0 Community Phase Pathways
2.1a: Prolonged drought or an unusually wet spring makes shadscale more susceptible to insects and disease, reducing the shadscale community.
2.1b: Inappropriate grazing management reduces deep-rooted perennial bunchgrass community.
2.2a: Release from drought.
2.2b: Release from drought combined with inappropriate grazing management that reduces deep-rooted perennial bunchgrass community.
2.3a: Release from inappropriate grazing management allows deep-rooted perennial grasses and palatable shrubs to re-establish and/or an unusually wet spring reduces the shadscale community allowing for the reestablishment of deep-rooted perennial bunchgrasses.

Transition T2A: Long-term inappropriate grazing management of cattle/horses/burros and/or long-term, chronic drought all reduce perennial bunchgrasses, favoring shrub growth.

Transition T2B: Long-term inappropriate grazing management or an unusually wet spring, increasing germination of invasive annual species.

Shrub State 3.0 Community Phase Pathways
3.1a: Long-term inappropriate grazing and/or other disturbance reduces palatable and/or non-sprouting shrub community.
3.2a: Time and lack of disturbance that allows for non-sprouting shrub reestablishment.

Transition T3A: Long-term inappropriate grazing management, long-term, chronic drought, or an unusually wet spring.



MLRA 29
Group 1
Gravelly Loam 5-8" P.Z.
R029XY087NV
Reference State 1.0
1.1
Bailey's greasewood, shadscale, and
Indian ricegrass dominate
Galleta is present in the understory
1.1a
1.2a
1.2
Shadscale minor component
Bailey's greasewood, bud sagebrush, and
other shrubs dominate the overstory
Indian ricegrass dominates understory
Galleta is present
T1A
Current Potential State 2.0
2.1
Bailey's greasewood, shadscale and
Indian ricegrass dominate
Galleta is present in the understory
Annual non-native species present
2.1a
2.2a
2.2
Shadscale minor component
Bailey's greasewood, bud sagebrush and other
shrubs dominate the overstory
Indian ricegrass dominates understory
Galleta is present
Annual non native species present
2.1b
2.3 (At Risk)
Bailey's Greasewood and/or other
unpalatable shrubs dominate
Indian ricegrass minor component
Galleta and/or sand dropseed increased
Annual non-native species present
Bare ground significant
2.3a
2.2b
T2A
T2B
Shrub State 3.0
3.1 (At Risk)
Bailey's Greasewood and/or other shrubs
dominate
Galleta and/or sand dropseed dominate
understory
Indian ricegrass trace or missing
Annual non-native species present
Bare ground significant
3.1a
3.2a
3.2 (At Risk)
Nevada ephedra and/or other sprouting shrubs
dominate overstory
Galleta and/or sand dropseed present
Indian ricegrass trace or missing
Annual non-native species increasing
Bare ground is large, connected, and increasing
Annual State 4.0
4.1 (At Risk)
Annual non-native species dominate
Bailey's greasewood and other shrubs trace or
missing
Perennial grass trace or missing
Bare ground abundant
T3A
T4A
T3B
Abiotic State 5.0
5.1
Extreme soil loss and redistribution
Vegetative cover is minimal, but dominated
by non-native forbs and grasses
Trace amounts of desirable species
Bare ground interspaces large and
connected

MLRA 29
Group 1
Gravelly Loam 5-8" P.Z.
R029XY087NV

Reference State 1.0 Community Phase Pathways
1.1a: Prolonged drought or unusually wet spring reduces the shadscale component.
1.2a: Release from drought, insect infestation, and/or disease.

Transition T1A: Introduction of non-native annual species such as halogeton, Russian thistle, cheatgrass and annual mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Prolonged drought or an unusually wet spring makes shadscale more susceptible to insects and disease, reducing the shadscale component. Bailey’s greasewood and other drought tolerant shrubs may increase.
2.1b: Inappropriate grazing management reduces deep-rooted perennial bunchgrass community.
2.2a: Release from drought.
2.2b: Release from drought combined with inappropriate grazing management that reduces deep-rooted perennial bunchgrass community.
2.3a: Release from inappropriate grazing management allows deep-rooted perennial grasses to re-establish and/or an unusually wet spring reduces the shadscale component of the community allowing for the reestablishment of deep-rooted perennial bunchgrasses.

Transition T2A: Long-term inappropriate grazing management of cattle/horses/burros and/or long-term, chronic drought will reduce bunchgrasses, favoring shrub growth.

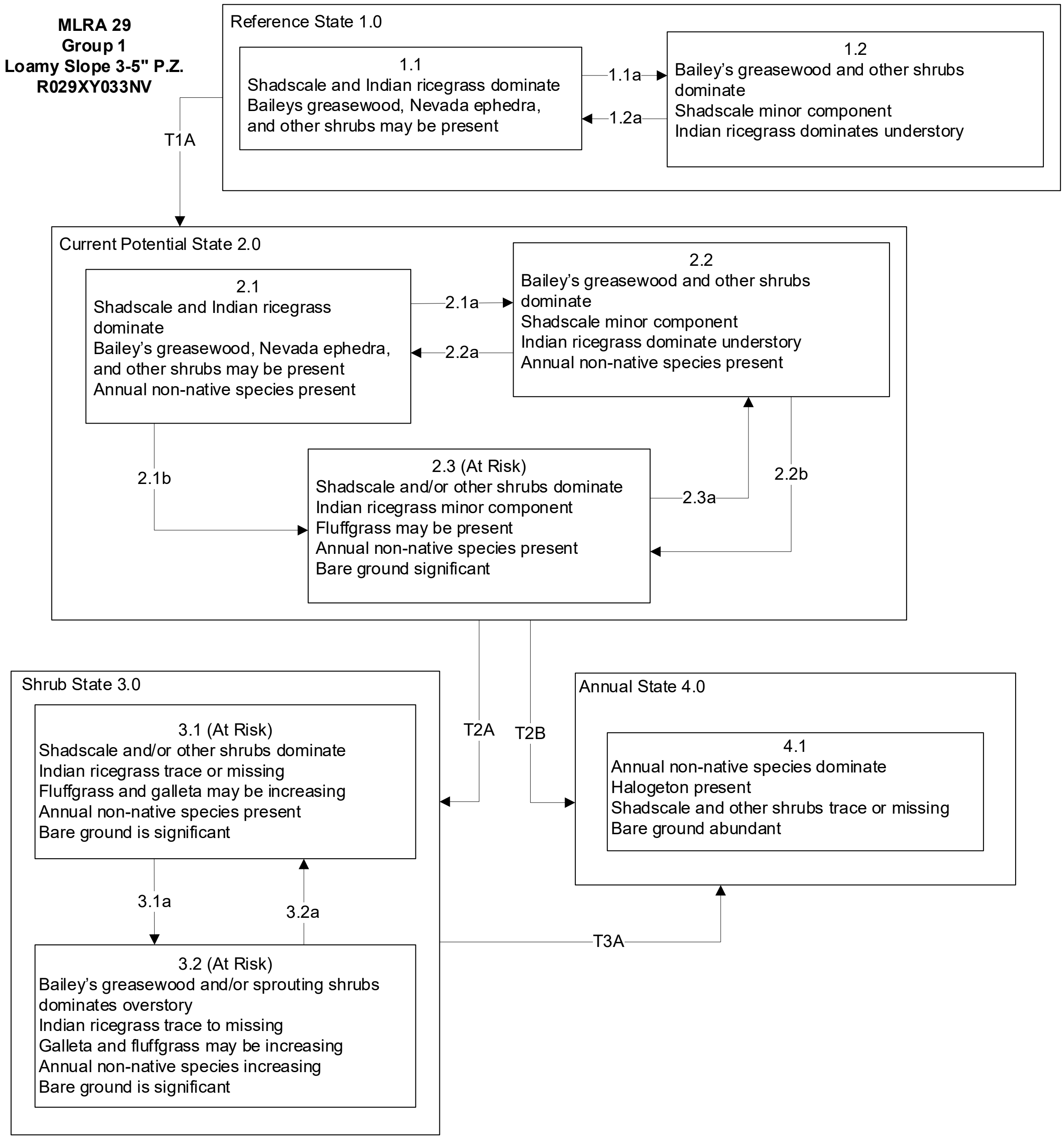
Transition T2B: Long-term inappropriate grazing management and/or an unusually wet spring, increasing germination of invasive annual species.

Shrub State 3.0 Community Phase Pathways
3.1a: Long-term inappropriate grazing, soil disturbance, or other disturbance reduces the palatable and/or non-sprouting shrub community.
3.2a: Time and lack of disturbance that allows for shadscale reestablishment.

Transition T3A: Long-term inappropriate grazing management, long-term, chronic drought, or an unusually wet spring.

Transition T3B: Long-term, extremely inappropriate grazing management, and/or severe drought, and/or unsuccessful soil disturbing treatments (drill seeding, roller chopper, etc.) combined with significant soil loss and redistribution.

Transition T4A: Long-term, inappropriate grazing management, and/or severe drought, and/or unsuccessful soil disturbing treatments (drill seeding, roller chopper, etc.) combined with significant soil loss and redistribution.



MLRA 29
Group 1
Loamy Slope 3-5" P.Z.
R029XY033NV
Reference State 1.0
1.1
Shadscale and Indian ricegrass dominate
Baileys greasewood, Nevada ephedra, and other shrubs may be present
1.1a
1.2a
1.2
Bailey's greasewood and other shrubs dominate
Shadscale minor component
Indian ricegrass dominates understory
T1A
Current Potential State 2.0
2.1
Shadscale and Indian ricegrass dominate
Bailey's greasewood, Nevada ephedra, and other shrubs may be present
Annual non-native species present
2.1a
2.2a
2.2
Bailey's greasewood and other shrubs dominate
Shadscale minor component
Indian ricegrass dominate understory
Annual non-native species present
2.1b
2.3 (At Risk)
Shadscale and/or other shrubs dominate
Indian ricegrass minor component
Fluffgrass may be present
Annual non-native species present
Bare ground significant
2.3a
2.2b
Shrub State 3.0
3.1 (At Risk)
Shadscale and/or other shrubs dominate
Indian ricegrass trace or missing
Fluffgrass and galleta may be increasing
Annual non-native species present
Bare ground is significant
T2A
T2B
Annual State 4.0
4.1
Annual non-native species dominate
Halogeton present
Shadscale and other shrubs trace or missing
Bare ground abundant
3.1a
3.2a
T3A
3.2 (At Risk)
Bailey's greasewood and/or sprouting shrubs dominates overstory
Indian ricegrass trace to missing
Galleta and fluffgrass may be increasing
Annual non-native species increasing
Bare ground is significant

MLRA 29
Group 1
Loamy Slope 3-5" P.Z.
R029XY033NV

Reference State 1.0 Community Phase Pathways
1.1a: Prolonged drought or unusually wet spring reduces the shadscale community.
1.2a: Release from drought.

Transition T1A: Introduction of non-native annual species such as halogeton, Russian thistle, cheatgrass and annual mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Prolonged drought or an unusually wet spring makes shadscale more susceptible to insects and disease, reducing the shadscale community.
2.1b: Inappropriate grazing management reduces deep-rooted perennial bunchgrass community.
2.2a: Release from drought.
2.2b: Release from drought combined with inappropriate grazing management that reduces deep-rooted perennial bunchgrass community.
2.3a: Release from inappropriate grazing management allows deep-rooted perennial grasses to re-establish and/or an unusually wet spring reduces the shadscale community allowing facilitating an increase in shrubs and bunchgrasses.

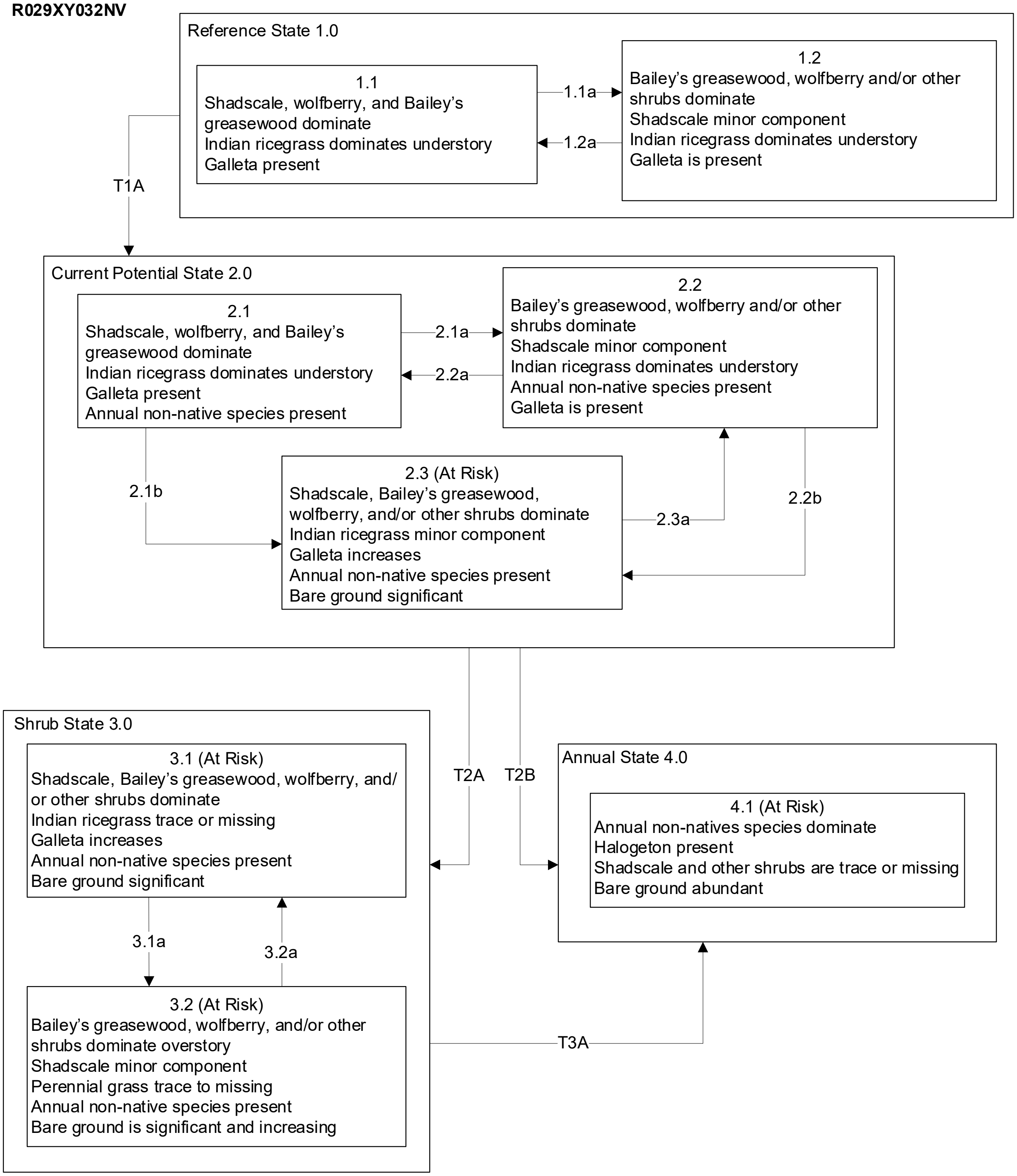
Transition T2A: Long-term inappropriate grazing management of cattle/horses/burros and/or long-term, chronic drought will reduce bunchgrasses, favoring shrub growth.

Transition T2B: Long-term inappropriate grazing management or an unusually wet spring, increasing germination of invasive annual species.

Shrub State 3.0 Community Phase Pathways
3.1a: Long-term inappropriate grazing, soil disturbance, or other disturbance reduces non-sprouting and/or palatable shrub community.
3.2a: Time and lack of disturbance that allows for reestablishment of palatable and/or non-sprouting shrubs.

Transition T3A: Long-term inappropriate grazing management, long-term chronic drought, or an unusually wet spring.

MLRA 29
Group 1
Sodic Loam 3-5" P.Z.
R029XY032NV



MLRA 29
Group 1
Sodic Loam 3-5" P.Z.
R029XY032NV

Reference State 1.0 Community Phase Pathways
1.1a: Prolonged drought or unusually wet spring reduces the shadscale community.
1.2a: Release from drought.

Transition T1A: Introduction of non-native annual species such as halogeton, Russian thistle, cheatgrass and annual mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Prolonged drought or an unusually wet spring makes shadscale more susceptible to insects and disease, reducing the shadscale community.
2.1b: Inappropriate grazing management reduces deep-rooted perennial bunchgrass community.
2.2a: Release from drought.
2.2b: Release from drought combined with inappropriate grazing management that reduces deep-rooted perennial bunchgrass community.
2.3a: Release from inappropriate grazing management allows deep-rooted perennial grasses to re-establish and/or an unusually wet spring reduces the shadscale community allowing for the reestablishment of deep-rooted perennial bunchgrasses.

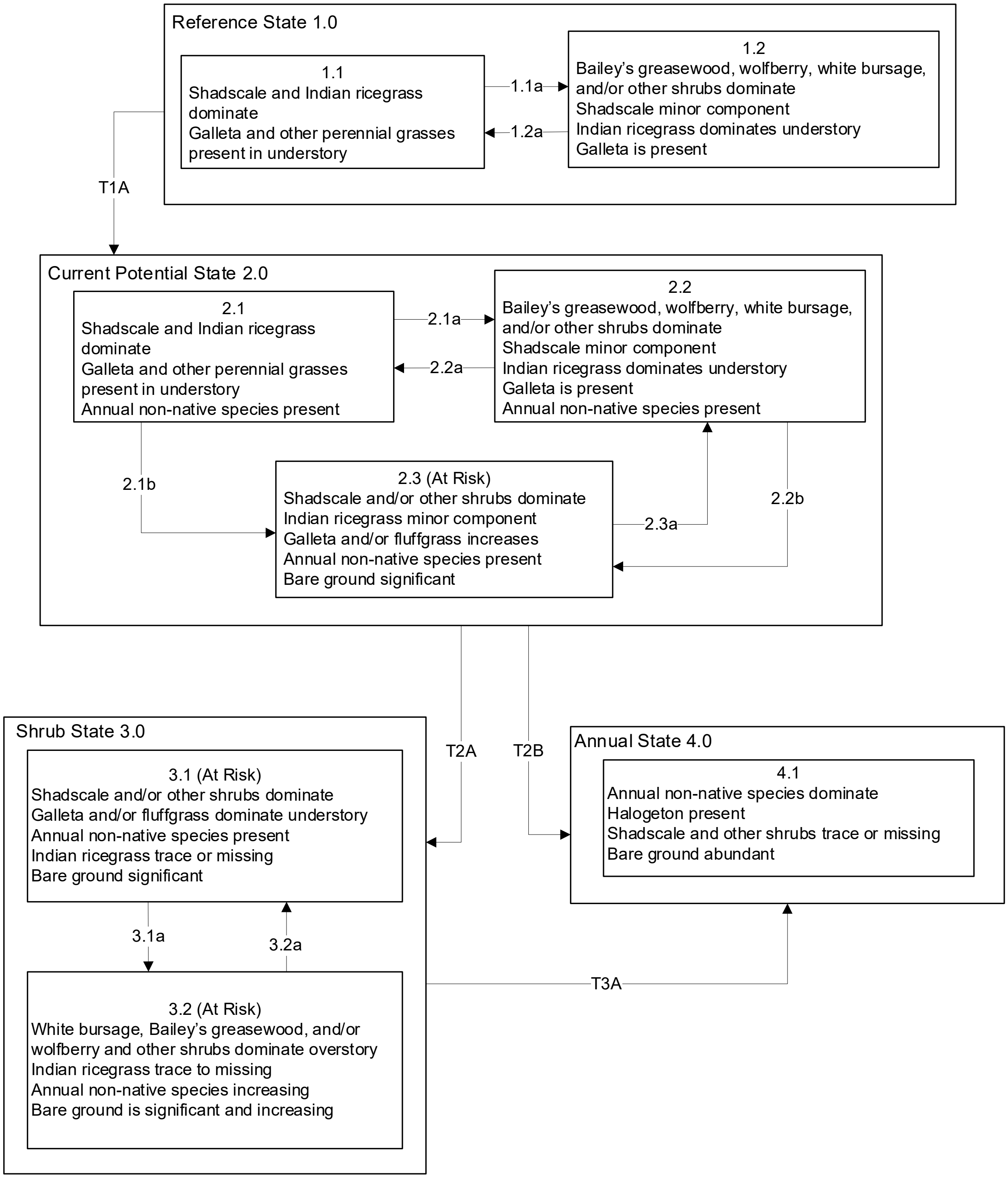
Transition T2A: Long-term inappropriate grazing management of cattle/horses/burros and/or long-term, chronic drought will reduce bunchgrasses and palatable shrubs.

Transition T2B: Long-term inappropriate grazing management, or an unusually wet spring, increasing germination of invasive annual species.

Shrub State 3.0 Community Phase Pathways
3.1a: Long-term inappropriate grazing, soil disturbance, or other disturbance reduces non-sprouting and/or palatable shrub community.
3.2a: Time and lack of disturbance that allows for reestablishment of palatable and/or non sprouting shrubs.

Transition T3A: Long-term inappropriate grazing management, long-term, chronic drought, or an unusually wet spring.

MLRA 29
Group 1
Coarse Gravelly Loam 3-5" P.Z.
R029XY039NV



MLRA 29
Group 1
Coarse Gravelly Loam 3-5" P.Z.
R029XY039NV

Reference State 1.0 Community Phase Pathways
1.1a: Prolonged drought or an unusually wet spring that promotes growth of a pythiaceous fungi reduces the shadscale community. Drought favors other shrubs over shadscale.
1.2a: Absence of drought, insect infestation, and/or disease.

Transition T1A: Introduction of non-native annual species such as halogeton, Russian thistle, cheatgrass and annual mustards.

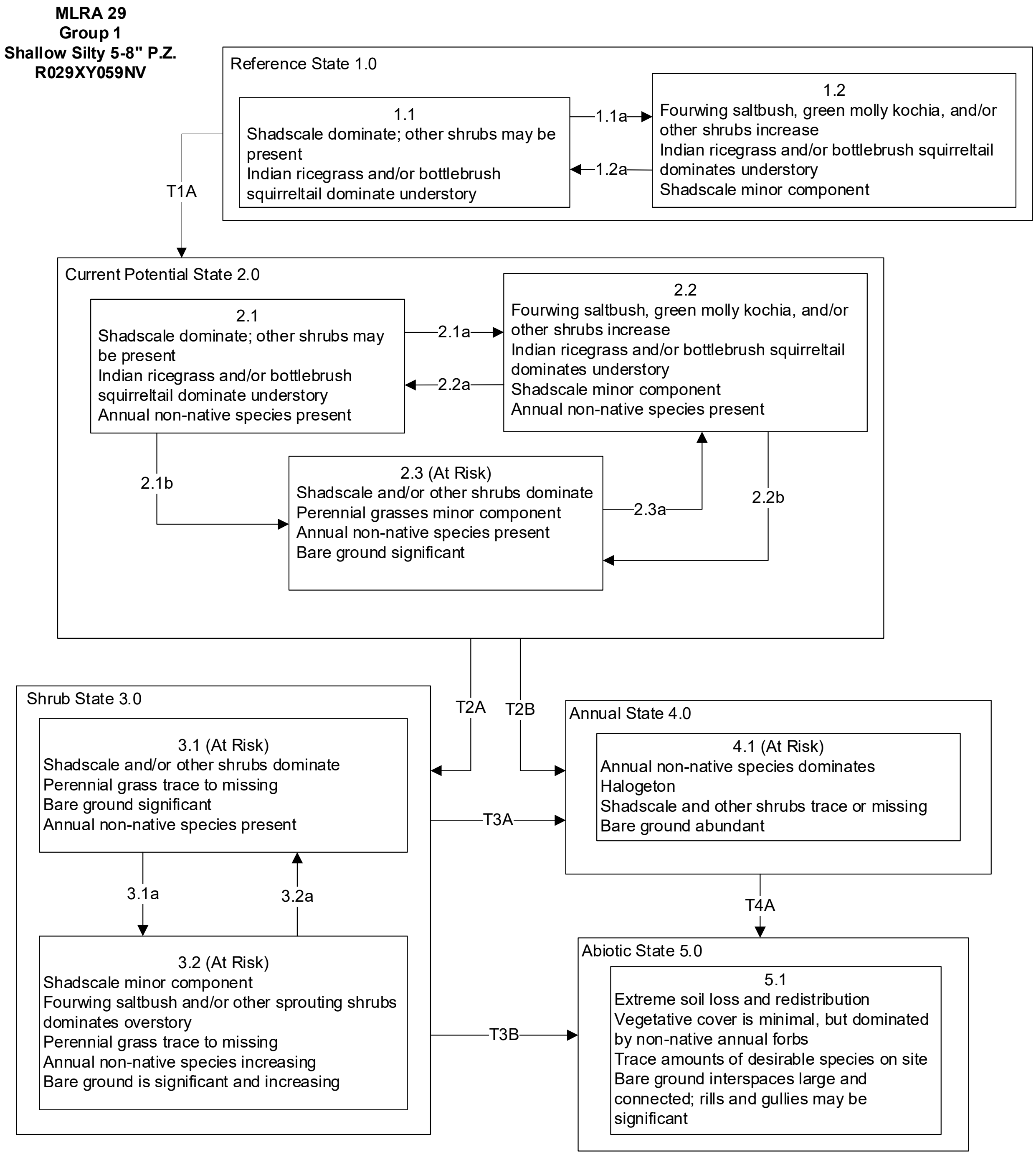
Current Potential State 2.0 Community Phase Pathways
2.1a: Prolonged drought or an unusually wet spring makes shadscale more susceptible to insects and disease, reducing the shadscale community.
2.1b: Inappropriate grazing management reduces deep-rooted perennial bunchgrass community.
2.2a: Release from drought.
2.2b: Release from drought combined with inappropriate grazing management that reduces deep-rooted perennial bunchgrass community.
2.3a: Absence of inappropriate grazing management allows deep-rooted perennial grasses to re-establish and/or an unusually wet spring reduces the shadscale community facilitating an increase in other shrubs and bunchgrasses.

Transition T2A: Long-term inappropriate grazing management of cattle/horses/burros and/or long-term, chronic drought will reduce bunchgrasses, favoring shrub growth.

Transition T2B: Long-term inappropriate grazing management and/or an unusually wet spring, increasing germination of invasive annual species.

Shrub State 3.0 Community Phase Pathways
3.1a: Long-term inappropriate grazing, soil disturbance, or other disturbance reduces non-sprouting shrub community.
3.2a: Time and lack of disturbance that allows for shrub reestablishment.

Transition T3A: Long-term inappropriate grazing management, long-term chronic drought, or an unusually wet spring.


MLRA 29
Group 1
Shallow Silty 5-8" P.Z.
R029XY059NV
Reference State 1.0
1.1
Shadscale dominate; other shrubs may be present
Indian ricegrass and/or bottlebrush squirreltail dominate understory
1.1a
1.2a
1.2
Fourwing saltbush, green molly kochia, and/or other shrubs increase
Indian ricegrass and/or bottlebrush squirreltail dominates understory
Shadscale minor component
T1A
Current Potential State 2.0
2.1
Shadscale dominate; other shrubs may be present
Indian ricegrass and/or bottlebrush squirreltail dominate understory
Annual non-native species present
2.1a
2.2a
2.2
Fourwing saltbush, green molly kochia, and/or other shrubs increase
Indian ricegrass and/or bottlebrush squirreltail dominates understory
Shadscale minor component
Annual non-native species present
2.1b
2.3 (At Risk)
Shadscale and/or other shrubs dominate
Perennial grasses minor component
Annual non-native species present
Bare ground significant
2.3a
2.2b
T2A
T2B
Shrub State 3.0
3.1 (At Risk)
Shadscale and/or other shrubs dominate
Perennial grass trace to missing
Bare ground significant
Annual non-native species present
3.1a
3.2a
3.2 (At Risk)
Shadscale minor component
Fourwing saltbush and/or other sprouting shrubs dominates overstory
Perennial grass trace to missing
Annual non-native species increasing
Bare ground is significant and increasing
T3A
T3B
Annual State 4.0
4.1 (At Risk)
Annual non-native species dominates
Halogeton
Shadscale and other shrubs trace or missing
Bare ground abundant
T4A
Abiotic State 5.0
5.1
Extreme soil loss and redistribution
Vegetative cover is minimal, but dominated by non-native annual forbs
Trace amounts of desirable species on site
Bare ground interspaces large and connected; rills and gullies may be significant

MLRA 29
Group 1
Shallow Silty 5-8" P.Z.
R029XY059NV

Reference State 1.0 Community Phase Pathways
1.1a: Prolonged drought or unusually wet spring reduces the shadscale community.
1.2a: Release from drought.

Transition T1A: Introduction of non-native annual species such as halogeton, Russian thistle, cheatgrass and annual mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Prolonged drought or an unusually wet spring makes shadscale more susceptible to insects and disease, reducing the shadscale community.
2.1b: Inappropriate grazing management reduces deep-rooted perennial bunchgrass community.
2.2a: Release from drought.
2.2b: Release from drought combined with inappropriate grazing management that reduces deep-rooted perennial bunchgrass community.
2.3a: Release from inappropriate grazing management allows deep-rooted perennial grasses to re-establish and/or an unusually wet spring reduces the shadscale community allowing for the reestablishment of deep-rooted perennial bunchgrasses.

Transition T2A: Long-term inappropriate grazing management of cattle/horses/burros and/or long-term, chronic drought will reduce bunchgrass and palatable shrubs.

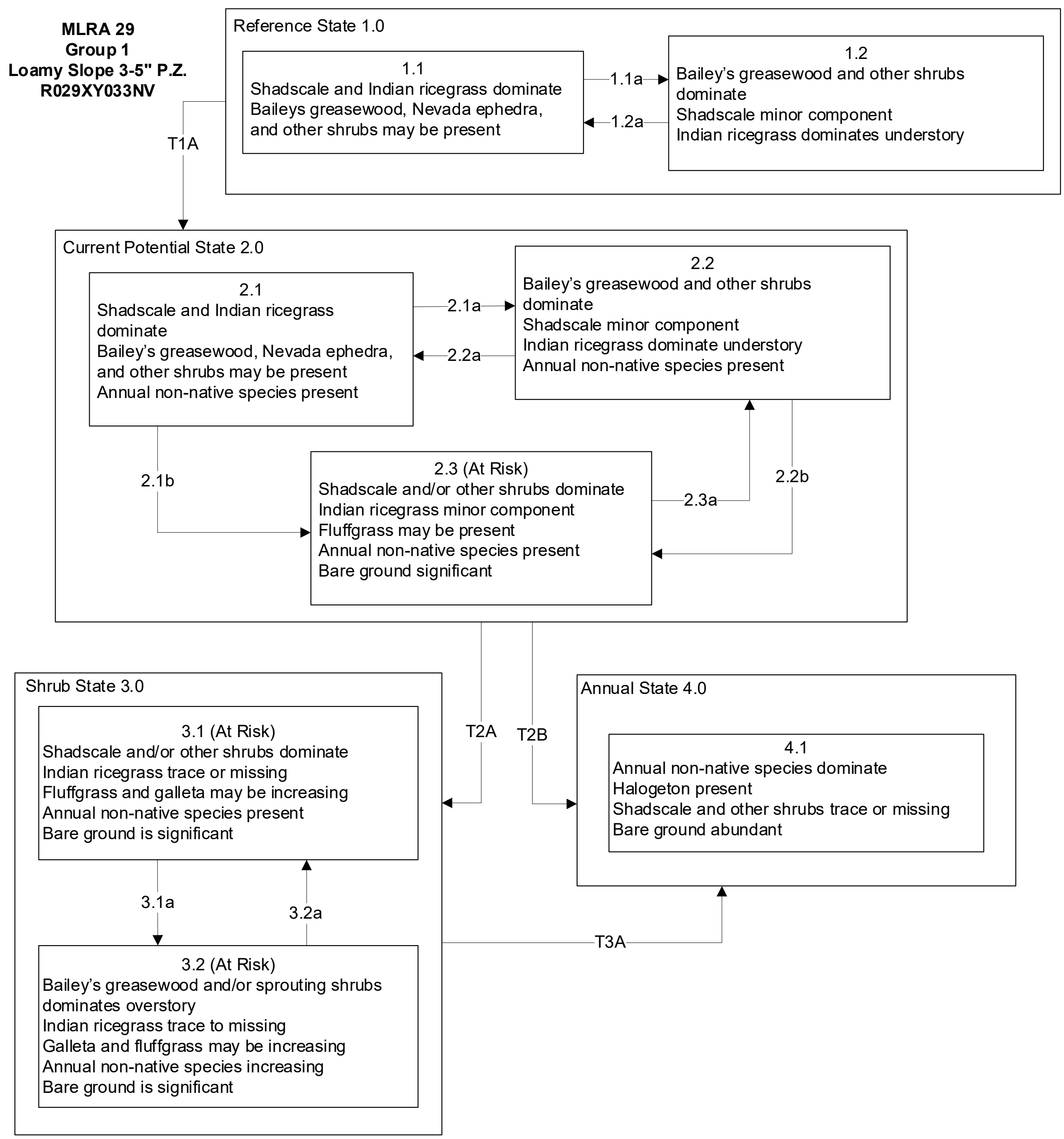
Transition T2B: Long-term inappropriate grazing management, unsuccessful soil disturbing treatments (drill seeding, etc.), or an unusually wet spring.

Shrub State 3.0 Community Phase Pathways
3.1a: Long-term inappropriate grazing, soil disturbance, or other disturbance reduces non-sprouting and/or palatable shrub community.
3.2a: Time and lack of disturbance that allows for establishment of palatable and/or non-sprouting shrubs.

Transition T3A: Long-term inappropriate grazing management, long-term, chronic drought, or an unusually wet spring.

Transition T3B: Long-term, extremely inappropriate grazing management, severe drought, and/or extreme moisture event leading to gully formation. Significant soil loss and redistribution.

Transition T4A: Long-term, extremely inappropriate grazing management, severe drought, and/or extreme moisture event leading to gully formation. Significant soil loss and redistribution.


MLRA 29
Group 1
Loamy Slope 3-5" P.Z.
R029XY033NV
Reference State 1.0
1.1
Shadscale and Indian ricegrass dominate
Baileys greasewood, Nevada ephedra, and other shrubs may be present
1.1a
1.2a
1.2
Bailey's greasewood and other shrubs dominate
Shadscale minor component
Indian ricegrass dominates understory
T1A
Current Potential State 2.0
2.1
Shadscale and Indian ricegrass dominate
Bailey's greasewood, Nevada ephedra, and other shrubs may be present
Annual non-native species present
2.1a
2.2a
2.2
Bailey's greasewood and other shrubs dominate
Shadscale minor component
Indian ricegrass dominate understory
Annual non-native species present
2.1b
2.3 (At Risk)
Shadscale and/or other shrubs dominate
Indian ricegrass minor component
Fluffgrass may be present
Annual non-native species present
Bare ground significant
2.3a
2.2b
T2A
T2B
Shrub State 3.0
3.1 (At Risk)
Shadscale and/or other shrubs dominate
Indian ricegrass trace or missing
Fluffgrass and galleta may be increasing
Annual non-native species present
Bare ground is significant
3.1a
3.2a
3.2 (At Risk)
Bailey's greasewood and/or sprouting shrubs dominates overstory
Indian ricegrass trace to missing
Galleta and fluffgrass may be increasing
Annual non-native species increasing
Bare ground is significant
Annual State 4.0
4.1
Annual non-native species dominate
Halogeton present
Shadscale and other shrubs trace or missing
Bare ground abundant
T3A

Reference State 1.0 Community Phase Pathways
1.1a: Prolonged drought or an unusually wet spring that promotes growth of a pythiaceous fungi reduces the shadscale community. Drought favors other shrubs over shadscale and perennial bunchgrasses.
1.2a: Release from drought, insect infestation, and/or disease.

Transition T1A: Introduction of non-native annual species such as halogeton, Russian thistle, cheatgrass and annual mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Prolonged drought or an unusually wet spring makes shadscale more susceptible to insects and disease, reducing the shadscale community.
2.1b: Inappropriate grazing management reduces deep-rooted perennial bunchgrass community.
2.2a: Release from drought.
2.2b: Release from drought combined with inappropriate grazing management that reduces deep-rooted perennial bunchgrass community.
2.3a: Release from inappropriate grazing management allows deep-rooted perennial grasses to re-establish and/or an unusually wet spring reduces the shadscale community facilitating an increase in shrubs and perennial grasses.

Transition T2A: Long-term inappropriate grazing management of cattle/horses/burros and/or long-term, chronic drought will reduce bunchgrasses, favoring shrub growth.

Transition T2B: Long-term inappropriate grazing management or an unusually wet spring, increasing germination of invasive annual species.

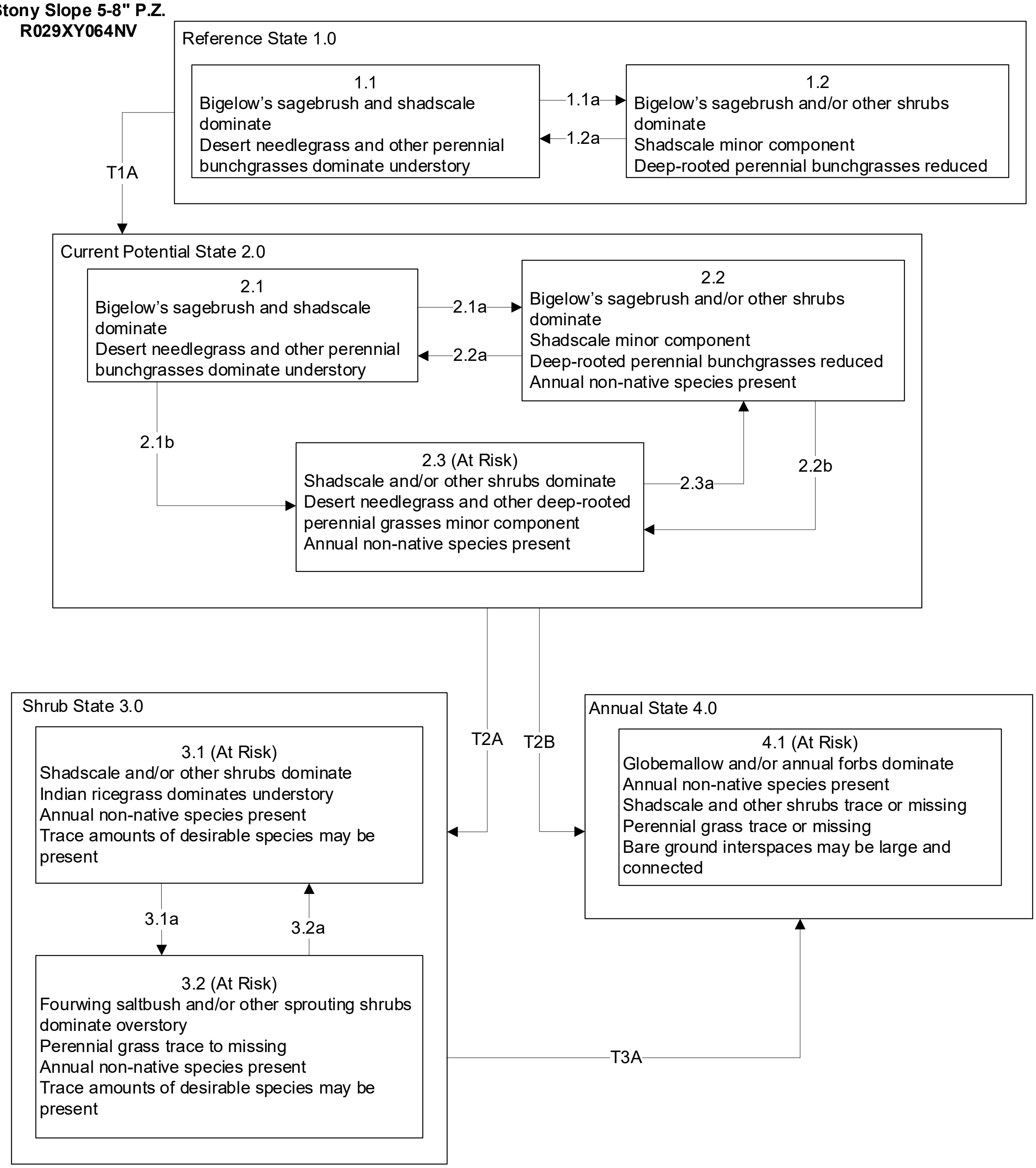
Shrub State 3.0 Community Phase Pathways
3.1a: Long-term inappropriate grazing, soil disturbance, or other disturbance reduces non-sprouting and/or palatable shrub community.
3.2a: Time and lack of disturbance that allows for reestablishment of palatable and/or non-sprouting shrubs.

Transition T3A: Long-term inappropriate grazing management, long-term, chronic drought, or an unusually wet spring.

Transition T3B: Long-term, inappropriate grazing management, severe drought, and/or unsuccessful soil disturbing treatments (drill seeding, roller chopper, etc.) combined with significant soil loss and redistribution.

Transition T4A: Long-term, inappropriate grazing management, severe drought, and/or unsuccessful soil disturbing treatments (drill seeding, roller chopper, etc.) combined with significant soil loss and redistribution.

MLRA 29
Group 1
Stony Slope 5-8" P.Z.
R029XY064NV



Reference State 1.0 Community Phase Pathways
1.1a: Prolonged drought or unusually wet spring reduces the shadscale community.
1.2a: Release from drought.

Transition T1A: Introduction of non-native annual species such as halogeton, Russian thistle, cheatgrass and annual mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Prolonged drought or an unusually wet spring that reduces the shadscale community.
2.1b: Inappropriate grazing management reduces deep-rooted perennial bunchgrass community.
2.2a: Release from drought.
2.2b: Release from drought combined with inappropriate grazing management that reduces deep-rooted perennial bunchgrass community.
2.3a: Release from inappropriate grazing management allows deep-rooted perennial grasses to re-establish and/or an unusually wet spring reduces the shadscale community allowing for the reestablishment of deep-rooted perennial bunchgrasses.

Transition T2A: Long-term inappropriate grazing management of cattle or horses and/or long-term, chronic drought.

Transition T2B: Long-term inappropriate grazing management, unsuccessful soil disturbing treatments (drill seeding, roller chopper, Lawson aerator etc.), or an unusually wet spring.

Shrub State 3.0 Community Phase Pathways
3.1a: Long-term inappropriate grazing, soil disturbance, or other disturbance reduces non-sprouting shrub community.
3.2a: Time and lack of disturbance that allows for shrub reestablishment.

Transition T3A: Long-term inappropriate grazing management, unsuccessful soil disturbing treatments (drill seeding, roller chopper, Lawson aerator etc.), long-term, chronic drought, or an unusually wet spring.

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MLRA 29 Group 2: Alluvial soils with spiny menodora and Indian ricegrass

Description of MLRA 29 Disturbance Response Group 2

Disturbance Response Group (DRG) 2 consists of seven ecological sites. The precipitation ranges from 5 to 10 in. Slopes range from 2 to 75% with 30% or less being typical. Elevation ranges from 4,000 to about 6,500 ft. Annual production for a normal year can range from 125 to 450 lb/ac. Soils are formed from various sources, including volcanic rock, siltstone, basalt, granite, limestone, dolomite, and quartzite, sandstone and ignimbrite. These soils are typically salty and calcareous or carbonatic and are often modified with high amounts of gravel, cobbles, or stones on the surface and throughout the profile. The available water holding capacity ranges from very low to high and is typically moderate. Soils are well-drained; runoff is slow to rapid and the potential for sheet and rill erosion is low to moderate. The soil moisture *regime* is aridic and the soil temperature regime is mesic. The potential native plant community for these sites varies depending on precipitation, elevation, and landform. The reference plant communities are dominated by spiny menodora (*Menodora spinescens*), shadscale saltbush (*Atriplex confertifolia*), bud sagebrush (*Picrothamnus desertorum*), and Nevada jointfir or ephedra (*Ephedra nevadensis*). The perennial grass community is dominated by Indian ricegrass (*Achnatherum hymenoides*), galleta (*Pleuraphis jamesii*), and desert needlegrass (*Achnatherum speciosum*). Other species important to these sites include globemallow (*Sphaeralcea* spp.) and penstemon (*Penstemon* spp.).

Disturbance Response Group 2 Ecological Sites:

Cobbly Loam 5-8" P.Z. – Modal	R029XY036NV
Cobbly Slope 5-8" P.Z.	R029XY037NV
Shallow Cobbly Loam 8-10" P.Z.	R029XY161NV
Granitic Cobbly Loam 8-10" P.Z.	R029XY107NV
Eroded Slope 8-10" P.Z.	R029XY162NV
Shallow Loam 5-8" P.Z.	R029XY074NV
Cobbly Loam 8-10" P.Z.	R029XY038NV

Modal Site:

The Cobbly Loam 5-8" P.Z. ecological site is the modal site that represents this DRG, as it has the most acres mapped. This site occurs on lower piedmont slopes and alluvial flats of basin floors on all aspects. Slopes range from 2 to 30%, though slopes of 2 to 15% are most common. Elevation ranges from 4,500 to 5,500 ft. Annual vegetation production is 300 lb/ac in a normal year, though it ranges from 100 lb/ac in an unfavorable year and up to 400 lb/ac in a favorable year. Approximate ground cover (basal and crown) cover is 4 to 12%. Soils are formed in mixed alluvium from volcanic rock. Soil surfaces are stony or very cobbly, with loamy texture, and subsoils may have a restrictive layer within the main rooting depths. Water intake rates and available water holding capacity are moderate. These soils are well drained, and runoff is medium to slow. The shrub component on this site is primarily dominated by spiny menodora, with other common shrubs including shadscale, Bailey's greasewood (*Sarcobatus baileyi*), Nevada ephedra, and bud sagebrush. The herbaceous component is dominated by Indian ricegrass, with galleta as the sub-dominant grass. Bottlebrush squirreltail (*Elymus elymoides*) and King's desertgrass (*Blepharidachne kingii*) are present in minor amounts. A wide variety of annual and perennial forbs may be present including globemallow, four o'clock (*Mirabilis* spp.), princesplume (*Stanleya* spp.) and rockcress (*Boechera* spp.).

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasives. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans a unique area in Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area. Flashy, summer storm events contribute significantly to annual precipitation as well. Air and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

Periodic drought regularly influences these ecosystems and drought duration, and severity has increased throughout the 20th century in much of the Intermountain West (Miller et al. 2008b). Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006).

The shrub communities that dominate this DRG are characterized by high spatial and temporal variability in precipitation, both over years and within growing seasons. Nutrient availability is typically low but increases with elevation and closely follows moisture availability. The resource supporting the greatest amount of plant growth is usually water stored in the soil profile during the winter (Comstock and Ehleringer 1992). The invasibility of plant communities is often linked to resource availability. Disturbance can increase resources for invasive species through native species mortality or damage. Soil water and nutrient availability can increase with native species mortality and decomposition further aiding invasive species establishment. The introduction of annual non-native species, like cheatgrass (*Bromus tectorum*), may cause an increase in fire frequency. Conversely, increased fire return intervals, driven by inappropriate grazing management and fire suppression, facilitates an increase in woody species cover.

Spiny menodora is a dense, mounded shrub with forked branches that end in sharp thorns and grows about 3 ft tall. It is commonly found in dwarf shrublands of the Great Basin and Mojave Desert alongside Nevada ephedra, spiny hopsage (*Grayia spinosa*), and other shrub species (Evens et al. 2020). Spiny menodora is typically found on rocky hills and dry washes in sparse, spread-out plant communities (Sawyer and Keeler-Wolf 1995). It mainly spreads through seed dispersal on the wind and by birds (Chumley 2007), but plants can sprout when top-killed by fire (Novak-Echenique 2020).

Shadscale is a densely clumped, rounded, compact native shrub. It generally attains heights of 8 to 32 in. and widths of 12 to 68 in. (Blaisdell and Holmgren 1984). Shadscale is considered an evergreen to partially deciduous shrub, since a small percentage of leaves are dropped in the winter (Smith and Nobel 1986). Shadscale possesses wider ecological amplitude than most *Atriplex* species (Crofts and Epps 1975), and shows ploidy levels from diploid (2x) to decaploid (10x). The extensive polyploidy of shadscale is an important consideration when implementing revegetation projects because ploidy levels are usually associated with distinct habitats (Sanderson et al. 1990). Diploid individuals are unlikely to perform as well in areas where tetraploids are more common. Diploid individuals generally occur above Pleistocene Lake levels, whereas lake floors are usually occupied by autotetraploids. Overall, tetraploids are the most widespread throughout its range (Carlson 1984). Thus, the diploid most associated with this site is a tetraploid.

Bud sagebrush, a common shrub in this group, is a native, summer-deciduous shrub. It is low growing, spinescent, and aromatic in nature with a height of 4 to 10 in. and a spread of 8 to 12 in. (Stubbendieck et al. 2017). Chambers and Norton (1993) found that the species does not break dormancy until fall precipitation penetrates the soil and reaches its deep, spreading root structure at 10 to 12 in. It will then produce new leaves but not elongate its stems until spring and go dormant by early summer (Wood and Brotherson 1986). The bud sagebrush root system is able to penetrate deeper into the soil and branch out significantly more than shadscale (Chambers and Norton 1993). This allows the shrub to compete for valuable resources.

Nevada ephedra can be found in small clumps or large, independent stands in various plant communities, including sagebrush, desert shrub, and pinyon-juniper communities (Stanton 1973). Nevada ephedra is a dominant plant community in Nevada (West et al. 1998) and can be codominant with many species, including spiny menodora, winterfat (*Krascheninnikovia lanata*), yellow rabbitbrush (*Chrysothamnus viscidiflorus*), desert bitterbrush (*Purshia glandulosa),* and others (Minnich 1999). Nevada ephedra primarily reproduces by seed (Welsh et al. 1987), but plants can produce through crown sprouting in response to disturbance such as fire or herbicide (Hunter et al. 1978).

The primary perennial grasses include Indian ricegrass and galleta. These species have shallower root systems than the shrubs, but root densities are often as high as or higher than those of shrubs in the upper 20 in. of the soil profile. General differences in root depth distributions between grasses and shrubs result in resource partitioning in these shrub/grass systems (Lee and Lauenroth 1994).

Indian ricegrass is a long-lived, cool-season perennial bunchgrass that grows from 4 to 24 in. in height (Blaisdell and Holmgren 1984). Primarily adapted to coarse textured soils, its deep, fibrous root system makes Indian ricegrass one of the most drought-tolerant native species (Booth et al. 1980). Unlike other cool-season species, Indian ricegrass does not require vernalization (exposure to cold) to produce flowers and flowering can continue into late fall with favorable environmental conditions. This allows the seeds in each panicle to ripen over a longer period of time than most other species thus providing a greater opportunity for successful seed production (Jones 1990).

Galleta is a mat-forming, rhizomatous, native grass that is 11 to 19 in. tall (Stubbendieck et al. 1992). This warm-season, perennial species is more water efficient than its cool-season counterparts. This allows galleta grass to survive in low precipitation zones where a significant portion of rainfall occurs during summer months (Banner et al. 2011). Everett et al. (1980) found that galleta grass initiated more than one phenological cycle with summer precipitation, allowing the species to grow and set seed more than once. This plant is typical of southern Nevada and the transition zone between the Great Basin and the Mojave Desert. It is most common in fine-textured soils (Stubbendieck et al. 1992).

Bottlebrush squirreltail is a short, cool-season bunchgrass that grows between 4 to 45 in. tall. It is an allotetraploid that can self-pollinate and hybridize with other grasses, including other species of *Elymus* and some species of *Hordeum* (barley) (Welsh et al. 1987). Squirreltail is a very adaptable grass that is found across western North America in the United States, Canada, and Mexico. Squirreltail can be found above 2,000 ft in elevation, and in areas that receive at least 5 in. of precipitation per year (Welsh et al. 1987). Squirreltail is commonly found in shadscale or sagebrush communities along with other perennial bunchgrasses (Medin 1990).

King's desertgrass, or King's eyelashgrass, is a warm-season, densely tufted perennial bunchgrass that grows up to 4 in. tall (Welsh et al. 1987, Huang et al. 2022). It is widespread across the Great Basin and is found in California, Utah, and Oregon (Olson 2019). King's desertgrass is typically found in the understory of shadscale and sagebrush communities on dry, calcareous, gravelly, or rocky, limestone basin floors, slopes, and washes, typically from 4,000 to 6,200 ft (Welsh et al. 1987, Kartesz 1988).

Annual Invasive Species:

The sites in this DRG are not likely to be dominated by annual non-native grasses or forbs. However, trace amounts of cheatgrass, halogeton (*Halogeton glomeratus*), and Russian thistle (*Salsola tragus*) are common. The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and depress competition or increase resource pools by the decomposition of dead plant material. Excessive grazing pressure during settlement and into the 20th century has increased the overall presence of cheatgrass, Halogeton, Russian thistle, and weedy mustard species (*Brassica* spp.) (Peters and Bunting 1994).

The species most likely to invade the ecological sites in this DRG is cheatgrass. Cheatgrass is a cool-season annual grass that maintains an advantage over native plants, in part, because it is a prolific seed producer, can germinate in the autumn or spring, tolerates grazing, and increases with frequent fire (Klemmedson and Smith 1964, Miller et al. 1999). Cheatgrass originated from Eurasia and was first reported in North America in the late 1800s (Furbush 1953, Mack and Pyke 1983). Bradley et al. (2018) found that cheatgrass has expanded to greater than 15% cover over 210,000 km^2 (130,488 mi^2), roughly 31% of the Intermountain West. In the Great Basin, cheatgrass is expanding at a rate of expansion of 3,700 km^2 (2,300 mi^2) annually and is a land management issue that will require creative solutions (Smith et al. 2022). Mapping potential or current invasion vectors is a management method designed to increase the cost-effectiveness of control methods. Recent modeling and empirical work by Lauenroth and Bradford (2006) suggest that seasonal patterns of precipitation input and temperature are also key factors determining regional variation in the growth, seed production, and spread of invasive annual grasses. The phenomenon of cheatgrass "die-off" provides opportunities for restoration of perennial native species (Baughman et al. 2016, Baughman et al. 2017). The causes of these events are not fully understood, but there is ongoing work to try to predict where they occur, in the hopes of aiding conservation planning (Weisberg et al. 2017, Brehm 2019).

Halogeton is an introduced, succulent annual of the goosefoot family (*Chenopodiaceae*) native to semi-desert lands in the Altai region of central Asia. It possesses a strong taproot that penetrates 4 to 5 in. and an extensive root system spanning up to 2 ft in lateral spread and depth (Tisdale and Zappetini 1953). Halogeton is characterized by its small fleshy leaves that can appear slightly red or purple as the plants matures (BIA 2022). This plant can produce as many as 25,000 seeds while typical plants sizes of about 3 in. can produce up to 800. These seeds are spread minorly through wind with the majority coming from fruit ingestion and movement (Tisdale and Zappetini 1953). Halogeton is well adapted to alkaline and saline soils and is prevalent on disturbed and overgrazed sites (BIA 2022). These plants accumulate salt that can leach from dead plant materials, increasing the soil salinity in top soil, which favors continued germination and spread in invaded sites (BIA 2022).

Russian thistle is a tap-rooted, C4 photosynthesis (warm-season) annual forb, introduced from southeastern Europe and central Asia. The seeds have a remarkable capability to germinate in a variety of soil temperatures and very little precipitation and even move back into dormancy after initial germination (Wallace et al. 1968). The seeds, however, are not persistent and generally remain viable in the seed bank for less than two years (Boerboom 1993, Young et al. 1995). Russian thistle has been observed to provide initial establishment in completely de-vegetated sites and create a microsite habitat that may allow increased establishment of other species (Allen and Allen 1988). The successful establishment of other species, particularly later seral species that form mycorrhizal associations, may reduce the cover of Russian thistle as mycorrhizal inoculation has been observed to reduce the size and vigor of Russian thistle while encouraging later seral species such as perennial bunchgrasses (Johnson 1998b).

Fire Ecology:

The mean fire return interval for saltbush desert scrub communities is estimated at 237 to 1,978 years (LANDFIRE 2020). Although the fire return interval is long for this DRG, spiny menodora is tolerant to fire due to its morphology and sprouting ability. Plant communities dominated by spiny menodora are typically sparse and individual plants are widely spaced (Sawyer and Keeler-Wolf 1995). In addition, the dense, woody branches of spiny menodora do not burn easily, and if the plant is top-killed by fire, it readily sprouts (Moody et al. 2010). These characteristics make spiny menodora tolerant of fire, and it is likely to dominate the site after low-severity fire.

Shadscale and bud sagebrush do not sprout, and establishment occurs only from seed (Banner 1992, West 1994). The increased presence of non-native annual grasses has greatly altered fire regimes in areas of the Intermountain West where shadscale is a dominant vegetation type, however, annual non-native species invasion and increased fire frequency has not been observed in this DRG in MLRA 29.

Nevada ephedra typically sprouts after being top-killed by low-severity fire (Bates 1983). However, high-severity fire may kill belowground regenerative structures (McLaughlin and Bowers 1982). The communities in which Nevada ephedra is found can have varied fire regimes. Periods of increased precipitation can lead to an increased amount of annual grasses on the site, which can fuel more intense fires (McLaughlin and Bowers 1982), while fires are smaller and less frequent on sites with lower grass density (Paysen et al. 2000).

The condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species' response. Thus, fire mortality is correlated to duration and intensity of heat, which is related to culm density, culm-leaf morphology, size of the plant, and abundance of old growth (Wright 1971, Young 1983). Boyd et al. (2015) found soil color and depth of burn to be accurate predictors of bunchgrass mortality in post fire landscapes. They also found that bunchgrasses in close proximity of shrubs had up to five-fold higher mortality than bunchgrasses located in the interspaces.

Indian ricegrass is fairly fire tolerant (Wright 1985), which is likely due to its low culm density and below ground plant crowns. Vallentine (1989) cites several studies in the sagebrush zone that classified Indian ricegrass as being slightly damaged from late summer burning. Indian ricegrass has also been found to reestablish on burned sites through seed dispersed from adjacent unburned areas (Young 1983, West 1994). Thus, the presence of surviving, seed-producing plants facilitates the reestablishment of this species. Grazing management following fire to promote seed production and establishment of seedlings is important. When properly planted and managed, Indian ricegrass can be a key factor in a community recovering from disturbance because it can grow in rough, rocky, coarse, and otherwise unattractive soils (Booth et al. 1980).

Galleta grass has been found to increase following fire likely due to its rhizomatous root structure and ability to resprout (Jameson 1962). Sandberg's bluegrass, another minor component of these ecological sites, has also been found to increase following fire due to its low stature, early dormancy, and low productivity (Daubenmire 1975). Both grass species may retard reestablishment of deeper-rooted bunchgrasses.

Squirreltail is a short-lived perennial grass adapted to a broad suite of environmental conditions. It is found in plant communities ranging from salt desert scrub to alpine meadows, from 2,000 to 11,500 ft in elevation, from Mexico to British Columbia (Monsen et al. 2004b). Bottlebrush squirreltail is considered one of the most fire-resistant bunchgrasses due to its small size, coarse stems, and sparse leafy material (Wright and Klemmedson 1965, Wright 1971, Britton et al. 1990). Post-fire regeneration occurs from surviving root crowns and from on- and off-site seed sources (Bradley et al. 1992). Squirreltail reproduces primarily through seed. The long awns of the fruit allow for wind dispersal up to 130 ft away from the parent plant (Hironaka and Tisdale 1963, Marlette and Anderson 1986). Bottlebrush squirreltail has the ability to produce large numbers of highly germinable seeds, with relatively rapid germination (Young and Evans 1977) when exposed to the correct environmental cues. Squirreltail is capable of facultative fall or spring germination, developing extensive roots at low temperatures, and producing seeds early in the season (Reynolds and Fraley 1989, Hironaka 1994, Monsen et al. 2004b). Recent research indicates that squirreltail is capable of relatively rapid natural selection to improve survival in low-water, competitive environments (Kulpa and Leger 2013). These traits and others make squirreltail competitive with cheatgrass and medusahead (Hironaka and Sindelar 1975, Hironaka 1994).

Livestock/Wildlife Grazing Interpretations:

The seeds and stalks of spiny menodora are not particularly attractive forage for wildlife, though some herbivores will occasionally eat it (Chumley 2007). It provides important habitat for many bird species and is often the shrub species that most significantly impacts bird population density in an area, especially the black-throated sparrow (*Amphispiza bilineata*) and ash-throated flycatcher (*Myiarchus cinerascens*) (Hamilton 1999). Spiny menodora has low palatability, but it is grazed by cattle and elk in the spring before the stems become woody and spiny (Moody et al. 2010).

Shadscale is a valuable browse species for a wide variety of wildlife and livestock (Blaisdell and Holmgren 1984). The spinescent growth habit of shadscale lends to its browsing tolerance with no more than 15 to 20% utilization by domestic sheep being reported (Blaisdell and Holmgren 1984) and significantly less utilization by cattle. Increased presence of shadscale within grazed versus ungrazed areas is generally a result of the decreased competition from more heavily browsed associates (Cibils et al. 1998). Reduced competition from more palatable species in heavily grazed areas may increase shadscale germination and establishment. Chambers and Norton (1993) found shadscale establishment higher under spring than winter browsing as well as heavy compared to light browsing. During years of below average precipitation, shadscale has been found to be very susceptible to grazing pressure regardless of season (Chambers and Norton 1993). Following fire, grazing exclusion for two or more years is beneficial for revegetation of shadscale communities as first year shadscale seedlings lack spines and are highly susceptible to browsing. Spines develop in the second year (Zielinski 1994).

Bud sagebrush is also a palatable, nutritious forage for upland game birds, small game, big game and domestic sheep (*Ovis aries*) in winter, particularly late winter (Johnson 1978); however, it can be poisonous or fatal to calves when eaten in quantity (Stubbendieck et al. 1992). Bud sagebrush is highly susceptible to effects of browsing. It decreases under browsing due to year-long palatability of its buds and is particularly susceptible to browsing in the spring when it is physiologically most active (Harper et al. 1990, Chambers and Norton 1993). Heavy browsing (>50%) may kill bud sagebrush rapidly (Wood and Brotherson 1986). Sheep find bud sagebrush palatable, especially in winter (Johnson 1978), while it is slightly toxic and less palatable to cattle (Stubbendieck et al. 1992). Winterfat, on the other hand, is highly palatable to both cattle and domestic sheep, but is not a preferred forage species for sheep (Sampson and Jespersen 1963, Severson and May 1967). Due to this difference in preference, the type of grazer present in a bud sagebrush/winterfat community can tip the composition of the plant community in favor of one species or another.

Winterfat, a highly nutritious winter feed species that is present in small amounts on these sites, shows similar results to bud sagebrush with significant declines in density with late winter or early spring grazing (Harper et al. 1990). Interestingly the same 54-year study also showed winterfat density decreasing in the ungrazed plots. Winterfat is a valuable forage species with an average of 10% crude protein during winter when there are few nutritious options for livestock and wildlife (Welch 1989). However, excessive grazing throughout the West has negatively impacted the survival of winterfat stands (Hilton 1941, Statler 1967, Stevens et al.

1977). Time of grazing is critical for winterfat with the active growing period being most critical (Romo et al. 1995). Stevens et al. (1977) found that both vigor and reproduction of winterfat were reduced in Steptoe Valley, Nevada by improper season of use, and he recommended no more than 25% utilization during periods of active growth and up to 75% utilization during dormant season use. Rasmussen and Brotherson (1986) found significantly greater foliar cover and density of winterfat in areas ungrazed for 26 years versus winter grazed areas in Utah. In exclosures protected from grazing between 5 and 16 years, (Rice and Westoby 1978) found that winterfat increased in foliar cover but not in density where it was dominant, and in both foliar cover and density in shadscale-perennial grass communities where it was not dominant.

In addition to grazing by cattle (*Bos taurus*), winterfat is browsed by rabbits, antelope, and other wildlife species (Stevens et al. 1977, Ogle et al. 2001). Winterfat and perennial grasses average 80% of jackrabbits' diet in southeastern Idaho, with shrubs being grazed in fall and winter particularly (Johnson and Anderson 1984). Pronghorn (*Antilocapra americana*) and rabbits browse stems, leaves, and seed stalks of winterfat year-round, especially during periods of active growth (Stevens et al. 1977). Management of wildlife browse is difficult, and browse may be harmful to winterfat reestablishment as seed production and regrowth are curtailed if grazing occurs as the plant begins to grow (Eckert 1954).

Nevada ephedra is grazed by livestock and wildlife year-round. Its relative abundance in winter makes it valuable forage when other shrub production decreases, and cattle, sheep, goats, and mule deer (*Odocoileus hemionus*) consume large amounts of ephedra in the winter (Dayton 1931). When new growth is available in spring and summer, ephedra is browsed by mule deer, bighorn sheep (*Ovis canadensis*), and pronghorn (Beale and Smith 1970). Nevada ephedra provides cover for pronghorn, small mammals, and both game and nongame birds (Dittberner and Olson 1983). Small mammals and birds eat Nevada ephedra seeds (Meyer 2008b).

Indian ricegrass is a preferred forage species for livestock and wildlife and cures well, providing nutritious winter feed (Cook 1962, Booth et al. 1980). It is also readily utilized in early spring, being a source of green feed before most other perennial grasses have produced new growth (Quinones 1981). Booth et al. (1980) note that the plant does well when utilized in winter and spring. In eastern Idaho, productivity of Indian ricegrass was at least 10 times greater in undisturbed plots than in heavily (60% utilization) grazed ones (Pearson 1965). Cook and Child (1971) found significant reduction in crown cover, plant vigor and herbage yield of Indian ricegrass when the species was utilized at 90% during any season. However, they found no reductions at 30% utilization during any season and no reductions at 60% utilization during winter and early spring grazing (Cook and Child 1971). The seed crop may be reduced where grazing is heavy (Bich et al. 1995). Tolerance to grazing increases after May, thus, spring deferment may be necessary for stand enhancement (Pearson 1964, Cook and Child 1971); however, utilization of less than 60% is recommended. In summary, adaptive management is required to manage this bunchgrass well.

Galleta is a highly palatable forage species for cattle, sheep, deer, antelope, and horses (*Equus ferus*) during late spring and summer while it is green (Stubbendieck et al. 2017). Due to its rhizomatous characteristics, galleta grass is particularly tolerant of heavy grazing and trampling (Pratt et al. 2002). This species will also initiate more than one phenological cycle if summer precipitation is present (Everett et al. 1980), allowing galleta to grow and propagate after defoliation.

King's eyelashgrass (also known as King's desertgrass), is a densely-tufted perennial bunchgrass that grows 2 to 10 cm tall (1 to 4 in.) (Welsh et al. 1987). King's eyelashgrass is typically found in the understory of shadscale and sagebrush communities on dry, calcareous, gravelly or rocky, limestone basin floors, slopes, and washes, typically from 4,000 to 6,200 ft (Welsh et al. 1987, Kartesz 1988). Despite its relative abundance in some areas, King's eyelashgrass is unpalatable to livestock due to its sharp-pointed blades and low stature (Holmgren and Holmgren 1977).

Inappropriate grazing management during the spring growing season will cause a decline in understory plants such as Indian ricegrass and galleta. Growing season grazing by cattle several years in a row causes a decrease in the bunchgrass component and gives a competitive advantage to shrub species (Eckert et al. 1972). Reduced bunchgrass vigor or density provides an opportunity for galleta and/or Sandberg bluegrass expansion to occupy interspaces. Galleta and/or Sandberg bluegrass increases under grazing pressure (Jameson 1962, Tisdale and Hironaka 1981).

State and Transition Model Narrative for Group 2:

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 29 Disturbance Response Group 2.

Reference State 1.0:

The Reference State 1.0 is representative of the natural range of variability under pristine conditions. The reference state has two general community phases: a shrub-grass dominant phase and a shrub dominant phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. Reference state is a functional ecological state with high resilience to disturbance, characterized by the presence of all key structural and functional plant groups. Community phases occur across a shifting mosaic are influenced by chronic drought cycles, variable herbivory pressures, and an insect or disease attack.

Community Phase 1.1:

This community is co-dominated by spiny menodora and Indian ricegrass, with galleta and other perennial grasses present in minor amounts. Shrubs such as bud sagebrush, Nevada ephedra, and shadscale are common. Bare ground is common and shrub production is significantly higher than grass production. Potential vegetative composition by air-dry weight is 20% grasses, 5% forbs and 75% shrubs. Approximate ground cover (basal and crown) is 4 to 12%. Total annual air-dry production ranges from 100 to 400 lb/ac.

Cobbly Slope 5-8" P.Z. (R029XY037NV), Reference State 1.1, T. Stringham, May 2021

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
Chronic, multi-year drought and/or inappropriate herbivory can result in a substantial decline of the perennial bunchgrass component. Herbaceous cover is reduced, leading to increased dominance by shrubs, especially spiny menodora and bud sagebrush. Bare ground may further increase.

Community Phase 1.2:
This phase is dominated by a high density of shrubs, particularly spiny menodora and bud sagebrush. Perennial bunchgrasses are reduced in density and/or production. Galleta may be increasing. Sites in this phase often show signs of past drought stress or prolonged ungulate use.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0:

Trigger: Introduction of non-native annual species.

Slow variables: Over time, the annual non-native plants will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

This state is similar to the Reference State 1.0 with two community phases. Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of invasive species. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-native high seed output, persistent seed bank, rapid growth rate, ability to cross-pollinate, and adaptations for seed dispersal. Additionally, the presence of highly flammable, non-native species reduces State resilience because these species can promote fire where historically fire has been infrequent, leading to positive feedbacks that further the degradation of the system.

Community Phase 2.1:
This community is co-dominated by spiny menodora and Indian ricegrass, with galleta and other perennial grasses present in minor amounts. Shrubs such as bud sagebrush, Nevada ephedra, and shadscale are common. Bare ground is common and shrub production is significantly higher than grass production. Trace amounts of invasive species are present.

Cobbly Loam 5-8" P.Z. (R029XY036NV), Current Potential State 2.1, T. Stringham, September 2023

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
Chronic, multi-year drought and/or inappropriate grazing, including wild horses and burros, can result in a substantial decline of the perennial grass component. Herbaceous cover is reduced, leading to increased dominance by shrubs, especially spiny menodora and bud sagebrush. Bare ground may further increase.

Community Phase 2.2:
Spiny menodora comprises the majority of shrub cover. Bud sagebrush, shadscale and other shrubs may increase. Perennial bunchgrasses are reduced in density and/or production. Galleta may be increasing. Sites in this phase often show signs of past drought stress or prolonged inappropriate grazing management or wildlife/horse/burro use.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Recovery of the grass component is possible but contingent on significant changes to land use, such as appropriate grazing management and favorable climatic conditions. Even degraded sites can show early signs of deep-rooted perennial grass recruitment in some microsites, particularly where shrub cover provides shade and wind protection.

T2A: Transition from Current Potential State 2.0 to Shrub State 3.0:

Trigger: To Community Phase 3.1: Inappropriate cattle/horse/burro grazing will decrease or eliminate deep-rooted perennial bunchgrasses, increase galleta grass and favor shrub growth and establishment.

Slow variables: Long-term decrease in deep-rooted perennial grass density.

Threshold: Loss of deep-rooted perennial bunchgrasses changes nutrient cycling, nutrient redistribution, and reduces soil organic matter.

Shrub State 3.0:

This state has one community phases in which the overstory is dominated by either spiny menodora or sprouting shrubs such as yellow rabbitbrush, broom snakeweed (*Gutierrezia sarothrae*), and/or ephedra. Galleta grass may dominate the understory. A site in this state has crossed a biotic threshold and site processes are being controlled by shrubs. Site resources such as soil water, nutrient capture, nutrient cycling, and soil organic matter are temporally and spatially redistributed by the vegetation composition. Bare ground has increased and pedestalling of grasses may be excessive.

Community Phase 3.1:
Spiny menodora is the primary overstory species with bud sagebrush as sub-dominant. Nevada ephedra and other shrubs may be a significant component. Perennial bunchgrass cover is trace or completely absent. Galleta may be present to increasing. Invasive species are present in trace amounts. Interspaces are large and connected.


Cobbly Loam 5-8" P.Z. (R029XY036NV), Shrub State 3.1, P. Novak-Echenique, May 2021


Cobbly Loam 5-8" P.Z. (R029XY036NV), Shrub State 3.1, T. Stringham, May 2021

States not Observed in Group 2:

An Annual State was not observed during field work for this DRG. While trace amounts of non-native annuals have been noted, there is no evidence of dominant non-native annual communities. Fire, a primary vector for annual state conversion in other systems, is *not* a player in this ecosystem due to sparse fuel continuity, low productivity, and fire-resistant shrub architecture.

Potential Resilience Differences with Other Ecological Sites in this Group:

Cobbly Slope 5-8" P.Z. R029XY037NV

The reference plant community is dominated by spiny menodora, desert needlegrass and galleta. This site occurs on summits and sideslopes of low hills, piedmont slopes, pedisediments and rock pediments. Slopes range from 15 to 75%. Elevations range from 4,500 to 5,500 ft. The soils on this site are shallow to very shallow to bedrock. Runoff is medium to rapid and water intake rates are moderate. Total annual air-dry production ranges from 100 to 300 lb/ac. This site is similar to the modal with three stable states.

Shallow Cobbly Loam 8-10" P.Z. R029XY161NV

The reference plant community is dominated by spiny menodora, Nevada ephedra, and Indian ricegrass. This site occurs on rockier soils at higher elevations (more precipitation) than the modal site, at elevations from approximately 4,250 to 6,400 ft. This site occurs on summits and sideslopes of fan remnants and partial ballenas. The soils are shallow to a duripan and well drained. Runoff is high to very high and available water capacity is very low. Water intake rates are moderate. Total annual air-dry production ranges from 200 to 400 lb/ac. This site is similar to the modal with three stable states.

Granitic Cobbly Loam 5-8" P.Z. R029XY107NV

The reference plant community is dominated by spiny menodora and desert needlegrass. This site occurs on mid- to lower piedmont slopes. Slopes range from 0 to 50% but slope gradients of 2 to 15% are typical. Soil surfaces are stony or cobbly and coarse-textured. Water intake rates are rapid and runoff is low. Available water capacity is low. This site naturally has a larger composition of grass (40%) in the community and is more productive than the modal (250 to 600 lb/ac). This site is more resilient than the modal due to higher productivity but will have the same three stable states.

Eroded Slope 8-10" P.Z. R029XY162NV

The reference plant community is dominated by Nevada dalea (*Psorothamnus polydenius*), rubber rabbitbrush (*Ericameria nauseosa*), and Indian ricegrass. This site occurs on eroding sideslopes of hills and lower mountains. Slopes range from 15 to 50% and elevations range from 4,250 to 6,400 ft. The soils are very shallow to a duripan. Runoff is high to very high, available water capacity is very low and water intake rates are moderate. Total annual air-dry production is very low (75 to 175 lb/ac). This site is similar to the modal with three stable states.

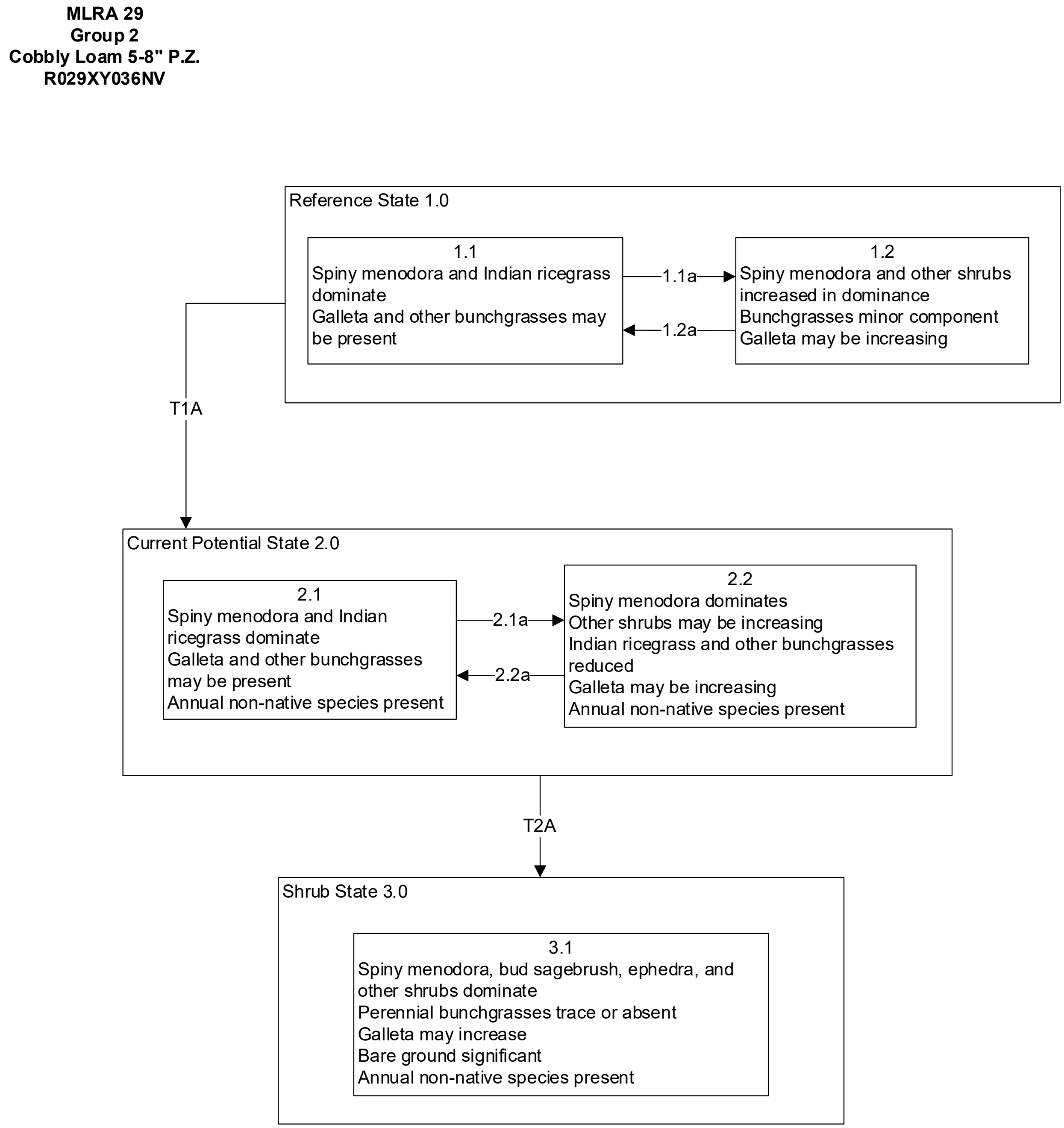
Shallow Loam 5-8" P.Z. R029XY074NV

The reference plant community is dominated by Nevada dalea, rubber rabbitbrush (*Ericameria nauseosa*), and Indian ricegrass. This site occurs on summits and sideslopes of fan piedmonts. Slopes range from 2 to 50% but slope gradients of 2 to 30% are typical. The soils are shallow to very shallow and moderately to strongly alkaline. This site exhibits very low water holding capacity and very slow permeability into the soil. Production is greater on this site at 450 lb/ac in a normal year. This site is similar to the modal with three stable states.

Cobbly Loam 8-10" P.Z. R029XY038NV

The reference plant community is dominated by spiny menodora, Wyoming big sagebrush (*Artemisia tridentata ssp. wyomingensis*), and Indian ricegrass. Bud sagebrush, Nevada ephedra, and fourwing saltbush (*Atriplex canescens*) are other important species. This site occurs on piedmont slopes and low hills on slopes ranging from 0 to 50%. Elevations range from 5,200 to approximately 6,500 ft. The soils are typically shallow and well drained. Surfaces are usually cobbly or stony. Water intake rates are moderate and runoff is medium. Total annual air-dry production ranges from 200 to 700 lb/ac. This site has more resilience than the modal due to higher elevations and productivity but will have the same three stable states.

Modal State and Transition Model for Group 2 in MLRA 29:



MLRA 29
Group 2
Cobbly Loam 5-8" P.Z.
R029XY036NV

Reference State 1.0 Community Pathways
1.1a: Drought and/or inappropriate herbivory reduces herbaceous cover allowing increase in shrub establishment.
1.2a: Release from drought and/or herbivory allows for perennial bunchgrass re-establishment.

Transition T1A: Introduction of non-native annual species.

Current Potential State 2.0 Community Pathways:
2.1a: Chronic multi-year drought and/or prolonged inappropriate grazing management reduces perennial grass cover, facilitating and increase in shrub dominance.
2.2a: Appropriate grazing management and favorable climatic conditions can facilitate recovery of the bunchgrass component.

Transition T2A: Inappropriate cattle/horse/burro grazing will decrease or eliminate palatable shrubs and deep rooted perennial bunchgrasses, increase galleta grass and favor shrub growth and establishment, leading to Shrub State 3.1.

Additional State and Transition Models for Group 2 in MLRA 29:

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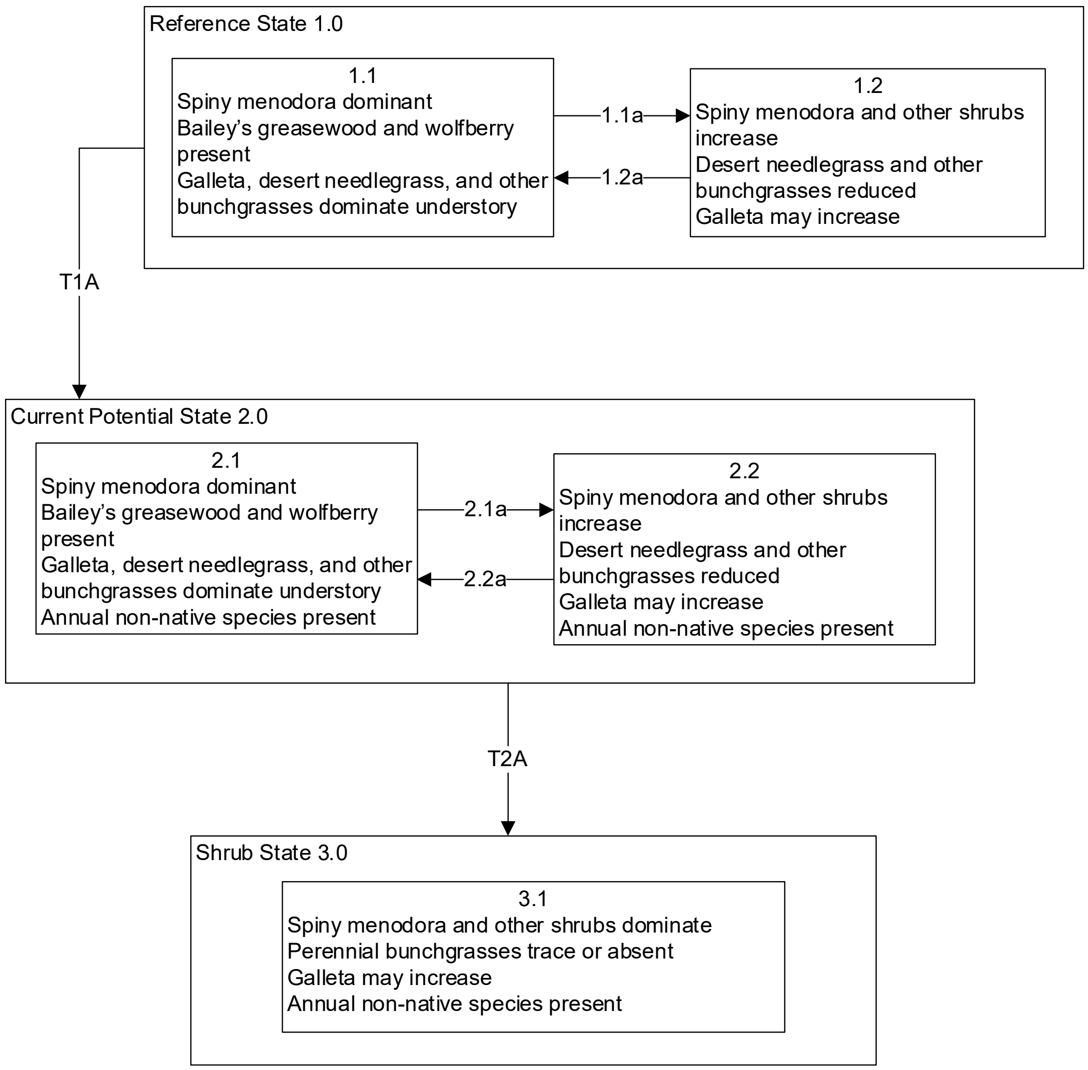
MLRA 29
Group 2
Cobbly Slope 5-8" P.Z.
R029XY037NV



MLRA 29
Group 2
Cobbly Slope 5-8" P.Z.
R029XY037NV

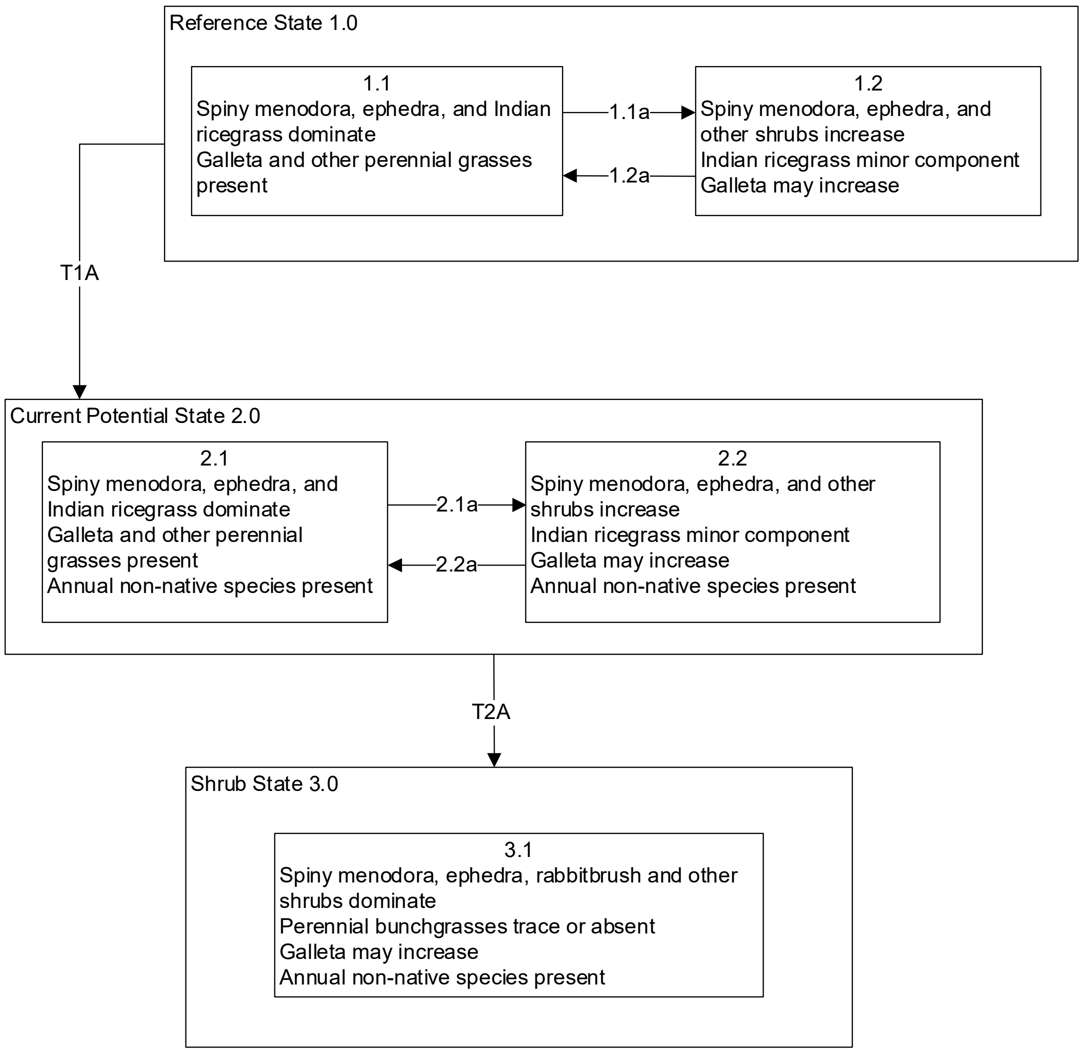
Reference State 1.0 Community Pathways
1.1a: Drought and/or inappropriate herbivory reduces herbaceous cover allowing increase in shrub establishment.
1.2a: Release from drought and/or herbivory allows for perennial bunchgrass re-establishment.

Transition T1A: Introduction of non-native annual species.

Current Potential State 2.0 Community Pathways:
2.1a: Chronic multi-year drought and/or prolonged inappropriate grazing management reduces perennial grass cover, facilitating and increase in shrub dominance.
2.2a: Appropriate grazing management and favorable climatic conditions can facilitate recovery of the bunchgrass component.

Transition T2A: Inappropriate cattle/horse/burro grazing will decrease or eliminate deep rooted perennial bunchgrasses, increase galleta grass and favor shrub growth and establishment, leading to Shrub State 3.1.

MLRA
Group 2
Shallow Cobbly Loam 8-10" P.Z.
R029XY161NV



MLRA 29
Group 2
Shallow Cobbly Loam 8-10" P.Z.
R029XY161NV

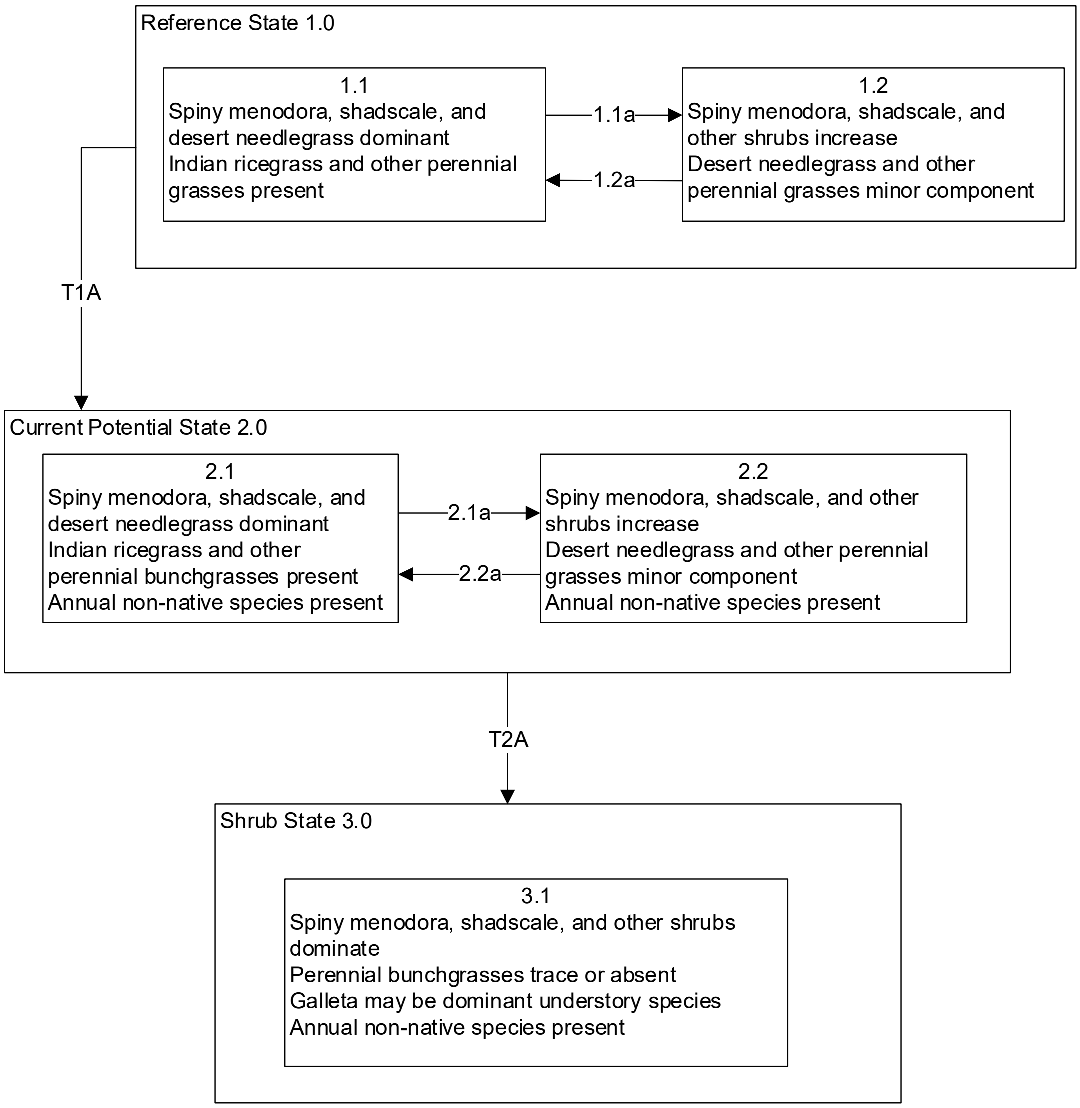
Reference State 1.0 Community Pathways
1.1a: Drought and/or inappropriate herbivory reduces herbaceous cover allowing increase in shrub establishment.
1.2a: Release from drought and/or herbivory allows for perennial bunchgrass re-establishment.

Transition T1A: Introduction of non-native annual species.

Current Potential State 2.0 Community Pathways:
2.1a: Chronic multi-year drought and/or prolonged inappropriate grazing management reduces perennial grass cover, facilitating and increase in shrub dominance.
2.2a: Appropriate grazing management and favorable climatic conditions can facilitate recovery of the bunchgrass component.

Transition T2A: Inappropriate cattle/horse/burro grazing will decrease or eliminate deep rooted perennial bunchgrasses, increase galleta grass and favor sprouting shrub growth and establishment, leading to Shrub State 3.1.

MLRA 29
Group 2
Granitic Cobbly Loam 5-8" P.Z.
R029XY107NV



MLRA 29
Group 2
Granitic Cobbly Loam 5-8" P.Z.
R029XY107NV

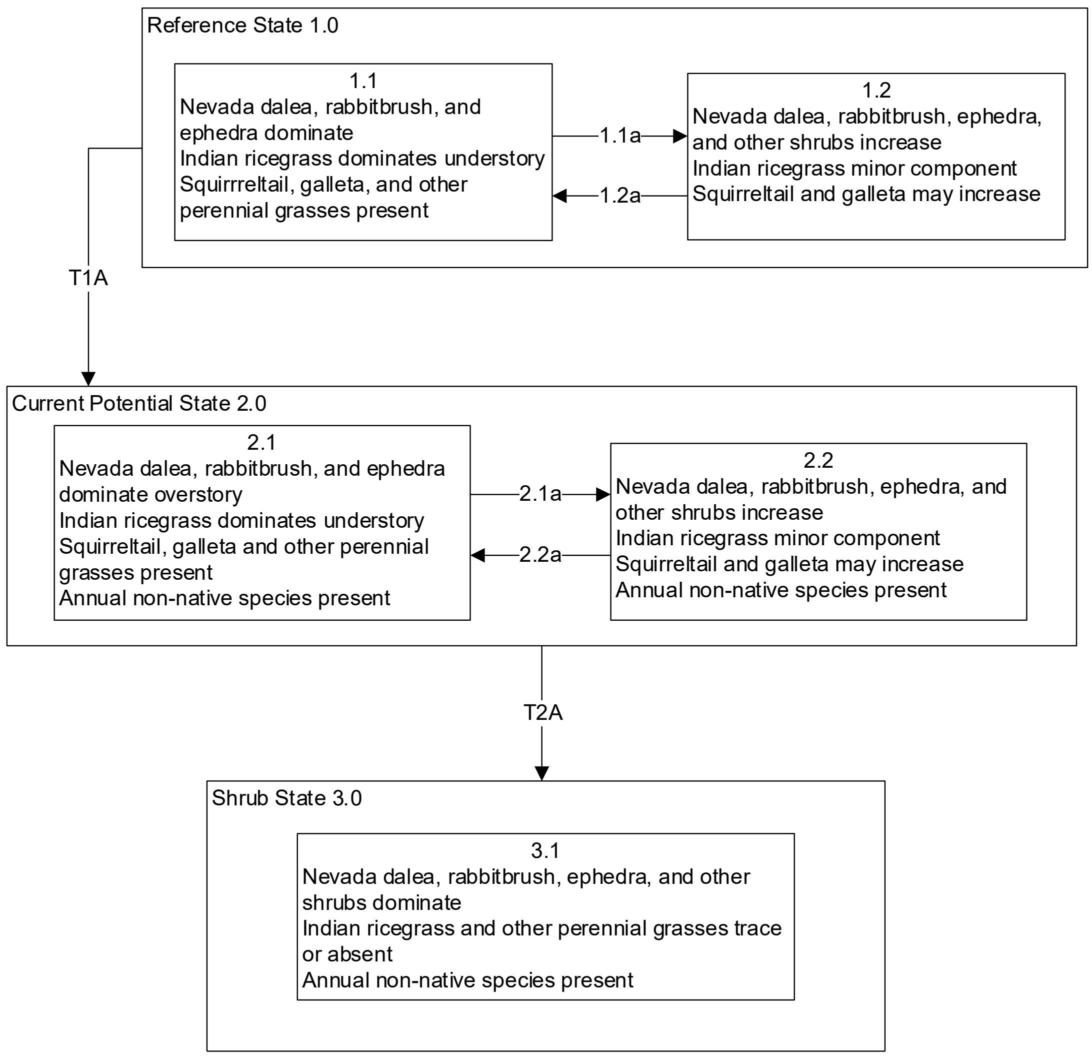
Reference State 1.0 Community Pathways
1.1a: Drought and/or inappropriate herbivory reduces herbaceous cover allowing increase in shrub establishment.
1.2a: Release from drought and/or herbivory allows for perennial bunchgrass re-establishment.

Transition T1A: Introduction of non-native annual species.

Current Potential State 2.0 Community Pathways:
2.1a: Chronic multi-year drought and/or prolonged inappropriate grazing management reduces perennial grass cover, facilitating and increase in shrub dominance.
2.2a: Appropriate grazing management and favorable climatic conditions can facilitate recovery of the bunchgrass component.

Transition T2A: Inappropriate cattle/horse/burro grazing will decrease or eliminate deep rooted perennial bunchgrasses, increase galleta grass and favor shrub growth and establishment, leading to Shrub State 3.1.

MLRA 29
Group 2
Eroded Slope 8-10" P.Z.
R029XY162NV



MLRA 29
Group 2
Eroded Slope 8-10" P.Z.
R029XY162NV

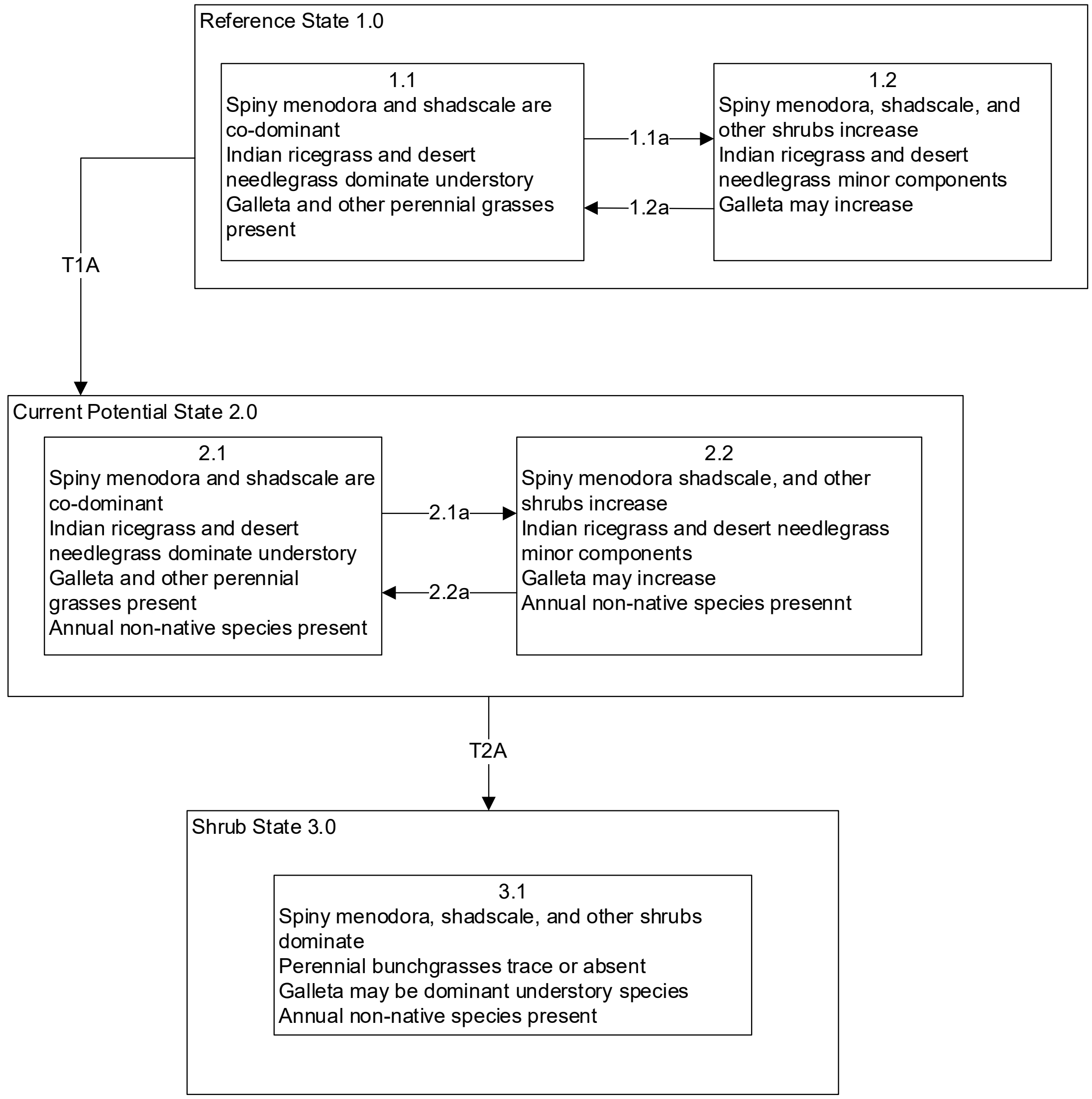
Reference State 1.0 Community Pathways
1.1a: Drought and/or inappropriate herbivory reduces herbaceous cover allowing increase in shrub establishment.
1.2a: Release from drought and/or herbivory allows for perennial bunchgrass re-establishment.

Transition T1A: Introduction of non-native annual species.

Current Potential State 2.0 Community Pathways:
2.1a: Chronic multi-year drought and/or prolonged inappropriate grazing management reduces perennial grass cover, facilitating and increase in shrub dominance.
2.2a: Appropriate grazing management and favorable climatic conditions can facilitate recovery of the bunchgrass component.

Transition T2A: Inappropriate cattle/horse/burro grazing will decrease or eliminate deep rooted perennial bunchgrasses, potentially increase galleta grass and favor shrub growth and establishment, leading to Shrub State 3.1.

MLRA 29
Group 2
Shallow Loam 5-8" P.Z.
R029XY074NV



MLRA 29
Group 2
Shallow Loam 5-8" P.Z.
R029XY074NV

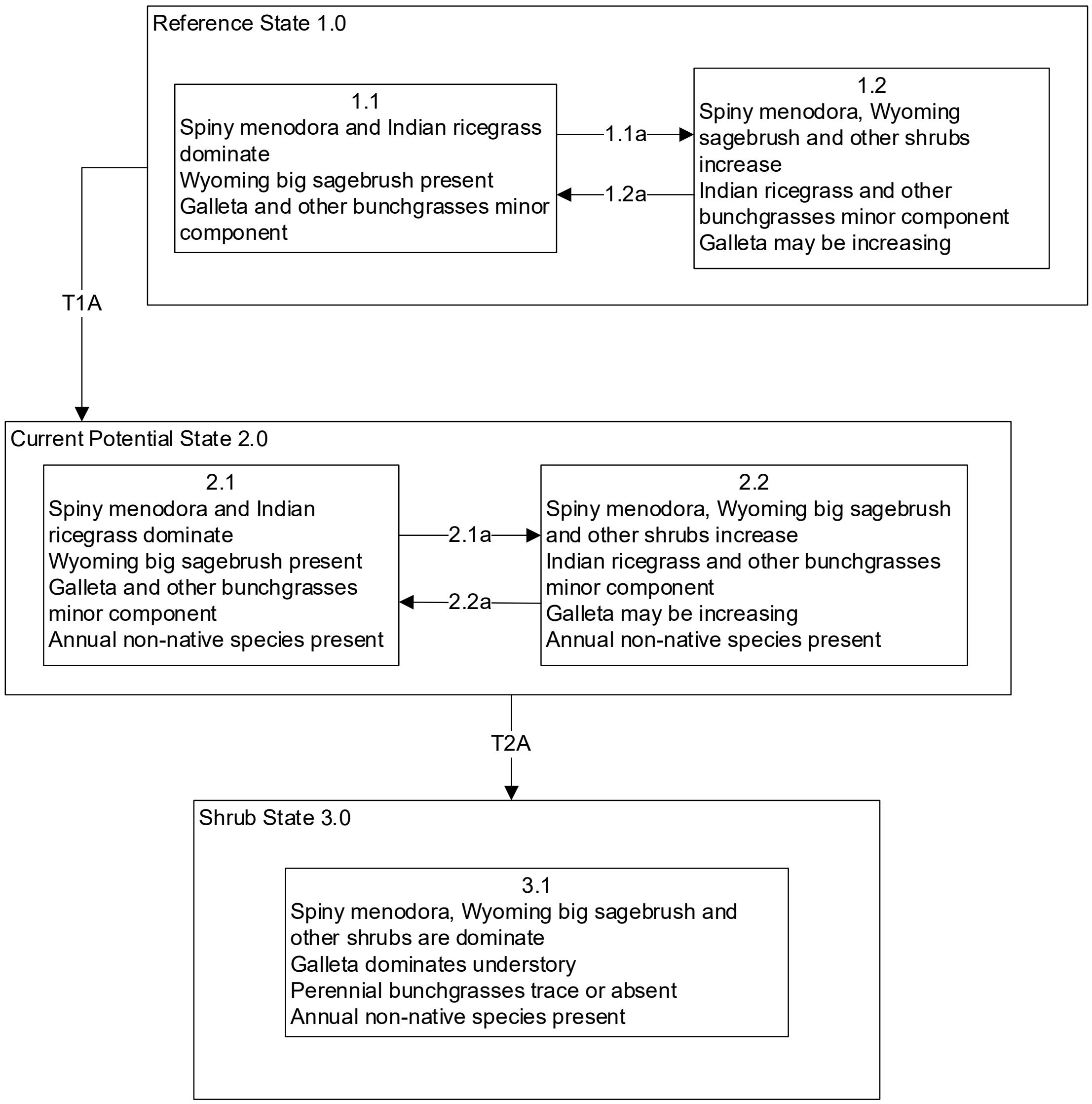
Reference State 1.0 Community Pathways
1.1a: Drought and/or inappropriate herbivory reduces herbaceous cover allowing increase in shrub establishment.
1.2a: Release from drought and/or herbivory allows for perennial bunchgrass re-establishment.

Transition T1A: Introduction of non-native annual species.

Current Potential State 2.0 Community Pathways:
2.1a: Chronic multi-year drought and/or prolonged inappropriate grazing management reduces perennial grass cover, facilitating and increase in shrub dominance.
2.2a: Appropriate grazing management and favorable climatic conditions can facilitate recovery of the bunchgrass component.

Transition T2A: Inappropriate cattle/horse/burro grazing will decrease or eliminate deep rooted perennial bunchgrasses, increase galleta grass and favor shrub growth and establishment, leading to Shrub State 3.1.

MLRA 29
Group 2
Cobbly Loam 8-10" P.Z.
R029XY038NV



MLRA 29
Group 2
Cobbly Loam 8-10" P.Z.
R029XY038NV

Reference State 1.0 Community Pathways
1.1a: Drought and/or inappropriate herbivory reduces herbaceous cover allowing increase in shrub establishment.
1.2a: Release from drought and/or herbivory allows for perennial grass re-establishment.

Transition T1A: Introduction of non-native annual species.

Current Potential State 2.0 Community Pathways:
2.1a: Chronic, multi-year drought and/or prolonged inappropriate grazing management reduces perennial grass cover, facilitating an increase in shrub dominance.
2.2a: Appropriate grazing management and favorable climatic conditions can facilitate recovery of the bunchgrass component.

Transition T2A: Inappropriate cattle/horse/burro grazing will decrease or eliminate deep rooted perennial bunchgrasses, increase galleta grass and favor shrub growth and establishment, leading to Shrub State 3.1.

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MLRA 29 Group 3: Sandy sites dominated by saltbush and Indian ricegrass

Description of MLRA 29 Disturbance Response Group 3

Disturbance Response Group (DRG) 3 consists of four ecological sites. The precipitation zone is 3 to 8 in. The soils correlated to this site occur on inset fans, sand sheets on lower piedmont slopes, and alluvial plains. Parent materials consist of mixed alluvium and aeolian sands. Slopes range from 0 to 30%, but slope gradients of 0 to 15% are typical. Elevations range from 3,500 to about 6,550 ft. Soil temperature regime is mesic and the soil moisture regime is typic aridic. These soils are porous and are well drained to excessively drained. If soils are not protected by plant cover, they are highly susceptible to wind erosion. Little to no runoff is expected, as moisture penetrates the soil rapidly. Vegetative production in a normal year can range between 250 to 500 lb/ac. The reference plant community for these sites is dominated by Indian ricegrass (*Achnatherum hymenoides*), fourwing saltbush (*Atriplex canescens*), and winterfat (*Krascheninnikovia lanata*). Other important plants are bud sagebrush (*Picrothamnus desertorum*), spiny menodora (*Menodora spinescens*), wolfberry (*Lycium* spp.), James' galleta (*Pleuraphis jamesii*), and needle-and-thread (*Hesperostipa comata*).

Disturbance Response Group 3 Ecological Sites:

Sandy Loam 5-8" P.Z. – Modal	R029XY046NV
Sandy 5-8" P.Z.	R029XY012NV
Shallow Sandy Loam 5-8" P.Z.	R029XY080NV
Sandy 3-5" P.Z.	R029XY034NV

Modal Site:

The Sandy Loam 5-8" P.Z. ecological site is the modal site for this group as it has the most acres mapped. It occurs on inset fans of lower piedmont slopes and on axial-stream floodplain terraces of basin floors. Elevation ranges from 4,000 to about 5,500 ft. Slopes range from 0 to 15%, but slope gradients of 2 to 8% are typical. Soils correlated to this site are well drained and moderately deep to deep. Soils have coarse-textured surfaces which are generally underlain at shallow depths by a layer restrictive to root development. Soil temperature regime is mesic, and the soil moisture regime is typic aridic. Runoff is slow and water infiltration is moderate to high. The potential for rill and sheet erosion is moderate. Normal year production is 500 lb/ac. This site is dominated by fourwing saltbush, winterfat, and Indian ricegrass. Other important species are spiny hopsage (*Grayia spinosa*), bud sagebrush, galleta, and sand dropseed (*Sporobolus cryptandrus*).

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasive species. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans across Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area, especially in eastern Nevada, when strong convection storms contribute significantly to annual precipitation. Moisture and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992) and the rapid rate at which this precipitation often occurs and runs-off. Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

Periodic drought regularly influences these ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West (Miller et al. 2008a). Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006). Altered precipitation regimes combined with historical anthropogenic land uses (i.e. grazing) and aggressive introduced species have altered these communities in many of the locations visited during the field work efforts included in this publication.

The ecological sites in this DRG are historically dominated by the deep-rooted cool season perennial bunchgrasses, including Indian ricegrass and needle-and-thread grass. Warm-season grasses, predominantly sand dropseed and galleta grass, occur within each ecological site included in this DRG, however, these are generally sub-dominant in reference condition. While soil textures are generally coarse in this group, restrictive layers are common in the soils correlated to these ecological sites. This often impacts the ability of water to infiltrate to greater depths within the soil, as well as the ability of plants to root beyond the restrictive feature. The presence of restrictive layers may increase soil water availability for grass, forbs, and shallow-rooted shrubs, by reducing deep percolation of precipitation and maintaining moisture in the rooting zone.

Fourwing saltbush is the most widely distributed and abundant saltbush in the southwest USA (Mozingo 1987c). It is a native, long-lived woody shrub that grows on a variety of landforms and soils from sand dunes, sand sheets, alluvial fans and plains, hills and mountains, and washes. It tolerates salinity but is not restricted to saline soils (Henrickson 1977). It is a polymorphic species and is evergreen or deciduous depending on climate (Ogle et al. 2012a). Fourwing saltbush has a long taproot of depths of 6 to 12 m (20 to 40 ft) and many small lateral roots (Van Dersal 1938, Barrow et al. 1997). It has been found that the roots compose 40% of the total mass of adult plants (Wallace et al. 1974). Fourwing saltbush is classified as a phreatophyte and has been documented at water tables occurring from 8 to 62 ft in New Mexico (Meinzer 1927). *Atriplex* species are considered medium to short-lived shrubs and possess a number of morphological and physiological traits that enable them to cope with drought. Some of these traits include: a) photosynthesis through the C_4 carboxylation pathway; b) production of leaf trichomes (hair) and accumulation of salt crystals on the leaf surface to increase reflectance; c) accumulation and synthesis of inorganic and organic solutes to maintain turgor; and 4) root association with endomycorrhiza that allows absorption of soil moisture at very low water potentials (Newton and Goodin 1989, Dobrowolski et al. 1990, Cibils et al. 1998).

Winterfat is a long-lived, drought tolerant native shrub typically about 30 cm (12 in.) in height. It has a woody base from which annual branchlets grow (Welsh et al. 1987). The most common variety is a low growing dwarf form (less than 15 in.), which is most often found on desert valley floors (Stevens et al. 1977). Total winter precipitation is a primary growth driver and lower than average spring precipitation can reverse the impact of plentiful winter precipitation. While summer rainfall has a limited impact, heavy August through September rain can cause a second flowering of winterfat (West and Gasto 1978). Winterfat reproduces from seed and primarily pollinates via wind (Stevens et al. 1977). Seed production, especially in desert regions, is dependent on precipitation (West and Gasto 1978) with good seed years occurring when there is appreciable summer precipitation and little browsing (Stevens et al. 1977). Winterfat has multiple dispersal mechanisms: diaspores are shed in the fall or winter, dispersed by wind, rodent-cached, or carried on animals (Majerus 2003). Diaspores take advantage of available moisture, tolerating freezing conditions as they progress from imbibed seeds to germinants to nonwoody seedlings (Booth 1989). Under some circumstances, the degree of reproduction may be dependent on mature plant density (Freeman and Emlen 1995).

Perennial bunchgrasses generally have somewhat shallower root systems than shrubs, but root densities are often as high as or higher than those of shrubs in the upper 0.5 m (20 in.). General differences in root depth distributions between grasses and shrubs result in resource partitioning in these shrub/grass systems. The perennial bunchgrasses that are sub-dominant with the shrubs include Indian ricegrass and needle-and-thread. The dominant grass within this site, Indian ricegrass, is a hardy, cool-season, densely tufted, long-lived perennial bunchgrass that grows from 4 to 24 inches in height (Blaisdell and Holmgren 1984). Its deep, fibrous root system makes Indian ricegrass one of the most drought tolerant native species. Indian ricegrass can be found in low deserts associated with fourwing saltbush, shadscale saltbush (*Atriplex confertifolia*), and winterfat and in elevations up to 10,000 ft. It can be found throughout MLRA 29, including on ridges, canyons, dunes, hills, plains, and mountains. Indian ricegrass is a key plant in recovering communities disturbed by grazing, mining, and fire because it is a hardy grass that is able to grow in rough, rocky, and coarse soils and still provides very valuable forage. When successfully planted or recovered and managed, Indian ricegrass can help rehabilitate disturbed areas by competing with invasive plants and providing cover and forage (Booth et al. 1980). Indian ricegrass germination and establishment appears to occur in strong pulses, with the plant preferring spring conditions, characterized by slightly higher than normal early soil temperatures, followed by lower than normal temperatures later in the growing season (Pearson 1979).

Galleta is a mat-forming, rhizomatous, warm-season grass that is 11 to 19 in. tall (Stubbendieck et al. 2003). This warm-season (C4), perennial species is more water-efficient than its cool-season counterparts. This allows galleta grass to survive in low precipitation zones where a significant portion of rainfall occurs during summer months (Banner et al. 2011). It has been found that galleta grass initiated more than one phenological cycle with the presence of summer precipitation, allowing the species to grow and set seed more than once (Everett et al. 1980). This plant is typical of southern Nevada and the transition zone between the Great Basin and the Mojave Desert. It is most common in fine-textured soils (Stubbendieck et al. 2003) but is also present on sandy and coarse-textured soils.

Sand dropseed is a perennial warm-season bunchgrass that prefers the coarser soil textures of this DRG, including increased sand and less silt and clay than other perennial grasses (Soil Survey Staff 2024). This C4 grass has clonal reproduction and low palatablility of the mature plants which make the plant resistant to grazing. In areas which receive inappropriate grazing, this plant has a tendancy to increase and may become dominant along with other species in the same genus *Sporobolus.* The plant is consumed and killed by fire, however appears to reestablish from seeds stored in the seedbank (Abrams 1988). Given the grasses use of summer monsoonal moisture, spring and summer forage is most useful to ruminants (Anderson and Scherzinger 1975).

The ecological sites in this DRG have moderate resilience to disturbance and resistance to invasion. Increased resilience generally increases with elevation, aspect, increased precipitation, and increased nutrient availability. Four alternative states have been identified for this ecological site, including an annual state primarily dominated by invasive forbs, and an abiotic state which appears to be more common than in many other DRGs. The current potential state contains a range of perennial plants such as Indian ricegrass, winterfat, galleta, and trace non-native annual species, while more rabbitbrush (*Chrysothamnus* spp.) and bud sagebrush dominated the overstory in the shrub state.

Annual Invasive Species:

While invasive annual grasses are well known and documented to establish in salt-desert plant communities, this particular group of ecological sites was not documented to be dominated by annual grasses in the course of fieldwork for this project. The presence of annual grasses, predominantly cheatgrass (*Bromus tectorum*), was noted at many of the sites visited, however, the species was not found to dominate the sites, likely due to coarse soils and limited winter precipitation. The annual invasive species found were Russian thistle (*Salsola tragus*) and halogeton (*Halogeton glomeratus*). Both species are summer annuals, germinating and growing in late spring and maturing in late summer/early fall. The summer rainfall associated with this DRG likely facilitates the growth of these two taprooted, invasive forbs.

The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and depressed competition or can increase resource pools by the decomposition of dead plant material following disturbance. Disturbance can decrease resource uptake due to damage or mortality of the native species, and decomposition of dead plant material following disturbance further increases resource pools. Historically, salt-desert shrub communities were free of exotic invaders; however, excessive grazing pressure during settlement and into the 20th century has increased the overall presence of cheatgrass, halogeton, Russian thistle and weedy mustard species (*Brassicaceae* spp.) (Peters and Bunting 1994). The presence of exotic annual plants within these ecosystems decreases ecosystem resilience and resistance to disturbance through competition for limited resources. Dobrowolski et al. (1990) cite multiple authors on the extent of the soil profile exploited by the competitive exotic annual cheatgrass. Specifically, the depth of rooting is dependent on the size the plant achieves, and in competitive environments, cheatgrass roots were found to penetrate only 15 cm (6 in.), whereas isolated plants and pure stands were found to root at least 1 m (39 in.) in depth with some plants rooting as deep as 1.5 to 1.7 m (59 to 67 in.).

Russian thistle is a taprooted, C4 photosynthesis (warm-season) annual forb, introduced from southeastern Europe and central Asia. The seeds have a remarkable capability to germinate in a variety of soil temperatures and very little precipitation and even move back into dormancy after initial germination (Wallace et al. 1968). The seeds, however, are not persistent and generally remain viable in the seed bank for less than two years (Boerboom 1993, Young et al. 1995). Russian thistle has been observed to provide initial establishment in completely de-vegetated sites and create a microsite habitat that may allow increased establishment of other species (Allen and Allen 1988). The successful establishment of other species, particularly later seral species that form mycorrhizal associations, may reduce the cover of Russian thistle as mycorrhizal inoculation has been observed to reduce the size and vigor of Russian thistle while encouraging later seral species such as perennial bunchgrasses (Johnson 1998a).

Halogeton is a non-native succulent annual of the goosefoot family (*Chenopodiaceae* spp.) native to semi-desert lands in the Altai region of central Asia (Tisdale and Zappetini 1953). It possesses a strong taproot that penetrates 4 to 5 in. and an extensive root system spanning up to 2 ft in lateral spread and depth (Tisdale and Zappetini 1953). Halogeton is characterized by its small fleshy leaves that can appear slightly red or purple as the plant matures. This plant can produce as many as 25,000 seeds, while typical plant sizes of about 3 in. can produce up to 800 seeds. These seeds are spread primarily through fruit ingestion and fruit movement, but can also be spread through wind (Tisdale and Zappetini 1953). Halogeton is well adapted to alkaline and saline soils and is prevalent on disturbed and overgrazed sites These plants accumulate salt that can leach from dead plant materials, increasing the soil salinity in topsoil, which favors continued germination and spread in invaded sites (Cronin 1965).

Fire Ecology:

Fourwing saltbush's ability to sprout following fire may depend on the population and fire severity. One study showed a 58% mortality rate of fourwing saltbush following fire in New Mexico, the surviving shrubs produced sprouts shortly after fire (Parmenter 2008). While fourwing saltbush is able to resprout after fire, it primarily reestablishes from seed (Stutz 1979, Wasser 1982). This plant can also sprout from a below ground crown or rootstock and layers after fire, which can aid in the drought tolerance and nutrient uptake of the species (Wasser 1982). High severity fire in more productive sites occurring in the upper elevation range of this DRG will result in an increased presence of xerohalophytes, or resprouting shrubs like fourwing saltbush, winterfat, green molly (*Bassia americana*), and black greasewood (*Sarcobatus vermiculatus*) (West 1994).

Winterfat tolerates environmental stress, extremes of temperature and precipitation, and competition from other perennials but not the disturbances of fire or overgrazing (Ogle et al. 2001). Fire is rare within these communities due to low fuel loads. There are conflicting reports in the literature about the response of winterfat to fire. In one of the first published descriptions, it was reported that winterfat sprouts vigorously after fire (Dwyer and Pieper 1967). This observation was frequently cited in subsequent literature, but recent observations have suggested that winterfat can be completely killed by fire (Pellant and Reichert 1984). The response is apparently dependent on fire severity. Winterfat is able to sprout from buds near the base of the plant. However, if these buds are destroyed, winterfat will not sprout. Research has shown that winterfat seedling growth is depressed in growth by at least 90% when growing in the presence of cheatgrass (Hild et al. 2007). Repeated, frequent fires will increase the likelihood of conversion to a non-native, annual plant community with trace amounts of winterfat.

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The initial condition of bunchgrasses within the site, along with seasonality and intensity of the fire all factor into the individual species response. The two dominant grasses on this site, Indian ricegrass and needle-and-thread grass, have different responses to fire. Needle-and-thread is top-killed by fire but is likely to resprout if fire does not consume above-ground stems (Akinsoji 1988, Bradley et al. 1992). The season of burn rather than fire intensity seemed to be the crucial factor in mortality for needle-and-thread grass (Wright and Klemmedson 1965). Early spring season burning was found to kill the plants while August burning had no effect.

Indian ricegrass, is fairly fire tolerant (Wright 1985), which is likely due to its low culm density and below ground plant crowns. Several studies in the sagebrush zone classified Indian ricegrass as being slightly damaged from late summer burning (Vallentine 1989). Indian ricegrass has also been found to reestablish on burned sites through seed dispersed from adjacent unburned areas (Young 1983, West 1994). Thus, the presence of surviving, seed-producing plants facilitates the reestablishment of Indian ricegrass. Grazing management following fire to promote seed production and establishment of seedlings is important. When successfully planted and managed, Indian ricegrass can be a key factor in a community recovering from disturbance because it can grow in rough, rocky, coarse-textured soils (Booth et al. 1980).

Galleta grass, a minor component of these ecological sites, has been found to increase following fire likely due to its rhizomatous root structure and ability to re-sprout (Jameson 1962). This species may retard reestablishment of deeper-rooted bunchgrasses due to site resource availability. Sand dropseed tends to be top-killed by fire and significantly reduces post fire, however appears to reestablish from seed (Abrams 1988). Repeated frequent fire in this community will reduce fourwing saltbush, significantly decrease bunchgrass density, and facilitate the establishment of an annual non-native community with varying amounts of galleta and rabbitbrush, the predominant sprouting shrub in this community along with Nevada ephedra (*Ephedra nevadensis*) (Abrams 1988).

Invasion by annual forbs and grasses decreases site resilience, increases the risk of stand-replacing fire, and decreases the potential for four-wing saltbush and Indian ricegrass reestablishment. Soil movement associated with fire and other activities such as OHV use has been observed.

Livestock/Wildlife Grazing Interpretations:

The salt-desert shrub community is typically regarded as a browse-specific plant community. It is characterized by low productivity, which requires substantial acreage for grazing animals—about 1.5 to 3 ac/sheep/month and 10 to 20 ac/cow. Within this vegetation type, it is acknowledged that 65 to 90% of the available forage is browse (Costello 1944).

Fourwing saltbush is one of the most important forage shrubs in arid sites. Its importance is due to its abundance, accessibility, size, large volume of forage, evergreen habitat, high palatability and nutritive value (USFS 1937, Van Epps 1975). The palatability rates from fairly good to good for cattle, and is good for domestic sheep and goats. Deer (*Odocoileus* spp.) usually consume it as a winter browse (USFS 1937). It has similar protein, fat, and carbohydrate levels as alfalfa (*Medicago sativa*) (Catlin 1925). Fourwing saltbush is especially valuable as winter forage. It was noted that sheep readily grazed fourwing saltbush when introduced into a new pasture (Otsyina et al. 1982). Fourwing saltbush is a dioecious plant, though nutrient levels have been shown not to significantly vary between male, female, and labile plants (Tiedemann et al. 1984). Differences were found seasonally, in the spring, when males tended to have higher levels of chlorophyll and nonstructural carbohydrate levels. Generally, the plant has appeared moderately or not affected by spring and fall or early summer utilization. Moderate utilization (60% defoliation of the current year growth) during rapid growth, seed set, and quiescence tended to stimulate twig growth. High intensity utilization however (> 90% defoliation of current year growth) at high frequency (four or more times) could cause plant mortality (Buwai and Trlica 1977).

Winterfat is a valuable forage species with an average of 10% crude protein during winter when there are few nutritious options for livestock and wildlife (Welch 1989). However, excessive grazing throughout the West has negatively impacted survival of winterfat stands (Hilton 1941, Statler 1967, Stevens et al. 1977). Time of grazing is critical for winterfat with the active growing period being most critical (Romo et al. 1995). Active growing season for winterfat occurs from early spring to mid-spring, which in southern portions of the Great Basin, can occur earlier than in other areas. Stevens et al. (1977) found that both vigor and reproduction of winterfat were reduced in Steptoe Valley, Nevada by improper season of use, which they recommended no more than 25% utilization during periods of active growth and up to 75% utilization during dormant season use. Significantly greater foliar cover and density of winterfat was found in areas ungrazed for 26 years versus winter grazed areas in Utah (Rasmussen and Brotherson 1986). In exclosures protected from grazing for between 5 and 16 years, it was found that winterfat increased in foliar cover but not in density where it was dominant, and in both foliar cover and density in shadscale-perennial grass communities where it was sub-dominant (Rice and Westoby 1978).

In addition to grazing by cattle, winterfat is browsed by western rabbits (*Sylvilagus* spp.), antelope (*Antilocapra* spp.), and other wildlife species (Stevens et al. 1977, Ogle et al. 2001). Winterfat and perennial grasses average 80% of jackrabbits' (*Lepus californicus*) diet in southeastern Idaho, with shrubs being grazed in fall and winter particularly (Johnson and Anderson 1984). Pronghorn (*Antilocapra americana*) and rabbits browse stems, leaves, and seed stalks of winterfat year round, especially during periods of active growth (Stevens et al. 1977). Management of wildlife browse is difficult and browse may be harmful to winterfat reestablishment as seed production and regrowth are curtailed if grazing occurs as the plant begins to grow (Eckert 1954).

Sheep find bud sagebrush palatable, especially in winter (Johnson 1978), while it is slightly toxic and less palatable to cattle (Stubbendieck et al. 1992). Winterfat, on the other hand, is highly palatable to both cattle and sheep, but is not a preferred forage species for sheep (Sampson and Jespersen 1963, Severson and May 1967). Due to this difference in preference, the type of grazer present in a bud sagebrush/winterfat community can tip the composition of the plant community in favor of one species or another.

Indian ricegrass is a preferred forage species for livestock and wildlife (Cook 1962, Booth et al. 1980). This species is often heavily utilized in winter because it cures well (Booth et al. 1980). It is also readily utilized in early spring, being a source of green feed before most other perennial grasses have produced new growth (Quinones 1981). The plant does well when utilized in winter and spring (Booth et al. 1980). However, it has been found that repeated heavy grazing, particularly in early spring, reduced crown cover, stand density, and plant vigor, which may reduce seed production, density, and basal area of these plants (Cook and Child 1971). In eastern Idaho, productivity of Indian ricegrass was at least 10 times greater in undisturbed plots than in heavily grazed ones (Pearson 1979), however Cook and Child (1971) found a significant reduction in plant cover after 7 years of rest from heavy (90%) and moderate (60%) spring use. Tolerance to grazing increases after May, thus spring deferment may be necessary for stand enhancement (Pearson 1964, Cook and Child 1971); however, utilization of less than 60% is recommended. In summary, adaptive management is required to manage this bunchgrass well.

Galleta is a highly palatable forage species for cattle, domestic sheep, deer, antelope, and horses during late spring and summer while it is green (Stubbendieck et al. 2017). Due to its low growth form and rhizomatous characteristics, galleta is particularly tolerant of heavy grazing and trampling, and may increase as bunchgrasses decline (Pratt et al. 2002). This species will also initiate more than one phenological cycle if summer precipitation is present (Everett et al. 1980), allowing galleta to grow and propagate after defoliation.

Sand dropseed has low palatability however, due to its ability to remain green longer into the winter than other forage species, it becomes an important forage species for cattle, horses, sheep, elk (*Cervus canadensis*), deer and pronghorn in winter months (Tilley et al. 2010). Additionally, the plant and seeds are eaten by small birds, rodents and other small mammals, as well as providing cover for sage grouse (*Centrocercus urophasianus*) (Tilley et al. 2010).

Inappropriate grazing management during the spring growing season will cause a decline in understory plants such as Indian ricegrass and needle-and-thread. Growing season grazing by cattle several years in a row causes a decrease in the bunchgrass component and palatable shrubs (Eckert et al. 1972). Reduced bunchgrass vigor or density provides an opportunity for galleta, sand dropseed, and/or invasive species such as halogeton or Russian thistle to occupy interspaces. Thus, depending on the season of use, the type of grazing animal, and site conditions, either galleta, sand dropseed, or invasive annual forbs may become the dominant understory with inappropriate grazing management.

Halogeton is a highly adapted annual species that exploits the ecological void left by repeated disturbance such as livestock trails and unpaved roads that were periodically graded, trampled areas near watering points or corrals, and rangeland areas denuded by excessive grazing (Young 2002). Halogeton is notable for its toxicity to grazing livestock, primarily affecting sheep. With as little as 300 grams (11 oz) of the plant being potentially fatal to sheep. Halogeton may accumulate up to 30% oxalates, these oxalates precipitate calcium from the blood resulting in hypocalcemia, formation of calcium oxalate crystals in blood streams, and uremia (Rood et al. 2014). This toxicity has caused the deaths of hundreds of sheep and is a vital component of sheep grazing planning and management.

State and Transition Model Narrative for Group 3:

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 29 Disturbance Response Group 3.

Reference State 1.0:

The Reference State 1.0 is a representative of the natural range of variability under pristine conditions. The reference state has two general community phases; a shrub-grass dominated phase, and a shrub dominated phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Fire in salt- desert shrub communities is very infrequent, with fire return intervals estimated at >500 years (Miller and Tausch 2001). Due to infrequent fire, plant community phase changes are primarily driven by climactic extremes (drought or flooding) and/or insect or disease attack (Nelson et al. 1989, Ewing and Dobrowolski 1992).

Community Phase 1.1:
Fourwing saltbush, winterfat and Indian ricegrass dominate the site. Bud sagebrush and spiny hopsage are also common. Galleta, sand dropseed, and other perennial grasses may also be present in the understory. Perennial and annual forbs are present but not abundant. Potential vegetative composition by air-dry weight is approximately 45% grasses, 5% forbs and 50% shrubs. Approximate ground cover (basal and canopy) is 15 to 25%. Total annual air-dry production ranges from 300 to 700 lb/ac.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
Long-term drought, time, and herbivory from wildlife favor an increase in unpalatable shrubs over deep-rooted perennial bunchgrasses, fourwing saltbush, and winterfat. Sand dropseed and galleta may increase.

Community Phase 1.2:
Fourwing saltbush and winterfat are reduced as well as Indian ricegrass. Shallow-rooted perennials including galleta and sand dropseed will increase alongside less palatable

shrubs including Douglas rabbitbrush (*Chrysothamnus viscidiflorus*) and horsebrush (*Tetradymia* spp.).

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
Release from drought and/or absence of disturbance over time allows for fourwing saltbush, winterfat, and Indian ricegrass to recover.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0:

Trigger: This transition is caused by the introduction of non-native annual weeds, such as Russian thistle, halogeton, cheatgrass, and mustards.

Slow variables: Over time the annual non-native plants will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

This state is similar to the Reference State 1.0. This state has three general community phases, a shrub-grass dominated phase, a less palatable perennial bunchgrass grass-sprouting shrub dominated phase, and a shrub dominated phase. Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of non-native annual species. The non-native species may increase in abundance but will not become dominant within this state. These non-natives can be highly flammable and can promote fire where historically fire had been very infrequent. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These feedbacks include the presence of all structural and functional groups, low fine fuel loads and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate and adaptations for seed dispersal.

Community Phase 2.1:
Fourwing saltbush, winterfat, and Indian ricegrass dominate the site. Bud sagebrush and spiny hopsage are common. Galleta, sand dropseed, and other perennial grasses may be present in the understory. Perennial and annual forbs make up a smaller percentage by weight of the understory. Non-native annual species are present.

Sandy 5-8" P.Z. (R029XY012NV), Current Potential 2.1, D. Snyder, September 2020

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
Repeated, chronic grazing from domestic livestock and/or wild horses/burros (*Equus asinus*) during the late summer to early spring period reduces the cover of fourwing saltbush and winterfat. Indian ricegrass, galleta, and sand dropseed increase.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.3:
Time and lack of disturbance allow for fourwing saltbush and winterfat to increase in density. Inappropriate growing season grazing from domestic livestock and/or wild horses/burros reduces deep-rooted perennial bunchgrasses and facilitates shrub dominance.

Community Phase 2.2:
Fourwing saltbush and winterfat are reduced. Indian ricegrass, galleta, and sand dropseed will increase along with less palatable shrubs, including Douglas rabbitbrush and horsebrush. Annual, non-native species are present and may be increasing.

Sandy 5-8" P.Z. (R029XY012NV), Current Potential 2.2, T. Stringham, June 2022

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Time and lack of disturbance allows re-establishment of fourwing saltbush and winterfat. Appropriate late summer to early spring grazing management facilitates an increase in fourwing saltbush and winterfat.

Community Phase 2.3 (At Risk):
This community is at risk of crossing a threshold to a shrub-dominated state. Fourwing saltbush, winterfat, and sprouting shrubs like Douglas rabbitbrush dominate the overstory. Indian ricegrass is a minor component, while galleta and sand dropseed have increased. Continuous growing season grazing favors the shrub component and reduces Indian ricegrass while sand dropseed and galleta increase. Annual non-native species are present.

Sandy 5-8" P.Z. (R029XY012NV), Current Potential 2.3, D. Snyder, September 2020

Community Phase Pathway 2.3a, from Phase 2.3 to 2.1:
Grazing management that reduces shrubs, such as late-summer through winter grazing, may reduce the palatable shrub overstory and facilitate an increase in perennial bunchgrasses like Indian ricegrass. While fire is not a primary driver for change in this community, a low severity fire would create a fourwing saltbush/grass mosaic.

T2A: Transition from Current Potential State 2.0 to Shrub State 3.0:

Trigger: Inappropriate, long-term, growing season grazing reduces the vigor and reproductive capabilities of perennial bunchgrasses facilitating a transition to Community Phase 3.1. Long-term drought and/or inappropriate grazing would favor unpalatable shrubs, including Douglas rabbitbrush and horsebrush and initiates a transition to Community Phase 3.2. Understory vegetation in these communities is dominated by less palatable C4 grasses - galleta and sand dropseed.

Slow variables: Long-term decrease in deep-rooted perennial Indian ricegrass density.

Threshold: Loss of deep-rooted perennial bunchgrasses, primarily Indian ricegrass, changes spatial and temporal nutrient cycling and nutrient redistribution, and reduces soil organic matter.

T2B: Transition from Current Potential State 2.0 to Annual State 4.0:

Trigger: Catastrophic fire would cause a transition to Community Phase 4.1.

Slow variables: Increased production and cover of non-native annual species.

Threshold: Increased, continuous fine fuels modify the fire regime by changing intensity, size and spatial variability of fires. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and fourwing saltbush truncate energy capture and impact the nutrient cycling and distribution.

Shrub State 3.0:

This state consists of two community phases, one is dominated by shrubs with an understory of grazing tolerant grasses, such as galleta or sand dropseed. The second phase is dominated by sprouting shrubs such as rabbitbrush and/or unpalatable shrubs with limited understory. This site has crossed a biotic threshold and site processes are being controlled by shrubs. Bare ground has increased and invasive species may be increasing.

Community Phase 3.1:

Perennial bunchgrasses like Indian ricegrass are reduced and the site is dominated by fourwing saltbush, winterfat, and bud sagebrush. Other shrubs like spiny hopsage, Douglas rabbitbrush, and Anderson wolfberry (*Lycium andersonii*) are common. Galleta and sand dropseed may be present. Bare ground is increasing, with interspaces that are large and connected. Annual non-native species are present.

Shallow Sandy Loam 5-8" P.Z. (R029XY080NV) Shrub State 3.1, T. Stringham, April 2023

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:
Severe drought and/or chronic, inappropriate late-summer to early spring grazing would decrease or eliminate the overstory of palatable shrubs. Non-palatable sprouting shrubs increase with the reduction in fourwing saltbush, winterfat, and bud sagebrush.

Community Phase 3.2:
Sprouting shrubs such as yellow (aka Douglas) rabbitbrush (*Chrysothamnus viscidiflorus*), dominate the community. Perennial bunchgrasses, like Indian ricegrass, are trace to missing. Galleta and sand dropseed may be present. Bare ground has increased and interspaces are large and connected. Wind erosion may be significant and lead to soil redistribution under shrubs, significantly reducing reestablishment of desirable shrubs. Trace amounts of fourwing saltbush may be present. Annual non-native species are present and increasing.

Sandy Loam 5-8" P.Z. (R029XY046NV), Shrub State 3.2, T. Stringham, June 2020

Community Phase Pathway 3.2a, from Phase 3.2 to 3.1:
Time and lack of disturbance may allow for regeneration of fourwing saltbush and winterfat.

T3A: Transition from Shrub State 3.0 to Annual State 4.0

Trigger: Long-term, inappropriate grazing management in the presence of annual non-native species in combination with higher-than-normal spring/early summer precipitation causes an increase in Russian thistle, halogeton, and mustards. While fire is infrequent in a salt-desert shrub community, a severe fire will also cause a transition to Annual State.

Slow variables: Increased production and cover of non-native annual species.

Threshold: Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses, winterfat, and saltbush truncate energy capture and impact water and nutrient cycling and distribution.

Annual State 4.0

This state has one community phase. In this state, a biotic threshold has been crossed and state dynamics are driven by the dominance and persistence of the exotic annual species. Russian thistle, halogeton, tumble mustard (*Sisymbrium altissimum*) and/or cheatgrass dominate the plant community. Bare ground may be abundant, and desirable native vegetation is trace or missing.

Community Phase 4.1:

This community is dominated by annual non-native species. Russian thistle and halogeton most commonly invades these sites. Trace amounts of fourwing saltbush and other desirable species may be present, but are not contributing to overall site function. Bare ground is abundant, especially during low precipitation years. Soil redistribution may be evident.

Sandy 5-8" P.Z. (R029XY012NV), Annual State 4.1, T. Stringham, September 2023

T4A: Transition from Annual State 4.0 to Abiotic State 5.0:

Trigger: Long-term, extremely inappropriate grazing management, severe drought, and/or severe flooding, significantly reducing vegetative cover leads to significant soil loss and redistribution.

Slow variables: Long-term decrease in density of native, perennial vegetation combined with soil movement and loss.

Threshold: Increased wind or water erosion resulting in soil loss, preventing the establishment of native perennials and/or invasive species. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and shrubs truncate energy capture spatially and temporally, thus impacting nutrient cycling and distribution.

Abiotic State 5.0:

This state consists of one community phase in which abiotic factors (i.e. wind or water erosion) have dramatically altered the site. It is characterized by the loss of vegetative cover along with the redistribution and loss of the soil surface. Feedback contributing to the stability of this state include soil loss, nutrient loss, soil surface degradation led to significant bare ground.

Community Phase 5.1:
This community is the result of extreme soil loss and redistribution. The vegetative cover is minimal, but is dominated by introduced non-native forbs and/or grasses. Trace amounts of desirable species may be present and bare ground interspaces are large and connected. Site function is controlled by soil erosion and soil temperature. Rehabilitation of this community is unknown.

Sandy 3-5" P.Z. (R029XY034NV), Abiotic State, T. Stringham, May 2021

Potential Resilience Differences with Other Ecological Sites in this Group:

Sandy 5-8" P.Z. (R029XY012NV):

This site occurs on sand sheets that occur on lower fan remnants and alluvial fans. The soils of this site have formed in coarse-textured alluvium or aeolian deposits from mixed rock sources. Some soils have a thick layer of overblown or alluvial sand. These soils have rapid infiltration and percolation rates, low available water capacity and are excessively drained with low to no runoff. The potential for wind erosion on these sites is high. The potential native plant community is dominated by Indian ricegrass and spiny hopsage. This site is similar to the modal site with five alternative states. Resilience on this site is considered to be similar to that of the Modal site (Sandy Loam 5-8” P.Z.), with the reduced presence of galleta grass. The coarse soil texture, which can aid in scarification of dormant Indian ricegrass seed and rapid infiltration of water onsite, has led to positive responses after cessation of years of inappropriate grazing management, suggesting moderate resiliency.

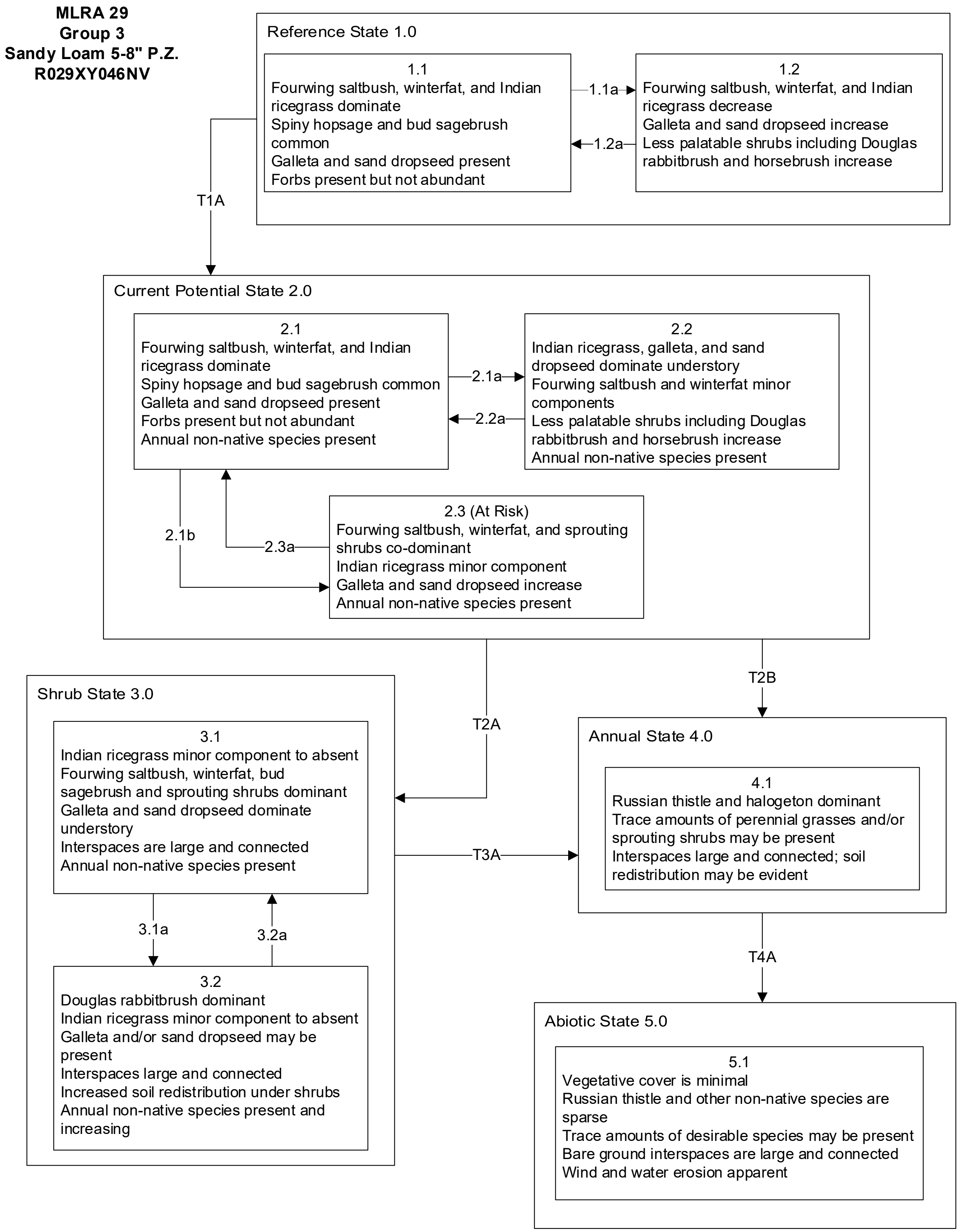
Shallow Sandy Loam 5-8" P.Z. (R029XY080NV):

This site occurs on shallower, but similarly coarse soils. The shallower soil reduces water holding capacity thus reducing site resiliency. This results in a more droughty plant community, including reduced grass cover and an increased presence of salt-desert shrubs, including spiny menodora, Nevada ephedra, and Anderson's wolfberry. Winterfat may be present, but is less common than on the modal site (Sandy Loam 5-8" P.Z.). For these reasons, transition to the Shrub State and loss or reduction of the deep-rooted perennial grass understory is more likely. Field observations recorded multiple shrub-dominated sites with characteristics that resembled conditions of a limited understory.

Sandy 3-5" P.Z. (R029XY034NV):

This soil is among the coarsest soils of the ecological sites in this group. It is excessively drained and low in organic matter, making it a very challenging site for plant establishment. Resilience is less than the modal site and conversion to a Shrub State will occur more rapidly. In addition, an Abiotic State was observed during fieldwork. Abiotic and Annual states observed in sandy sites were dominated by yellow rabbitbrush, littleleaf horsebrush (*Tetradymia glabrata*), Nevada dalea (*Psorothamnus polydenius*), and various potential non-native annual species.

Modal State and Transition Model for Group 3 in MLRA 29:



MLRA 29
Group 3
Sandy Loam 5-8" P.Z.
R029XY046NV

Reference State 1.0 Community Phase Pathways
1.1a: Long term drought, time, and/or herbivory favors increase of shrubs over deep-rooted perennial grasses. Galleta and sand dropseed may increase.
1.2a: Time and lack of disturbance and/or release from drought allows saltbush, winterfat, and Indian ricegrass to recover.

Transition T1A: Introduction of non-native annual species such as cheatgrass, halogeton, Russian thistle, and mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Chronic grazing during the late summer to early spring period reduces fourwing saltbush and winterfat. Indian ricegrass, galleta, and sand dropseed increase.
2.1b: Time, lack of disturbance allows fourwing saltbush and winterfat to increase in density. Inappropriate growing season grazing reduces deep-rooted perennial bunchgrasses.
2.2a: Time, lack of disturbance allows fourwing saltbush and winterfat to recover. Appropriate late summer to early spring grazing management facilitates an increase in fourwing saltbush and winterfat.
2.3a: Late-summer through winter grazing that reduces shrubs facilitates an increase in Indian ricegrass and a decrease in palatable shrubs. Low severity fire, while not a primary driver of change in this community, would create a fourwing saltbush/ grass mosaic.

Transition T2A: Long-term inappropriate grazing management during the growing season (to 3.1). Long term drought or grazing management that favors unpalatable shrubs would cause transition to Community Phase 3.2.

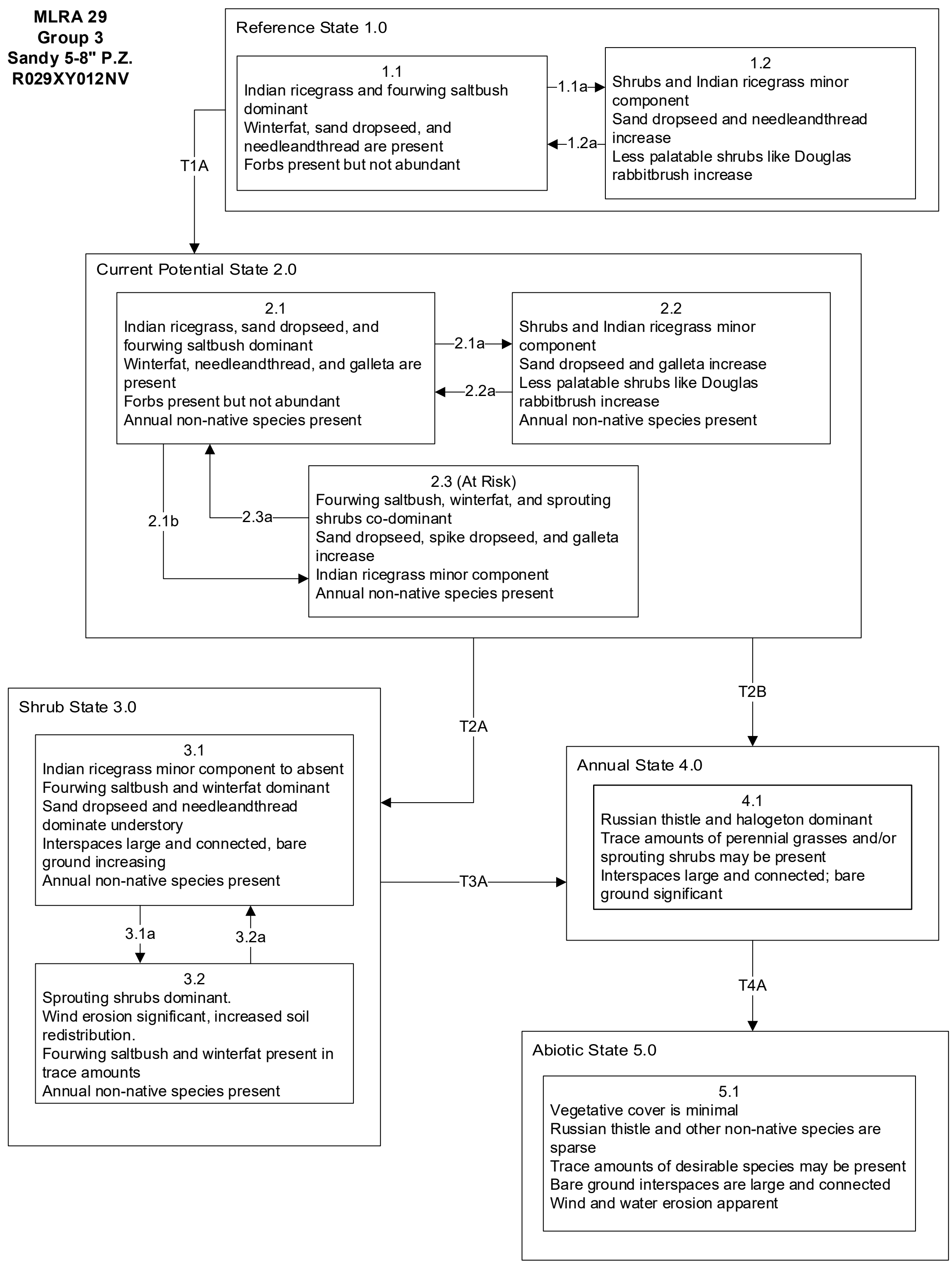
Transition T2B: Catastrophic fire.

Shrub State 3.0 Community Phase Pathways
3.1a: Severe drought and/or chronic, improper late-summer to early spring grazing management decreases or eliminates the overstory of palatable shrubs.
3.2a: Time, lack of disturbance allows for regeneration of fourwing saltbush and winterfat.

Transition T3A: Severe fire and/or long-term inappropriate grazing management with higher than normal spring precipitation increases the presence of non-native annual species. High severity fire will also cause a transition to an Annual State (4.0).

Transition T4A: Long-term, extremely inappropriate grazing management, severe drought, and/or soil disturbing treatments, combined with significant soil loss and redistribution.

Additional State and Transition Models for Group 3 in MLRA 29:



MLRA 29
Group 3
Sandy 5-8" P.Z.
R029XY012NV

Reference State 1.0 Community Phase Pathways
1.1a: Long term drought, time and/or herbivory favors increase of shrubs over deep-rooted perennial grasses. Galleta and sand dropseed may increase.
1.2a: Time and lack of disturbance and/or release from drought allows saltbush, winterfat, and Indian ricegrass to recover.

Transition T1A: Introduction of non-native annual species such as cheatgrass, halogeton, Russian thistle, and mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Chronic grazing during the late summer to early spring period reduces fourwing saltbush and winterfat. Indian ricegrass, galleta, and sand dropseed increase.
2.1b: Time, lack of disturbance allows fourwing saltbush and winterfat to increase in density. Inappropriate growing season grazing reduces deep-rooted perennial bunchgrasses.
2.2a: Time, lack of disturbance allows fourwing saltbush and winterfat to recover. Appropriate late summer to early spring grazing management facilitates an increase in fourwing saltbush and winterfat.
2.3a: Late-summer through winter grazing that reduces shrubs facilitates an increase in Indian ricegrass and a decrease in palatable shrubs. Low severity fire, while not a primary driver of change in this community, would create a fourwing saltbush/ grass mosaic.

Transition T2A: Long-term inappropriate grazing management during the growing season (to 3.1). Long term drought or grazing management that favors unpalatable shrubs would cause transition to Community Phase 3.2.

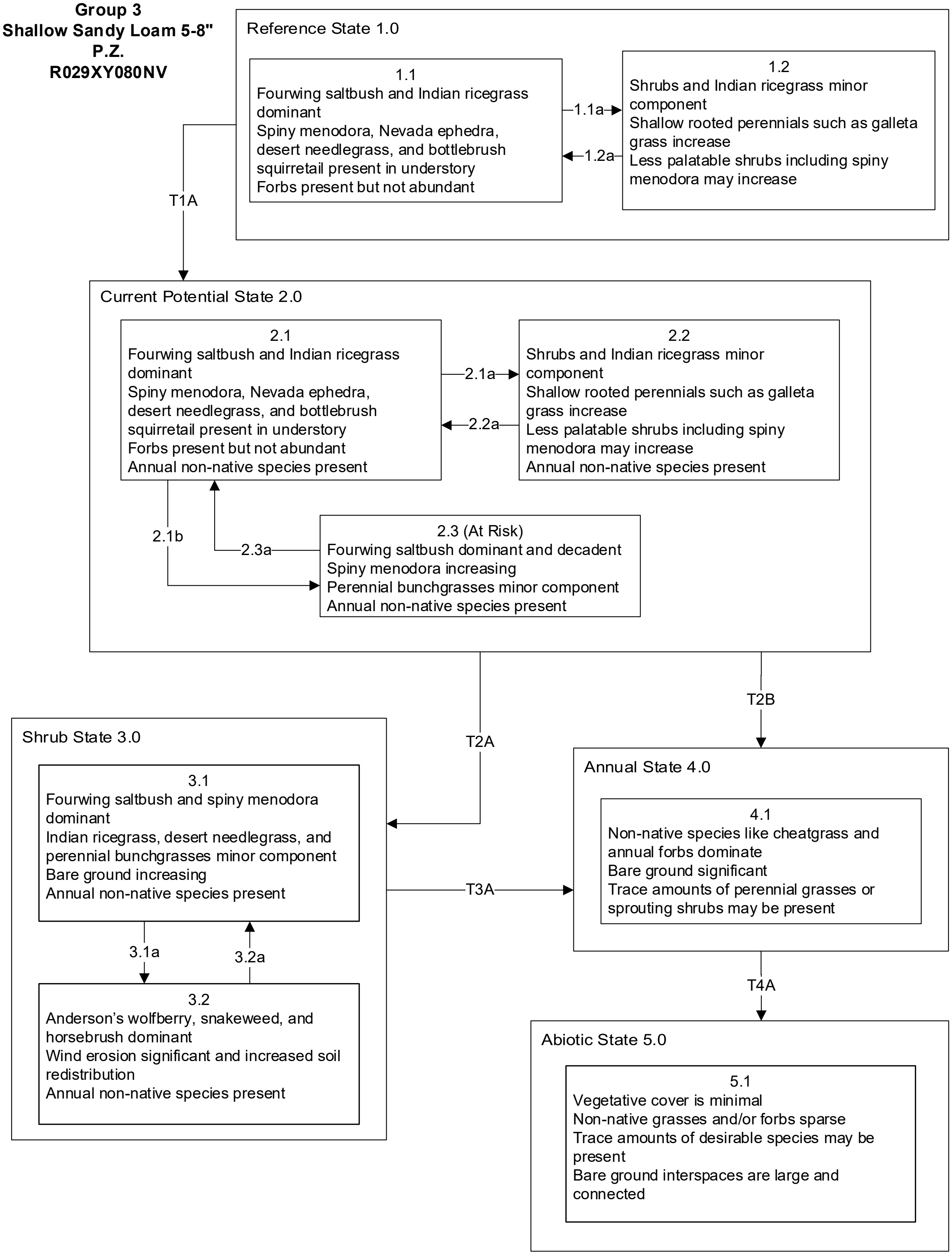
Transition T2B: Catastrophic fire.

Shrub State 3.0 Community Phase Pathways
3.1a: Severe drought and/or chronic, improper late-summer to early spring grazing management decreases or eliminates the overstory of palatable shrubs.
3.2a: Time, lack of disturbance allows for regeneration of fourwing saltbush and winterfat.

Transition T3A: Severe fire and/or long-term inappropriate grazing management with higher than normal spring precipitation increases the presence of non-native annual species. High severity fire will also cause a transition to an Annual State (4.0).

Transition T4A: Long-term, extremely inappropriate grazing management, severe drought, and/or soil disturbing treatments, combined with significant soil loss and redistribution.

MLRA 29
Group 3
Shallow Sandy Loam 5-8" P.Z.
R029XY080NV



MLRA 29
Group 3
Shallow Sandy Loam 5-8"
P.Z.
R029XY080NV

Reference State 1.0 Community Phase Pathways
1.1a: Long term drought, time and/or herbivory favors increase of shrubs over deep-rooted perennial grasses. Galleta and desert needlegrass may increase.
1.2a: Time and lack of disturbance and/or release from drought allows saltbush and Indian ricegrass to recover.

Transition T1A: Introduction of non-native annual species such as cheatgrass, halogeton, Russian thistle, and mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Chronic grazing during the late summer to early spring period reduces fourwing saltbush. Indian ricegrass, galleta, and desert needlegrass increase.
2.1b: Time, lack of disturbance allows fourwing saltbush to increase in density. Inappropriate growing season grazing reduces deep-rooted perennial bunchgrasses.
2.2a: Time, lack of disturbance allows fourwing saltbush to recover. Appropriate late summer to early spring grazing management facilitates an increase in fourwing saltbush.
2.3a: Late-summer through winter grazing that reduces shrubs facilitates an increase in Indian ricegrass and a decrease in palatable shrubs. Low severity fire, while not a primary driver of change in this community, would create a fourwing saltbush/ grass mosaic.

Transition T2A: Long-term inappropriate grazing management during the growing season (to 3.1). Long term drought or grazing management that favors unpalatable shrubs would cause transition to Community Phase 3.2.

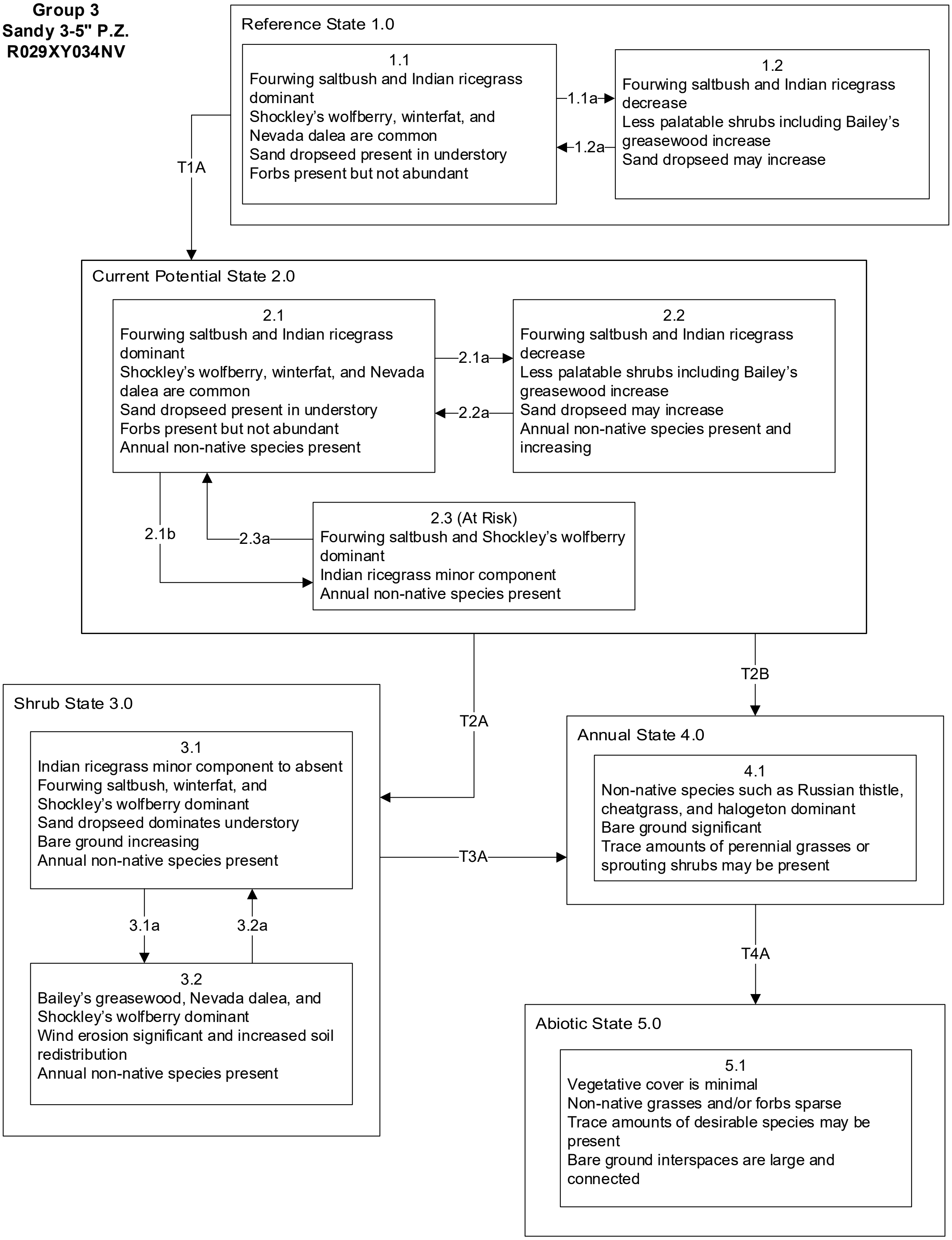
Transition T2B: Catastrophic fire.

Shrub State 3.0 Community Phase Pathways
3.1a: Severe drought and/or chronic, improper late-summer to early spring grazing management decreases or eliminates the overstory of palatable shrubs.
3.2a: Time, lack of disturbance allows for regeneration of fourwing saltbush.

Transition T3A: Severe fire and/or long-term inappropriate grazing management with higher than normal spring precipitation increases the presence of non-native annual species. High severity fire will also cause a transition to an Annual State (4.0).

Transition T4A: Long-term, extremely inappropriate grazing management, severe drought, and/or soil disturbing treatments, combined with significant soil loss and redistribution.

MLRA 29
Group 3
Sandy 3-5" P.Z.
R029XY034NV



MLRA 29
Group 3
Sandy 3-5" P.Z.
R029XY034NV

Reference State 1.0 Community Phase Pathways
1.1a: Long term drought, time, and/or herbivory favors increase of shrubs over deep-rooted perennial grasses. Sand dropseed may increase.
1.2a: Time and lack of disturbance and/or release from drought allows saltbush and Indian ricegrass to recover.

Transition T1A: Introduction of non-native annual species such as cheatgrass, halogeton, Russian thistle, and mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Chronic grazing during the late summer to early spring period reduces fourwing saltbush and winterfat. Indian ricegrass and sand dropseed increase.
2.1b: Time, lack of disturbance allows fourwing saltbush and Shockley's wolfberry to increase in density. Inappropriate growing season grazing reduces deep-rooted perennial bunchgrasses.
2.2a: Time, lack of disturbance allows fourwing saltbush to recover. Appropriate late summer to early spring grazing management facilitates an increase in fourwing saltbush and Indian ricegrass.
2.3a: Late-summer through winter grazing that reduces shrubs facilitates an increase in Indian ricegrass and a decrease in palatable shrubs. Low severity fire, while not a primary driver of change in this community, would create a fourwing saltbush/ grass mosaic.

Transition T2A: Long-term inappropriate grazing management during the growing season (to 3.1). Long term drought or grazing management that favors unpalatable shrubs would cause transition to Community Phase 3.2.

Transition T2B: Catastrophic fire.

Shrub State 3.0 Community Phase Pathways
3.1a: Severe drought and/or chronic, improper late-summer to early spring grazing management decreases or eliminates the overstory of palatable shrubs.
3.2a: Time, lack of disturbance allows for regeneration of fourwing saltbush and winterfat.

Transition T3A: Severe fire and/or long-term inappropriate grazing management with higher than normal spring precipitation increases the presence of non-native annual species. High severity fire will also cause a transition to an Annual State (4.0).

Transition T4A: Long-term, extremely inappropriate grazing management, severe drought, and/or soil disturbing treatments, combined with significant soil loss and redistribution.

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MLRA 29 Group 4: Silty soils with winterfat and Indian ricegrass

Description of MLRA 29 Disturbance Response Group 4

Disturbance Response Group (DRG) 4 consists of two ecological sites. The precipitation ranges from 5 to 8 in. Slopes range from 0 to 15%. Elevations range from 4,000 to about 6,000 ft. Production ranges from 350 to 450 lb/ac for a normal year. The soils on these sites are typically deep to very deep and are moderately well to excessively drained. The water holding capacity can range from low to high. The reference plant community is dominated by winterfat (*Krascheninnikovia lanata*) and/or Indian ricegrass (*Achnatherum hymenoides*). Other important species include, bud sagebrush (*Picrothamnus desertorum*), galleta (*Pleuraphis jamesii*), bottlebrush squirreltail (*Elymus elymoides*), fourwing saltbush (*Atriplex canescens*), sand dropseed (*Sporobolus cryptandrus*).

Disturbance Response Group 4 Ecological Sites:

Coarse Silty 5-8" P.Z. – Modal	R029XY042NV
Silty 5-8" P.Z.	R029XY020NV

Modal Site:

The Coarse Silty 5-8" P.Z. ecological site is the modal site that represents this DRG, as it has the most acres mapped. This site occurs on lower fan piedmonts and inset fans on all exposures. Slopes range from 2 to 15%, but slope gradients of 2 to 8% are typical. Elevations are 4,500 to 6,000 ft. Surface soils are typically moderately coarse to coarse-textured. The coarse surface textures provide rapid water infiltration and enhance the effective moisture supply. The soils of this site are typically deep to very deep and well drained to somewhat excessively drained. The soils are moderately to strongly alkaline and calcareous throughout the profile. The soil temperature regime is mesic and the soil moisture regime is typic. Potential for sheet and rill erosion is slight. The native plant community is dominated by Indian ricegrass and winterfat. Other important species include bud sagebrush, galleta, bottlebrush squirreltail, and fourwing saltbush.

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasives. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans a unique area in Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area. Flashy summer storm events contribute significantly to annual precipitation. Air and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species within MLRA 29 (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations, combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

Periodic drought regularly influences sagebrush ecosystems, with drought duration and severity increasing throughout the 20th century in much of the Intermountain West (Miller et al. 2008a). Major shifts away from historical precipitation patterns have the potential to alter ecosystem function, vegetative composition and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006).

The ecological sites in this DRG are dominated by deep-rooted, cool-season perennial bunchgrasses and drought tolerant shrubs with high root to shoot ratios. Native bunchgrasses generally have somewhat shallower root systems than the shrubs, but root densities are often as high, or higher, than those of the shrubs in the upper 0.5 m (20 in.) of the soil profile (Dobrowolski et al. 1990). General differences in root depth distributions between grasses and shrubs results in resource partitioning in these shrub – grass systems. Although not dominant, warm-season grasses are present within all of these sites.

Winterfat, the dominant shrub of this group, is a native, cool-season, long-lived and drought tolerant species (Mozingo 1987c). It has a woody base from which annual branchlets grow (Welsh et al. 1987). The most common variety is a low growing dwarf form (less than 38 cm or 15 in.), which is most often found on desert valley floors (Stevens et al. 1977). Winter precipitation and plentiful spring moisture is a primary growth driver for winterfat. Winterfat has a long growth period from April to September, and heavy August-September rain can cause a second late-season flowering (West and Gasto 1978). Winterfat reproduces from seed and primarily pollinates via wind (Stevens et al. 1977). Seed production, especially in desert regions, is dependent on precipitation (West and Gasto 1978) with good seed years occurring when there is appreciable summer precipitation and little browsing (Stevens et al. 1977). In years of low winter precipitation, winterfat greatly reduces seed production (West and Gasto 1978). Winterfat has multiple dispersal mechanisms: diaspores are shed in the fall or winter, dispersed by wind, rodent-cached, or carried on animals (Majerus 2003). Diaspores take advantage of available moisture, tolerating freezing conditions as they progress from imbibed seeds to germinants to nonwoody seedlings (Booth 1989). Under some circumstances, the degree of reproduction may be dependent on mature plant density (Freeman and Emlen 1995).

Bud sagebrush, a common shrub in this group, is a native summer-deciduous shrub. It is low growing, spinescent, and aromatic in nature with a height of 4 to 10 in. and a spread of 8 to 12 in. (Stubbendieck et al. 2017). Bud sagebrush roots are more branched and deeply penetrating than associated shrub species like winterfat and shadscale, so it more efficiently utilizes spring precipitation. This shrub typically actively grows between March and June, and is dormant for the rest of the year. This dormancy means bud sagebrush is not significantly affected by summer drought. Autumn rain can cause bud sage plants to partially emerge from dormancy and produce new leaves (Chambers and Norton 1993).

Indian ricegrass, the dominant understory species of this group, is a long-lived, cool-season perennial bunchgrass that grows from 10 to 60 cm (4 to 24 in.) in height (Blaisdell and Holmgren 1984). Primarily adapted to coarse-textured soils, its deep, fibrous root system makes Indian ricegrass one of the most drought-tolerant native species (Booth et al. 1980). Unlike other cool-season species, Indian ricegrass does not require vernalization (exposure to cold) in order to produce flowers and flowering can continue into late fall with favorable environmental conditions. This allows the seeds in each panicle to ripen over a longer period of time than most other species thus providing a greater opportunity for successful seed production (Jones 1990).

Galleta is a mat-forming, rhizomatous, native grass that is 30 to 50 cm tall (12 to 20 in.) (Stubbendieck et al. 2003). This warm-season, perennial species is more water efficient than its cool-season counterparts. This allows galleta grass to survive in low precipitation zones where a significant portion of rainfall occurs during summer months (Banner et al. 2011). Everett et al. (1980) found that galleta grass initiated more than one phenological cycle with the presence of summer precipitation, allowing the species to grow and set seed more than once a year. This plant is typical of southern Nevada and the transition zone between the Great Basin and the Mojave Desert. It is most common in fine-textured soils (Stubbendieck et al. 2003).

These communities often exhibit the formation of microbiotic crusts within the interspaces between shrubs. The effects of biological soil crusts are variable and dependent on ecosystem type and the composition of the crust's functional group. Faist et al. (2017) concludes that intact, light colored microbiotic crusts exhibited higher runoff and more sediment loss than the trampled or scraped crusts. Furthermore, the authors report the trampled dark colored microbiotic crusts shed slightly more water, after 30 min of intense rainfall (9 in./hr) than the intact comparison. Other authors report a reduction in microbiotic crust integrity with inappropriate grazing management, wildland fire and cheatgrass (*Bromus tectorum*) invasion (Belnap 2006, Ponzetti et al. 2007).

Annual Invasive Species:

The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species resulting in reduced competition while simultaneously increasing resource pools through the decomposition of dead plant material. Historically, winterfat communities were free of exotic invaders; however, excessive grazing pressure during settlement and into the 20th century has increased the overall presence of cheatgrass, red brome (*Bromus rubens*), halogeton (*Halogeton glomeratus*), Russian thistle (*Salsola tragus*) and weedy mustard species (*Brassicaceae* spp.) (Pellant and Reichert 1984, Peters and Bunting 1994). The presence of exotic annual plants within these ecosystems decreases ecosystem resilience and resistance to disturbance through competition for limited resources. Cheatgrass and halogeton are the species most likely to invade the ecological sites contained within this DRG.

Cheatgrass is a cool-season annual grass that maintains an advantage over native plants, in part, because it is a prolific seed producer, can germinate in the autumn or spring, tolerates grazing, and increases with frequent fire (Klemmedson and Smith 1964, Miller 1999). Cheatgrass originated from Eurasia and was first reported in North America in the late 1800s (Furbush 1953, Mack and Pyke 1983). Bradley et al. (2018) found that cheatgrass has expanded to greater than 15% cover over 210,000 km^2 (130,500 mi^2) – roughly 31% of the Intermountain West. In the Great Basin, cheatgrass is expanding at a rate of expansion of 3,700 km^2 (2,300 mi^2) annually and is a land management issue that will require creative solutions (Smith et al. 2022).

Methods to control cheatgrass include herbicide, targeted grazing, and seeding. The majority of research on cheatgrass control has focused on Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) dominated rangelands. Control options include spraying with herbicide (imazapic or imazapic + glyphosate, indaziflam) and seeding with desired perennial species (Sheley et al. 2012). Indaziflam, a relatively new herbicide for rangeland applications, is showing promise in its ability to control cheatgrass, red brome, and halogeton. Approved for rangelands in 2016, this pre-emergent herbicide works by inhibiting cell wall biosynthesis and therefore seed germination and root elongation (Kaapro and Hall 2012, Clark et al. 2019). Indaziflam effectively reduces the seed bank of invasive annuals with little to no effect on aboveground plant communities (Courkamp et al. 2022). It also has been proven to control invasive annuals longer than other herbicides, providing three or more years of control (Sebastian et al. 2017b). Sebastian et al. (2017b) found that indaziflam selectively controlled cheatgrass without impacting perennial grass and forb biomass as well. This led to significant increases in biomass of desirable species due to reductions in cheatgrass presence and competition (Sebastian et al.

2017b). Clark et al. (2019) found a similar result on plots in Colorado suggesting that indaziflam may be the best new herbicide on the market for invasive annual control.

Targeted grazing during the fall and winter can also control cheatgrass on invaded sites. Fall and winter grazing decreases standing dead biomass and reduces fuel continuity with minimal risk to native perennial herbaceous plants (Davies et al. 2016). This alters fire risk and severity by reducing fuel loads, flame height, rate of spread and area burned in Great Basin sagebrush systems (Davies et al. 2015a). Repetitive fall grazing can also reduce cheatgrass seed banks, however, the seed bank can rapidly recover if fall grazing efforts cease (Perryman et al. 2020). Halogeton is a non-competitive plant that tends to invade areas that are susceptible to repeated disturbance such as; livestock trails, roadsides, trampled areas near watering holes or corrals and rangeland areas stripped of the natural vegetation by excessive grazing or other soil disturbing activities (Young 2002). It was first introduced into the western U.S. during the 20th century with the first collection being made near Wells, Nevada in 1934. Halogeton is highly toxic to sheep and has been responsible for thousands of sheep deaths throughout the western U.S., which triggered a massive effort to eradicate the introduced species in the late 1900s (Young 2002).

Halogeton has two distinct seed forms; a black form which consists of the achene only and a brown form which consists of the achene and attached sepals (Tisdale and Zappetini 1953, Robocker et al. 1969). The black form of halogeton seed germinate readily under a wide range of pH and salt concentrations within the first year. The brown form of seed was found to be 100% viable at the end of two years and 15% viable at the end of 10 years, proving that halogeton seed may remain viable in the soil for up to 10 years (Robocker et al. 1969). Eradication of this species is problematic, therefore, appropriate range management practices focused on soil and rangeland integrity are necessary to control the species.

Fire Ecology:

Winterfat is able to tolerate environmental stress, extremes of temperature and precipitation, and competition from other perennials, however it does not tolerate fire or overgrazing well (Ogle et al. 2001). Fire was historically rare within these communities due to low fuel loads. There are conflicting reports in the literature about the response of winterfat to fire. In one of the first published descriptions, Dwyer and Pieper (1967) reported that winterfat sprouts vigorously after fire. This observation was frequently cited in subsequent literature, but recent observations have suggested that winterfat can be completely killed by fire (Pellant and Reichert 1984). The response is apparently dependent on fire severity. Winterfat is able to sprout from buds near the base of the plant. However, if these buds are destroyed, winterfat will not sprout. Research has shown that winterfat seedling growth is depressed in growth by at least 90% when growing in the presence of cheatgrass (Hild et al. 2007). Repeated, frequent fires will increase the likelihood of conversion to a non-native, annual plant community with trace amounts of winterfat or other desirable species.

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species' response. Thus, fire mortality is correlated to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant, and abundance of old growth (Wright 1971, Young 1983). Boyd et al. (2015) found soil color and depth of burn to be accurate predictors of bunchgrass mortality in post fire landscapes. They also found that bunchgrasses in close proximity of shrubs had up to five-fold higher mortality than bunchgrasses located in the interspaces (Boyd et al. 2015).

Indian ricegrass is fairly fire tolerant (Wright 1985), which is likely due to its low culm density and below-ground plant crowns. Vallentine (1989) cites several studies in the sagebrush zone that classified Indian ricegrass as being slightly damaged from late summer burning. Indian ricegrass has also been found to reestablish on burned sites through seeds dispersed from adjacent unburned areas (Young 1983, West 1994). Thus, the presence of surviving, seed-producing plants facilitates the reestablishment of Indian ricegrass. Grazing management following fire to promote seed production and establishment of seedlings is important. When properly managed, Indian ricegrass can be a key factor in a community recovering from disturbance because it can grow in rough, rocky, coarse, and otherwise unproductive soils (Booth et al. 1980).

Galleta grass, a minor component of these ecological sites, has been found to increase following fire likely due to its rhizomatous root structure and ability to resprout (Jameson 1962). This species may retard reestablishment of deeper-rooted bunchgrasses. Repeated frequent fire in this community will eliminate winterfat and bud sagebrush, significantly decrease deep-rooted bunchgrass density and facilitate the establishment of an annual weed community with varying amounts of galleta and sprouting shrubs.

Livestock/Wildlife Grazing Interpretations:

Winterfat is a valuable forage species for livestock and wildlife, with an average of 14% crude protein during winter and 21% during the spring and early summer months (Clements et al. 2010). However, excessive grazing throughout the west has negatively impacted survival of winterfat stands (Hilton 1941, Statler 1967, Stevens et al. 1977). Domestic sheep and cattle diets on Great Basin rangelands greatly overlap, with a similarity of 78% (Johnson 1979). Time of grazing is critical for winterfat with the active growing period being most critical (Romo et al. 1995). Winterfat is a highly nutritious winter feed and shows significant declines in density with late winter or early spring grazing (Harper et al. 1990). Stevens et al. (1977) found that both vigor and reproduction of winterfat were reduced in Steptoe Valley, Nevada by improper season of use, and he recommended no more than 25% utilization during periods of active growth and up to 75% utilization during dormant season use. Rasmussen and Brotherson (1986) found significantly greater foliar cover and density of winterfat in areas ungrazed for 26 years versus winter grazed areas in Utah. In exclosures protected from grazing for between 5 and 16 years, Rice and Westoby (1978) found that winterfat increased in foliar cover but not in density where it was dominant, and in both foliar cover and density in shadscale-perennial grass communities where it was not dominant.

In addition to grazing by sheep and cattle, winterfat is browsed by rabbits (*Leporidae* spp.), antelope (*Antilocapra americana*), and other wildlife species (Stevens et al. 1977, Ogle et al. 2001). Winterfat and perennial grasses average 80% of jackrabbits' (*Lepus* spp.) diet in southeastern Idaho, with shrubs being grazed in fall and winter particularly (Johnson and Anderson 1984). Pronghorn and rabbits browse stems, leaves, and seed stalks of winterfat year round, especially during periods of active growth (Stevens et al. 1977). Management of wildlife browse is difficult and browse may be harmful to winterfat reestablishment as seed production and regrowth are curtailed if grazing occurs as the plant begins to grow (Eckert 1954).

Bud sagebrush is also a palatable, nutritious forage for upland game birds, small game, big game and domestic sheep in winter, particularly late winter (Johnson 1978); however it can be poisonous or fatal to calves when eaten in quantity (Stubbendieck et al. 1992). Bud sagebrush is highly susceptible to effects of browsing. It decreases under browsing due to year-long palatability of its buds and is particularly susceptible to browsing in the spring when it is physiologically most active (Harper et al. 1990, Chambers and Norton 1993). Heavy browsing (>50%) may kill bud sagebrush rapidly (Wood and Brotherson 1986).

Indian ricegrass is a preferred forage species for livestock and wildlife and cures well, providing nutritious winter feed (Cook 1962, Booth et al. 1980). It is also readily utilized in early spring, being a source of green feed before most other perennial grasses have produced new growth (Quinones 1981). Booth et al. (1980) note that the plant does well when utilized in winter and spring. In eastern Idaho, productivity of Indian ricegrass was at least 10 times greater in undisturbed plots than in heavily (60% utilization) grazed ones (Pearson 1965). Cook and Child (1971) found significant reduction in crown cover, plant vigor and herbage yield of Indian ricegrass when the species was utilized at 90% during any season. However, they found no reductions at 30% utilization during any season and no reductions at 60% utilization during winter and early spring grazing (Cook and Child 1971). The seed crop may be reduced where grazing is heavy (Bich et al. 1995). Tolerance to grazing increases after May, thus spring deferment may be necessary for stand enhancement (Pearson 1964, Cook and Child 1971); however, utilization of less than 60% is recommended. In summary, adaptive management is required to manage this bunchgrass well.

Galleta is a highly palatable forage species for cattle, sheep, deer (*Odocoileus* spp.), antelope, and horses during late spring and summer while it is green (Stubbendieck et al. 2017). Due to its rhizomatous characteristics, galleta grass is particularly tolerant of heavy grazing and trampling (Pratt et al. 2002). This species will also initiate more than one phenological cycle if summer precipitation is present (Everett et al. 1980), allowing galleta to grow and propagate after defoliation.

State and Transition Model Narrative for Group 4:

Reference State 1.0:

The Reference State 1.0 is a representative of the natural range of variability under pristine conditions. This state has two community phases, one dominated by grass, and the other dominated by shrubs. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. This site is very stable, with little variation in plant community composition. Plant community changes would be reflected in production in response to drought or above average precipitation events. Wet years will increase grass production, while drought years will reduce production. Shrub production will also increase during wet years; however, recruitment of winterfat is episodic.

Community Phase 1.1:
This community is dominated by winterfat and Indian ricegrass. Galleta, bud sagebrush and fourwing saltbush are also important species on this site. Potential vegetative composition by air-dry weight is approximately 55% grasses, 5% forbs and 40% shrubs. Approximate ground cover (basal and canopy) is 15 to 30%. Total annual air-dry production ranges from 300 to 700 lb/ac.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
Prolonged drought and/or excessive herbivory reduces deep-rooted perennial grass while bare ground increases. Fires would also decrease vegetation on these sites but would be infrequent and patchy due to low fuel loads.

Community Phase 1.2:
Winterfat and bud sagebrush dominate the site. Indian ricegrass is reduced and bare ground has increased. Drought will favor shrubs over perennial bunchgrasses. However, long-term drought will result in an overall decline in the plant community, regardless of functional group.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
Time, lack of disturbance and recovery from drought would allow the vegetation to increase and bare ground would eventually decrease.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0:

Trigger: Introduction of non-native annual plants such as cheatgrass, Russian thistle, mustards, and/or halogeton.

Slow variables: Over time the annual non-native plants will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

In this state, ecological function has not changed, however the resiliency of the state has been reduced by the presence of invasive weeds and the introduction of domestic grazers and non-native horses and burros. Non-natives may increase in abundance but will not become dominant within this State. These non-natives can be highly flammable and can promote fire where historically fire had been infrequent. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These feedbacks include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal.

Community Phase 2.1:
This community is dominated by winterfat and Indian ricegrass. Galleta and bud sagebrush are also important species on this site. Non-native annual species are present.

Coarse Silty 5-8" P.Z. (R029XY042NV), Current Potential State 2.1, T. Stringham, June 2020

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
Drought will favor shrubs over perennial bunchgrasses. However, long-term drought will result in an overall decline in the plant community, regardless of functional group. Inappropriate livestock and/or horse and burro grazing will favor unpalatable shrubs

such as shadscale and Douglas rabbitbrush, and cause a decline in Indian ricegrass, winterfat and bud sagebrush.

Community Phase 2.2 (At Risk):
Winterfat and other shrubs dominate this community. Indian ricegrass and other deep rooted perennial bunchgrasses are a minor component, and galleta and/or sand dropseed are increasing. Annual non-natives are present. This community is at risk of crossing a threshold to either a Shrub State 3.0 or an Annual State 4.0.

Coarse Silty 5-8" P.Z. (R029XY042NV), Current Potential State 2.2, T. Stringham, June 2020

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1
Release from long term drought and/or growing season livestock and/or horse and burro grazing allows recovery of bunchgrasses, winterfat, and bud sagebrush.

T2A: Transition from Current Potential State 2.0 to Shrub State 3.0:

Trigger: Inappropriate, long-term grazing of Indian ricegrass and other perennial bunchgrasses during the growing season and/or long-term drought will favor shrubs and initiate a transition to Community phase 3.1.

Slow variables: Long term decrease in deep-rooted perennial grass density.

Threshold: Loss of deep-rooted Indian ricegrass and other perennial bunchgrasses changes nutrient cycling, nutrient redistribution, and reduces soil organic matter.

T2B: Transition from Current Potential State 2.0 to Annual State 4.0:

Trigger: Long term extremely inappropriate grazing and/or soil disturbing activities such as trampling of wet soil. Fire, following a year with above normal precipitation causing an increase in fine fuels.

Slow variables: Increased production and cover of non-native annual species.

Threshold: Loss of deep-rooted perennial bunchgrasses and shrubs truncates, spatially and temporally, nutrient capture and cycling within the community. Increased, continuous fine fuels from annual non-native plants modify the fire regime by changing intensity, size and spatial variability of fires.

Shrub State 3.0:

This state consists of two community phases. This site has crossed a biotic threshold and site processes are being controlled by shrubs. Bare ground has increased.

Community Phase 3.1 (At Risk):
Perennial bunchgrasses are significantly reduced or missing, winterfat and other shrubs are dominant. Annual non-native species are present and bare ground has increased. This community is at risk of transitioning to an Annual State 4.0 or an Abiotic State 5.0.

Coarse Silty 5-8" P.Z. (R029XY042NV), Shrub State 3.1, T. Stringham, June 2020

Silty 5-8" P.Z. (R029XY020NV), Shrub State 3.1, D. Snyder, June 2019

Community Phase Pathway 3.1a from Phase 3.1 to 3.2:
Inappropriate or excessive grazing reduces winterfat and/or bud sagebrush cover and allows for sprouting shrubs, such as Douglas rabbitbrush, to dominate the overstory. Brush treatments with minimal soil disturbance would also facilitate this community phase pathway.

Community Phase 3.2 (At Risk):
Rabbitbrush and/or other sprouting shrubs dominate the overstory. Annual non-native species may be increasing and bare ground is significant. Desirable species such as Indian ricegrass and/or winterfat may be present in trace amounts. This site is at risk for an increase in invasive annual weeds. This community phase is at risk of transitioning to an Annual State 4.0 or an Abiotic State 5.0.

Coarse Silty 5-8" P.Z. (R029XY042NV), Shrub State 3.2, D. Snyder, June 2019

Coarse Silty 5-8" P.Z. (R029XY042NV), Shrub State 3.2, T. Stringham, June 2020

Community Phase Pathway 3.2a from Phase 3.2 to 3.1:
Grazing and/or horse and burro management that favors the reestablishment and growth of winterfat and/or other non-sprouting shrubs.

T3A: Transition from Shrub State 3.0 to Annual State 4.0:

Trigger: Long-term inappropriate grazing and/or trampling on wet soil (4.1). Long-term inappropriate grazing, unsuccessful soil disturbing treatments such as drill seeding or brush mowing and/or long-term, chronic drought. Fire following a wet growing season (4.2).

Slow variables: Increased production and cover of non-native annual species.

Threshold: Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and shrubs truncate energy capture spatially and temporally thus impacting nutrient cycling and distribution.

T3B: Transition from Shrub State 3.0 to Abiotic State 5.0:

Trigger**:** Long-term, extremely inappropriate grazing management, flooding, severe drought and/or soil disturbing treatments such as drill seeding or roller chopper, etc. combined with significant soil loss and redistribution.

Slow variables: Long term decrease in density of native, perennial vegetation combined with soil movement and loss.

Threshold: Increased wind or water erosion resulting in soil loss preventing the establishment of native perennials. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and shrubs truncate energy capture spatially and temporally thus impacting nutrient cycling and distribution.

Annual State 4.0:

This state consists of two community phases. In this state, a biotic threshold has been crossed and state dynamics are driven by the dominance and persistence of the exotic annual species. Halogeton, Russian thistle, tumble mustard and/or cheatgrass dominate the plant community. Bare ground may be abundant and desirable, native vegetation is trace or missing.

Community Phase 4.1:
Annual non-native species are dominant. Sand dropseed and/or galleta may be sub-dominant. Winterfat and Indian ricegrass are a trace component or missing. Bare ground may be abundant, especially during low precipitation years.

Silty 5-8" P.Z. (R029XY020NV), Annual State 4.1, D. Snyder, September 2020

Community Phase Pathway 4.1a, from Phase 4.1 to 4.2:
Fire following a wet growing season or long-term inappropriate grazing, unsuccessful soil disturbing treatments such as drill seeding or brush mowing and/or long-term, chronic drought.

Community Phase 4.2:
This community is dominated by annual non-native species. Trace amounts of winterfat and other shrubs may be present, but are not contributing to site function. Bare ground may be abundant, especially during low precipitation years.

Silty 5-8" P.Z. (R029XY020NV), Annual State 4.2, D. Snyder, September 2020

Coarse Silty 5-8" P.Z. (R029XY042NV), Annual State 4.2, T. Stringham, May 2020

T4A: Transition from Annual State 4.0 to Abiotic State 5.0:

Trigger: Long-term, extremely inappropriate grazing management, flooding, severe drought and/or unsuccessful soil disturbing treatments such as drill seeding, roller chopper, etc. combined with significant soil loss and redistribution.

Slow variables: Long term decrease in density of native and non-native vegetation combined with soil movement and loss.

Threshold: Increased wind or water erosion resulting in soil loss preventing the establishment of native perennials and reduction in non-native species. Changes in plant community composition and spatial variability of vegetation due to the loss of vegetative density and cover of all functional groups truncates energy capture spatially and temporally thus impacting nutrient cycling and distribution.

Abiotic State 5.0:

This state consists of one community phase in which abiotic factors (ea. wind or water erosion) have dramatically altered the site. It is characterized by the loss of vegetative cover along with the redistribution and loss of the soil surface. Feedbacks contributing to the stability of this state include soil loss, nutrient loss, soil surface degradation and increased area, distribution and connectivity between patches of bare soil.

Community Phase 5.1:
This community is the result of extreme soil loss and redistribution. The vegetative cover is minimal, but is dominated by introduced non-native grasses and/or forbs. Trace amounts of desirable species may be present and bare ground interspaces are large and connected. Site function is controlled by soil erosion, wind and soil temperature. Rehabilitation of this community is unknown.

Coarse Silty 5-8" P.Z. (R029XY042NV), Abiotic State 5.1, T. Stringham, May 2021

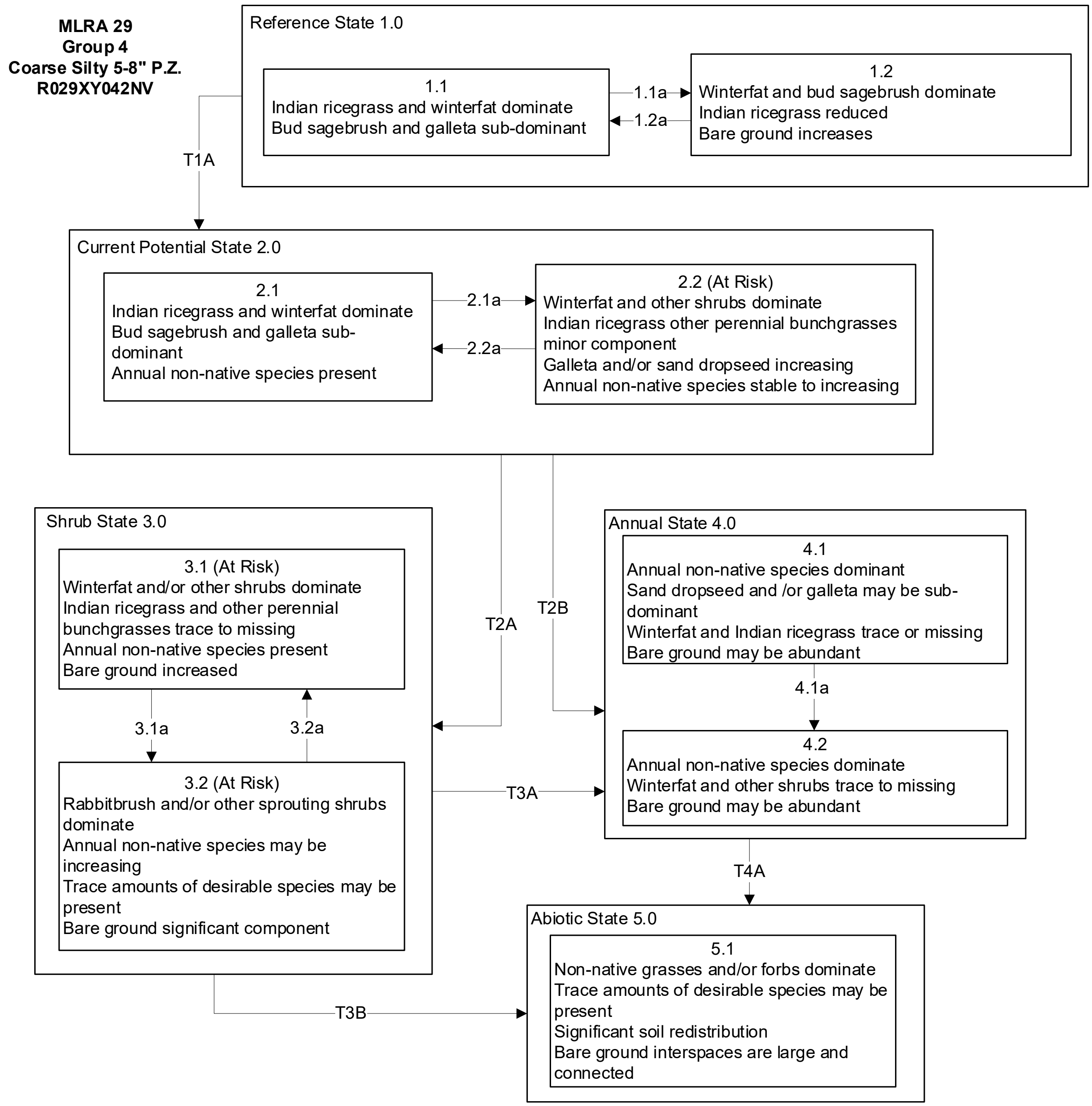
Silty 5-8" P.Z. (R029XY020NV), Abiotic State 5.1, D. Snyder, May 2021

Potential Resilience Differences with Other Ecological Sites in this Group:

Silty 5-8" P.Z. R029XY020NV:

This site occurs on alluvial plains, fan skirts, and inset fans on all exposures and is dominated by winterfat and bud sagebrush. Shrubs make up 70% of the potential species composition. Indian ricegrass and bottlebrush squirreltail dominate the understory. Production is 350 lb/ac in a normal year. This site is most likely invaded by Russian thistle, halogeton, and mustards rather than cheatgrass. The soils are highly erodible and with site degradation, gullies may form which interrupt and concentrate overland flow.

Modal State and Transition Model for Group 4 in MLRA 29:



Reference State 1.0 Community Phase Pathways
1.1a: Prolonged drought and/or excessive herbivory reduces deep-rooted perennial grass density and production. Fires would also decrease vegetation on these sites but would be infrequent and patchy due to low fuel loads.
1.2a: Time, lack of disturbance and recovery from drought would allow the vegetation to increase and bare ground would eventually decrease.

Transition T1A: Introduction of non-native annual species such as halogeton, Russian thistle, cheatgrass and annual mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Inappropriate cattle and/or horse grazing management during the growing season and/or prolonged drought reduces winterfat, bud sagebrush and Indian ricegrass. Less palatable shrubs and grasses may increase.
2.2a: Release from long term drought and/or growing season livestock and/or horse and burro grazing allows recovery of Indian ricegrass, winterfat, and bud sagebrush.

Transition T2A: Long-term inappropriate grazing of Indian ricegrass and other perennial bunchgrasses during the growing season and/or long term drought will favor shrub establishment.

Transition T2B: Fire, soil disturbing activities, (drill seeding, trampling of wet soil, etc.), and/or long-term inappropriate grazing management allows for increase in non-native annual species.

Shrub State 3.0 Community Phase Pathways
3.1a: Long-term inappropriate grazing and/or brush treatments with minimal soil disturbance reduce winterfat and/or bud sagebrush cover and allow increase in sprouting shrubs.
3.2a: Grazing and/or horse and burro management that favors the reestablishment and growth of winterfat and/or other non-sprouting shrubs.

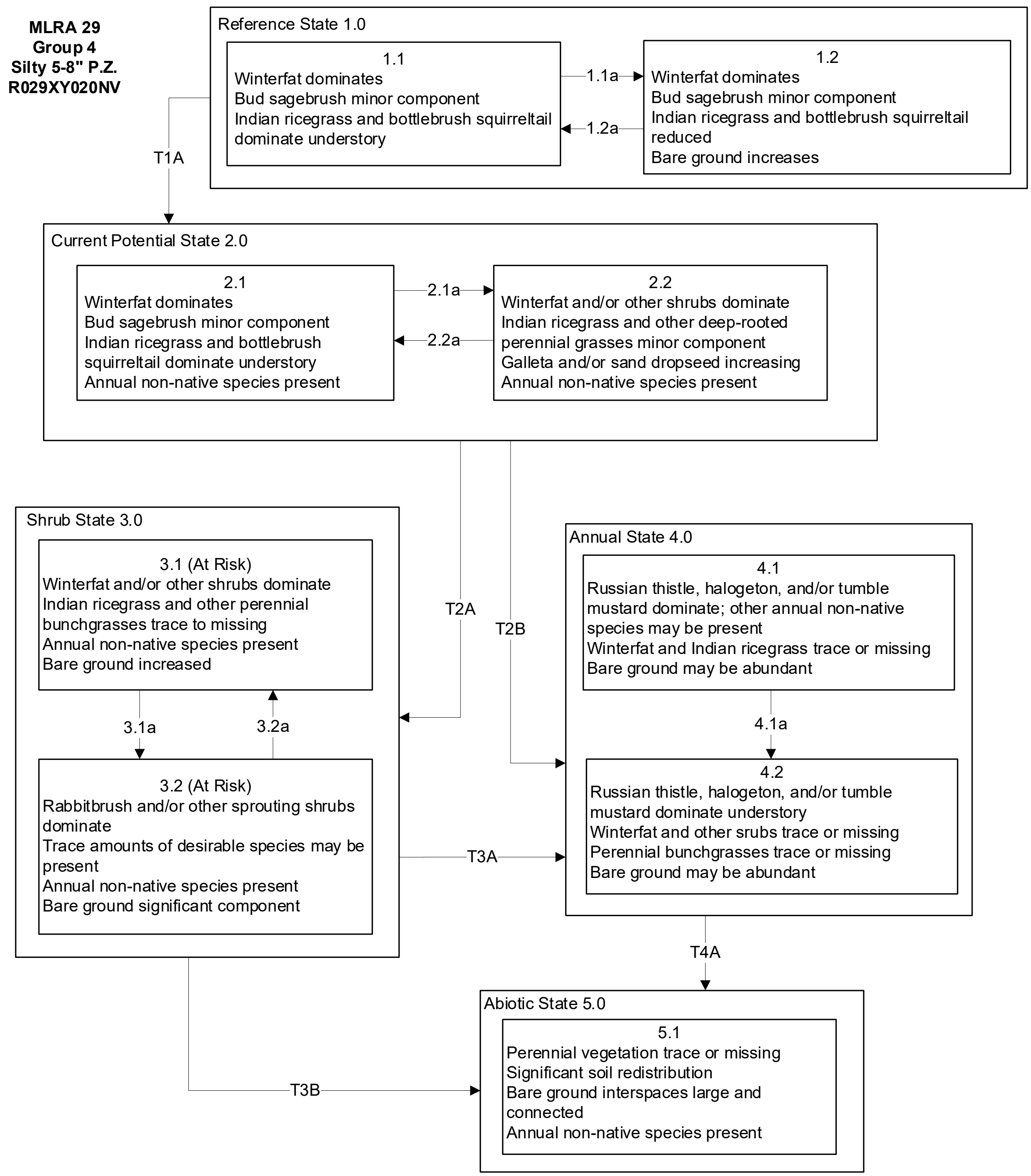
Transition T3A: Long-term inappropriate grazing and/or trampling on wet soil (4.1). Long-term inappropriate grazing, unsuccessful soil disturbing treatments such as drill seeding or brush mowing and/or long-term, chronic drought. Fire following a wet growing season (4.2).

Transition T3B:Long-term, extremely inappropriate grazing management, flooding, severe drought and/or unsuccessful soil disturbing treatments such as drill seeding or roller chopper, etc. combined with significant soil loss and redistribution.

Annual State 4.0 Community Pathways
4.1a: Fire following a wet growing season or long-term inappropriate grazing, unsuccessful soil disturbing treatments such as drill seeding or brush mowing and/or long-term, chronic drought.

Transition T4A: Long-term, extremely inappropriate grazing management, flooding, severe drought and/or unsuccessful soil disturbing treatments such as drill seeding, roller chopper, etc. combined with significant soil loss and redistribution.

Additional State and Transition Models for Group 4 in MLRA 29:



MLRA 29
Group 4
Silty 5-8" P.Z.
R029XY020NV

Reference State 1.0 Community Phase Pathways
1.1a: Prolonged drought and/or excessive herbivory reduces deep-rooted perennial grass density and production. Fires would also decrease vegetation on these sites but would be infrequent and patchy due to low fuel loads.
1.2a: Time, lack of disturbance and recovery from drought would allow the vegetation to increase and bare ground would eventually decrease.

Transition T1A: Introduction of non-native annual species such as halogeton, Russian thistle, cheatgrass and annual mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Inappropriate cattle and/or horse grazing management during the growing season and/or prolonged drought reduces winterfat, bud sagebrush and Indian ricegrass. Less palatable shrubs and grasses may increase.
2.2a: Release from long term drought and/or growing season livestock and/or horse and burro grazing allows recovery of Indian ricegrass, winterfat, and bud sagebrush.

Transition T2A: Long-term inappropriate grazing of Indian ricegrass and other perennial bunchgrasses during the growing season and/or long term drought will favor shrub establishment.

Transition T2B: Fire, soil disturbing activities, (drill seeding, trampling of wet soil, etc.), and/or long-term inappropriate grazing management allows for increase in non-native annual species.

Shrub State 3.0 Community Phase Pathways
3.1a: Long-term inappropriate grazing and/or brush treatments with minimal soil disturbance reduce winterfat and/or bud sagebrush cover and allow increase in sprouting shrubs.
3.2a: Grazing and/or horse and burro management that favors the reestablishment and growth of winterfat and/or other non-sprouting shrubs.

Transition T3A: Long-term inappropriate grazing and/or trampling on wet soil (4.1). Long-term inappropriate grazing, unsuccessful soil disturbing treatments such as drill seeding or brush mowing and/or long-term, chronic drought. Fire following a wet growing season (4.2).

Transition T3B:Long-term, extremely inappropriate grazing management, flooding, severe drought and/or unsuccessful soil disturbing treatments such as drill seeding or roller chopper, etc. combined with significant soil loss and redistribution.

Annual State 4.0 Community Pathways
4.1a: Fire following a wet growing season or long-term inappropriate grazing, unsuccessful soil disturbing treatments such as drill seeding or brush mowing and/or long-term, chronic drought.

Transition T4A: Long-term, extremely inappropriate grazing management, flooding, severe drought and/or unsuccessful soil disturbing treatments such as drill seeding, roller chopper, etc. combined with significant soil loss and redistribution.

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MLRA 29 Group 5: Seasonally flooded areas with basin wildrye

Description of MLRA 29 Disturbance Response Group 5

Disturbance Response Group (DRG) 5 consists of four ecological sites. The precipitation ranges from (3)4 to 12 in. Slopes range from 0 to 15% but ranges of 0 to 4% are typical. Elevation ranges from approximately 3,000 to 5,800 ft. These sites occur on inset fans, lake plains, and axial-stream floodplains. The soils on these sites are typically deep to very deep and somewhat poorly to moderately well drained. The soils are formed in silty alluvium and are subject to flooding, which causes surface crusting as they dry. The soil profile is affected by water table fluctuations and is salt and sodium affected. The soil temperature regime is mesic typic or mesic aeric and the soil moisture regime is typic aridic. Runoff is very slow to medium, water holding capacity is moderate to high, and permeability is moderately slow to slow. The reference plant communities are dominated by basin wildrye (*Leymus cinereus*), alkali sacaton (*Sporobolus airoides),* black greasewood (*Sarcobatus vermiculatus*), basin big sagebrush (*Artemisia tridentata* ssp. *tridentata*), and Torrey's saltbush (*Atriplex torreyi*). Sub-dominant species include rubber rabbitbrush (*Ericameria nauseosa*), littleleaf horsebrush (*Tetradymia glabrata*), yellow rabbitbrush (*Chrysothamnus viscidiflorus*), and inland saltgrass (*Distichlis spicata*). Shadscale saltbush (*Atriplex confertifolia*) and Indian ricegrass (*Achnatherum hymenoides*) may be present. Production ranges from 800 to 1,300 lb/acre with an average of 1,070 lb/ac in a normal year.

Disturbance Response Group 5 Ecological Sites:

Saline Bottom – Modal	R029XY004NV
Sodic Terrace 8-10" P.Z.	R029XY091NV
Deep Sodic Fan	R029XY093NV
Dry Floodplain	R029XY156NV

Modal Site:

The Saline Bottom ecological site (R029XY004NV) is the modal site that represents this DRG, as it has the most acres mapped. The precipitation ranges from 4 to 8 in. Slopes range from 0 to 2% with elevation ranging from approximately 4,300 to 5,700 ft. This site occurs on alluvial flats, lake plains, and axial stream floodplains. The soils on this site are usually deep to very deep and are medium to moderately-fine textured. The soils at this site, formed in mixed alluvium, are strongly affected by salt and sodium in the upper profile, with concentrations decreasing with depth. A fluctuating seasonal high water table typically occurs from 20 to as deep as 60 in. Additional moisture from runoff and occasional stream overflow in winter and early spring dilutes salt and sodium levels, causing salinity and alkalinity to fluctuate throughout the year. These soils are mostly somewhat poorly to poorly drained, with a mesic soil temperature regime and an aquic soil or typic arid soil moisture regime. The plant community is dominated by basin wildrye, alkali sacaton, and black greasewood. Torrey's saltbush and whiteflower rabbitbrush (*Chrysothamnus albidus*) may be present.

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasive species. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans a unique area in Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area. Flashy, summer storm events contribute significantly to annual precipitation as well. Air and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

Periodic drought regularly influences these ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West (Miller et al. 2008a). Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006).

Hydrology, Drought, Groundwater Interpretations:

Black greasewood, the dominant shrub of this group, is a cool-season (C3), spiny, semi-evergreen shrub that grows from 3 to 10 ft tall with bright green to olive green, fleshy leaves

(Benson et al. 2007). The native shrub is generally monoecious but can also be dioecious (having separate male and female plants). Black greasewood flowers from May through July with fruit maturing from July through September. During dry periods, the shrub relies on access to shallow groundwater rather than precipitation for survival (Meinzer 1927, Mozingo 1987c, Trent et al. 1997, Naumburg et al. 2005). Black greasewood covers roughly two million acres, making it the most extensive groundwater dependent vegetation type in Nevada (Saito et al. 2020).

Black greasewood is classified as a phreatophyte, and its distribution is well correlated with the distribution of groundwater (Mozingo 1987c, Eddleman 2008). Meinzer (1927) discovered that the taproots of black greasewood could penetrate from 20 to 57 ft below the surface. Romo (1984) found water tables ranging from 3.5 to 15 m (12 to 49 ft) under black greasewood-dominated communities in Oregon. Black greasewood stands develop best where moisture is readily available, either from surface or subsurface runoff (Brown 1971). It is commonly found on floodplains that are either subject to periodic flooding, have a high water table at least part of the year, or have a water table less than 34 ft deep (Harr and Price 1972, Blauer et al. 1976, Branson et al. 1976, Blaisdell and Holmgren 1984, Eddleman 2002). Ganskopp (1986) reported that water tables within 9.8 to 11.8 in. of the surface had no effect on black greasewood in Oregon. However, a study, conducted in California, found that black greasewood did not survive 6 months of continuous flooding (Groeneveld and Crowley 1988, Groeneveld 1990). Black greasewood is usually a deep-rooted shrub but has some shallow roots near the soil surface; the maximum rooting depth can be determined by the depth to a saturated zone (Harr and Price 1972).

Basin big sagebrush, a dominant species on the Sodic Terrace 8-10" P.Z. and the Dry Floodplain ecological sites, is widely distributed throughout the western United States, particularly in arid and semi-arid environments (Weber and Wittmann 2012). This perennial, native shrub is adapted to a variety of soil types, including sandy, loamy, and clayey soils, and is commonly found in foothills, basins, and along montane slopes (Stubbendieck et al. 2017). Basin big sagebrush is highly drought-tolerant and can thrive in areas with low precipitation, though it prefers areas with moderate winter moisture (Tilley et al. 2002). This species typically grows to heights of 1 to 2 m (3.3 to 6.6 ft) and exhibits a robust root system, including a deep taproot that can extend up to 3 m (9.9 ft) deep, allowing it to access water in dry conditions. Basin big sagebrush is considered a phreatophyte, with the ability to tap into shallow groundwater sources (Klepper et al. 1985). Physiologically, it is well-adapted to drought stress, using C3 photosynthesis and producing resinous compounds that help reduce water loss and deter herbivores (Bates et al. 2006). Basin big sagebrush also plays an important ecological role, providing crucial habitat for a variety of wildlife species, including sage grouse (*Centrocercus urophasianus*) (Davies et al. 2011).

Torrey’s saltbush, also referred to as Torrey’s saltbush, is a 10 to 20 cm (4 to 8 in.) tall dioecious shrub spanning a large geographical area encapsulating portions of California, Nevada, and Utah (Mozingo 1987d, Perryman 2014c). It is characterized by its dense gray-farinose herbage, pale-green erect stems, pale to dark-gray bark, 2 to 4 mm long fruiting bracts, and inflorescence of its glomerules in axillary spikes and terminal (Perryman 2014c). It occurs on basin floors, old lake plains, axial steam floodplains, lower elevation inset fans, alluvial flats, fan skirts and beach terraces from 600 to 6,000 ft in elevation (Perryman 2014c). Torrey's saltbush is typically found on very deep, calcareous, and saline-sodium affected soils where subsurface water is readily available (Benson and Darrow 1981a, Mozingo 1987d, Perryman 2014c). Torrey's saltbush is most commonly found associated with black greasewood, fourwing saltbush (*Atriplex canescens*), and Mojave seablite (*Suaeda moquinii*), however it can be found occasionally in small pure stands (Mozingo 1987d).

Littleleaf horsebrush is a moderately branched shrub between 30 cm and 1 m tall (12 to 40 in.) and typically as wide or wider (Mozingo 1987b, Perryman 2014b). It occurs on summits of basalt plateaus, backslopes, summits, and shoulders of fan remnants, beach terraces, inset fans, low hills, and plateaus, inter-plateau basins, upper fan piedmonts, and travertine deposits with slopes on 0 to 50% at elevations between 3,500 and 8,000 ft (Perryman 2014b). Littleleaf horsebrush is typically found on moderately deep to deep basalt clays, shallow to deep granitic, ashy, silty, or calcareous loams (Perryman 2014b). It is characterized by its ascending branches which are white-pubescent except for narrow short smooth streaks below each leaf node and its flat-topped clusters of yellow flowers (Mozingo 1987b). Littleleaf horsebrush separates itself from other shrubs due to its early growth period, often leafing out in February, flowering from April to July, and transitioning to drier brown leaves by midsummer while other shrubs have just begun developing flower buds (Mozingo 1987b). However, it is an opportunistic shrub and can remain green and even produce new leaves and shoots if enough water is present (Mozingo 1987b). Additionally, littleleaf horsebrush possess two unique leaf phases, with the first appearing at each node as rigid, awe-shaped affairs between 8 to 12 mm (0.3–0.5 in.) by being quickly lost and follow by clusters of soft, narrow, elongate and succulent leaves about the same length or longer (Mozingo 1987b). Shortspine horsebrush (*Tetradymia spinosa*) and spineless horsebrush (*Tetradymia canescens*), may also be present. In general, all horsebrush species propagate from seeds and root crown sprouting, however shortspine horsebrush also possesses rhizomes that extend from the parent plant about 30 cm (12 in.) further facilitating vegetative reproduction (St. John and Tilley 2012).

Rubber rabbitbrush, a sub-dominant canopy species in this group, is a widespread and abundant shrub found across the western United States, particularly in arid and semi-arid environments (Stubbendieck et al. 2017). This perennial, native, woody shrub thrives in a variety of soils, ranging from sandy and rocky to clayey, and is commonly found in plains, foothills, and along washes. It is highly adaptable to a wide range of climatic conditions, from hot, dry deserts to cooler mountain environments. It exhibits a wide range of morphological forms and can be either deciduous or evergreen, depending on local environmental factors (Hickman 1993). Rubber rabbitbrush develops a deep taproot, often reaching depths of 1 to 3 m (3.3 to 10 ft), with an extensive network of lateral roots that help it access water in dry conditions (Klepper et al. 1985). This species is classified as a phreatophyte and has been observed to tap into water tables that range from 1 to 6 m (3.3 to 20 ft) deep (Robinson 1958).

Rubber rabbitbrush has several physiological adaptations that help it cope with drought, including C3 photosynthesis and production of waxy leaf coatings to reduce water loss (Francis 2004).

Yellow rabbitbrush is a native, warm-season, perennial shrub that grows between 12 to 48 in. tall. It has a deep root system with a taproot and reproduces via both seeds and sprouting (USFS 2017a). Yellow rabbitbrush is typically found with other rabbitbrush species and is typically a minor component. After disturbance, yellow rabbitbrush density greatly increases, but rabbitbrush communities are short-lived. Yellow rabbitbrush is affected by the larvae of the flat-headed bald cypress sapwood borer (also known as “hairy yellow-marked buprestid” *(Acentimetersaeodera pulchella)*, which kill rabbitbrush plants by boring tunnels in plant stems (Young and Evans 1974). Whiteflower rabbitbrush may also be present as a minor component of certain ecological sites within this DRG.

Alkali sacaton is a long-lived, warm-season, densely tufted perennial bunchgrass. It is considered a phreatophyte and a facultative wetland species in this region (Mathie et al. 2011). Alkali sacaton has deep, coarse roots allowing it to reach water tables at depths from 4 to 27 ft (Meinzer 1927). It reproduces from seeds and tillers and is a prolific seed producer. The seeds remain viable for several years because of the hard, waxy seed coats (USFS 1988). General differences in root depth distributions between grasses and shrubs results in resource partitioning in these shrub/grass systems (Lee and Lauenroth 1994).

Basin wildrye is the largest of the native grasses commonly found on western ranges. It is a coarse, robust plant with stems up to 12 ft high, growing in large bunches, often several feet in diameter. This grass usually grows in moist or wet saline situations in bottomlands and basins, where spring water tables are within its rooting zone. The species is weakly rhizomatous and has been found to root to depths of 1 m (3.3 ft) or more and to exhibit greater lateral root spread than many other grass species (Abbott et al. 1991).

Inland saltgrass, a common perennial grass in this group, is a warm-season, rhizomatous species that grows 10 to 60 centimeters (4 to 24 in.) tall. This native species is highly adapted to saline areas (Comstock and Ehleringer 1992, Newman and Gates 2000) and has been reported to withstand full strength seawater soil salinity under dry salt playa conditions – similar to those in Nevada playas (Qian et al. 2006). Inland saltgrass generally occurs where the water table is within 8 to 12 ft of the soil surface even in dry periods (Meinzer 1927). The species is also adapted to low water conditions, as it can distribute water for long distances through its connected rhizomes (Alpert 1990). Marcum and Kopec (1997) found inland saltgrass more tolerant of increased levels of salinity than alkali sacaton; therefore, dewatering and/or long-term drought causing increased levels of salinity would create environmental conditions more favorable to inland saltgrass over alkali sacaton. A lowering of the water table can occur with groundwater pumping simulating drought in these sites. This can contribute to the loss of deep-rooted species such as greasewood, alkali sacaton, and basin wildrye, which is replaced by an increase in saltgrass, rabbitbrush, shadscale and other species in the absence of drought.

Seasonally high water tables have also been found necessary for maintenance of productivity and reestablishment of basin wildrye following disturbances such as fire, drought or excessive herbivory (Eckert Jr et al. 1973). The sensitivity of basin wildrye seedling establishment to reduced soil water availability is increased as soil pH increases (Stuart et al. 1971). Lowering of the water table through extended drought or water pumping will decrease basin wildrye production and establishment while black greasewood, basin big sagebrush, rubber rabbitbrush, and invasive weeds will increase. Drought will initially cause a decline in bunchgrasses. Prolonged drought may cause a decline in black greasewood, while annual weedy species and bare ground will increase.

Annual Invasive Species:

Western tansymustard (*Descurainia pinnata*) and Mojave seablite are native species that may be present. These species are likely to be found on disturbed sites and increase in response to disturbance. Annual non-native species such as halogeton (*Halogeton glomeratus*), Russian thistle (*Salsola tragus)*, and tall tumblemustard (*Sisymbrium altissimum*) invade these sites where competition from perennial species is decreased. Cheatgrass (*Bromus tectorum*) may also be present. The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and depressed competition or can increase resource pools by the decomposition of dead plant material following disturbance. Excessive grazing pressure during settlement and into the 20th century has increased the overall presence of cheatgrass, halogeton, Russian thistle, and weedy mustard species (Brassicaceae family) (Peters and Bunting 1994). The presence of non-native annual plants within these ecosystems decreases ecosystem resilience and resistance to disturbance through competition for limited resources. Dobrowolski et al. (1990) cite multiple authors on the extent of the soil profile exploited by the competitive exotic annual cheatgrass. Specifically, the depth of rooting is dependent on the size the plant achieves, and in competitive environments, cheatgrass roots were found to penetrate only 15 centimeters (6 in.), whereas isolated plants and pure stands were found to root at least 1 m in depth with some plants rooting as deep as 1.5 to 1.7 m (60 to 67 in.).

Cheatgrass is a cool-season annual grass that maintains an advantage over native plants in part because it is a prolific seed producer, can germinate in the autumn or spring, tolerates grazing, and increases with frequent fire (Klemmedson and Smith 1964, Miller et al. 1999). Cheatgrass originated from Eurasia and was first reported in North America in the late 1800s (Furbush 1953, Mack and Pyke 1983). Bradley et al. (2018) found that cheatgrass has expanded to greater than 15% cover over 210,000 km^2 (130,488 mi^2), roughly 31% of the Intermountain West. In the Great Basin, cheatgrass is expanding at a rate of expansion of 3,700 km^2 (2,300 mi^2) annually and is a land management issue that will require creative solutions (Smith et al. 2022). Mapping potential or current invasion vectors is a management method designed to increase the cost-effectiveness of control methods.

Recent modeling and empirical work by Lauenroth and Bradford (2006) suggest that seasonal patterns of precipitation input and temperature are also key factors determining regional variation in the growth, seed production, and spread of invasive annual grasses. The phenomenon of cheatgrass "die-off" provides opportunities for restoration of perennial native species (Baughman et al. 2016, Baughman et al. 2017). The causes of these events are not fully understood, but there is ongoing work to try to predict where they occur, in the hopes of aiding conservation planning (Weisberg et al. 2017, Brehm 2019).

Halogeton is a poisonous noxious annual weed introduced to the United Stated from Eurasia in the early 20th century (Tilley et al. 2008). It inhabits disturbed sites, road sides, and arid lands in poor ecological condition and is uniquely adapted to basic and saline soils (Tilley et al. 2008). Halogeton possesses a taproot that can reach depths of 20 in. with lateral roots spreading 18 in. in all directions (Tilley et al. 2008). It is particularly detrimental since it accumulates salt from the soil within its plant tissue which is then leaches out of dead plants and roots increasing the overall salinity of the soil and favoring the establishment of halogeton over other species (Tilley et al. 2008). In addition, halogeton is a prolific seed generator, producing as many as 75 seeds/in. of stem or about 400 lb/ac of seed (Tilley et al. 2008). This poses a threat to livestock as halogeton accumulates soluble oxalates within its plant tissue which is highly toxic to sheep and cattle, requiring the consumption of less than 1.5 pounds to be fatal (Tilley et al. 2008). Proper management of site disturbance is crucial to reducing risk of halogeton invasion, however mechanical and chemical methods can be implemented if an infestation is detected early (Tilley et al. 2008).

Russian thistle is a tap-rooted, C4 photosynthesis (warm-season) annual forb, introduced from southeastern Europe and central Asia. The seeds have a remarkable capability to germinate in a variety of soil temperatures and in areas with very little precipitation, and even move back into dormancy after initial germination (Wallace et al. 1968). The seeds however, are not persistent and generally remain viable in the seedbank for less than two years (Boerboom 1993, Young et al. 1995). Russian thistle has been observed to provide initial establishment in completely de-vegetated sites and create microsite habitat which may allow increased establishment of other species (Allen and Allen 1988). The successful establishment of other species, particularly later seral species which forms mycorrhizal associations may reduce cover of Russian thistle as mycorrhizal inoculation has been observed to reduce the size and vigor of Russian thistle, while encouraging later seral species such as perennial bunchgrasses (Johnson 1998a).

Fire Ecology:

Fire is a rare disturbance in these salt-desert plant communities likely occurring in years with above average production. Natural fire return intervals are estimated to vary between less than 35 years up to 100 years in salt-desert ecosystems with basin wildrye (Paysen et al. 2000). Historically, black greasewood-saltbush communities had sparse understories and bare soil in intershrub spaces, making these communities somewhat resistant to fire (Young 1983, Paysen et al. 2000). They may burn only during high fire hazard conditions; for example, years with high precipitation can result in almost continuous fine fuels, increasing fire hazard (West 1994, Paysen et al. 2000).

Black greasewood may be killed by severe fires, but can resprout after low to moderate severity fires (Robertson 1983, West 1994). Black greasewood sprouts vigorously following burning, which may result in increased stem density (Anderson 2004). A study following a Nevada wildfire found that black greasewood sprouts reached approximately 2.5 ft within 3 years (Anderson 2004). Grazing and other disturbance may result in increased biomass production due to sprouting and increased seed production, also leading to greater fuel loads (Sanderson and Stutz 1994). Higher production sites would have experienced fire more frequently than lower production sites.

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The initial condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species response. For most forbs and grasses, the growing points are located at or below the soil surface providing relative protection from disturbances which decrease above-ground biomass, such as grazing or fire. Thus, fire mortality is more correlated to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant and abundance of old growth (Wright 1971, Young 1983). However, season and severity of the fire will influence plant response. Plant response will vary depending on post-fire soil moisture availability.

Rabbitbrush, particularly rubber rabbitbrush, is relatively fire-tolerant, sprouting vigorously from root crowns and establishing from windblown seed (Tueller and Payne 1987). It is an early seral species that is found in mainly coarse soils along roadways and in damaged sites, following a fire or human-induced disturbance (Brehm 2019). Presence of rabbitbrush may inhibit the establishment of other shrub species, but may contribute to the development of the soil structure and prevent non-native species from invading the site. Subdominant in many basin big sagebrush communities, rabbitbrush is likely to become a more prominent in the genetic pool than sagebrush following fire (Call 2021).

Basin wildrye is relatively resistant to fire, particularly dormant season fire, as plants sprout from surviving root crowns and rhizomes (Zschaechner 1985). Miller et al. (2013) reports fall and spring burning increased total shoot and reproductive shoot densities in the first year, although live basal areas were similar between burn and unburned plants. By year two, there was little difference between burned and control treatments.

Alkali sacaton is tolerant of, but not resistant to fire. Alkali sacaton is typically top-killed, but will resprout from tillers. A severe fire can kill it and summer fires have more of an effect than winter fires (Brakie 2007). Recovery of alkali sacaton after fire has been reported as 2 to 4 years (Bock and Bock 1978). It is tolerant to drought or flooding conditions and not to shade, which increases its establishment in open areas and allows for the development of pure stands. Alkali sacaton is renowned for being effective at growing in saline soils with a range in pH that classifies it as a primary and/or secondary invader to damaged or reclaimed sites (Brakie 2007).

Livestock/Wildlife Grazing Interpretations:

During settlement, many of the cattle in the Great Basin were wintered on extensive basin wildrye stands however due to sensitivity to spring use many stands were decimated by early in the 20th century (Young et al. 1976). Less palatable species such as black greasewood, rabbitbrush and inland saltgrass increased in dominance along with invasive non-native species such as halogeton, Russian thistle, mustards and cheatgrass (Roundy 1985). Black greasewood is typically not considered an important browse species for wildlife and livestock. However, in a study by Smith et al. (1992), utilization of new growth on greasewood shrubs by cattle was 77% in summer, and greasewood was found to have the highest amounts of crude protein when compared to perennial and annual grasses. Black greasewood plants have been found to contain high amounts of sodium and potassium oxalates which are toxic to livestock and caution should be taken when grazing these communities. These shrubs can be used lightly in the spring as long as there is a substantial amount of other preferable forage available and can provide good cover for wildlife species (Benson et al. 2011).

Spring defoliation of basin wildrye and/or consistent, heavy grazing during the growing season has been found to significantly reduce basin wildrye production and density (Krall et al. 1971). Basin wildrye is valuable forage for livestock (Ganskopp et al. 2007) and wildlife, but is intolerant of heavy, repeated, spring grazing (Krall et al. 1971). Basin wildrye is used often as a winter feed for livestock and wildlife; not only providing roughage above the snow but also cover in the early spring months (Majerus 1992).

Alkali sacaton has been found to be sensitive to early growing season defoliation whereas late growing season and/or dormant season use allowed recovery of depleted stands (Hickey and Springfield 1966). Horses and cattle graze early season plants when more desirable forage is unavailable and before the plant matures into tough, unpalatable foliage (USFS 1988). This plant provides food for deer, jackrabbits and various types of birds and waterfowl throughout arid and semi-arid regions throughout the West (Brakie 2007).

Under favorable soil and moisture conditions, inland saltgrass has proven to be a valuable forage species for pastures irrigated with saline water (Skaradek and Miller 2010). Total dry matter yields of 9,081 kg/ha (8,102 lb/ac) and protein production of 1,300 kg/ha (1,160 lb/ac) (Skaradek and Miller 2010). It is grazed by both cattle and horses with a fair to good forage value, however 4 in. of regrowth after fire is recommended before the restart of grazing (Skaradek and Miller 2010). Notably, inland saltgrass stays green during drought periods when many other grasses dry out, and it is highly resistant to both grazing and trampling (Skaradek and Miller 2010). In addition, inland saltgrass is vital to salt marshes, which provide nesting grounds for birds, fish and larvae of many aquatic species (Skaradek and Miller 2010). As inland saltgrass decomposes, it steadily releases its stored nutrients, providing a source of food for clams, crabs, and fish (Skaradek and Miller 2010).

Inadequate rest and recovery from defoliation can cause a decrease in basin wildrye and an increase in rabbitbrush and black greasewood, along with inland saltgrass and non-native weeds (Young et al. 1976, Roundy 1985). Roundy (1985) found that although basin wildrye is adapted to seasonally dry saline soils, high and frequent spring precipitation is necessary to establish it from seed suggesting that establishment of natural basin wildrye seedlings occurs only during years of unusually high precipitation. Therefore, reestablishment of a stand that has been decimated by grazing may be episodic.

Spineless horsebrush and littleleaf horsebrush have been shown to be of virtually no value as forage for domestic animals (Mozingo 1987a). However, they are notable for their toxicity to livestock, particularly sheep who have been known to develop bighead disease (Mozingo 1987a). Consumption of leaves as little as 0.5% of the animal's body weight is enough to cause liver damage and sensitization to light which can manifest into bighead disease (Mozingo 1987a).

State and Transition Model Narrative for Group 5:

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 29 Disturbance Response Group 5.

Four possible stable states have been identified for this DRG including a shrub dominated state and an abiotically controlled state. An annual state, for similar DRG's, has been noted in MLRA's 24 and 28B, but was not observed in this DRG in MLRA 29 during field verification. It appears possible and likely that weedy dominance could occur under the correct conditions, however, more often the site vegetation dynamics become driven by abiotic processes, and large, connected bare ground areas, incapable of supporting vegetation occur.

Reference State 1.0:

The Reference State 1.0 is a representative of the natural range of variability under pristine conditions. The reference state has three general community phases; a shrub-grass dominant phase, a perennial grass dominant phase and a shrub dominant phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire, periodic drought and/or insect or disease attack.

Community Phase 1.1:
The reference plant community is dominated by basin wildrye, alkali sacaton, and black greasewood. Inland saltgrass, alkali or rubber rabbitbrush and other shrubs make up minor components. Potential vegetative composition by air-dry weight is approximately 75% grasses, 5% forbs and 20% shrubs. Approximate ground cover (basal and crown) is 40 to 60%. Total annual air-dry production ranges from 800 to 1,800 lb/acre.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
A long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge resulting in a reduction of black greasewood. A low severity fire would temporally decrease the overstory cover of black greasewood and allow for the understory perennial grasses to increase. Fires are typically low severity resulting in a mosaic pattern due to low fuel loads. A fire following an unusually wet spring facilitating an increase in fine fuels may be more severe and reduce black greasewood cover to trace amounts.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.3:
Absence of disturbance over time, chronic growing season herbivory, long-term spring/summer drought or combinations of these would allow the black greasewood overstory to increase and dominate the site. This will generally cause a reduction in perennial bunchgrasses and an increase in black greasewood. Inland saltgrass will increase with chronic growing season herbivory, however it may decrease with long-term spring/summer drought.

Community Phase 1.2:
This community phase is characteristic of a post-disturbance, early-seral, grass dominated community phase. Basin wildrye and alkali sacaton dominate the community. Black greasewood is a minor component but will likely sprout and return to pre-disturbance levels within a few years. Sprouting shrubs such as rabbitbrush may increase.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
Time and lack of disturbance and/or release from chronic winter drought will allow black greasewood to increase.

Community Phase 1.3:
Black greasewood and rabbitbrush increase in the absence of disturbance. Decadent shrubs dominate the overstory and deep-rooted perennial bunchgrasses in the understory are reduced either from competition with shrubs, herbivory, growing season drought or combinations of these.

Community Phase Pathway 1.3a, from Phase 1.3 to 1.1:
Long-term reduction in winter snow accumulation may lead to reduced groundwater recharge resulting in a reduction in black greasewood. Additionally, a low severity fire

would decrease the overstory of black greasewood and allow for the perennial bunchgrasses to dominate the site.

Community Phase Pathway 1.3b, from Phase 1.3 to 1.2:
A high severity fire would significantly reduce the black greasewood overstory, releasing the deep-rooted bunchgrasses.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0:

Trigger: Introduction of non-native annual plants.

Slow variables: Over time the annual non-native plants will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

This state is similar to the Reference State 1.0 with three similar community phases. Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of non-native invasive species. Non-natives may increase in abundance but will not become dominant within this State. These non-natives can be highly flammable and can promote fire where historically fire had been infrequent. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These feedbacks include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal.

Community Phase 2.1:
This community phase is compositionally similar to the Reference State Community Phase 1.1 with the presence of non-native species in trace amounts. This community is dominated by basin wildrye, alkali sacaton and black greasewood. Rubber rabbitbrush and other shrubs make up the minor components. In drier locations in this site concept, basin wildrye will drop from a dominant to minor component. Non-native annual species such as halogeton and cheatgrass are present.

Saline Bottom (R029XY004NV), Current Potential 2.1, T. Stringham, June 2023

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
A long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge resulting in a reduction of black greasewood. Additionally, a low severity fire would decrease the overstory of black greasewood and allow for the understory perennial grasses to increase. Fires are typically low severity resulting in a mosaic pattern due to low fuel loads. A fire following an unusually wet spring or a change in management favoring an increase in fine fuels may be more severe and reduce black greasewood cover to trace amounts. Annual non-native species are likely to increase after fire.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.3:
Absence of disturbance over time, long term spring/summer drought, inappropriate grazing management or combinations of these would allow the black greasewood overstory to increase and dominate the site. Inappropriate grazing management reduces the perennial bunchgrass understory; conversely inland saltgrass may increase in the understory.

Community Phase 2.2:
This community phase is characteristic of a post-disturbance, early-seral community where annual non-native species are present. Perennial bunchgrasses such as alkali sacaton, inland saltgrass, and basin wildrye dominate the site. Depending on fire severity patches of intact shrubs may remain. Black greasewood and rabbitbrush may be sprouting. Annual non-native species are stable to increasing in the community.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Time, release from chronic winter drought, lack of disturbance and/or grazing management that favors the establishment and growth of black greasewood allows the shrub component to recover.

Community Phase 2.3 (At Risk):
Black greasewood dominates the overstory and perennial bunchgrasses in the understory are reduced, either from competition with shrubs or from inappropriate grazing, chronic spring/summer drought, or combinations. Rabbitbrush may be a significant component. Annual non-native species are stable or increasing. This community is at risk of crossing a threshold to State 3.0 (grazing or fire).

Community Phase Pathway 2.3a, from Phase 2.3 to 2.1:
Grazing management that reduces shrubs will allow for the perennial bunchgrasses in the understory to increase. Heavy late-fall/winter grazing may cause mechanical damage to black greasewood promoting the perennial bunchgrass understory. Annual non-native species are present and may increase in the community. A low severity fire would decrease the overstory of black greasewood and allow for the understory perennial grasses to increase. Additionally, long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge resulting in a reduction of black greasewood.

Community Phase Pathway 2.3b, from Phase 2.3 to 2.2:
High severity fires, due to the dominance of black greasewood and other shrubs, would significantly decrease the shrub overstory and may allow for an increase in perennial bunchgrasses. Annual non-native species are present and may increase in the community.

T2A: Transition from Current Potential State 2.0 to Shrub State 3.0:

Trigger: To Community Phase 3.1: Long-term, inappropriate cattle/horse grazing and/or spring/summer drought will decrease or eliminate deep-rooted perennial bunchgrasses and favor shrub growth and establishment. Lowering of the water table due to groundwater pumping may decrease black greasewood and allow for rabbitbrush and other shrubs to increase.

Slow variables: Long-term decrease in deep-rooted perennial grass density and/or black greasewood.

Threshold: Loss of deep-rooted perennial bunchgrasses changes nutrient cycling, nutrient redistribution, and reduces soil organic matter. Reduction of long-lived, black greasewood changes the temporal and depending on the replacement shrub, the spatial distribution of nutrient cycling.

Shrub State 3.0:

This state has one community phase characterized by a dominance of black greasewood, possibly co-dominant with rabbitbrush. This site has crossed a biotic threshold and site processes are being controlled by shrubs. Bare ground has increased, wind and water redistribution of soil is evident. Shrubs may be mounded.

Community Phase 3.1 (At Risk to Abiotic):
Black greasewood dominates the overstory. Rabbitbrush may be a significant component. Deep-rooted perennial bunchgrasses such as basin wildrye have significantly declined. Annual non-native species increase. Bare ground is significant. Formation of black greasewood and rabbitbrush hummocks is prevalent due to soil displacement caused by water and wind erosion. Invasive forbs likely dominate the understory.

Saline Bottom (R029XY004NV), Shrub State 3.1, T. Stringham, June 2022

Deep Sodic Fan (R029XY093NV), Shrub State 3.1 At Risk to Abiotic, T. Stringham, June 2023

T3A: Transition from Shrub State 3.0 to Abiotic State 4.0:

Trigger**:** Long-term, inappropriate grazing management, flooding, severe drought, groundwater pumping, or combinations. Significant soil loss and redistribution is occurring.

Slow variables: Long-term decrease in density of native, perennial vegetation combined with soil movement and loss.

Threshold: Reduced black greasewood density due to groundwater pumping and/or long-term winter drought facilitates wind redistribution of soil creating mounding under and around shrubs. Interspace areas increase in size and connectivity, ponding and evaporation of water increases soil crusting. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial grasses and shrubs truncate energy capture spatially and temporally thus impacting nutrient cycling and distribution. Soil redistribution from interspaces to shrub mounds leads to decreased infiltration, increased flow path length, ponding and salt accumulation on interspace soils surface.

Abiotic State 4.0:

This state consists of one community phase in which abiotic factors (i.e. wind or water erosion) control site processes. It is characterized by the loss of vegetative cover along with the redistribution and loss of the soil surface. Feedbacks contributing to the stability of this state include soil loss, nutrient loss, soil surface degradation, increased bare ground patch size, and increased connectivity between patches of bare soil.

Community Phase 4.1:
This community is the result of significant soil redistribution and loss. The vegetative cover is minimal; dominated by widely-spaced shrubs and introduced non-native forbs. Shrub roots may be exposed with significant shrub decadence or death. Trace amounts of desirable species may be present and bare ground interspaces are large and connected. Site function is controlled by soil erosion and redistribution and soil temperature. Rehabilitation of this community is unknown.

Deep Sodic Fan (R029XY093NV), Abiotic State 4.1, T. Stringham, June 2023

Sodic Terrace 8-10" P.Z. (R029XY091NV), Abiotic State 4.1, T. Stringham, September 2023

Potential Resilience Differences with Other Ecological Sites in this Group:

Sodic Terrace 8-10" P.Z. (R029XY091NV):

Basin big sagebrush, black greasewood, and Torrey's saltbush dominate this site. Basin wildrye and other grasses comprise approximately 15% of the production of the site, with total production ranging from 500 to 1,000 lb/ac, significantly less than the modal site. This site is less resilient than the modal site as reflected in total production dominated by shrubs. Inappropriate grazing easily transitions this site to a shrub state. This ecological site may develop an Annual Invasive State; however, this condition was not observed during field data collection.

Deep Sodic Fan (R029XY093NV):

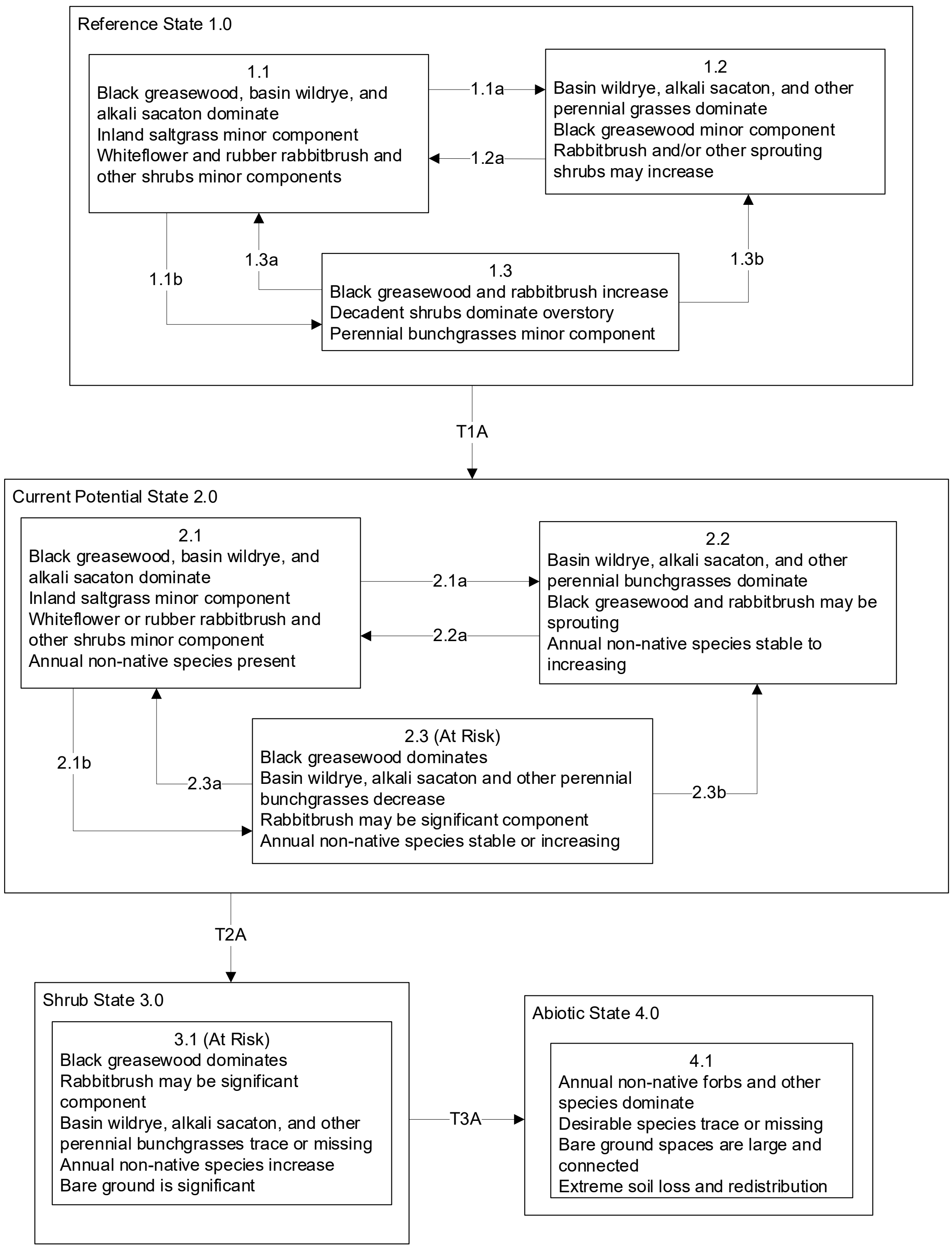
Torrey's saltbush, black greasewood and basin wildrye dominate this ecological site. Shrubs comprise approximately 60% by weight of the plant community. Flooding and run-in from higher landscapes onto this site results in supplemental moisture. Soils are well-drained and have a typic aridic soil moisture regime. Resilience is not significantly different than the modal site.

Dry Floodplain (R029XY156NV):

Basin wildrye dominates the site, making up 70% of production by weight. Basin big sagebrush is the dominant shrub with sub-dominants of black greasewood and rabbitbrush. This ecological site is subject to water overflow in the spring providing supplemental moisture. There is typically insufficient moisture to leach salts and sodium from the soil, resulting in moderate salinity of the soil and formation of a thick surface crust as soils dry. These soils are highly susceptible to gully formation. Resilience is similar to the modal site.

Modal State and Transition Model for Group 5 in MLRA 29:

MLRA 29
Group 5
Saline Bottom
R029XY004NV



MLRA 29
Group 5
Saline Bottom
R029XY004NV
KEY

Reference State 1.0 Community Pathways
1.1a: Low severity fire resulting in mosaic pattern or reduced groundwater recharge reduces shrub cover allowing bunchgrasses to dominate. High severity fire, following an unusually wet spring or change in management, will significantly reduce black greasewood.
1.1b: Time and lack of disturbance such as fire, drought, inappropriate grazing management, or combinations of these. Black greasewood and inland saltgrass increase.
1.2a: Time and lack of disturbance and/or release from chronic winter drought.
1.3a: Low severity fire or reduced groundwater recharge reduces shrub cover allowing bunchgrasses to dominate.
1.3b: High severity fire, due to shrub dominance, significantly reduces shrub cover and increases perennial bunchgrasses.

Transition T1A: Introduction of non-native plants.

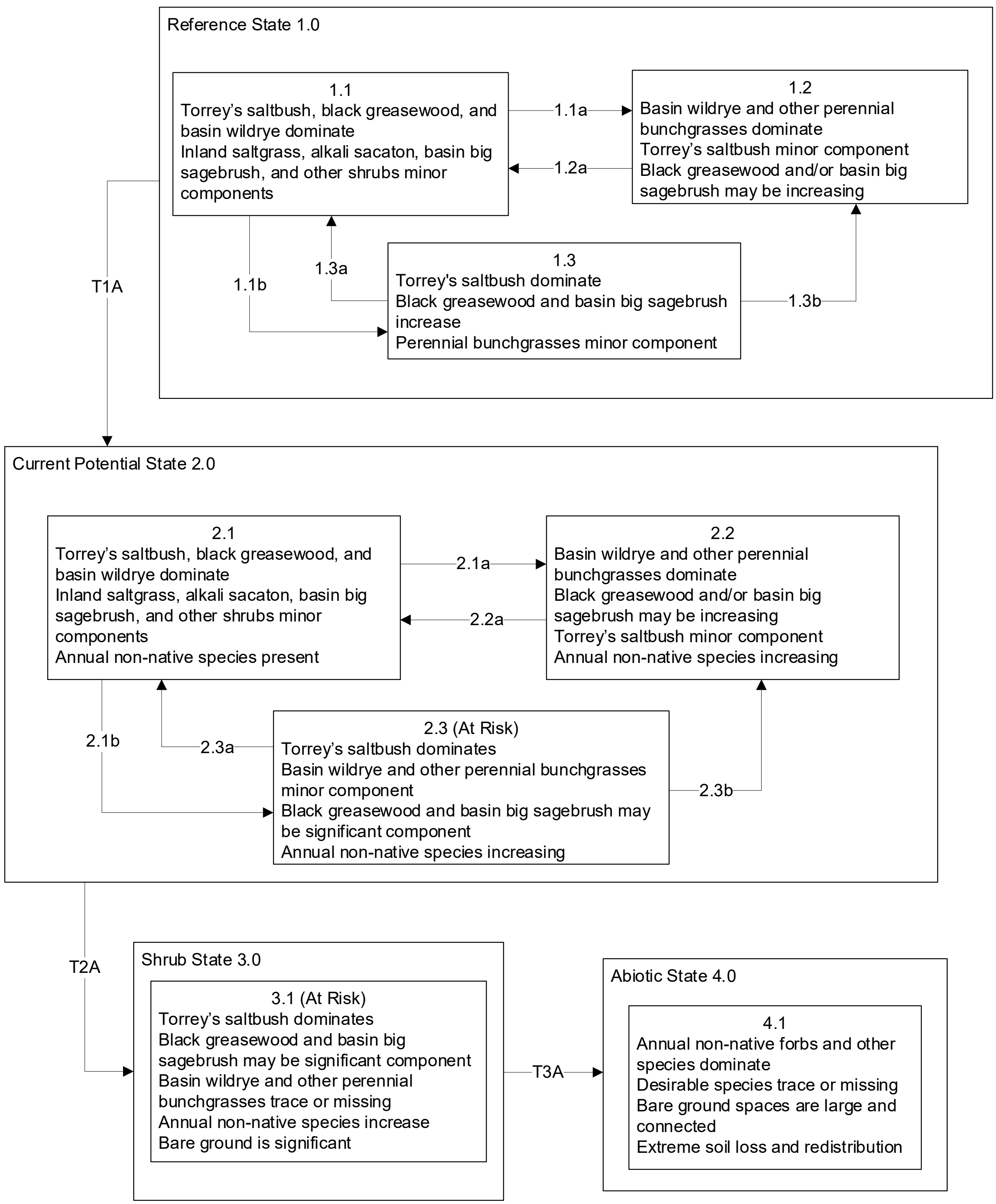
Current Potential State 2.0 Community Pathways:
2.1a: Low severity fire resulting in mosaic pattern or reduced groundwater recharge reduces shrub cover allowing bunchgrasses to dominate. High severity fire, following an unusually wet spring or change in management, will significantly reduce black greasewood.
2.1b: Time and lack of disturbance such as fire, drought, inappropriate grazing management, or combinations of these. Black greasewood and inland saltgrass increase.
2.2a: Time, lack of disturbance, release from chronic winter drought, and/or shrub-favored grazing management.
2.3a: Heavy late fall/winter grazing causing mechanical damage to shrubs, low severity fire, and/or reduced groundwater recharge.
2.3b: High severity fire, due to shrub dominance, significantly reduces shrub cover and increases perennial bunchgrasses.

Transition T2A: Long-term inappropriate cattle/horse grazing and/or spring/summer drought or lowering of the water table due to groundwater pumping.

Transition T3A: Long-term, inappropriate grazing management, flooding, severe drought, groundwater pumping, or combinations. Significant soil loss and redistribution is occurring.

Additional State and Transition Models for Group 5 in MLRA 29:

MLRA 29
Group 5
Deep Sodic Fan
R029XY093NV



MLRA 29
Group 5
Deep Sodic Fan
R029XY093NV
KEY

Reference State 1.0 Community Pathways
1.1a: Low severity fire resulting in mosaic pattern or reduced groundwater recharge reduces shrub cover allowing bunchgrasses to dominate. High severity fire, following an unusually wet spring or change in management, will significantly reduce Torrey's saltbush.
1.1b: Time and lack of disturbance such as fire, drought, herbivory, or combinations of these will increase the shrub component.
1.2a: Time and lack of disturbance and/or release from chronic winter drought.
1.3a: Low severity fire or reduced groundwater recharge reduces shrub cover allowing bunchgrasses to dominate.
1.3b: High severity fire significantly reduces shrub cover and increases perennial bunchgrasses.

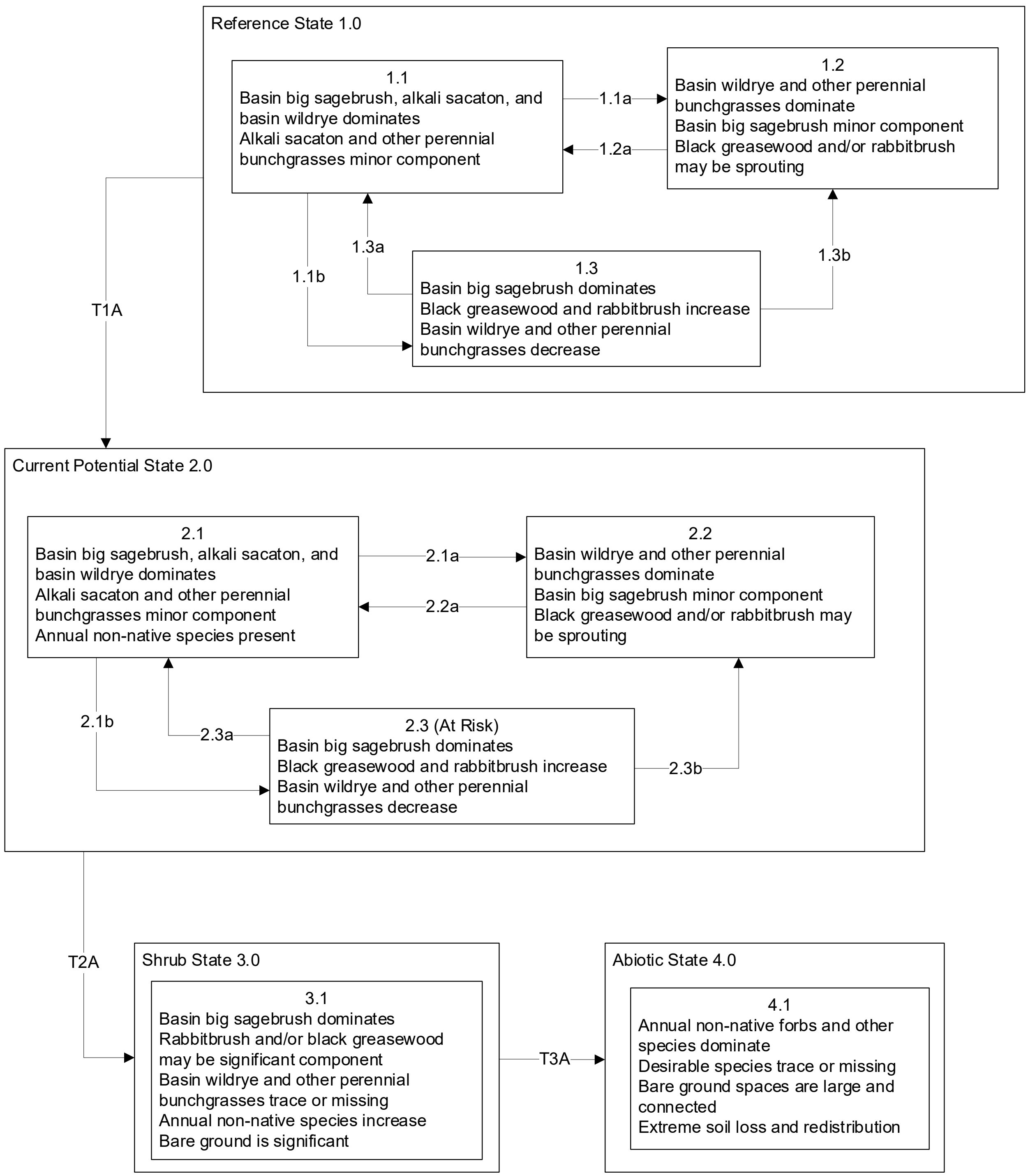
Transition T1A: Introduction of non-native plants.

Current Potential State 2.0 Community Pathways:
2.1a: Low severity fire resulting in mosaic pattern or reduced groundwater recharge reduces shrub cover allowing bunchgrasses to dominate. High severity fire, following an unusually wet spring or change in management, will significantly reduce Torrey's saltbush.
2.1b: Time and lack of disturbance such as fire, drought, inappropriate grazing management, or combinations of these will increase the shrub component.
2.2a: Time, lack of disturbance, release from chronic winter drought and/or shrub-favored grazing management.
2.3a: Heavy late fall/winter grazing causing mechanical damage to shrubs, low severity fire and/or reduced groundwater recharge.
2.3b: High severity fire decreases shrub cover and increases perennial bunchgrasses.

Transition T2A: Long-term inappropriate cattle/horse grazing and/or spring/summer drought or lowering of the water table due to groundwater pumping.

Transition T3A: Long-term, inappropriate grazing management, flooding, severe drought, groundwater pumping, or combinations. Significant soil loss and redistribution is occurring.

MLRA 29
Group 5
Dry Floodplain
R029XY156NV



MLRA 29
Group 5
Dry Floodplain
R029XY156NV
KEY

Reference State 1.0 Community Pathways
1.1a: Low severity fire resulting in mosaic pattern or reduced groundwater recharge reduces shrub cover allowing bunchgrasses to dominate. High severity fire, following an unusually wet spring or change in management, will significantly reduce non-sprouting shrubs.
1.1b: Time and lack of disturbance such as fire, drought, herbivory, or combinations of these. Black greasewood and rabbitbrush increase.
1.2a: Time and lack of disturbance and/or release from chronic winter drought.
1.3a: Low severity fire or reduced groundwater recharge reduces shrub cover allowing bunchgrasses to dominate.
1.3b: High severity fire significantly reduces shrub cover, releasing bunchgrasses.

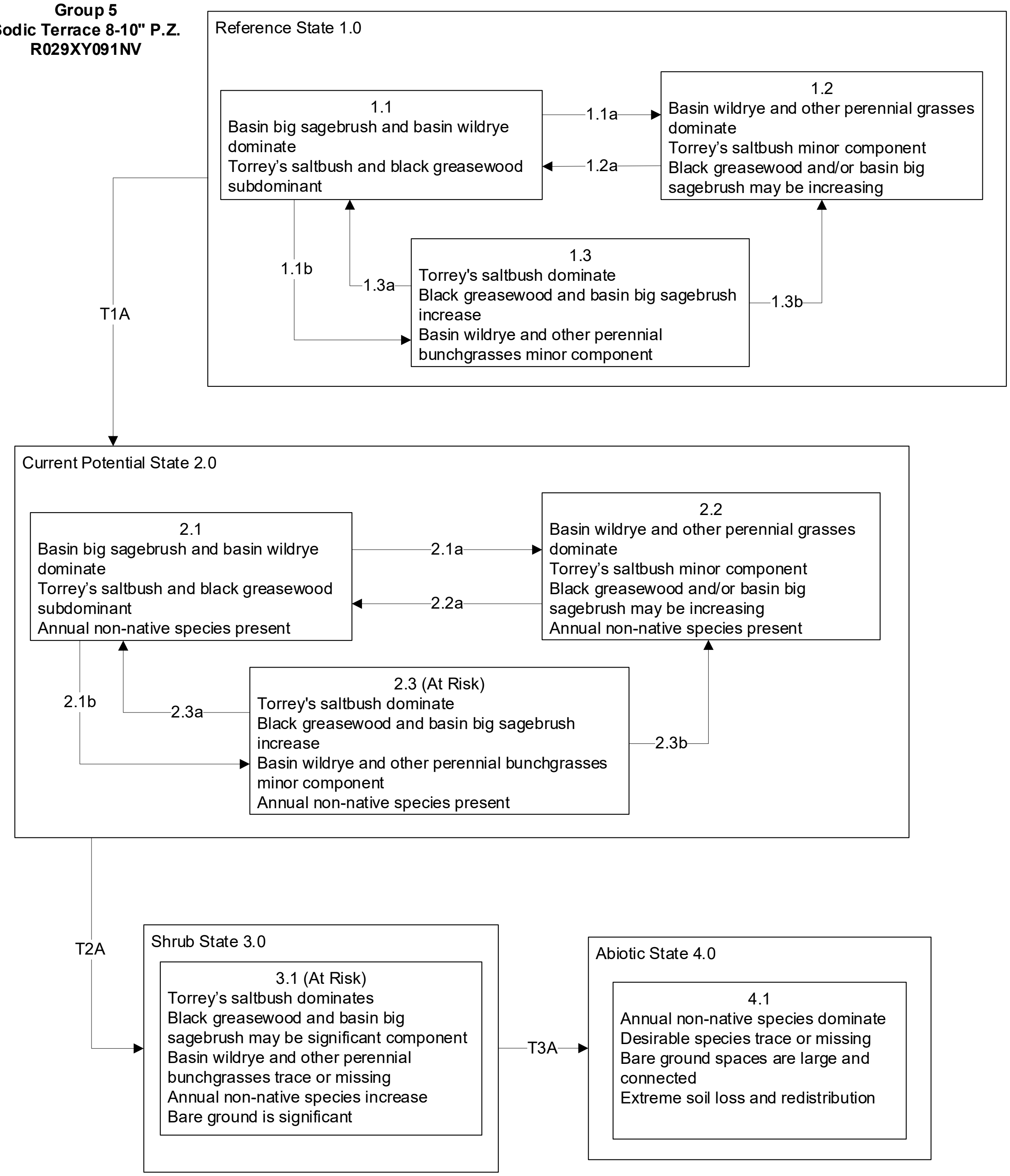
Transition T1A: Introduction of non-native plants.

Current Potential State 2.0 Community Pathways:
2.1a: Low severity fire resulting in mosaic pattern or reduced groundwater recharge reduces shrub cover allowing bunchgrasses to dominate. High severity fire, following an unusually wet spring or change in management, will significantly reduce non-sprouting shrubs.
2.1b: Time and lack of disturbance such as fire, drought, inappropriate grazing management, or combinations of these. Black greasewood and rabbitbrush increase.
2.2a: Time, lack of disturbance, release from chronic winter drought and/or shrub-favored grazing management.
2.3a: Heavy late fall/winter grazing causing mechanical damage to shrubs, low severity fire and/or reduced groundwater recharge.
2.3b: High severity fire decreases shrub cover, increasing perennial bunchgrasses.

Transition T2A: Long-term, inappropriate cattle/horse grazing and/or spring/summer drought or lowering of the water table due to groundwater pumping.

Transition T3A: Long-term, inappropriate grazing management, flooding, severe drought, groundwater pumping, or combinations. Significant soil loss and redistribution is occurring.

MLRA 29
Group 5
Sodic Terrace 8-10" P.Z.
R029XY091NV



MLRA 29
Group 5
Sodic Terrace 8-10" P.Z.
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Reference State 1.0 Community Pathways
1.1a: Low severity fire resulting in mosaic pattern or reduced groundwater recharge reduces shrub cover allowing bunchgrasses to dominate. High severity fire, following an unusually wet spring or change in management, will significantly reduce non-sprouting shrubs.
1.1b: Time and lack of disturbance such as fire, drought, inappropriate grazing management, or combinations of these. Black greasewood and basin big sagebrush increase.
1.2a: Time and lack of disturbance and/or release from chronic winter drought.
1.3a: Low severity fire or reduced groundwater recharge reduces shrub cover allowing bunchgrasses to dominate.
1.3b: High severity fire significantly reduces shrub cover, releasing bunchgrasses.

Transition T1A: Introduction of non-native plants.

Current Potential State 2.0 Community Pathways:
2.1a: Low severity fire resulting in mosaic pattern or reduced groundwater recharge reduces shrub cover allowing bunchgrasses to dominate. High severity fire, following an unusually wet spring or change in management, will significantly reduce non-sprouting shrubs..
2.1b: Time and lack of disturbance such as fire, drought, inappropriate grazing management, or combinations of these. Black greasewood and Basin big sagebrush increase.
2.2a: Time, lack of disturbance, release from chronic winter drought and/or shrub-favored grazing management.
2.3a: Heavy late fall/winter grazing causing mechanical damage to shrubs, low severity fire and/or reduced groundwater recharge.
2.3b: High severity fire decreases shrub cover.

Transition T2A: Long-term inappropriate cattle/horse grazing and/or spring/summer drought or lowering of the water table due to groundwater pumping.

Transition T3A: Long-term, inappropriate grazing management, flooding, severe drought, groundwater pumping, or combinations. Significant soil loss and redistribution is occurring.

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MLRA 29 Group 6: Salty soils with shadscale and black greasewood

Description of MLRA 29 Disturbance Response Group 6

Disturbance Response Group (DRG) 6 consists of three ecological sites. The precipitation ranges from 3 to 8 in. Slopes range from 0 to 8%, but slopes of 0 to 2% are most typical. Elevations range from 3,000 to about 6,000 ft. Production ranges from 100 to 350 lb/ac for a normal year with 75% to 80% of total production coming from the shrub component. These sites occur on alluvial flats, plains, and fan skirts. Soils are typically deep to very deep and well drained. Soil surfaces are typically coarse-textured and sometimes loamy. These soils are formed in alluvium and lacustrine deposits. Soils are typically alkaline or salt and sodium affected. The available water holding capacity is very low to high. The soil temperature regime is mesic typic or sodic and the soil moisture regime is typic aridic. The reference plant communities are dominated by shadscale *(Atriplex confertifolia)*, black greasewood *(Sarcobatus vermiculatus)*, and Indian ricegrass *(Achnatherum hymenoides)*. Other important species to these sites are green molly *(Bassia americana)*, Bailey's greasewood *(Sarcobatus baileyi)*, bud sagebrush *(Picrothamnus desertorum)*, fourwing saltbush *(Atriplex canescens)*, and bottlebrush squirreltail *(Elymus elymoides)*.

Disturbance Response Group 6 Ecological Sites:

Sodic Terrace 5-8" P.Z. – Modal	R029XY024NV
Dry Sodic Terrace	R029XY063NV
Saline Terrace 5-8" P.Z.	R029XY120NV

Modal Site:

The Sodic Terrace 5-8" P.Z. (R029XY024NV) ecological site is the modal site that represents this DRG, as it has the most acres mapped. This site occurs on alluvial plains and flats, fan skirts, lake plain terraces and stream terraces. Average annual precipitation ranges from 5 to 8 in. Slopes range from 0 to 8%, but slope gradients of 0 to 4% are most typical. Elevations are 4,000 to about 6,000 ft. The soils are deep to very deep and well drained. Surface soils are medium to moderately coarse-textured and less than 10 in. thick. The surface layer will normally crust and bake upon drying, inhibiting water infiltration and seeding emergence. These soils are strong to very strongly salt and sodium affected within 10 in. of the surface. A seasonal water table forms in these soils below depths of 5 ft that can supply additional moisture to deep-rooted shrubs. Runoff is slow to very slow depending on degree of soil surface crusting, sodium content of the surface layer, and slope gradients. The soil temperature regime is mesic typic and the soil moisture regime is typic aridic. Production for a normal year is 350 lb/ac.

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasives. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans across Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area, especially in eastern Nevada, when strong convection storms contribute significantly to annual precipitation. Moisture and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992) and the rapid rate at which this precipitation often occurs and runs-off. Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

Periodic drought regularly influences these ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West (Miller et al. 2008a). Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006). Altered precipitation regimes combined with historical anthropogenic land uses (i.e. grazing) and aggressive introduced species have altered these communities in many of the locations visited during the field work efforts included in this publication.

Shadscale, a C_4 species, the dominant shrub in this group, is considered an evergreen to partially deciduous shrub, since a small percentage of leaves are dropped in the winter (Smith and Nobel 1986).Shadscale possesses wider ecological amplitude than most *Atriplex* species (Crofts and Epps 1975), and shows ploidy levels from diploid (2x) to decaploid (10x). The extensive polyploidy of shadscale is an important consideration when implementing revegetation projects because ploidy levels are usually associated with distinct habitats

(Sanderson et al. 1990). Diploid individuals are unlikely to perform as well in areas where tetraploids are more common. Diploid individuals generally occur above Pleistocene lake levels, whereas lake floors are usually occupied by autotetraploids. Overall, tetraploids are the most widespread throughout its range (Carlson 1984). Thus, the diploid most associated with this site is a tetraploid.

Shadscale is thought to live 40 to 60 years and experience high mortality in the early years as well as at the end of its lifespan. It has been observed that "*A. confertifolia* (shadscale) is susceptible to the effects of below-average precipitation and that these effects are exacerbated by grazing" (Chambers and Norton 1993). Alternatively, Chambers and Norton (1993) found that the plots impacted by grazing tended to have the highest recruitment. This could possibly be attributed to declines in more palatable species, thus freeing up space for shadscale seedlings. Repeated, heavy defoliation events have been noted to kill individuals (Buwai and Trlica 1977). While there are differences between species, research points to shadscale being relatively sensitive to high levels of defoliation, related to the inability to resprout upon removal of new growth buds (Mohebby et al. 2012). Large-scale die-offs have been observed historically and were generally believed to be a combination of browsing, drought or higher than average precipitation. Mortality was observed in the rooting portions of the plants, with fine rootlet mortality and active rot and decay in larger roots observed. Die-off has been observed occurring in large complete areas in the basin bottoms, or gradually in higher landform positions. Shadscale community die-off has been attributed to the following factors: large animal use, winter injury, drought, soil salinity, anaerobiosis (resultant from soil saturation), insect epidemics and plant disease (Nelson et al. 1989). Climactic extremes have emerged as a common factor, and appear to have historically been a driving force in vegetation community dynamics in this plant community (Nelson et al. 1989). Increased soil moisture and lower slope landforms occurring at valley bottoms appears to be linked to die-off in *Atriplex confertifolia* (Ewing and Dobrowolski 1992). Concerns with die-off include replacement by weedy species including cheatgrass (*Bromus tectorum*), halogeton (*Halogeton glomeratus*), Russian thistle *(Salsola tragus*) and tansy mustard (*Descurania sophia*) (Nelson et al. 1989).

Black greasewood is classified as a phreatophyte (Eddleman 2008), and its distribution is well correlated with the distribution of groundwater (Mozingo 1987c). Meinzer (1927) discovered that the taproots of black greasewood could penetrate from 20 to 57 ft below the surface. (Romo 1984) found water tables ranging from 3.5 to 15 m (11 to 49 ft) under black greasewood-dominated communities in Oregon. Black greasewood stands develop best where moisture is readily available, either from surface or subsurface runoff (Brown 1971). It is commonly found on floodplains that are either subject to periodic flooding, have a high water table at least part of the year, or have a water table less than 34 ft deep (Harr and Price 1972, Blauer et al. 1976, Branson et al. 1976, Blaisdell and Holmgren 1984, Eddleman 2008). Ganskopp (1986) reported that water tables within 9.8 to 11.8 in. of the surface had no effect on black greasewood in Oregon. However, a study, conducted in California, found that black greasewood did not survive 6 months of continuous flooding (Groeneveld and Crowley 1988, Groeneveld 1990). Black greasewood is usually a deep-rooted shrub but has some shallow roots near the soil surface; the maximum rooting depth can be determined by the depth to a saturated zone (Harr and Price 1972).

Bailey's greasewood is a small, densely spined, deciduous shrub that can grow up to 0.5 m (1.6 ft) tall. They grow on mounds of accumulated sand and silt. In response to drought, it conserves energy by delaying flowering—and sometimes leaf emergence—for years at a time (Young and Clements 2006). It has been commonly found coexisting with shadscale in areas slightly south of cheatgrass zones.

Green molly is a halophytic C3 subshrub that is most often found in soils with high alkalinity and salinity at around 1.4% (Kadereit and Freitag 2011, Bradbury and Parrot 2020). It is adapted for arid environments and is commonly found growing in the same areas as shadscale. They tend to dominate regions with minimal vegetative competition due to their relative tolerance to high pH soils (Clark and Wagner 1984, Bradbury and Parrot 2020). A study of plant communities around the Great Salt Lake in Utah found that green molly grows primarily in clay loam soils (Bradbury and Parrot 2020). Green molly has a deep, fibrous root and can alter its root zone to create a higher ratio of sand to improve water infiltration and nutrient availability. It is also effective in erosion control and can be an ecologically significant species for stabilizing disturbed landscapes (Bradbury and Parrot 2020).

Fourwing saltbush is the most widely distributed and abundant saltbush in the southwest (Mozingo 1987c). It is a native, long-lived woody shrub that grows on a variety of soils, landforms, and climatic conditions from sand dunes, sand sheets, alluvial fans and plains, hills and mountains, and washes. It tolerates salinity but is not restricted to saline soils (Howard 2003a). It is a polymorphic species and is evergreen or deciduous depending on climate (Ogle et al. 2012a). Fourwing saltbush has a long taproot of depths of 5 to 15 m (16 to 49 ft) and many small lateral roots (Van Dersal 1938, Barrow 1997). Wallace et al. (1974) found that the roots compose 40% of the total mass of adult plants. Fourwing saltbush is classified as a phreatophyte and has been documented at water tables occurring from 8 to 62 ft in New Mexico (Meinzer 1927). *Atriplex* species are considered medium to short-lived shrubs and possess a number of morphological and physiological traits that enable them to cope with drought. Some of these traits include: a) photosynthesis through the C_4 carboxylation pathway; b) production of leaf trichomes and accumulation of salt crystals on the leaf surface to increase reflectance; c) accumulation and synthesis of inorganic and organic solutes to maintain turgor; and d) root association with endomycorrhizae that allows absorption of soil moisture at very low water potentials (Newton and Goodin 1989, Dobrowolski et al. 1990, Cibils et al. 1998).

Perennial bunchgrasses generally have somewhat shallower root systems than shrubs, but root densities are often as high as or higher than those of shrubs in the upper 0.5 m (1 to 2 ft). General differences in root depth distributions between grasses and shrubs result in resource partitioning in these shrub/grass systems. The perennial bunchgrasses that are sub-dominant with the shrubs include Indian ricegrass and galleta.

Indian ricegrass, the dominant grass in this group, is a hardy, cool-season, densely tufted, long-lived perennial bunchgrass that grows from 4 to 24 inches in height (Blaisdell and Holmgren 1984). Its deep, fibrous root system makes Indian ricegrass one of the most drought tolerant native species. Indian ricegrass can be found in low deserts associated with fourwing saltbush, shadscale and winterfat and in elevations up to 10,000 ft. It can be found throughout MLRA 29, including on ridges, canyons, dunes, hills, plains, and mountains. Indian ricegrass is a key plant in recovering communities disturbed by grazing, mining, and fire because it is a hardy grass that is able to grow in rough, rocky, and coarse soils and still provides very valuable forage. When successfully planted or recovered and managed, Indian ricegrass can help rehabilitate disturbed areas by competing with invasive plants and providing cover and forage (Booth et al. 1980). Indian ricegrass germination and establishment appears to occur in strong pulses, with the plant preferring spring conditions, characterized by slightly higher than normal early soil temperatures, followed by lower than normal temperatures later in the growing season (Pearson 1979).

Galleta is a mat-forming, rhizomatous, native grass that is 11 to 19 in. tall (Stubbendieck et al. 2003). This warm-season (C_4), perennial species is more water-efficient than its cool-season counterparts. This allows galleta grass to survive in low precipitation zones where a significant portion of rainfall occurs during summer months (Banner et al. 2011). It has been found that galleta grass initiated more than one phenological cycle with the presence of summer precipitation, allowing the species to grow and set seed more than once (Everett et al. 1980). This plant is typical of southern Nevada and the transition zone between the Great Basin and the Mojave Desert. It is most common in fine-textured soils (Stubbendieck et al. 2003) but is also common on sandy and coarse-textured soils.

Squirreltail is a short, cool-season bunchgrass that grows between 10 to 45 cm (4 to 19 in.) tall. It is an allotetraploid that can self-pollinate and is able to hybridize with other grasses, including other species of *Elymus* and some species of *Hordeum* (barley). Squirreltail is a very adaptable grass and occurs throughout western North America in the United States, Canada, and Mexico. Squirreltail can be found above 2,000 ft in elevation, and in areas that receive at least 5 in. of precipitation per year.

The ecological sites in this DRG have moderate resilience to disturbance and resistance to invasion. Increased resilience generally increases with elevation, aspect, increased precipitation, and increased nutrient availability. Annual non-native species such as Russian thistle and halogeton invade these sites where competition from perennial species is decreased.

Four possible stable states have been identified for this DRG. They are Reference, Current Potential State, Shrub State, and Abiotic State. An invasive annual grass or forb state was not quantified during fieldwork, however an invasive Annual State has been identified in Major Land Resource Area 24 and may exist in MLRA 29 (Stringham et al. 2021).

Annual Invasive Species:

The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and depressed competition or can increase resource pools by the decomposition of dead plant material following disturbance. Historically, shadscale dominant salt-desert shrub communities were free of non-native invasive species; however, excessive grazing pressure during settlement and into the 20th century has increased the overall presence of cheatgrass (*Bromus tectorum*), halogeton, Russian thistle and weedy mustard species (Brassicaceae family) (Peters and Bunting 1994). The presence of exotic annual plants within these ecosystems decreases ecosystem resilience and resistance to disturbance through competition for limited resources. Dobrowolski et al. (1990) cite multiple authors on the extent of the soil profile exploited by the competitive exotic annual cheatgrass. Specifically, the depth of rooting is dependent on the size the plant achieves, and in competitive environments, cheatgrass roots were found to penetrate only 15 cm (6 in.) whereas isolated plants and pure stands were found to root at least 1 m (3.3 ft) in depth with some plants rooting as deep as 1.5 to 1.7 m (1.5 to 5.5 ft).

While invasive annual grasses are well known and documented to establish in salt-desert plant communities, this particular group of ecological sites was not documented to be dominated by annual grasses in the course of fieldwork for this project. The presence of annual grasses, predominantly cheatgrass, was noted at many of the sites visited, however, the species was not found to dominate the sites, likely due to coarse soils and limited winter precipitation. The annual invasive species most likely to invade this DRG are Russian thistle and halogeton. Both species are summer annuals, germinating and growing in late spring and maturing in late summer/early fall. The summer rainfall associated with this DRG likely facilitates the growth of these two tap-rooted, invasive forbs.

Russian thistle is a tap-rooted, C4 photosynthesis (warm-season) annual forb, introduced from southeastern Europe and central Asia. The seeds have a remarkable capability to germinate in a variety of soil temperatures and very little precipitation and even move back into dormancy after initial germination (Wallace et al. 1968). The seeds, however, are not persistent and generally remain viable in the seed bank for less than two years (Boerboom 1993, Young et al. 1995). Russian thistle has been observed to provide initial establishment in completely de-vegetated sites and create a microsite habitat that may allow increased establishment of other species (Allen and Allen 1988). The successful establishment of other species, particularly later seral species that form mycorrhizal associations, may reduce the cover of Russian thistle as mycorrhizal inoculation has been observed to reduce the size and vigor of Russian thistle while encouraging later seral species such as perennial bunchgrasses (Johnson 1998a).

Halogeton is an introduced, succulent annual of the goosefoot family (*Chenopodiaceae*) native to semi-desert lands in the Altai region of central Asia (Tisdale and Zappetini 1953). It possesses a strong tap root that penetrates 4 to 5 in. and an extensive root system spanning up to 2 ft in lateral spread and depth (Tisdale and Zappetini 1953). Halogeton is characterized by its small fleshy leaves that can appear slightly red or purple as the plant matures. This plant can produce as many as 25,000 seeds, while typical plant sizes of about 3 in. can produce up to 800 seeds. These seeds are spread primarily through fruit ingestion and fruit movement, but can also be spread through wind (Tisdale and Zappetini 1953). Halogeton is well adapted to alkaline and saline soils and is prevalent on disturbed and overgrazed sites (Cook and Stoddart 1953). These plants accumulate salt that can leach from dead plant materials, increasing the soil salinity in topsoil, which favors continued germination and spread in invaded sites (Cronin 1965). In addition, halogeton is poisonous to livestock (Rood et al. 2014). Multiple, catastrophic deaths have been reported in sheep, while recorded death losses in cattle are less common, however anecdotal reports from ranchers suggest that the impact of halogeton losses in cattle herds in the western United States is more widespread than originally thought (Rood et al. 2014).

Fire Ecology:

Fire is a rare disturbance in these plant communities likely occurring in years with above-average production. Historically, shadscale-black greasewood communities had sparse understories and bare soil in interspaces, making these communities somewhat resistant to fire (Young 1983, Paysen et al. 2000). They may burn only during high fire hazard conditions; for example, years with high precipitation can result in almost continuous fine fuels, increasing fire hazard (West 1994, Paysen et al. 2000).

The lack of continuous fuels to carry fires made fire rare to nonexistent (Young and Tipton 1990), thus it is not surprising that shadscale and bud sagebrush are both fire intolerant (Banner 1992, West 1994). Shadscale does not readily recover from fire, except for establishment through seed (West 1994). The slow reestablishment allows for easy invasion by non-native weedy species (Sanderson et al. 1990).

Black greasewood may be killed by severe fires but usually sprouts vigorously after low to moderate severity fire (Young 1983, Rickard and McShane 1984, West 1994). Bentz et al. (2008) reported that following a Nevada wildfire, black greasewood sprouts reached approximately 2.5 ft within 3 years. In a study by Rickard and McShane (1984) black greasewood sprouted following wildfire and canopy cover was at 47% of pre-burn levels two years following fire. They also counted 185 shrubs before wildfire and 210 shrubs two years following fire.

Fourwing saltbush's ability to sprout following fire may depend on the population and fire severity. One study showed a 58% mortality rate of fourwing saltbush following fire in New Mexico, the surviving shrubs produced sprouts shortly after fire (Parmenter 2008). While fourwing saltbush is able to resprout after fire, it primarily reestablishes from seed (Stutz 1979, Wasser 1982).

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The initial condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species' response. For most forbs and grasses the growing points are located at or below the soil surface providing relative protection from disturbances that decrease above-ground biomass, such as grazing or fire. Thus, fire mortality is more correlated to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant, and abundance of old growth (Wright 1971, Young 1983). However, season and severity of the fire will influence plant response. Plant response will vary depending on post-fire soil moisture availability.

Indian ricegrass is fairly fire tolerant (Blaisdell and Holmgren 1984, Wright 1985), likely due to its low culm density and below-ground plant crowns. Vallentine (1989) cites several studies in the sagebrush zone that classified Indian ricegrass as being slightly damaged from late summer burning. Indian ricegrass has been found to reestablish on burned sites through seed dispersed from adjacent unburned areas (Young 1983). Thus, the presence of surviving, seed-producing plants is necessary for reestablishment of Indian ricegrass. Grazing management following fire to promote seed production and establishment of seedlings is important.

Squirreltail is a short-lived perennial grass adapted to a very broad suite of environmental conditions. Squirreltail is considered one of the most fire-resistant bunchgrasses due to its small size, coarse stems, and sparse leafy material (Wright and Klemmedson 1965, Wright 1971, Britton et al. 1990). Post-fire regeneration occurs from surviving root crowns and from on- and off-site seed sources (Bradley et al. 1992). Bottlebrush squirreltail has the ability to produce large numbers of highly germinable seeds, with relatively rapid germination (Young and Evans 1977) when exposed to the correct environmental cues. Squirreltail is capable of facultative fall or spring germination, develops extensive roots at low temperatures, and produces seeds early in the season (Reynolds and Fraley 1989, Hironaka 1994, Monsen et al. 2004a). Recent research indicates that squirreltail is capable of relatively rapid natural selection to improve survival in low-water, competitive environments (Kulpa and Leger 2013). Squirreltail reproduces primarily through seed. The long awns of the fruit allow for wind dispersal up to 130 ft away from the parent plant (Hironaka and Tisdale 1963, Marlette and Anderson 1986).

Galleta grass, a minor component of these ecological sites, has been found to increase following fire likely due to its rhizomatous root structure and ability to re-sprout (Jameson 1962). This species may retard reestablishment of deeper-rooted bunchgrasses due to site resource availability.

Livestock/ Wildlife Grazing Interpretations:

Traditionally, shadscale-black greasewood plant communities provided good winter forage for the expanding sheep and cattle industry in the arid West. Shadscale is a valuable browse species for a wide variety of wildlife and livestock (Blaisdell and Holmgren 1984). The spinescent growth habit of shadscale lends to its browsing tolerance with no more than 15 to 20% utilization by sheep being reported (Blaisdell and Holmgren 1984) and significantly less utilization by cattle. Increased presence of shadscale within grazed versus ungrazed areas is generally a result of the decreased competition from more heavily browsed associates (Cibils et al. 1998). Reduced competition from more palatable species in heavily grazed areas may increase shadscale germination and establishment. Chambers and Norton (1993) found shadscale establishment higher under spring than winter browsing as well as heavy compared to light browsing. During years of below-average precipitation, shadscale has been found very susceptible to grazing pressure regardless of season (Chambers and Norton 1993). Additionally, due to its abundance on winter ranges and the collection of fallen leaves beneath the shrub, it is a very important forage for big game and livestock (Wood et al. 1995). Shadscale habitats also serve as avian breeding grounds, primarily for the horned lark (*Eremophila alpestris*) which makes up 91–95% of total bird density observed in these plant communities (Medin 1990). Following fire, grazing exclusion for two or more years is beneficial for revegetation of shadscale communities as first year shadscale seedlings lack spines and are highly susceptible to browsing. Spines develop in the second year (Zielinski 1994).

Black greasewood is typically not considered an important browse species for wildlife and livestock. However, in a study by Smith et al. (1992), utilization of new growth on greasewood shrubs by cattle was 77% in summer, and greasewood was found to have the highest amounts of crude protein when compared to perennial and annual grasses. Black greasewood plants have been found to contain high amounts of sodium and potassium oxalates which are toxic to livestock and caution should be taken when grazing these communities. These shrubs can be used lightly in the spring as long as there is a substantial amount of other preferable forage available (Benson et al. 2011). Black greasewood also provides good cover for wildlife species (Benson et al. 2011). Conversely, Bailey's greasewood, through field observation, has been shown to increase under inappropriate grazing, suggesting the species is not palatable.

Indian ricegrass is a preferred forage species for livestock and wildlife (Cook 1962, Booth et al. 2006). This species is often heavily utilized in winter because it cures well (Booth et al. 2006). It is also readily utilized in early spring, being a source of green feed before most other perennial grasses have produced new growth (Quinones 1981). Booth et al. (2006) note that the plant does well when utilized in winter and spring. Cook and Child (1971), however, found that repeated heavy grazing reduced crown cover, which may reduce seed production, density, and basal area of these plants. Additionally, heavy early spring grazing reduces plant vigor and stand density (Stubbendieck et al. 1985). In eastern Idaho, productivity of Indian ricegrass was at least 10 times greater in undisturbed plots than in heavily grazed ones (Pearson 1965). Cook and Child (1971) found significant reduction in plant cover after 7 years of rest from heavy (90%) and moderate (60%) spring use. The seed crop may be reduced where grazing is heavy (Bich et al. 1995). Tolerance to grazing increases after May, thus spring deferment may be necessary for stand enhancement (Pearson 1964, Cook and Child 1971); however, utilization of less than 60% is recommended. In summary, adaptive management is required to manage this bunchgrass well.

Squirreltail has the ability to produce large numbers of highly germinable seeds, with relatively rapid germination (Young and Evans 1977) when exposed to the correct environmental cues. Early spring growth and ability to grow at low temperatures contribute to the persistence of squirreltail among cheatgrass dominated ranges (Hironaka and Tisdale 1973). Squirreltail generally increases in abundance when moderately grazed or protected (Hutchings and Stewart 1953). In addition, moderate trampling by livestock in big sagebrush rangelands of central Nevada enhanced squirreltail seedling emergence compared to untrampled conditions. Heavy trampling however was found to significantly reduce germination sites (Eckert and Spencer 1987). Squirreltail is more tolerant of grazing than Indian ricegrass but all bunchgrasses are sensitive to overutilization within the growing season.

Galleta is a highly palatable forage species for cattle, sheep, deer, antelope, and horses during late spring and summer while it is green (Stubbendieck et al. 2017). Due to its low growth form and rhizomatous characteristics, galleta grass is particularly tolerant of heavy grazing and trampling, and may increase as bunchgrasses decline (Pratt et al. 2002). This species will also initiate more than one phenological cycle if summer precipitation is present (Everett et al. 1980), allowing galleta to grow and propagate after defoliation.

Inappropriate grazing management during the spring growing season will cause a decline in understory plants such as Indian ricegrass. Growing season grazing by cattle several years in a row causes a decrease in the bunchgrass component and palatable shrubs (Eckert et al. 1972). Reduced bunchgrass vigor or density provides an opportunity for less palatable shrubs such as Bailey's greasewood to increase. In addition, less preferred grasses such as galleta and sand dropseed and/or invasive species such as halogeton or Russian thistle may increase. Thus, depending on the season of use, the type of grazing animal, and site conditions, either galleta, sand dropseed, or invasive annual forbs may become the dominant understory with inappropriate grazing management.

State and Transition Model Narrative for Group 6:

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 29 Disturbance Response Group 6.

Reference State 1.0:

Reference State 1.0 is representative of the natural range of variability under pristine conditions. The Reference State has two general community phases: a grass-shrub dominated phase and a shrub-grass dominated phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention organic matter and nutrients. Plant community phase changes are primarily driven by drought or excessive rainfall.

Community Phase 1.1:

Indian ricegrass, alkali sacaton, and inland saltgrass are well-represented in the understory. Black greasewood and shadscale co-dominate the overstory. This phase is typically observed on less-disturbed sites with intact soil crusts and functional nutrient cycling. Potential vegetative composition by air-dry weight is approximately 15% grasses, 5% forbs and 80% shrubs. Approximate ground cover (basal and crown) is 10 to 20%. Total annual air-dry production ranges from 150 to 500 lb/ac.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
Drought reduces herbaceous vigor and seed production, allowing shrubs to gain a competitive edge. Excessive rainfall can create temporary saturation or soil salinization, leading to a decrease in shadscale and favoring black greasewood or other shrub expansion. Indian ricegrass and alkali sacaton decline in cover and frequency, while black greasewood, and occasionally rabbitbrush increase.

Community Phase 1.2:
A shift toward shrub dominance occurs in response to drought or episodic rainfall events. Herbaceous species decline, and shrub cover increases. Black greasewood and other shrubs are the dominant structural components.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
With a return to average precipitation patterns and absence of significant disturbance, deep-rooted bunchgrasses can gradually increase. Soil moisture availability in spring allows grasses to recover. Competition from shrubs may persist, so recovery may be slow and patchy.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0:

Trigger: This transition is caused by the introduction of non-native annual plants, such as cheatgrass, halogeton, and Russian thistle.

Slow variables: Over time the annual non-native species will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

This state is similar to the Reference State 1.0 with two community phases. Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of non-native species. Non-natives may increase in abundance but will not become dominant within this state. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These feedbacks include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal.

Community Phase 2.1:
Shrubs such as black greasewood and shadscale dominate with Indian ricegrass and squirreltail in the understory. Annual non-native species are present but not dominant. This is the most resilient phase within the Current Potential State. Negative feedbacks (e.g., perennial competition, intact soils) still restrain annual dominance of non-natives.

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
Drought weakens bunchgrasses, especially Indian ricegrass, and may cause partial shrub dieback, particularly shadscale. Excessive rainfall can favor annual non-natives and lead to temporary saturation zones that also reduce shadscale. Growing-season grazing selectively removes palatable bunchgrasses, reducing their density and competitive ability. Black greasewood and other shrubs persist or expand, annuals increase, and perennial herbaceous cover declines.

Community Phase 2.2:
Perennial grasses are greatly reduced or patchy. Shadscale may decline in response to drought. Other shrubs may increase following shadscale and bunchgrass dieback, and annual non-natives may spread in interspaces. Sites may exhibit signs of stress: low production, increased bare ground, minor soil redistribution (e.g., small mounds, crusting). Ecological function is still mostly intact, but trajectory is toward degradation if stressors persist.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Appropriate grazing management allows bunchgrasses to recover. Favorable precipitation years with moist, cool springs support germination and establishment of Indian ricegrass and other bunchgrasses. Some shrub reduction may occur, particularly if grazing favors herbaceous growth over woody species. Soil surface conditions improve; annual non-natives may persist but stabilize.

Transition T2A: From Current Potential State 2.0 to Shrub State 3.0:

Trigger: To Community Phase 3.1: Inappropriate cattle/sheep/horse grazing will decrease or eliminate deep-rooted perennial bunchgrasses and favor shrub growth and establishment. To Community Phase 3.2: Soil disturbing brush treatments will reduce black greasewood and possibly increase non-native annual species. Lowering of the water table due to groundwater pumping will also decrease black greasewood and allow for other shrubs to increase.

Slow variables: Long-term decrease in deep-rooted perennial bunchgrasses density and/or black greasewood.

Threshold: Loss of deep-rooted perennial bunchgrasses changes nutrient cycling, nutrient redistribution, and reduces soil organic matter. Loss of long-lived, black greasewood changes the temporal and depending on the replacement shrub, the spatial distribution of nutrient cycling.

Shrub State 3.0:

This state is characterized by dominance of shrubs, reduced grass understory, and increased bare ground. Soil redistribution (e.g., mounding, crusting, pedestalling) suggests elevated risk of transition to an abiotic condition.

Community Phase 3.1:
Dominated by black greasewood and other shrubs. Shadscale is present but often declining. Indian ricegrass and other bunchgrasses are reduced to trace amounts. Galleta may increase due to its grazing tolerance. Annual non-natives are present; wind erosion and crusting may increase. Soil pedestalling and redistribution indicate loss of stabilizing vegetation.

Sodic Terrace 5-8" P.Z. (R029XY024NV), Shrub State 3.1, T. Stringham, August 2021

Saline Terrace 5-8" P.Z. (R029XY120NV), Shrub State 3.1, T. Stringham, June 2020

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:
Long-term drought causes additional shrub mortality; black greasewood may die back. Groundwater declines (e.g., due to pumping) may also reduce black greasewood cover. Soil conditions worsen: crusting thickens, hydrophobicity increases, erosion risk rises.

Community Phase 3.2 (At Risk)
Shrubs persist, but no perennial grasses remain**.** Non-native annuals may dominate the few herbaceous niches left, often around disturbed microsites. Bare ground is widespread, and soil surface shows signs of abiotic transition—mounding, crusting, and loss of aggregation. This phase is highly vulnerable to further degradation.

Dry Sodic Terrace (R029XY063NV), Shrub State 3.2, T. Stringham, June 2021

Community Phase Pathway 3.2a, from Phase 3.2 to 3.1:
Appropriate grazing management and a sequence of favorable precipitation years may allow black greasewood and some grasses to reestablish. Recovery is partial and slow, often limited by altered hydrology and residual weed pressure.

Transition T3A: From Shrub State 3.0 to Abiotic State 4.0:

Trigger: To Community Phase 4.1: A mixture of climatic variables (drought/excessively wet), and/or chronic inappropriate cattle/sheep/horse grazing, and/or soil disturbing activities, which will eliminate shrubs.

Slow variables: Long-term decrease in density of native, perennial vegetation combined with soil movement and loss.

Threshold: Increased wind or water erosion resulting in soil loss preventing the establishment of native perennials. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and shrubs truncate energy capture spatially and temporally thus impacting nutrient cycling and distribution.

Abiotic State 4.0:

This state consists of one community phase in which abiotic factors (i.e. wind or water erosion) have dramatically altered the site. It is characterized by the loss of vegetative cover along with the redistribution and loss of the soil surface. Feedbacks contributing to the stability of this state include soil loss, nutrient loss, soil surface degradation and increased area, distribution and connectivity between patches of bare soil.

Community Phase 4.1:
This community is the result of extreme soil loss and redistribution. The vegetative cover is minimal, but is dominated by shrubs. Trace amounts of introduced non-native species of forbs and grasses. Desirable species may be present and bare ground interspaces are large and connected. Site function is controlled by soil erosion, wind and soil temperature. Rehabilitation of this community is unknown.

Sodic Terrace 5-8" P.Z. (R029XY024NV), Abiotic State 4.1, P. Novak-Echenique, June 2021

Potential Resilience Differences with Other Ecological Sites in this Group:

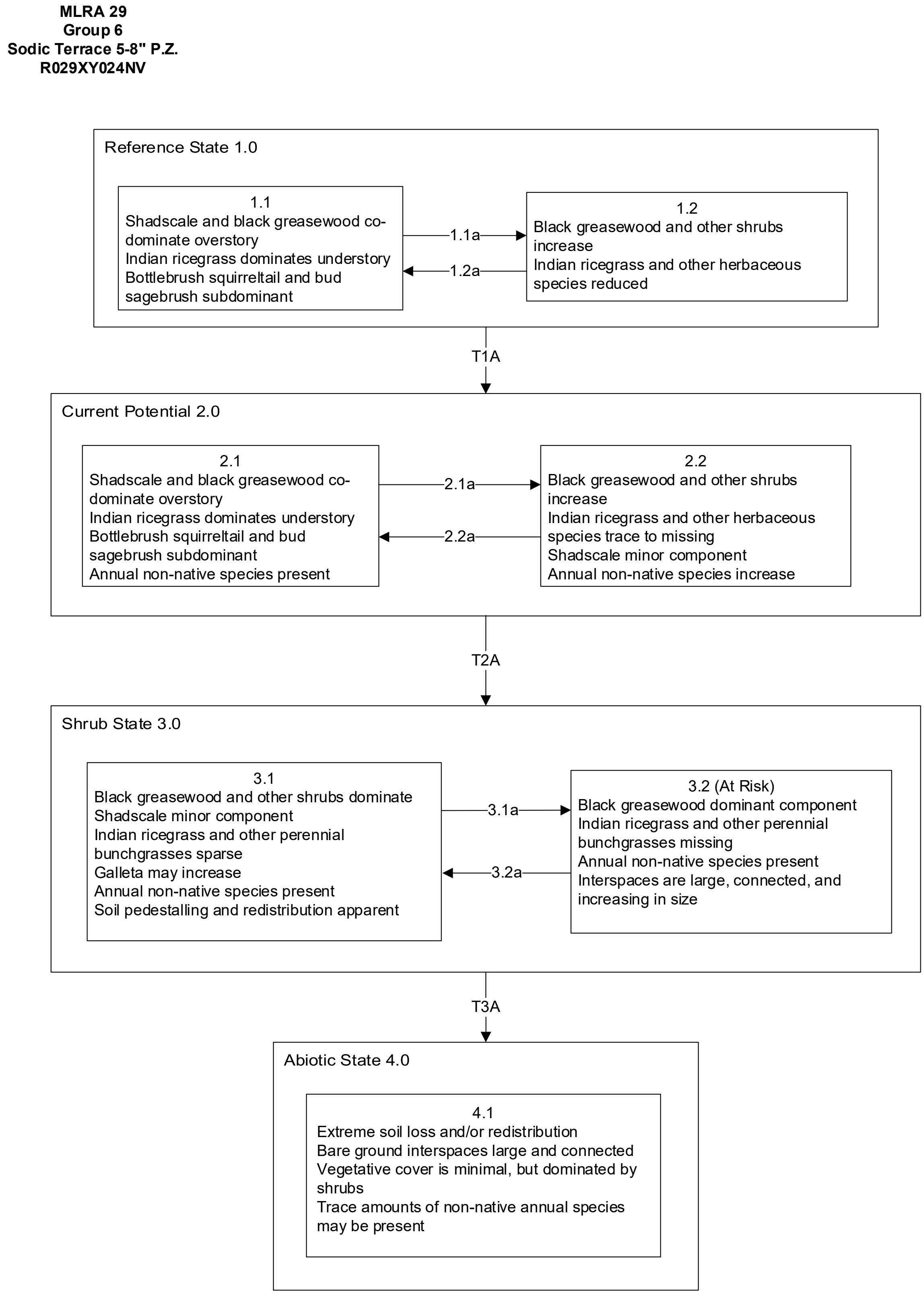
Dry Sodic Terrace (R029XY063NV):

This plant community is dominated by shadscale, black greasewood and Bailey's greasewood. Although shadscale makes up most of the annual production, black greasewood is often prevalent enough to dominate the visual aspect. The resilience of this site is lower than the modal site and degradation potential is higher. It has less production than the modal with 100 lb/ac in a normal year. Potential vegetative composition by air-dry weight is approximately 80% shrubs, 15% grasses and 5% forbs. Bailey's greasewood dominates in the Shrub State.

Saline Terrace 5-8" P.Z. (R029XY120NV):

This plant community is dominated by Indian ricegrass, green molly, and shadscale. Bud sagebrush and galleta are important species associated with this site. Site occurs on alluvial flats with near negligible runoff and is affected by alkaline or sodic conditions. Resilience is similar to the modal site. Potential vegetative composition by air-dry weight is approximately 80% shrubs, 15% grasses, and 5% forbs. An Abiotic State was not observed for this site.

Modal State and Transition Model for Group 6 in MLRA 29:



MLRA 29
Group 6
Sodic Terrace 5-8" P.Z.
R029XY024NV

Reference State 1.0
1.1a: Drought reduces perennial bunchgrasses' vigor and seed production, decreasing understory cover, and increasing shrub cover. Excessive rainfall can reduce shadscale allowing black greasewood and other shrubs to increase.
1.2a: Time and lack of disturbance and/or return to average precipitation patterns allows perennial bunchgrasses and shadscale to gradually increase.

Transition T1A: The introduction of non-native annual species.

Current Potential 2.0
2.1a: Drought and/or growing-season grazing reduces perennial bunchgrass cover while shrub cover persists or expands. Excessive rainfall can reduce shadscale allowing black greasewood and other shrubs to increase.
2.2a: Improved grazing management and/or favorable precipitation years supports perennial bunchgrass establishment and shadscale to gradually increase.

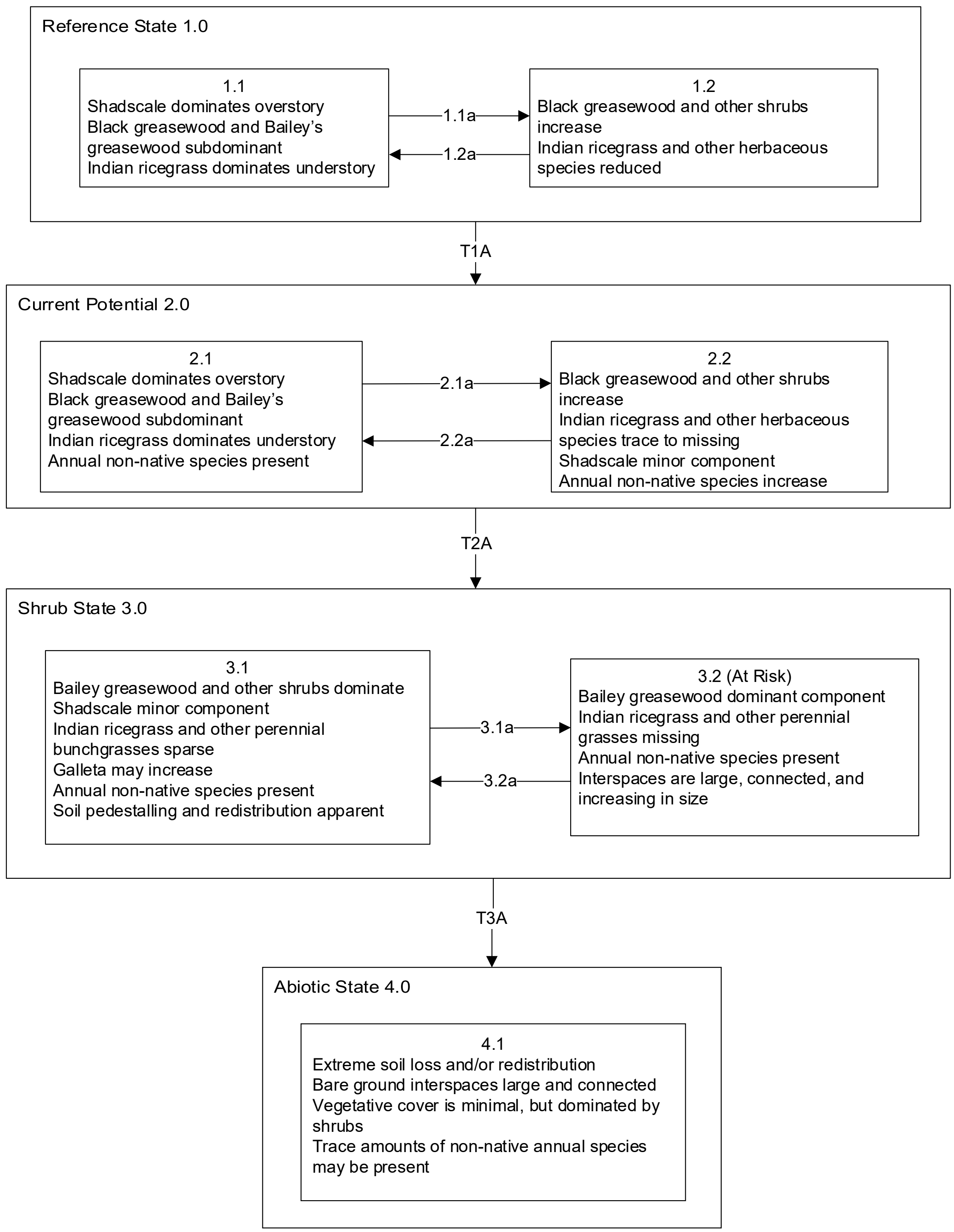
Transition T2A: To Community Phase 3.1: Inappropriate cattle/sheep/horse grazing will decrease or eliminate deep-rooted perennial bunchgrasses and favor shrub growth and establishment. To Community Phase 3.2: Soil-disturbing brush treatments or lowering of the water table due to groundwater pumping will reduce black greasewood and possibly increase non-native annual species.

Shrub State 3.0
3.1a: Long-term drought and/or lowering of water table by groundwater pumping reducing black greasewood and increasing size of interspace.
3.2a: Appropriate grazing management and a sequence of favorable precipitation years may allow black greasewood and some grasses to reestablish. Recovery is partial and slow.

Transition T3A: A mixture of climatic variables (drought/excessively wet), chronic inappropriate cattle/sheep/horse grazing, and/or soil disturbing activities will eliminate shrubs.

Additional State and Transition Models for Group 6 in MLRA 29:

MLRA 29
Group 6
Dry Sodic Terrace
R029XY063NV



MLRA 29
Group 6
Dry Sodic Terrace
R029XY063NV

Reference State 1.0
1.1a: Drought reduces perennial bunchgrasses' vigor and seed production, decreasing understory cover, and increasing shrub cover. Excessive rainfall may reduce shadscale allowing other shrubs to increase.
1.2a:Time and lack of disturbance and/or return to average precipitation patterns allows perennial bunchgrasses and shadscale to gradually increase.

Transition T1A: The introduction of non-native annual species.

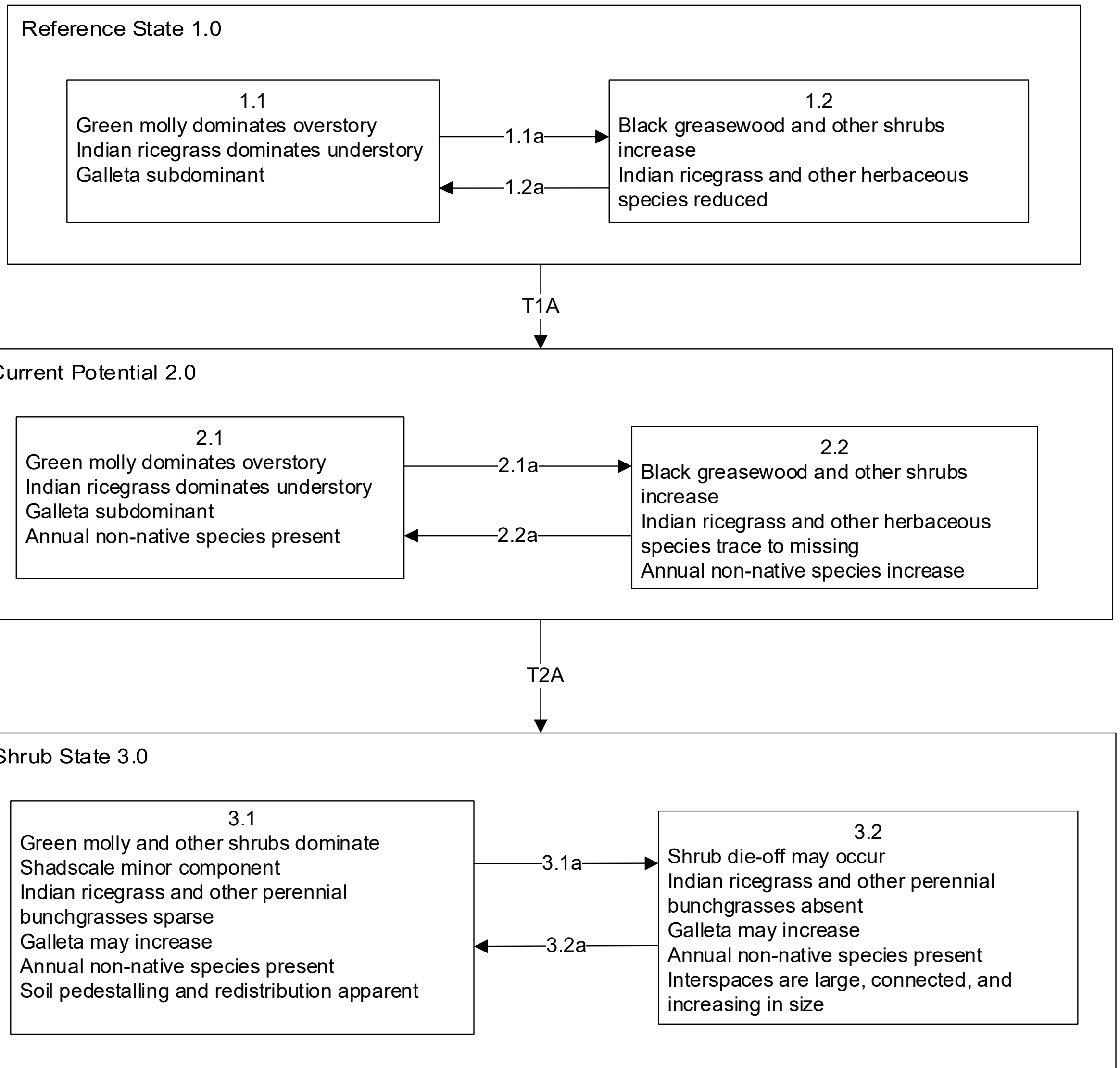
Current Potential 2.0
2.1a: Drought and/or growing-season grazing reduces perennial bunchgrass cover while shrub cover persists or expands. Excessive rainfall may reduce shadscale allowing other shrubs to increase.
2.2a: Improved grazing management and/or favorable precipitation years supports perennial grass establishment and shadscale to gradually increase.

Transition T2A: To Community Phase 3.1: Inappropriate cattle/sheep/horse grazing will decrease or eliminate deep-rooted perennial bunchgrasses and favor shrub growth and establishment. To Community Phase 3.2: Soil-disturbing brush treatments or lowering of the water table due to groundwater pumping and will reduce black greasewood and possibly increase non-native annual species.

Shrub State 3.0
3.1a: Long-term drought and/or lowering of water table by groundwater pumping reducing black greasewood and increasing size of interspace.
3.2a: Appropriate grazing management and a sequence of favorable precipitation years may allow shrubs and some grasses to reestablish. Recovery is partial and slow.

Transition T3A: A mixture of climatic variables (drought/excessively wet), chronic inappropriate cattle/sheep/horse grazing, and/or soil disturbing activities will eliminate shrubs.

MLRA 29
Group 6
Saline Terrace 5-8"
R029XY120NV



MLRA 29
Group 6
Saline Terrace 5-8"
R029XY120NV

Reference State 1.0
1.1a: Drought and/or excessive rainfall reduces perennial bunchgrasses' vigor and seed production, decreasing understory cover, and increasing shrub cover.
1.2a: Time and lack of disturbance and/or return to average precipitation patterns allows perennial bunchgrasses to gradually increase.

Transition T1A: The introduction of non-native annual species.

Current Potential 2.0
2.1a: Drought, excessive rainfall, and/or growing-season grazing reduces perennial bunchgrass cover while shrub cover persists or expands.
2.2a: Improved grazing management and/or favorable precipitation years supports perennial bunchgrass establishment and potential shrub reduction.

Transition T2A: To Community Phase 3.1: Inappropriate cattle/sheep/horse grazing will decrease or eliminate deep-rooted perennial bunchgrasses and favor shrub and galleta growth and establishment. To Community Phase 3.2: Long-term drought or excessive rainfall causes additional shrub mortality.

Shrub State 3.0
3.1a: Long-term drought, excessive rainfall, and/or lowering of water table by groundwater pumping decreases shrub cover and increases size of interspace.
3.2a: Release from drought and/or return to average precipitation patterns and/or grazing may allow for shrub reestablishment. Recovery is partial and slow. Galleta grass may also increase.

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MLRA 29 Group 7: Salt-affected soils with greasewood, iodinebush, and warm-season grasses

Description of MLRA 29 Disturbance Response Group 7

Disturbance Response Group (DRG) 7 consists of two ecological sites. These sites are found primarily on lake plains, alluvial flats, and lake plain terraces, usually adjacent to playas. These areas are characterized by deep, fine-textured, salt-affected soils. The upper portion of the soil profile is strongly salt and sodium affected due to capillary movement of dissolved salts upward from the groundwater table. The available water holding capacity is reduced by the high salt concentrations of the soil. The soil surface typically will crust and bake upon drying, inhibiting water infiltration and seedling emergence. The soil temperature regime is mesic and the soil moisture regime is aridic. Effective rooting depths are limited by a water table that fluctuates from 40 to over 60 in. below the surface. Plant growth is attenuated by water table fluctuation, soil pH, and natural ponding and crusting of the soil surface. Seasonal flooding is common. Precipitation ranges from 5 to 10 in. Slopes range from 0 to 2%. Elevations range from 3,500 to about 6,000 ft. Production ranges from 250 to 300 lb/ac for a normal year. The reference plant communities are dominated by black greasewood (*Sarcobatus vermiculatus*), iodinebush (*Allenrolfea occidentalis*), inland saltgrass (*Distichlis spicata*), and alkali sacaton (*Sporobolus airoides*). Other important species include basin wildrye (*Leymus cinereus*), shadscale saltbush (*Atriplex confertifolia*), Parry's saltbush (*Atriplex parryi*), fourwing saltbush (*Atriplex canescens*), Torrey's saltbush (*Atriplex torreyi*), seepweed (*Suaeda nigra*), and rubber rabbitbrush (*Ericameria nauseosa*).

Disturbance Response Group 7 Ecological Sites:

Sodic Flat – Modal	R029XY076NV
Sodic Floodplain	R029XY094NV

Modal Site:

The Sodic Flat ecological site is the modal site that represents this DRG, as it has the most acres mapped. This site occurs on lake plains and lake plain terraces, usually immediately adjacent to playas. Slope gradients of less than 2% are most typical. Elevations are 3,500 to about 5,500 ft, and annual production in a normal year is 250 lb/ac. The soils on this site are deep to very deep and somewhat poorly to well drained. Surface soils are medium to moderately fine textured and normally less than 10 in. thick to the subsoil or underlying material. The upper portion of these soils are strongly salt and sodium affected due to capillary movement of dissolved salts upward from a shallow groundwater table. Effective rooting depths are limited by a water table that fluctuates from 40 to over 60 in. below the soil surface. High salt concentrations reduce the available water holding capacity. The soil temperature regime is mesic and the soil moisture regime is aridic. The reference plant community is dominated by black greasewood and inland saltgrass. Other important species include alkali sacaton, basin wildrye, and shadscale.

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasives. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans a unique area in Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area. Flashy, summer storm events contribute significantly to annual precipitation as well. Air and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980, Witwicki et al. 2016).

Periodic drought regularly influences these ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West (Qian et al. 2006). Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity (Snyder et al. 2019). Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006).

Hydrology, Drought, Groundwater Interpretations:

Black greasewood, the dominant shrub of this group, is a cool-season (C3), spiny, semi-evergreen shrub that grows from 3 to 10 ft tall with bright green to olive green, fleshy leaves (Benson et al. 2007). The native shrub is generally monoecious but can also be dioecious (having separate male and female plants). Black greasewood flowers from May through July with fruit maturing from July through September. During dry periods, the shrub relies on access to shallow groundwater rather than precipitation for survival (Meinzer 1927, Mozingo 1987c, Trent et al. 1997, Naumburg et al. 2005). Black greasewood covers roughly two million acres, making it the most extensive groundwater dependent vegetation type in Nevada (Saito et al. 2020).

Black greasewood's maximum rooting depth can be determined by the depth to a saturated zone (Harr and Price 1972). It is commonly found on floodplains that are either subject to periodic flooding, have a high water table at least part of the year, or have a water table less than 34 ft deep (Harr and Price 1972, Blauer et al. 1976, Branson et al. 1976, Blaisdell and Holmgren 1984, Eddleman 2008). Ganskopp (1986) reported that water tables within 9.8 to 11.8 in. of the surface had no negative effect on black greasewood in Oregon. However, a study, conducted in California, found that black greasewood did not survive 6 months of continuous flooding (Groeneveld and Crowley 1988, Groeneveld 1990). This species also tolerates strongly sodic soils as well as strongly saline soils that are primarily fine-textured, including heavy clays and loams (Benson et al. 2007).

Black greasewood is capable of rooting to exceptional depths to access the water table in drought conditions. The taproots of black greasewood can penetrate from 20 to 57 ft below the surface with lateral roots extending from 3 to 12 ft from the shrub (Meinzer 1927, Benson et al. 2007). Disturbances such as long-term drought and groundwater extraction that lower the water table beyond the rooting depths of these plants threaten communities of phreatophytic vegetation (Naumburg et al. 2005, Elmore et al. 2006). Recent remote sensing research in black greasewood and saltgrass communities shows a reduction in plant productivity over time with lowered water tables associated with groundwater pumping (Huntington et al. 2016). The exact groundwater level at which greasewood can no longer survive is not yet known (Devitt and Bird 2016). Lowering of the water table and subsequent loss of greasewood has been observed in other MLRAs. Death of phreatophytes in this system leaves the site open to invasion by non-native species (Devitt and Bird 2016, Provencher et al. 2020). Because of the high salt content of these soils, other more drought-tolerant native plants such as basin big sagebrush may be unlikely to colonize the site.

Shadscale, the sub-dominant shrub on the modal site, exhibits the ability to withstand drought conditions on a short-term basis, the forty-year photographic record (1951–1990) from the Raft River Valley of south-central Idaho visually demonstrates the impact of multiple years of drought on shadscale communities (Sharp et al. 1990). Scale insects have also been implicated in the death of shadscale (Sharp et al. 1990), however, the data on this subject remains inconclusive (Nelson et al. 1990b). Interestingly, periods of above normal springtime precipitation are also linked to shadscale die-off. Nelson et al. (1990a) investigated areas of severe shadscale die-off that were, for the most part, located in low areas in valley bottoms or upland depressions that apparently incurred prolonged high soil moisture during a wet period. The high soil moisture appeared to be correlated with increased pythiaceous fungi leading to rootlet mortality and plant stress (Nelson et al. 1990a). The authors suggest that depending on the degree and duration of plant stress, injury could range from a sustained disease to rapid death. However, mass die-offs in shadscale stands have been witnessed to bounce back presumably through a persistent seed bank (Sharp et al. 1990, Meyer et al. 1998, Haubensak et al. 2009).

Iodinebush, the dominant shrub on the Sodic Floodplain ecological site, is a cool-season, halophytic plant that grows near playas. This typically 2- to 3-foot-tall shrub is characterized by jointed, succulent stems that grow in rounded clumps. The succulent tissues of iodinebush store salt molecules which causes water to flow from the soil into the plant – a unique adaption to salty soils (Bowers 1993). Iodinebush is generally found on eolian mounds at the margins of salt marshes and salt playas (Trent et al. 1997, Gul and Weber 1999). These mounds average 0.3 m (1 ft) in height and appear to be favorable for plant recruitment and survivorship, however, this value is lost after a number of years because of accumulation of salts (Blank et al. 1998). Iodinebush grows well in soils with 6% sodium chloride (NaCl). It is one of the most salt tolerant species in the Great Basin and Mojave deserts. The dry summer season allows for salt to accumulate on the soil surface which prevents most plants from growing, except for iodinebush (Weber et al. 2002). Iodinebush roots were extracted from a mound and found that roots extended over 10 m (33 ft) into the unvegetated playa (Blank et al. 1998). The diameter of larger roots was over 5 cm (2 in.), and many had between 90 and 120 growth rings, indicating that iodinebush is quite long-lived. The large taproot of iodinebush can reach water table depths of 25 ft (Meinzer 1927). Iodinebush relies on a persistent seedbank that can remain dormant until salinity stress is alleviated (Gul and Weber 2001).

The two dominant grass species in this group, alkali sacaton and inland saltgrass, are both warm-season grasses, which means they use the C4 photosynthetic pathway. This adaptation makes these plants more efficient in their use of nitrogen and water (Taylor et al. 2010). The C4 grasses can adjust their growth more quickly to drought or wet conditions when compared to C3 grasses (Witwicki et al. 2016).

Alkali sacaton, a hardy, warm-season species, is a densely tufted, native perennial bunchgrass that grows from 20 to 60 inches in height (Brakie 2007). Its roots are coarse, fibrous, tough, and deep, often reaching capillary fringes of moderately deep water tables (Wasser et al. 1986). This species tolerates salt-affected and poor fertility soils (Pessarakli 2017). Alkali sacaton grows in soils of all textures except unstable sands. The species is highly tolerant of alkaline, saline, sodic (alkali), and saline-sodic soils, however it is also found on nonsaline soils, rocky sites, open plains, valleys and bottom lands (USFS 1937, Wasser et al. 1986). Alkali sacaton, a prolific seeder, reproduces from seeds and tillers. The seeds remain viable for several years because of their hard, waxy seed coats (Blaisdell and Holmgren 1984).

Inland saltgrass, a common perennial grass in this group, is a warm-season, rhizomatous species that grows 10 to 60 cm (4 to 24 in.) tall. This native species is highly adapted to saline areas (Comstock and Ehleringer 1992, Newman and Gates 2000) and has been reported to withstand full strength seawater soil salinity under dry salt playa conditions, similar to those in Nevada playas (Qian et al. 2006). Inland saltgrass generally occurs where the water table is within 8 to 12 ft of the soil surface even in dry periods (Meinzer 1927). The species is also adapted to low water conditions, as it can distribute water for long distances through its connected rhizomes (Alpert 1990). Marcum and Kopec (1997) found inland saltgrass more tolerant of increased levels of salinity than alkali sacaton; therefore, dewatering and/or long-term drought causing increased levels of salinity would create environmental conditions more favorable to inland saltgrass over alkali sacaton. Alkali sacaton is considered a facultative species in this region; it is tolerant of drought and inundation (Brakie 2007). A lowering of the water table can occur with groundwater pumping simulating drought in these sites. This can contribute to the loss of deep-rooted species such as greasewood and alkali sacaton which is replaced by an increase in saltgrass, rabbitbrush, shadscale and other species in the absence of drought.

These communities often exhibit the formation of microbiotic crusts within the interspaces. These crusts influence the soils on these sites and their ability to reduce erosion and increase infiltration. They may also alter the soil structure and possibly increase soil fertility (Fletcher and Martin 1948, Williams 1993). Finer-textured soils such as silts tend to support more microbiotic cover than coarse-textured soils (Anderson et al. 1982). Disturbances such as hoof action from inappropriate grazing and cheatgrass (*Bromus tectorum*) invasion can reduce biotic crust integrity (Anderson et al. 1982, Ponzetti et al. 2007) and increase erosion, however the chemistry of the soil on this site precludes cheatgrass invasion. Other annual non-native species such as halogeton, also known as saltlover (*Halogeton glomeratus*), prickly Russian thistle (*Salsola tragus*), tall tumblemustard (*Sisymbrium altissimum*) also invade these sites where competition from perennial species is decreased. Native annual forbs like western tansymustard (*Descurainia pinnata*) can also become weedy on this site. Density of western tansymustard increases with supplemental water (Gutierrez and Whitford 1987); it may become a dominant understory plant in years with favorable moisture regimes. With increased production and density, these annual species increase the risk of fire in this community.

The ecological sites in this DRG have moderate resilience to disturbance and resistance to invasion. Primary disturbances on these sites include extended drought, excessive livestock grazing, lowering of the water table, and conversion to agricultural land and urban development. Four possible stable states have been identified for this DRG.

Annual Invasive Species:

The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and depressed competition or can increase resource pools by the decomposition of dead plant material following disturbance. Historically, shadscale dominant salt-desert shrub communities were free of exotic invaders; however, excessive grazing pressure during settlement and into the 20th century has increased the overall presence of cheatgrass (*Bromus tectorum*), halogeton (*Halogeton glomeratus*), Russian thistle (*Salsola* spp.) and weedy mustard species

(*Brassicaceae* spp.) (Peters and Bunting 1994). The presence of exotic annual plants within these ecosystems decreases ecosystem resilience and resistance to disturbance through competition for limited resources.

The species most likely to invade the ecological sites in this DRG is cheatgrass. Cheatgrass is a cool-season annual grass that maintains an advantage over native plants, in part, because it is a prolific seed producer, can germinate in the autumn or spring, tolerates grazing, and increases with frequent fire (Klemmedson and Smith 1964, Miller et al. 1999). Cheatgrass originated from Eurasia and was first reported in North America in the late 1800s (Furbush 1953, Mack and Pyke 1983). Bradley et al. (2018) found that cheatgrass has expanded to greater than 15% cover over 210,000 km^2 (130,488 mi^2), roughly 31% of the Intermountain West. In the Great Basin, cheatgrass is expanding at a rate of expansion of 3,700 km^2 (2,300 mi^2) annually and is a land management issue that will require creative solutions (Smith et al. 2022).

Mapping potential or current invasion vectors is a management method designed to increase the cost-effectiveness of control methods. Recent modeling and empirical work by Lauenroth and Bradford (2006) suggest that seasonal patterns of precipitation input and temperature are also key factors determining regional variation in the growth, seed production, and spread of invasive annual grasses. The phenomenon of cheatgrass "die-off" provides opportunities for restoration of perennial native species (Baughman et al. 2016, Baughman et al. 2017). The causes of these events are not fully understood, but there is ongoing work to try to predict where they occur, in the hopes of aiding conservation planning (Weisberg et al. 2017, Brehm 2019).

Halogeton is a non-competitive plant that tends to invade areas that are susceptible to repeated disturbance such as; livestock trails, roadsides, trampled areas near watering holes or corrals and rangeland areas stripped of the natural vegetation by excessive grazing or other soil disturbing activities (Young 2002). It was first introduced into the western U.S. during the 20th century with the first collection being made near Wells, Nevada in 1934. Halogeton is highly toxic to sheep and has been responsible for thousands of sheep deaths throughout the western U.S., which triggered a massive effort to eradicate the introduced species in the late 1900s (Young 2002). Halogeton has two distinct seed forms; a black form which consists of the achene only and a brown form which consists of the achene and attached sepals (Tisdale and Zappetini 1953, Robocker et al. 1969). The black form of halogeton seed germinate readily under a wide range of pH and salt concentrations within the first year. The brown form of seed was found to be 100% viable at the end of two years and 15% viable at the end of 10 years, proving that halogeton seed may remain viable in the soil for up to 10 years (Robocker et al. 1969). Eradication of this species is problematic, therefore, appropriate range management practices focused on soil and rangeland integrity are necessary to control the species.

Fire Ecology:

Natural fire return intervals are estimated to vary between less than 35 years up to 100 years in these salt desert ecosystems (Paysen et al. 2000). Thus, fire is a rare disturbance in these plant communities likely only occurring in years with above-average production. Historically, black greasewood-saltbush communities had sparse understories and bare soil in intershrub spaces, making these communities resistant to fire (Young 1983, Paysen et al. 2000). They may burn only during high fire hazard conditions; for example, years with high precipitation can result in almost continuous fine fuels, increasing fire hazard (West 1994, Paysen et al. 2000).

Black greasewood may be killed by severe fire but can resprout after low to moderate severity fires (Robertson 1983, West 1994). Sheeter (1968) reported that following a Nevada wildfire, black greasewood sprouts reached approximately 2.5 ft within 3 years. Higher production sites would have experienced fire more frequently than lower production sites.

Shadscale is intolerant of fire and can only regenerate through seed (Zielinski 1994). Increases in the fire return interval leads to increases in the sprouting shrub component of the plant community, potentially facilitating increases in bare ground, inland saltgrass and invasive weeds. Fourwing saltbush and Torrey's saltbush regenerate following fire both through seed and re-sprouting. Both species are considered weak sprouters (West 1994).

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species' response. Thus, fire mortality is correlated to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant, and abundance of old growth (Wright 1971, Young 1983). Boyd et al. (2015) found soil color and depth of burn to be accurate predictors of bunchgrass mortality in post fire landscapes. They also found that bunchgrasses in close proximity of shrubs had up to five-fold higher mortality than bunchgrasses located in the interspaces (Boyd et al. 2015). The two dominant grasses on this site, alkali sacaton and inland saltgrass, have different responses to fire.

Alkali sacaton is tolerant of, but not completely resistant to fire. Many ranchers have reportedly used controlled winter or early spring burning to remove decadent plant material and encourage palatable new spring growth for livestock (Wasser et al. 1986). In one study in southeastern Arizona, alkali sacaton basal area fully recovered after two growing seasons following a winter-controlled burn and a natural summer wildfire (Bock and Bock 1978).

Inland saltgrass is tolerant of fire, as its rhizomatous roots are protected beneath the soil. This plant reproduces primarily through vegetative spread from rhizomes and is a poor seed producer (Monsen et al. 2004a). However, depth to ground water significantly affects the successful regeneration of alkali sacaton and inland saltgrass following fire (Pritchett and Manning 2009). Depth to ground water explained 77% of the grass cover variance in the post-fire burned area, and 87% and 94% of the grass cover variance in the pre-fire and post-fire unburned (control) areas, respectively. Pritchett and Manning (2009) documented vigorous regrowth and flowering of alkali sacaton and inland saltgrass in areas of shallow groundwater (within 2.6 m [8.5 ft] of the soil surface), however, in areas with deeper ground water, the species never advanced beyond the vegetative phase of growth to the flowering stage.

Livestock/Wildlife Grazing Interpretations:

Black greasewood is typically not considered an important browse species for wildlife and livestock. However, in a study by Smith et al. (1992), utilization of new growth on greasewood shrubs by cattle (*Bos taurus*) was 77% in summer, and greasewood was found to have the highest amounts of crude protein when compared to perennial and annual grasses. Black greasewood plants have been found to contain high amounts of sodium and potassium oxalates which are toxic to livestock and caution should be taken when grazing these communities. These shrubs can be used lightly in the spring as long as there is a substantial amount of other preferable forage available (Benson et al. 2007). Black greasewood also provides good cover for wildlife species (Benson et al. 2007). Kovalev and Krylova (1992) found that iodinebush is a possible feed for animals if mixed with other forage plants.

Shadscale is a valuable browse species for a wide variety of wildlife and livestock (Blaisdell and Holmgren 1984). The spinescent growth habit of shadscale lends to its browsing tolerance with no more than 15 to 20% utilization by sheep being reported (Blaisdell and Holmgren 1984) and significantly less utilization by cattle. Increased presence of shadscale within grazed versus ungrazed areas is generally a result of the decreased competition from more heavily browsed associates (Cibils et al. 1998). Reduced competition from more palatable species in heavily grazed areas may increase shadscale germination and establishment. Chambers and Norton (1993) found shadscale establishment higher under spring than winter browsing as well as heavy compared to light browsing. During years of below average precipitation, shadscale has been found very susceptible to grazing pressure regardless of season (Chambers and Norton 1993). There are conflicting reports on the palatability and forage value of inland saltgrass. Hansen et al. (1976) considered it an important forage species due to its relatively high crude protein content, however, Monsen et al. (2004a) claims that inland saltgrass is generally avoided by cattle unless it is late in the summer when other grasses have dried out. It is resistant to trampling and is generally considered an "increaser" under heavy grazing (Parker 1975). Nevertheless, Costello (1944) found that consistent grazing of inland saltgrass to a height of 2 in. or less is accompanied by a reduction in the volume of forage produced and invasion of less desirable species.

Alkali sacaton has been found to be sensitive to early growing season defoliation whereas late growing season and/or dormant season use allowed recovery of depleted stands (Hickey and Springfield 1966). Bock and Bock (1978) reported that the species is readily eaten by livestock only as new spring growth before it turns coarse after curing later in the season. However, alkali sacaton is significantly less nutritious during plant dormancy and is more efficiently utilized from a livestock producer standpoint during its active growing season (Howery et al. 2016). Sheep utilize the species lightly under normal winter range conditions, however, in the absence of other feed, they may utilize it heavily (60% utilization) (Cook et al. 1954). Inadequate rest and recovery from defoliation can cause a decrease in alkali sacaton and an increase in rabbitbrush and black greasewood, along with inland saltgrass and non-native weeds (Young et al. 1976, Roundy 1985).

State and Transition Model Narrative for Group 7:

Reference State 1.0:

The Reference State 1.0 is a representative of the natural range of variability under pristine conditions. The Reference State has three general community phases; a shrub-grass dominant phase, a perennial grass dominant phase, and a shrub dominant phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire or periodic long-term drought.

Community Phase 1.1:

The reference plant community is dominated by black greasewood. Shadscale and/or seepweed are also common. The herbaceous understory is dominated by inland saltgrass. Alkali sacaton and other perennial grasses and shrubs make up minor components. Potential vegetative composition by air-dry weight is approximately 20% grasses, 5% forbs and 75% shrubs. Approximate ground cover (basal and canopy) is 10 to 20%. Total annual air-dry production ranges from 100 to 450 lb/ac.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:

A long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge resulting in a reduction of black greasewood. Additionally, a low severity fire would temporarily decrease the overstory of black greasewood and allow for the perennial grass understory to increase. Fires are rare and typically low severity resulting in a mosaic pattern due to low fuel loads. A fire following an unusually wet spring facilitating an increase in fuels may be more severe and temporarily reduce black greasewood cover to trace amounts.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.3:

Absence of disturbance over time, chronic growing season herbivory, long term spring/summer drought or combinations of these would allow the black greasewood overstory to increase and dominate the site. This will generally cause a reduction in perennial bunchgrasses and an increase in black greasewood. Inland saltgrass will increase with chronic growing season herbivory, however it may decrease with long term spring/summer drought.

Community Phase 1.2:
This community phase is characteristic of a post-disturbance, early-seral community phase. Inland saltgrass, alkali sacaton and other perennial bunchgrasses dominate the community. Black greasewood is a minor component but will likely sprout and return to pre-disturbance levels within a few years. Other sprouting shrubs such as rubber rabbitbrush and fourwing saltbush or Torrey's saltbush, may increase following fire.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
Time, lack of disturbance and/or release from chronic winter drought will allow shrubs to increase.

Community Phase 1.3:
Black greasewood and shadscale increase in the absence of disturbance. Decadent shrubs dominate the overstory and deep-rooted perennial bunchgrasses in the understory are reduced either from competition with shrubs, herbivory, growing season drought or combinations of these. Inland saltgrass may increase with inappropriate growing season grazing, however it may also decline with chronic growing season drought.

Community Phase Pathway 1.3a, from Phase 1.3 to 1.1:
Long-term reduction in winter snow accumulation may lead to reduced groundwater recharge resulting in a reduction in black greasewood. Additionally, a low severity fire would decrease the overstory of black greasewood and allow for the perennial bunchgrasses to recover.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0:

Trigger: Introduction of non-native annual plants, such as halogeton, Russian thistle and mustards.

Slow variables: Over time the annual non-native species will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

This state is similar to the Reference State 1.0 with three similar community phases. Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of invasive weeds. Non-natives may increase in abundance but will not become dominant within this State. These non-natives can be highly flammable and can promote fire where historically fire had been infrequent. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These feedbacks include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal.

Community Phase 2.1:
This community phase is similar to the Reference State Community Phase 1.1. This community is dominated by black greasewood. Shadscale and/or seepweed are also common. The herbaceous understory is dominated by inland saltgrass. Alkali sacaton and other perennial grasses and shrubs make up minor components. Non-native annual species such as halogeton, Russian thistle and mustards are present.

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
A long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge resulting in a reduction of black greasewood. Additionally, a low severity fire would temporarily decrease the overstory of black greasewood and allow for the perennial grass understory to increase. Fires are typically low severity resulting in a mosaic pattern due to low fuel loads. A fire following an unusually wet spring or a change in management favoring an increase in fine fuels may be more severe and temporarily reduce black greasewood cover to trace amounts. Annual non-native species are likely to increase with disturbance.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.3:
Absence of disturbance over time, spring/summer drought, inappropriate grazing management or combinations of these would allow the black greasewood overstory to increase and dominate the site. This will generally cause a reduction in perennial bunchgrasses such as alkali sacaton and an increase black greasewood. Inland saltgrass will increase with chronic growing season grazing, however it may decrease with long term spring/summer drought.

Community Phase 2.2:
This community phase is characteristic of a post-disturbance, early-seral community phase. Inland saltgrass, alkali sacaton and other perennial bunchgrasses dominate the understory. Black greasewood is a minor component but will likely sprout and return to pre-disturbance levels within a few years. Other sprouting shrubs such as rubber rabbitbrush, fourwing saltbush, and Torrey's saltbush, may increase following fire. Annual non-native species are stable to increasing in the community.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Time, release from chronic winter drought, lack of disturbance and/or grazing management that favors the establishment and growth of black greasewood allows the shrub component to recover.

Community Phase 2.3:
Black greasewood dominates the overstory and perennial bunchgrasses in the understory are reduced, either from competition with shrubs, inappropriate grazing, chronic spring/summer drought or combinations. Inland saltgrass may increase. Annual non-native species are stable or increasing. This community is at risk of crossing a threshold to Shrub State 3.0.

Community Phase Pathway 2.3a, from Phase 2.3 to 2.1:
Grazing management that reduces shrubs will allow for the perennial bunchgrasses in the understory to increase. Heavy late-fall/winter grazing may cause mechanical damage to black greasewood promoting the perennial bunchgrass understory. Annual non-native species are present and may increase in the community. A low severity fire would decrease the overstory of black greasewood and allow for the understory perennial grasses to increase. Additionally, long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge resulting in a reduction of black greasewood.

Transition T2A: From Current Potential State 2.0 to Shrub State 3.0:

Trigger: To Community Phase 3.1: Inappropriate cattle/horse/burro grazing or spring/summer drought will decrease or eliminate deep rooted perennial bunchgrasses and favor shrub growth and establishment.

Slow variables: Long term decrease in deep-rooted perennial bunchgrass density.

Threshold: Loss of deep-rooted perennial bunchgrasses changes nutrient cycling, nutrient redistribution, and reduces soil organic matter.

Shrub State 3.0:

This state has one community phase characterized by a dominance of a black greasewood (Sodic Flat) or iodinebush (Sodic Floodplain). This site has crossed a biotic threshold and site processes are being controlled by shrubs. Bare ground has increased, wind and water movement of soil is present. Coppice mounding of black greasewood is occurring.

Community Phase 3.1:
Black greasewood dominates the overstory. Shadscale, fourwing saltbush, and seepweed may be a significant component. Iodinebush may be come dominant on the

Sodic Floodplain ecological site. Perennial grasses have significantly declined. Annual non-native species increase. Bare ground is significant.

Sodic Flat (R029XY076NV), Shrub State 3.1, T. Stringham, May 2021

Sodic Floodplain (R029XY094NV), Shrub State 3.1, T. Stringham, May 2021

T3A: Transition from Shrub State 3.0 to Annual State 4.0:

Trigger: Long-term winter drought and/or groundwater pumping lowers groundwater reducing vitality of black greasewood and/or iodinebush. May be combined with inappropriate grazing facilitating an increase in density and production of annual non-native forbs.

Slow variable: Reduction in perennial grass and shrubs leads to large bare ground interspaces facilitating the increase in non-native annual species. Non-native and native annual species perpetuate through seed production.

Threshold: Annual forbs dominate the site. Loss of perennial grasses changes spatial and temporal nutrient cycling and nutrient redistribution and reduces soil organic matter.

Annual State 4.0:

This state has one community phase characterized by the dominance of non-native species such as halogeton, Russian thistle, and annual native western tansymustard in the understory. Black greasewood is reduced in dominance and may be heavily browsed. Ecological dynamics are significantly altered in this state. Annual non-native species compete for water and nutrients effectively excluding desired perennial grasses. Nutrient cycling is spatially and temporally truncated as annual plants contribute significantly less to deep soil carbon. Some perennial grasses may remain but they are a minor component.

Community Phase 4.1:
Annual non-native forb species dominate. Black greasewood, other shrubs, and perennial grasses are a minor component or missing. Soil redistribution and erosion may be significant.

Sodic Flat (R029XY076NV), Annual State 4.1, T. Stringham, June 2023

T4A: Transition from Annual State 4.0 to Abiotic State 5.0:

Trigger: Lowering of water table either from ground water pumping and/or long-term winter drought, and/or inappropriate grazing combined with significant soil loss and redistribution.

Slow variables: Long term decrease in density of native, perennial shrubs combined with soil movement and loss.

Threshold: Reduced black greasewood and/or iodinebush density due to groundwater pumping and/or long-term drought facilitates wind redistribution of soil creating mounding under and around shrubs. Interspace areas increase in size and connectivity, ponding and evaporation of water increases salt accumulation on soil surface. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial grasses and shrubs truncate energy capture spatially and temporally thus impacting nutrient cycling and distribution. Soil redistribution from interspaces to shrub mounds leads to decreased infiltration, increased flow path length, ponding and salt accumulation on interspace soils surface.

Abiotic State 5.0:

This state consists of one community phase in which abiotic factors (i.e. wind or water erosion) have dramatically altered the site. It is characterized by the loss of vegetative cover along with the redistribution and loss of the soil surface. Feedbacks contributing to the stability of this state include soil loss, nutrient loss, soil surface degradation, increased bare ground patch size and extensive connectivity between patches of bare soil.

Community Phase 5.1:

This community is the result of extreme soil loss and redistribution. The vegetative cover is minimal, characterized by widely dispersed groups of mounded shrubs. Shrub roots may be exposed with significant shrub decadence or death. Trace amounts of desirable species may be present and bare ground interspaces are large and connected. Site function is controlled by soil erosion, wind and soil temperature. Rehabilitation of this community is unknown.

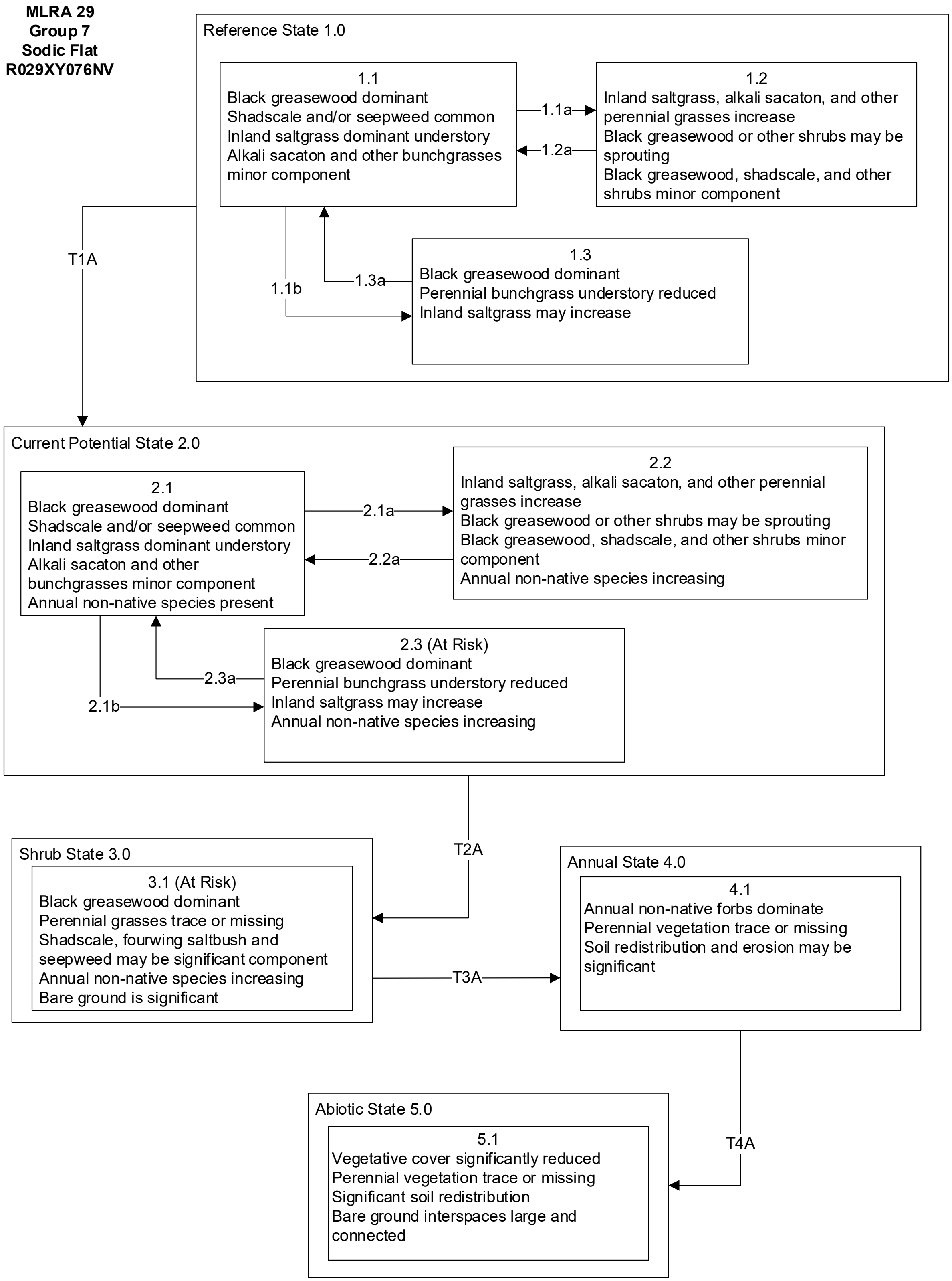
Sodic Flat (R029XY076NV), Abiotic State 5.1, T. Stringham, June 2021

Potential Resilience Differences with Other Ecological Sites in this Group:

Sodic Floodplain R029XY094NV:

This ecological site is found at elevations from 5,500 to 6,000 ft. This plant community is dominated by alkali sacaton and iodinebush where vegetation composition is 70% grasses, 25% shrubs and 5% forbs. Black greasewood is a small component of this ecological site. Long-term drought, groundwater pumping, and excessive ponding during high precipitation years are the dominant disturbances. Probability of fire is extremely low.

Modal State and Transition Model for Group 7 in MLRA 29:



MLRA 29
Group 7
Sodic Flat
R029XY076NV

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire or chronic winter drought reduces groundwater recharge leading to a temporary reduction in black greasewood. Creates grass/shrub mosaic.
1.1b: Time and lack of disturbance, spring/summer drought, chronic growing season herbivory or combinations of these allow black greasewood to increase.
1.2a: Time and lack of disturbance and/or release from chronic winter drought allows for shrub regeneration.
1.3a: Fire significantly reduces shrub cover and leads to early/mid-seral community and/or chronic winter drought reduces the shrub community.

Transition T1A: Introduction of non-native species such as cheatgrass, halogeton, Russian thistle, and mustards.

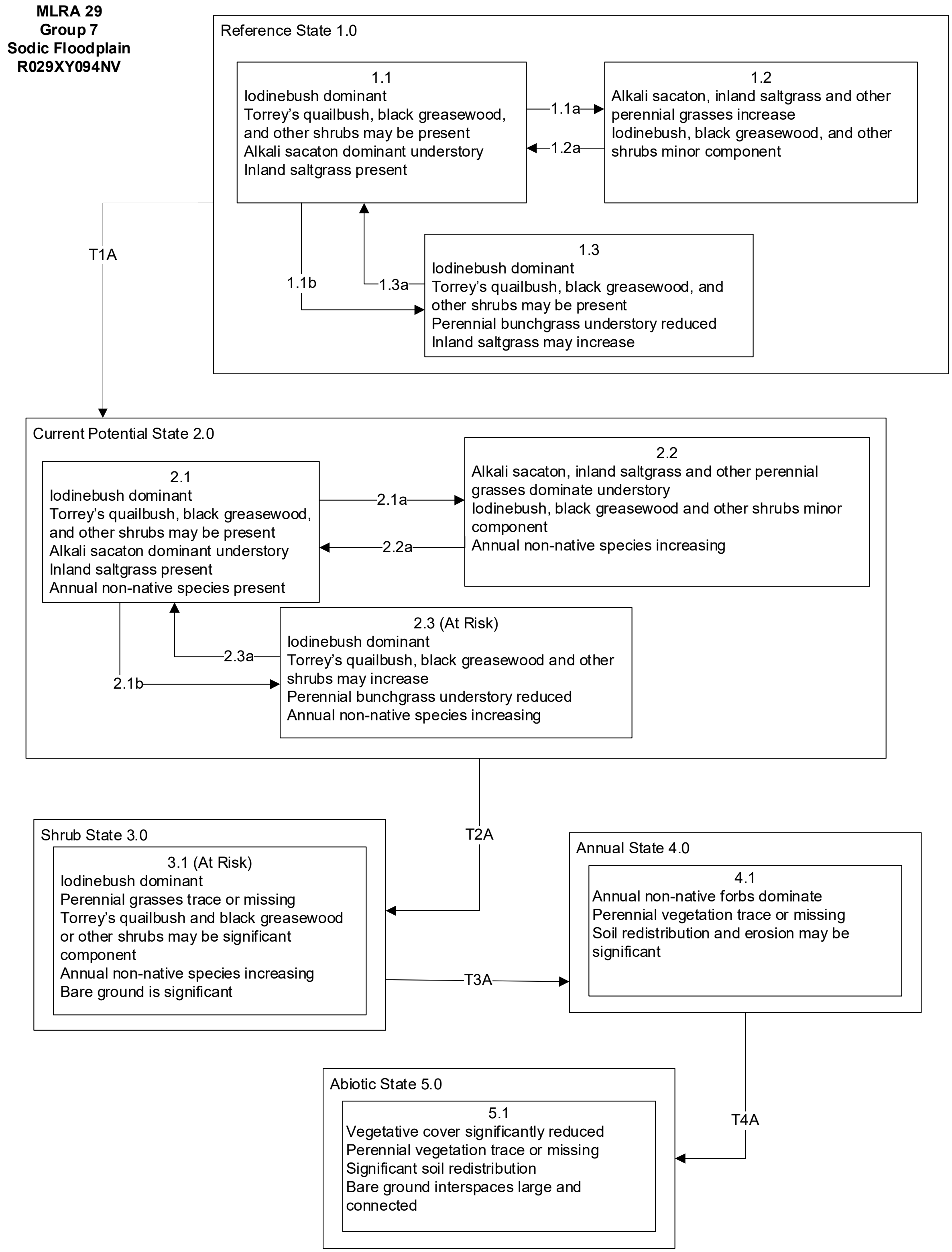
Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire or chronic winter drought reduces groundwater recharge leading to a temporary reduction in black greasewood. Creates grass/shrub mosaic. Invasive annual species increase.
2.1b: Time and lack of disturbance, spring/summer drought, inappropriate growing season grazing or combinations of these allow black greasewood to increase.
2.2a: Time and lack of disturbance and/or release from chronic winter drought allows for shrub regeneration, may be coupled with growing season grazing management favoring an increase in shrubs.
2.3a: Heavy late fall/winter grazing, low severity fire, and/or chronic winter drought that reduces the shrub community.

Transition T2A: Inappropriate grazing management would reduce the perennial understory and favor shrub growth and establishment.

Transition T3A: Long-term winter drought and/or groundwater pumping lowers groundwater reducing vitality of black greasewood. May be combined with inappropriate grazing facilitating an increase in non-native annual forbs.

Transition T4A: Lowering of water table from groundwater pumping and/or long-term inappropriate grazing management and/or severe drought during all seasons, combined with significant soil loss and redistribution.

Additional State and Transition Models for Group 7 in MLRA 29:



MLRA 29
Group 7
Sodic Floodplain
R029XY094NV

Reference State 1.0 Community Phase Pathways
1.1a: Chronic winter drought creates grass/shrub mosaic.
1.1b: Time and lack of disturbance, spring/summer drought, chronic growing season herbivory or combinations of these allow iodinebush to increase
1.2a: Time and lack of disturbance and/or release from chronic winter drought allows for shrub regeneration.
1.3a: Long-term winter drought reduces shrub cover and leads to early/mid-seral community.

Transition T1A: Introduction of non-native species such as halogeton, Russian thistle, and mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Chronic winter drought creates grass/shrub mosaic.
2.1b: Time and lack of disturbance, spring/summer drought, inappropriate growing season grazing or combinations of these allows iodinebush to increase
2.2a: Time and lack of disturbance and/or release from chronic winter drought allows for shrub regeneration, may be coupled with grazing management that facilitates an increase in shrubs.
2.3a: Chronic winter drought and/or inappropriate winter grazing that reduces the shrub community.

Transition T2A: Inappropriate grazing management would reduce the perennial understory and favor shrub growth and establishment.

Transition T3A: Long-term winter drought and/or groundwater pumping lowers groundwater reducing vitality of iodinebush and other shrubs. May be combined with inappropriate grazing facilitating an increase in non-native annual forbs.

Transition T4A: Lowering of water table from groundwater pumping and/or long-term inappropriate grazing management and/or severe drought during all seasons, combined with significant soil loss and redistribution.

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MLRA 29 Group 8: Sandy soils dominated by black greasewood and salt-desert shrubs

Description of MLRA 29 Disturbance Response Group 8

Disturbance Response Group (DRG) 8 consists of one ecological site, Sodic Dunes (R029XY018NV). This site occurs on partially stabilized sand dunes. This site ranges in precipitation from 5 to 8 in. The elevation range of this group is 3,000 to about 5,500 ft. Slopes can range from 0 to 30%, but slope gradients of 2 to 8% are typical. The extremely loose and unstable surface soils and low fertility of these soils are not favorable to uniform stands of grass. These soils are extremely susceptible to wind erosion. The soils of this site are windblown fine sands, typically more than 40 inches in depth. Groundwater occurs within the rooting depth of black greasewood *(Sarcobatus vermiculatus)*. These soils are moderately well drained to excessively drained, the soil temperature regime is mesic and the soil moisture regime is typic aridic to aridic bordering on aquic. Available water holding capacity is low and runoff is very low. The reference plant community is dominated by black greasewood and Indian ricegrass *(Achnatherum hymenoides)*. Other important species are needle-and-thread grass *(Hesperostipa comata)* and fourwing saltbush *(Atriplex canescens)*. Potential vegetative composition by air-dry weight is approximately 30% grasses, 10% forbs and 60% shrubs. Approximate ground cover (basal and crown) is 10 to 20%. Total annual air-dry production ranges from 150 to 500 lb/ac.

Disturbance Response Group 8 Ecological Sites:

Sodic Dunes – Modal	R029XY018NV

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasives. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans a unique area in Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area. Flashy, summer storm events contribute significantly to annual precipitation as well. Air and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980, Witwicki et al. 2016).

Aeolian processes, which are presumably the dominant mechanism of soil detachment and transport on this ecological site, are largely responsible for the removal of nutrient-rich soil particles from the intercanopy areas and the deposition onto shrub patches. This sediment redistribution leads to the accumulation of nutrients under the shrub canopies, a process known as "islands of fertility" (Schlesinger et al. 1990). Thus, the landscape exhibits a mosaic of sources and sinks, with bare soil interspaces acting as sources and vegetated patches as sinks of nutrients and sediments (Puigdefábregas 2005). Hydrological processes, such as infiltration and runoff, determine the conditions favorable for the establishment and survival of different vegetation functional groups with a consequent impact on the structure and function of these systems. Sand dunes have high rates of infiltration because of the soil's large pore spaces and low field capacity. These soils also have very high rates of saturated hydraulic conductivity allowing for deep percolation of moisture protected from evaporation. Moisture retention occurs below the upper 30 to 60 cm (12 to 24 in.) (Saltz et al. 1999).

Black greasewood is classified as a phreatophyte (Eddleman 2008), and its distribution is well correlated with the distribution of groundwater (Mozingo 1987c). Meinzer (1927) discovered that the taproots of black greasewood could penetrate from 20 to 57 ft below the surface. Romo (1984) found water tables ranging from 11.5 to 49 ft under black greasewood-dominated communities in Oregon. Black greasewood stands develop best where moisture is readily available, either from surface or subsurface sources (Brown 1971). It is commonly found on floodplains that are either subject to periodic flooding, have a high water table at least part of the year, or have a water table less than 34 ft deep (Harr and Price 1972, Blauer et al. 1976, Branson et al. 1976, Blaisdell and Holmgren 1984, Eddleman 2008). Ganskopp (1986) reported that water tables within 9.8 to 11.8 in. of the surface had no effect on black greasewood in Oregon. However, a study, conducted in California, found that black greasewood did not survive 6 months of continuous flooding (Groeneveld and Crowley 1988, Groeneveld 1990). Black greasewood is usually a deep-rooted shrub but has some shallow roots near the soil surface; the maximum rooting depth can be determined by the depth to a saturated zone (Harr and Price 1972).

Fourwing saltbush, the subdominant shrub on this site, is the most widely distributed and abundant saltbush in the southwest (Mozingo 1987c). It is a native, long-lived woody shrub that grows on a variety of soils, landforms, and climatic conditions from sand dunes, sand sheets, alluvial fans and plains, hills and mountains, and washes. It tolerates salinity but is not restricted to saline soils (Henrickson 1977). It is a polymorphic species and is evergreen or deciduous depending on climate (Ogle et al. 2012a). Fourwing saltbush has a long taproot of depths of 5 to 15 m (16 to 49 ft) and many small lateral roots (Van Dersal 1938, Barrow 1997). Wallace et al. (1974) found that the roots compose 40% of the total mass of adult plants. Fourwing saltbush is classified as a phreatophyte and has been documented at water tables occurring from 8 to 62 ft in New Mexico (Meinzer 1927). *Atriplex* species are considered medium to short-lived shrubs and possess a number of morphological and physiological traits that enable them to cope with drought. Some of these traits include: a) photosynthesis through the C_4 carboxylation pathway; b) production of leaf trichomes and accumulation of salt crystals on the leaf surface to increase reflectance; c) accumulation and synthesis of inorganic and organic solutes to maintain turgor; and 4) root association with endomycorrhizae that allows absorption of soil moisture at very low water potentials (Newton and Goodin 1989, Dobrowolski et al. 1990, Cibils et al. 1998).

Perennial bunchgrasses generally have shallower root systems than shrubs in these ecosystems, but their root densities in the upper 0.5 m (1.6 ft) are often as high as, or higher than, those of shrubs and then decline more rapidly with depth. General differences in root depth distributions between grasses and shrubs result in resource partitioning in these shrub/grass systems. The perennial bunchgrasses that are subdominant with the shrubs include Indian ricegrass and needle-and-thread. The dominant grass within this site, Indian ricegrass, is a hardy, cool-season, densely tufted, native perennial bunchgrass that grows from 4 to 24 inches in height (Blaisdell and Holmgren 1984).

Inland saltgrass (*Distichlis spicata*) is subdominant on this site, occurring in interspace locations. This species is a perennial, warm-season, low-growing, strongly rhizomatous plant. Saltgrass is tolerant of extremely salty and alkaline soils. Salt glands on the leaves extrude salt, allowing the grass to utilize salty water. It can survive flooding and saturated soils if the leaves are exposed to air, allowing air to be moved from the leaves to the roots through a series of interconnected passages. The scaly, tough, rhizomes can push through heavy soils, allowing saltgrass to colonize areas less favorable for seedling establishment (Bowns et al. 2025b).

Drought will initially cause a decline in bunchgrasses, but prolonged drought will eventually cause a decline in shrubs, including black greasewood. As site condition deteriorates, these sites may become a pure stand of black greasewood or a pure stand with an annual understory. A lowering of the water table can occur with groundwater pumping and this may contribute to the loss of deep-rooted species such as greasewood and basin wildrye, as well as an increase in rabbitbrush *(Chrysothamnus* spp.), shadscale saltbush (*Atriplex confertifolia*), fourwing saltbush, inland saltgrass and other species in the absence of drought.

The ecological site within this DRG may experience high wind erosion, especially with a decrease in vegetative cover. This can be caused by inappropriate grazing practices, drought, ground-water pumping, off-road vehicle use, and/or fire. As ecological condition declines the dunes become mobile, recruitment and establishment of perennial grasses is reduced. This can facilitate an increase in sprouting shrubs such as rabbitbrush and horsebrush (*Tetradymia* spp.) which are more adapted to disturbed sites. Annual non-native species such as Russian thistle *(Salsola tragus*), halogeton (*Halogeton glomeratus)*, and tall tumblemustard (*Sisymbrium altissimum*) invade these sites where competition from perennial species is decreased. The ecological site in this DRG has low resilience to disturbance and resistance to invasion. Increased resilience increases with elevation, aspect, increased precipitation, and increased nutrient availability. Three possible stable states have been identified for this DRG but an annual state has been noted for similar groups in other MLRAs.

Annual Invasive Species:

The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and depressed competition or can increase resource pools by the decomposition of dead plant material following disturbance. Historically, salt-desert shrub communities were free of exotic invaders; however, excessive grazing pressure during settlement and into the 20th century has increased the overall presence of cheatgrass (*Bromus tectorum*), halogeton, Russian thistle, and weedy mustard species (Brassicaceae family) (Peters and Bunting 1994). The presence of exotic annual plants within these ecosystems decreases ecosystem resilience and resistance to disturbance through competition for limited resources.

The species most likely to invade this site are halogeton, Russian thistle and tumblemustard. Halogeton was introduced from central Asia in the early 1930s, and was initially found in Elko County, Nevada, in 1934 (Stoddart and Clegg 1951, Pemberton 1986). The species aggressively invades, is a prolific seed producer, and may form dense stands, effectively excluding other species. Halogeton produces both black and brown seeds, with both maturing in late September. Brown seeds are viable but they do not germinate readily whereas black seeds germinate whenever sufficient moisture and heat are available. The two different seed types allow the species to invade rapidly (black seeds) and to persist as brown seeds, remaining viable for up to 10 years in the soil seed bank (Cronin and Williams 1966). Halogeton alters soil chemistry (increased soil electrical conductivity), changes nutrient availability (increase nitrogen, phosphorus, and potassium), and causes shifts in functional microbiologic soil diversity (Duda et al. 2003). These changes in soil properties inhibits germination of seeds from other plants (Cronin and Williams 1966). Revegetation using exotic perennial grasses such as crested wheatgrass (*Agropyron cristatum*) and/or forage kochia (*Bassia prostrata*), has proven effective (Cook 1965) when combined with herbicide (Young 2002).

Russian thistle is a taprooted, C_4 photosynthesis (warm-season) annual forb, introduced from Southeastern Europe and central Asia. The seeds have a remarkable capability to germinate in a variety of soil temperatures and in areas with very little precipitation, and even move back into dormancy after initial germination (Wallace et al. 1968). The seeds however, are not persistent and generally remain viable in the seedbank for less than two years (Boerboom 1993, Young et al. 1995). Russian thistle has been observed to provide initial establishment in completely de-vegetated sites and create microsite habitat which may allow increased establishment of other species (Allen and Allen 1988). The successful establishment of other species, particularly later seral species which forms mycorrhizal associations may reduce cover of Russian thistle as mycorrhizal inoculation has been observed to reduce the size and vigor of Russian thistle, while encouraging later seral species such as perennial bunchgrasses (Johnson 1998a).

Fire Ecology:

Fire is a rare disturbance in the salt-desert shrub communities likely occurring in years with above-average precipitation and corresponding biomass. Historically, salt-desert shrub communities had sparse understories and bare soil in intershrub spaces, making these communities somewhat resistant to fire (Young 1983, Paysen et al. 2000). They may burn only during high fire hazard conditions; for example, years with high precipitation can result in almost continuous fine fuels, increasing fire hazard (West et al. 1994, Paysen et al. 2000).

Black greasewood, the dominant shrub on these sites, can occur in almost pure stands. It is a salt-tolerant shrub usually found on saline soils. Black greasewood may be killed by severe fires, but usually sprouts vigorously after low to moderate severity fire (Young 1983, Rickard and McShane 1984, West 1994). Bentz et al. (2008) reported that following a Nevada wildfire, black greasewood sprouts reached approximately 2.5 ft within 3 years. In a study by Rickard and McShane (1984), black greasewood sprouted following wildfire and canopy cover was at 47% of pre-burn levels two years following fire. They also counted 185 shrubs before wildfire and 210 shrubs two years following fire.

Fourwing saltbush’s ability to sprout following fire may depend on the population and fire severity. A study by Parmenter (2008) showed 58% mortality rate of fourwing saltbush following fire in New Mexico, the surviving shrubs produced sprouts shortly after fire. While fourwing saltbush is able to resprout after fire, it primarily reestablishes from seed (Stutz 1979, Wasser 1982, Howard 2003a).

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The initial condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species' response. For most forbs and grasses the growing points are located at or below the soil surface providing relative protection from disturbances that decrease above-ground biomass, such as grazing or fire. Thus, fire mortality is more correlated to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant, and abundance of old growth (Wright 1971, Young 1983). However, season and severity of the fire will influence plant response. Plant response will also vary depending on post-fire soil moisture availability.

Indian ricegrass is fairly fire tolerant (Wright 1985), which is likely due to its low culm density and below-ground plant crowns. Vallentine (1989) cites several studies in the sagebrush zone that classified Indian ricegrass as being slightly damaged from late summer burning. Indian ricegrass has also been found to reestablish on burned sites through seeds dispersed from adjacent unburned areas (Young 1983, West 1994). Thus, the presence of surviving, seed-producing plants facilitates the reestablishment of Indian ricegrass. Grazing management following fire to promote seed production and establishment of seedlings is important. When properly planted and managed, Indian ricegrass can be a key factor in a community recovering from disturbance because it can grow in rough, rocky, coarse, and otherwise unattractive soils (Booth et al. 1980).

Needle-and-thread is a fine-leaf grass and is considered sensitive to fire (Akinsoji 1988, Bradley et al. 1992, Miller et al. 2013). In a study by Wright and Klemmedson (1965), season of burn rather than fire intensity seemed to be the crucial factor in mortality for needle-and-thread grass. Early spring season burning was seen to kill the plants while August burning had no effect. Thus, under wildfire scenarios, needle-and-thread is often present in the post-burn community.

Livestock/Wildlife Grazing Interpretations:

Black greasewood is typically not considered an important browse species for wildlife and livestock. However, in a study by Smith et al. (1992), utilization of new growth on greasewood shrubs by cattle was 77% in summer, and greasewood was found to have the highest amounts of crude protein when compared to perennial and annual grasses. Black greasewood plants have been found to contain high amounts of sodium and potassium oxalates which are toxic to livestock and caution should be taken when grazing these communities. These shrubs can be used lightly in the spring as long as there is a substantial amount of other preferable forage available (Benson et al. 2011). Black greasewood also provides good cover for wildlife species (Benson et al. 2011).

Fourwing saltbush is one of the most important forage shrubs in arid sites. Its importance is due to its abundance, accessibility, size, large volume of forage, evergreen habitat, high palatability, and nutritive value (USFS 1937, Van Epps 1975). The palatability rates range from fairly good to good for cattle, and good for domestic sheep and goats. Deer *(Odocoileus* spp.*)* usually consume it as a winter browse (USFS 1937). It has similar protein, fat, and carbohydrate levels as alfalfa (*Medicago sativa*) (Catlin 1925). Fourwing saltbush is especially valuable as winter forage. It was noted in a study by Otsyina et al. (1982) that domestic sheep readily grazed fourwing saltbush when introduced into a new pasture.

Indian ricegrass is a preferred forage species for livestock and wildlife (Cook 1962, Booth et al. 1980). This species is often heavily utilized in winter because it cures well (Booth et al. 1980). It is also readily utilized in early spring, being a source of green feed before most other perennial grasses have produced new growth (Quinones 1981). Booth et al. (1980) notes that the plant does well when utilized in winter and spring. Cook and Child (1971), however, found that repeated heavy (90% removal) grazing reduced crown cover, which may reduce seed production, density, and basal area of these plants. Additionally, heavy early spring grazing reduces plant vigor and stand density (Stubbendieck et al. 1985). In eastern Idaho, productivity of Indian ricegrass was at least 10 times greater in undisturbed plots than in heavily grazed ones (Pearson 1965). However, light (30%) to moderate (60%) winter/early spring grazing was found to not injure plant vigor (Cook and Child 1971). The seed crop may be reduced where grazing is heavy (Bich et al. 1995). Tolerance to grazing increases after May, thus occasional spring deferment may be necessary for stand enhancement (Pearson 1964). However, utilization of less than 60% is recommended.

Needle-and-thread grass is not grazing tolerant and will be one of the first grasses to decrease under heavy growing season grazing pressure (Smoliak et al. 1972, Tueller and Blackburn 1974). Heavy grazing is likely to reduce basal area of these plants (Smoliak et al. 1972). Moderate to light grazing during the growing season, combined with occasional deferment will facilitate plant longevity.

Livestock generally avoid saltgrass due to its coarse foliage. Saltgrass can be an important late summer forage in arid environments after other forage grasses have cured. The grass is rated fair to good forage because it stays green after most other grasses are cured out (Williams 1897, Hopper and Nesbitt 1930, Straub et al. 1989).

Inappropriate grazing management during the growing season will cause a decline in understory plants such as needle-and-thread and Indian ricegrass. Growing season grazing may initially cause a decrease in the bunchgrass component and give a competitive advantage to inland saltgrass and black greasewood.

Halogeton is toxic to domestic sheep, causing lethal neurologic effects (Cook and Stoddart 1953). Toxicity is less of a problem with cattle, however instances of death or locomotor difficulties have been noted (James 1970). Livestock losses usually occur when hungry animals graze where other forage is scant or lacking. Trailing through heavily infested areas or penning animals in corrals with dense stands of the weed has resulted in heavy losses (Cronin and Williams 1966). Control methods include herbicide, reseeding and proper grazing management. The most effective method of managing halogeton is the maintenance of healthy, perennial vegetation.

State and Transition Model Narrative for Group 8:

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 29 Disturbance Response Group 8.

Reference State 1.0:

The Reference State 1.0 is a representative of the natural range of variability under pristine conditions. The reference state has three general community phases; a shrub-grass dominant phase, a perennial grass dominant phase, and a shrub dominant phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire, periodic drought, and/or insect or disease attack.

Community Phase 1.1:
Black greasewood and Indian ricegrass dominate the site. Fourwing saltbush, inland saltgrass and several salt-desert shrubs and perennial grasses are also present. Perennial forbs are present but not abundant. Potential vegetative composition by air-dry weight is approximately 30% grasses, 10% forbs and 60% shrubs. Approximate ground cover (basal and crown) is 10 to 20%. Total annual air-dry production ranges from 150 to 500 lb/ac.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
A long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge resulting in a reduction of black greasewood. Additionally, a low severity fire would temporarily decrease the overstory of black greasewood and fourwing saltbush and allow for the perennial grass understory to increase. Fires are rare and typically low severity resulting in a mosaic pattern due to low fuel loads.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.3:
Absence of disturbance over time, chronic growing season herbivory, long term spring/summer drought or combinations of these would allow the black greasewood overstory to increase and dominate the site. This will generally cause a reduction in perennial bunchgrasses and an increase in black greasewood. Inland saltgrass will increase with chronic growing season herbivory, however it may decrease with long term spring/summer drought.

Community Phase 1.2:
This community phase is characteristic of a post-disturbance, early-seral community phase. Indian ricegrass and Inland saltgrass dominate. Black greasewood is a minor component but will likely sprout and return to pre-disturbance levels within a few years. Other sprouting shrubs such as rubber rabbitbrush and fourwing saltbush may increase.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
Time, lack of disturbance and/or release from chronic winter drought will allow shrubs to increase.

Community Phase 1.3:

Black greasewood, fourwing saltbush, and other shrubs increase in the absence of disturbance. Black greasewood and other shrubs dominate the overstory and inland saltgrass is codominant with Indian ricegrass. Perennial bunchgrasses are reduced from competition with shrubs and/or from herbivory. Decadent shrubs dominate the overstory and Inland saltgrass the understory. Deep-rooted perennial bunchgrasses are reduced either from competition with shrubs, herbivory, growing season drought or combinations of these.

Community Phase Pathway 1.3a, from Phase 1.3 to 1.1:
Long-term reduction in winter snow accumulation may lead to reduced groundwater recharge resulting in a reduction in black greasewood. Additionally, a low severity fire, herbivory, or combinations would reduce the black greasewood and fourwing saltbush overstory and create a black greasewood/fourwing saltbush/grass mosaic.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0:

Trigger: Introduction of non-native annual plants, such as halogeton, Russian thistle and mustards.

Slow variables: Over time, the annual non-native species will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

This state is similar to the Reference State 1.0. This state has the same three general community phases. Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of invasive weeds. Non-natives may increase in abundance but will not become dominant within this state. These non-natives can be highly flammable and can promote fire where historically fire had been infrequent. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These feedbacks include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, adaptations for seed dispersal and soil chemistry changes.

Community Phase 2.1:

Black greasewood and Indian ricegrass dominate the site. Fourwing saltbush, inland saltgrass, and needle-and-thread are also present. Perennial forbs are present but not abundant. Non-native annual forb species are present.

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
A long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge resulting in a reduction of black greasewood. Additionally, a low severity fire would temporarily decrease the overstory of black greasewood and allow for the perennial grass understory to increase. Fires are typically low severity resulting in a mosaic pattern due to low fuel loads. A fire following an unusually wet spring or a change in management favoring an increase in fine fuels may be more severe and temporarily reduce black greasewood and fourwing saltbush cover to trace amounts. Annual non-native species are likely to increase after fire.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.3:
Absence of disturbance over time, spring/summer drought, inappropriate grazing management, or combinations of these would allow the black greasewood overstory to increase and dominate the site. Long term drought will cause a decline in perennial bunchgrasses. Inappropriate grazing will cause a decrease in perennial bunchgrasses and fourwing saltbush facilitating an increase in black greasewood and inland saltgrass.

Community Phase 2.2:
This community phase is characteristic of a post-disturbance, early-seral community phase. Indian ricegrass and other perennial bunchgrasses dominate. Inland saltgrass is subdominant. Black greasewood cover is initially reduced but recovers quickly. Fourwing saltbush may sprout after fire depending on ecotype. Annual non-native species generally respond well after fire and may be stable to increasing within the community.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Time, release from chronic winter drought, lack of disturbance and/or grazing management that favors the establishment and growth of black greasewood allows the shrub component to recover.

Community Phase 2.3 (at-risk):
Black greasewood, fourwing saltbush and other shrubs increase in the absence of disturbance. Perennial bunchgrasses are reduced from competition with shrubs and/or from chronic growing season grazing. Inland saltgrass is codominant with Indian ricegrass. Annual non-native species are stable or increasing. This community is at risk of crossing a threshold to Shrub State 3.0.

Community Phase Pathway 2.3a, from Phase 2.3 to 2.1:
Long-term reduction in winter snow accumulation may lead to reduced groundwater recharge resulting in a reduction in black greasewood. Additionally, a low severity fire,

late fall/winter grazing, or combinations would reduce the black greasewood and fourwing saltbush overstory and create a black greasewood/fourwing saltbush/grass mosaic.

T2A: Transition from Current Potential State 2.0 to Shrub State 3.0:

Trigger: To Community Phase 3.1: Inappropriate grazing and/or spring/summer drought will decrease or eliminate deep-rooted perennial bunchgrasses and fourwing saltbush (grazing) while facilitating inland saltgrass, black greasewood, and other unpalatable shrubs.

Slow variables: Long-term increase in black greasewood and other shrubs along with a decrease in deep-rooted perennial bunchgrasses. Inland saltgrass stable to increasing.

Threshold: Loss of deep-rooted perennial bunchgrasses changes nutrient cycling, nutrient redistribution, and reduces soil organic matter. Increase in inland saltgrass changes the temporal and spatial distribution of energy and nutrient cycling.

Shrub State 3.0:

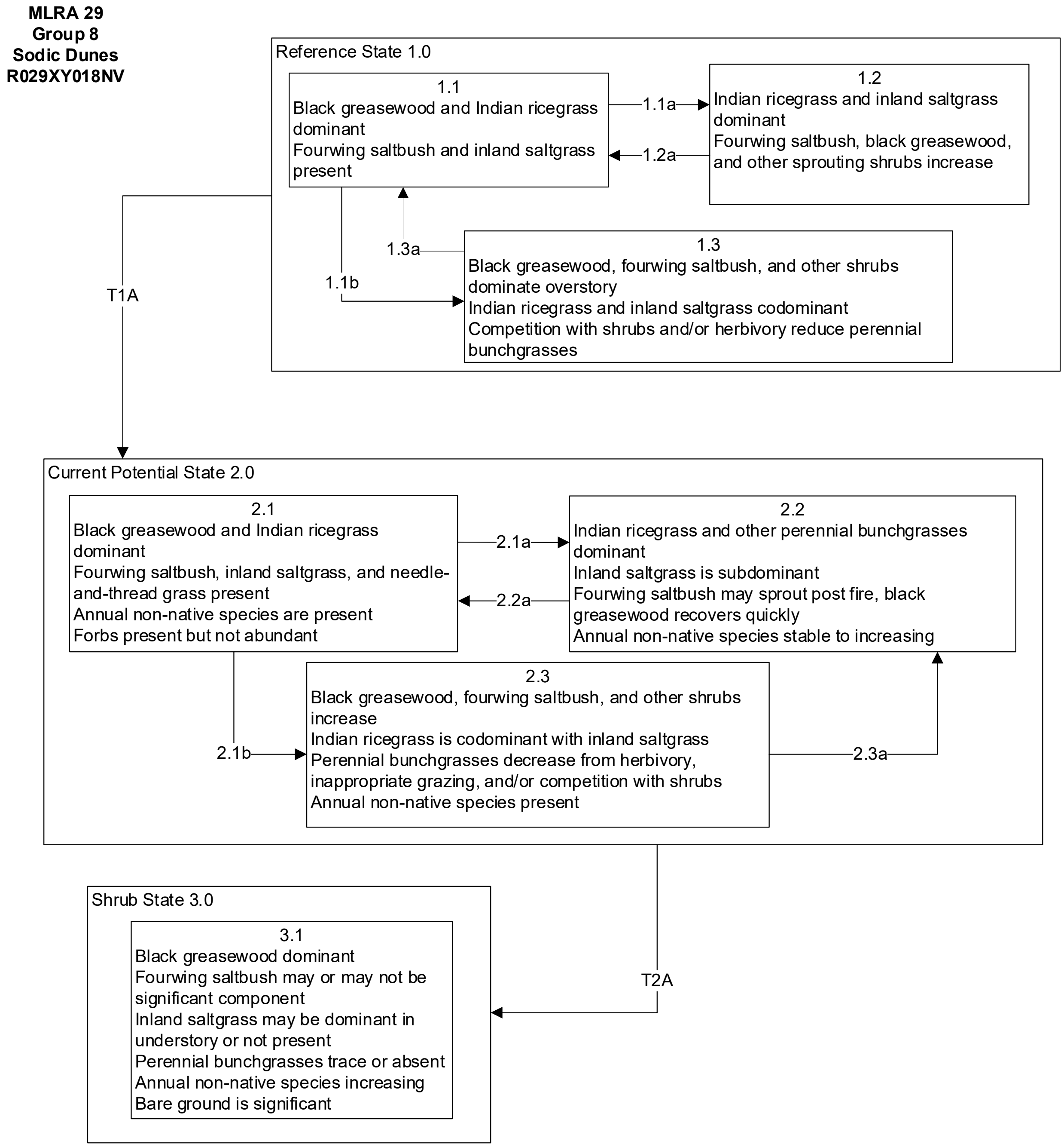
This state has one community phase characterized by a dominance of a black greasewood. The site has crossed a biotic threshold and site processes are being controlled by shrubs. Bare ground has increased, wind and water movement of soil is present. Coppice mounding of black greasewood and other shrubs is occurring. Inland saltgrass may dominate the understory or the grass component may be nonexistent. The shrub overstory may be decadent, reflecting stand maturity and lack of seedling establishment. The shrub overstory dominates site resources such that soil water, nutrient capture, nutrient cycling and soil organic matter are temporally and spatially redistributed. With a decrease in perennial bunchgrasses, the soils on these sites may become unstable and wind erosion may increase.

Community Phase 3.1:
Black greasewood dominates the overstory. Fourwing saltbush may be a significant component. Fourwing saltbush is still present but declining. Deep-rooted perennial bunchgrasses may be present in trace amounts or absent from the community. Inland saltgrass may be the dominant understory species or not present. Annual non-native species increase. Bare ground is significant.


Sodic Dunes (R029XY018NV), Shrub State 3.1, T. Stringham, May 2021


Sodic Dunes (R029XY018NV), Shrub State 3.1, T. Stringham, August 2021

Modal State and Transition Model for Group 8 in MLRA 29:



MLRA 29
Group 8
Sodic Dunes
R029XY018NV

Reference State 1.0 Community Phase Pathways
1.1a: Chronic winter drought leading to reduced groundwater recharge results in a reduction in black greasewood, allowing perennial bunchgrasses to dominate; a low severity fire (rare) will decrease shrub overstory and facilitate perennial grasses.
1.1b: Time and lack of disturbance, chronic growing season herbivory, and/or long term spring/summer drought will decrease perennial bunchgrasses and palatable shrubs, facilitating an increase in black greasewood and situationally inland saltgrass (herbivory).
1.2a: Time, release from chronic winter drought, allows for shrub regeneration.
1.3a: Long-term, chronic, winter drought reduces groundwater recharge resulting in a reduction in black greasewood and facilitates increase in perennial grasses. A low-severity fire (rare) would reduce the shrub component and create a shrub/grass mosaic.

Transition T1A: Introduction of non-native species such as Russian thistle, mustards, and cheatgrass.

Current Potential State 2.0 Community Phase Pathways
2.1a: Chronic winter drought leading to reduced groundwater recharge results in a reduction in black greasewood, allowing perennial bunchgrasses to dominate; a low severity fire (rare) will decrease shrub overstory and facilitate perennial grasses. Invasive forbs present.
2.1b: Time and lack of disturbance, chronic growing season grazing, and/or long term spring/summer drought will decrease perennial bunchgrasses and palatable shrubs facilitating and increase in black greasewood and inland saltgrass.
2.2a: Time, lack of disturbance, or change in grazing management allows for shrub regeneration.
2.3a: Chronic winter drought leading to reduced groundwater recharge, late fall/winter grazing management, or low severity fire (rare) facilitates a decrease in black greasewood, allowing perennial understory to increase.

Transition T2A: Inappropriate grazing management and/or spring/summer drought will decrease or eliminate deep-rooted perennial bunchgrasses and fourwing saltbush (grazing) while facilitating inland saltgrass, black greasewood, and other unpalatable shrubs.

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MLRA 29 Group 9: Sites associated with ephemeral streams

Description of MLRA 29 Disturbance Response Group 9

Disturbance Response Group (DRG) 9 consists of three ecological sites. The precipitation ranges from 5 to 12 in. Slope ranges from 0 to 30%, but slope gradients of 2 to 15% are typical. Elevations range from 3,500 to about 6,200 ft. The sites occur on ephemeral channels of inset fans and axial-stream terraces. The soils are formed in mixed alluvium and are very deep and excessively drained. The soils typically have high amounts of gravels and cobbles distributed throughout the soil profile as well as at the surface. The soils are quite variable as they continue to be re-worked by water. Runoff is low or very low, and water holding capacity is high. The soil moisture regime is typic aridic, and the soil temperature regime is mesic typic. Plant species that occur on these ecological sites include rubber rabbitbrush (*Ericameria nauseosa*), fourwing saltbush (*Atriplex canescens*), burrobrush (*Hymenoclea salsola*), basin big sagebrush (*Artemisia tridentata ssp. tridentata*), Indian ricegrass (*Achnatherum hymenoides*), desert almond (*Prunus fasciculata*) and woolly fruit bur ragweed (*Ambrosia eriocentra*). Production ranges from 300 to 700 lb/ac in a normal year.

Disturbance Response Group 9 Ecological Sites:

Dry Wash – Modal	R029XY041NV
Upland Wash	R029XY009NV
Valley Wash	R029XY072NV

Modal Site:

The Dry Wash (R029XY041NV) site is the ecological site that represents this DRG, as it has the most acres mapped. The precipitation ranges from 5 to 8 in. Slopes range from 0 to 30%, but slope gradients of 2 to 15% are typical. Elevations range from 3,500 to about 5,200 ft. This site occurs on inset fans having ephemeral water courses. The soils are formed in deep alluvium and are excessively drained. These soils typically have high amounts of gravels and cobbles distributed throughout the soil profile as well as at the surface. Textures are coarse-textured typically sands, loamy sands or sandy loams. Runoff is low or very low and available water supply is low to very low. Infiltration rates are high to very high. The soil moisture regime is typic aridic and the soil temperature regime is mesic. Production is 300 lb/ac in normal years. Wind erosion may be severe if this site is disturbed by off-road vehicles.

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasives. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans a unique area in Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area. Flashy, summer storm events contribute significantly to annual precipitation as well. Air and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

Periodic drought regularly influences these ecosystems and drought duration, and severity has increased throughout the 20th century in much of the Intermountain West (Miller et al. 2008b). Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006). The ecological sites in this DRG are dominated by deep-rooted, cool-season perennial bunchgrasses and drought tolerant shrubs with high root to shoot ratios. Native bunchgrasses generally have somewhat shallower root systems than the shrubs, but root densities are often as high as or higher than those of the shrubs in the upper 0.5 m (1.5 ft) of the soil profile. General differences in root depth distributions between grasses and shrubs results in resource partitioning in these shrub – grass systems. Although not dominant, warm-season grasses occur on all sites.

Rubber rabbitbrush, a sub-dominant overstory species in this group, is a widespread and abundant shrub found across the western United States, particularly in arid and semi-arid environments (Stubbendieck et al. 2017). This perennial, native, woody shrub thrives in a variety of soils, ranging from sands to clays, and is commonly found in plains, foothills, and along washes. It is highly adaptable to a wide range of climatic conditions, from hot, dry deserts to cooler mountain environments. Rabbitbrush is drought-tolerant and can survive in low-water conditions, although it does not require saline soils for growth (Davis 1990). It exhibits a wide range of morphological forms and can be either deciduous or evergreen, depending on local environmental factors (Hickman 1993). Rabbitbrush develops a deep taproot, often reaching depths of 1 to 3 m (3 to 10 ft) with an extensive network of lateral roots that help it access water in dry conditions (Klepper et al. 1985). Rabbitbrush has several physiological adaptations that help it cope with drought, including C3 photosynthesis and production of waxy leaf coatings to reduce water loss (Francis 2004).

Basin big sagebrush, a dominant species in the Upland Wash ecological site, is a native shrub adapted to a variety of soil types, including sandy, loamy, and clayey soils, and is commonly found in foothills, basins, and along montane slopes (Stubbendieck et al. 2017). Basin big sagebrush is highly drought-tolerant and can thrive in areas with low precipitation, though it prefers areas with moderate winter moisture (Tilley et al. 2002). This species typically grows to heights of 1 to 2 m (3 to 6.5 ft) and exhibits a robust root system, including a deep taproot that can extend up to 3 m (10 ft) deep, allowing it to access water in dry conditions. Physiologically, it is well-adapted to drought stress, using C3 photosynthesis and producing resinous compounds that help reduce water loss and deter herbivores (Bates et al. 2006). While it can resprout after low- to moderate-intensity fires, it is vulnerable to large, high-intensity fires that can damage its root system and prevent regeneration (Svejcar et al. 2023). Basin big sagebrush also plays an important ecological role, providing crucial habitat for a variety of wildlife species, including sage grouse (*Centrocercus urophasianus*) (Davies et al. 2011).

Fourwing saltbush, occurring on all three sites, is the most widely distributed and abundant saltbush in the southwest United States (Mozingo 1987c). It is a native, long-lived woody shrub that grows on a variety of soils, landforms, and climatic conditions from sand dunes, sand sheets, alluvial fans and plains, hills and mountains, and washes. It tolerates salinity but is not restricted to saline soils (Henrickson 1977). It is a polymorphic species and is evergreen or deciduous depending on climate (Ogle et al. 2012a). Fourwing saltbush has a long taproot of depths of 5 to 15 m (16 to 49 ft). and many small lateral roots (Van Dersal 1938, Barrow 1997). It has been found that the roots compose 40% of the total mass of adult plants (Wallace et al. 1974). *Atriplex* species are considered medium to short-lived shrubs and possess a number of morphological and physiological traits that enable them to cope with drought. Some of these traits include: a) photosynthesis through the C4 carboxylation pathway; b) production of leaf trichomes and accumulation of salt crystals on the leaf surface to increase reflectance; c) accumulation and synthesis of inorganic and organic solutes to maintain turgor; and 4) root association with endomycorrhizae that allows absorption of soil moisture at very low water potentials (Newton and Goodin 1989, Dobrowolski et al. 1990, Cibils et al. 1998). Fourwing saltbush is not particularly resilient to fire but may resprout in some instances when fire intensity is not too severe (Ogle et al. 2020).

Burrobrush, is a native, short-lived, drought-deciduous shrub, 1 to 2 m (3 to 6.5 ft) tall. It reproduces mostly by seed but can also reproduce by sprouting (Tesky 1992). It mostly occurs in the Colorado, Mojave and Sonoran deserts of Arizona, California, and Nevada. There is also a small relict population in the southern end of the Central Valley of California. It is commonly found in ephemeral washes, alluvial fans, and rocky hillslopes from elevations ranging from 2,200 to 3,000 ft. This shrub blooms in the spring (March-May) and seeds have high viability and germination rates compared to other desert shrubs. Burrobrush has a shallow root system consisting of a tap root and shallow lateral roots (Tesky 1992).

Desert almond, occurs on the Upland Wash site, and is a hardy shrub native to the southwestern United States commonly found in arid and semi-arid environments. This perennial shrub is well-suited to a range of soil types, including sandy and rocky soils, and thrives in areas with low annual precipitation, although it prefers areas with mild winters and occasional moisture (Turner and Randall 1987). Desert almond typically grows to a height of 1 to 2 m (3 to 6.5 ft) and features a deep, spreading root system that enables it to survive prolonged droughts by accessing deeper soil moisture. The species is highly drought-tolerant and is adapted to extreme temperatures, with mechanisms like thick, waxy leaves to reduce water loss and an ability to store water in its tissues (Borchert 2022). This shrub is important ecologically, providing valuable food and shelter for desert wildlife, including birds, small mammals, and pollinators (Bowers 1993).

Woolly fruit bur ragweed, occurs on the Valley Wash site, and is a species native to the Mojave and Arizona deserts of southern California, southwestern Utah, southern Nevada and western Arizona (Benson and Darrow 1981a). It commonly occurs on dry, open slopes and desert washes (Cronquist 1994). Woolly fruit bur ragweed typically grows to a height of 0.5 to 1 m (1.6 to 3 ft), with a deep taproot that allows it to access moisture during periods of drought (Benson and Darrow 1981a). Though it is capable of producing large quantities of pollen, which can cause allergic reactions in humans, *woolly fruit bur ragweed* plays an important role in local ecosystems as a nurse plant, providing shelter for another plant (Comus et al. 2015). It is spread by creeping roots suggesting that it has the capability of resprouting from its roots after low-intensity fires (Cronquist 1994).

Indian ricegrass, the dominant understory species of this group, is a hardy, cool-season, densely tufted, long-lived perennial bunchgrass that grows from 4 to 24 inches in height (Blaisdell and Holmgren 1984). Its deep, fibrous root system makes Indian ricegrass one of the most drought-tolerant native species. Indian ricegrass can be found in low deserts associated with shadscale (*Atriplex confertifolia*) and winterfat (*Krascheninnikovia lanata*) and in elevations up to 10,000 ft. It can be found throughout MLRA 29, including on ridges, canyons, dunes, hills, plains, and mountains. Indian ricegrass is a key plant in recovering communities disturbed by grazing, mining, and fire because it is a hardy grass that is able to grow in rough, rocky, and coarse soils and still provides very valuable forage. When properly planted and managed, Indian ricegrass can help recover disturbed areas by competing with invasives and providing cover and forage (Booth et al. 1980).

The ecological sites in this DRG are associated with ephemeral streams (dry washes) that are disturbance-dependent systems, topographically and edaphically distinct from the adjacent uplands. Periodic drought regularly influences desert ecosystems and drought duration and severity have increased throughout the 20th century in much of the Intermountain West. Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Plant species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006). Droughts increase the severity, duration and spatial extent of drying beyond usual drying conditions, however, studies on ecological responses to drought in intermittent river and ephemeral stream networks are rare and limited to a few climatic zones and organisms (Sarremejane et al. 2021).

The ecological sites in this DRG have high resilience to disturbance and low resistance to invasion. Fire is a rare disturbance in these sparsely vegetated communities while occasional flooding is a more common disturbance. Recreational activities such as hiking, camping, and off-road vehicle use can impact the ecological condition of these sites. Impacts include loss or changes in vegetation composition, structure and density; soil compaction; and increased soil erosion (Briggs 1996). Livestock overgrazing can alter plant composition, affect soil infiltration rates, increase soil erosion and impact habitats (Briggs 1996). In the presence of non-native, annual invasive species, soil disturbance could allow for further invasion into these ephemeral stream systems. Three possible alternative stable states have been identified for this DRG.

Annual Invasive Species:

The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and depressed competition or can increase resource pools by the decomposition of dead plant material following disturbance. Historically, shadscale dominant salt-desert shrub communities were free of exotic invaders; however, excessive grazing pressure during settlement and into the 20th century has increased the overall presence of cheatgrass, halogeton (*Halogeton glomeratus*), Russian thistle (*Salsola* spp.) and annual mustard species (*Sisymbrium* L.) (Peters and Bunting 1994). The presence of exotic annual plants within these ecosystems decreases ecosystem resilience and resistance to disturbance through competition for limited resources. Dobrowolski et al. (1990) cites multiple factors on the extent of the soil profile exploited by the competitive exotic annual cheatgrass. Specifically, the depth of rooting is dependent on the size the plant achieves, and in competitive environments, cheatgrass roots were found to penetrate only 15 cm (6 in.) whereas isolated plants and pure stands were found to root at least 1 m (3 ft) in depth with some plants rooting as deep as 1.5 to 1.7 m (5 to 5.5 ft).

The species most likely to invade these sites is cheatgrass. Cheatgrass is a cool-season annual grass that maintains an advantage over native plants in part because it is a prolific seed producer, can germinate in the autumn or spring, tolerates grazing, and increases with frequent fire (Klemmedson and Smith 1964, Miller et al. 1999). Cheatgrass originated from Eurasia and was first reported in North America in the late 1800s (Furbush 1953, Mack and Pyke 1983). Pellant and Hall (1994) found 3.3 million acres of public lands dominated by cheatgrass and suggested that another 76 million acres were susceptible to invasion by winter annuals including cheatgrass and medusahead (*Taeniatherum caput-medusae*).

Recent modeling and empirical work by Bradford and Lauenroth (2006) suggests that seasonal patterns of precipitation input and temperature are also key factors determining regional variation in the growth, seed production, and spread of invasive annual grasses. The phenomenon of cheatgrass “die-off” provides opportunities for restoration of perennial and native species (Baughman et al. 2016, Baughman et al. 2017). The causes of these events are not fully understood, but there is ongoing work to try to predict where they occur, in the hopes of aiding conservation planning (Weisberg et al. 2017, Brehm 2019).

Methods to control cheatgrass include herbicide application, fire, targeted grazing, and range seeding. Mapping potential or current invasion vectors is a management method designed to increase the cost-effectiveness of control methods. Spraying with herbicide (imazapic or imazapic + glyphosate) and seeding with crested wheatgrass and Sandberg bluegrass (*Poa secunda*) has been found to be more successful at combating cheatgrass (and medusahead) than spraying alone (Sheley et al. 2012). Perennial grasses, especially crested wheatgrass, are able to suppress cheatgrass growth when mature (Blank et al. 2020). Where native bunchgrasses are missing from the site, revegetation of annual grass-invaded rangelands has been shown to have a higher likelihood of success when using introduced perennial bunchgrasses such as crested wheatgrass (Davies et al. 2015b, Clements et al. 2017). Butler et al. (2011) tested four herbicides (imazapic, imazapic + glyphosate, rimsulfuron, and sulfometuron + chlorsulfuron) for suppression of cheatgrass, medusahead (*Taeniatherum caput-medusae*), and ventenata (*Ventenata dubia*) within residual stands of native bunchgrass. Additionally, the same four herbicides were tested followed by seeding of six bunchgrasses (native and non-native) with varying success. Herbicide-only treatments appeared to remove competition for established bluebunch wheatgrass by providing 100% control of ventenata and medusahead and greater than 95% control of cheatgrass (Butler et al. 2011). Caution in using these results is advised, as only 1 year of data was reported. In considering the combination of pre-emergent herbicide and prescribed fire for invasive annual grass control, it is important to assess the tolerance of desirable brush species to the herbicide being applied.

Hydrology:

These sites are characterized by occasional flooding, resulting in water flowing for a few days after heavy rain or rapid snowmelt events. These systems are driven by pulse events of water, nutrients, sediment and other materials through the system in response to runoff generated from snowmelt or short duration, high intensity thunderstorms that result in flash floods (Levick et al. 2007). Abrupt changes in channel characteristics can occur because of these flash flood events resulting in the destruction of streamside vegetation and extensive channel erosion (Briggs 1996). Sediment also moves from the adjacent uplands and hillslopes into the channels from overland flow. Ephemeral streams provide the same hydrologic functions as perennial streams by moving water, nutrients, and sediment through the watershed (Levick et al. 2007). Properly functioning ephemeral streams provide services such as landscape hydrologic connections; stream energy dissipation during high-water flows that reduces erosion and improves water quality; surface and subsurface water storage and exchange; groundwater recharge and discharge; sediment transport, storage and deposition aid in floodplain maintenance and development; nutrient cycling; wildlife habitat and movement/migration; support for vegetation communities that stabilize stream banks and provide wildlife services; and water supply and water quality filtering (Levick et al. 2007).

Functional services of the vegetative communities that occur in ephemeral washes include moderating soil and air temperatures, stabilizing channel banks and interfluves, seed banking and trapping of sediments favorable to the establishment of a diversity of floral and faunal species, and dissipating stream energy that aids in flood control (Levick et al. 2007). Many of the plant species that establish along ephemeral streams during flooding pulses arise from soil seed banks, which are large and diverse (Levick et al. 2007).

Plants that occur in habitats with a flooding regime possess traits for tolerance to soil waterlogging and/or submergence. Plant traits include the ability to grow adventitious roots, aerenchyma formation, shoot elongation, and new secondary roots under anaerobic conditions (Colmer and Voesenek 2009). Basin big sagebrush is considered a phreatophyte, with the ability to tap into shallow groundwater sources (Klepper et al. 1985), although big sagebrush roots are highly susceptible to anoxia and may be killed at deeper depths during periods of high soil moisture (Lunt et al. 1973, Ganskopp 1986). Fourwing saltbush is classified as a phreatophyte and has been documented at water tables occurring from 8 to 62 ft (2.5 to 19 m) in New Mexico (Meinzer 1927). It has resprouting ability and can withstand flooding for most of one growing season (Briggs 1996). Rabbitbrush is classified as a phreatophyte and has been observed to tap into water tables that range from 1 to 6 m (3 to 20 ft) deep (Robinson 1958). Rabbitbrush has the ability to resprout and survive long-term flooding (Groeneveld and Crowley 1988). Indian ricegrass does not resprout and has no anaerobic tolerance.

Fire Ecology:

Historically, ephemeral stream plant communities had infrequent fires because of low vegetative cover, low productivity, and discontinuous fuels. The introduction of annual weedy species, like cheatgrass, may cause an increase in fire frequency and eventually lead to an annual state. Wildfires can dramatically alter hydrologic processes of ephemeral stream channels including runoff and erosion.

Basin big sagebrush does not sprout after fire. Because of the time needed to produce seed, it is eliminated by frequent fires (Bunting et al. 1987). Basin big sagebrush establishment after disturbance is primarily by off-site seed or seed from plants that survive in unburned patches. Approximately 90% of big sagebrush seed is dispersed within 30 ft (9 m) of the parent shrub

(Goodrich et al. 1985) with maximum seed dispersal at approximately 108 ft (33 m) from the parent shrub (Shumar and Anderson 1986). Therefore, regeneration of basin big sagebrush after stand-replacing fires is difficult and dependent upon the proximity of residual mature plants and favorable moisture conditions (Johnson and Payne 1968, Humphrey 1984). Reestablishment after fire may require 50 to 120 or more years (Baker 2006).

Fourwing saltbush's ability to sprout following fire may depend on the population and fire severity. A study by Parmenter (2008) showed a 58% mortality rate of fourwing saltbush following fire in New Mexico, the surviving shrubs produced sprouts shortly after fire. While fourwing saltbush is able to resprout after fire, it primarily reestablishes from seed (Stutz 1979, Wasser 1982).

Rubber rabbitbrush, a fire-adapted species, is typically top-killed by fire but can resprout and can also reestablish from seed, with recovery time often being rapid to very rapid (Young 1983). Sprouting response depends to burning conditions, weather, season of burn, varieties, and ecotypic variation (Sapsis 1990). Rubber rabbitbrush is often one of the first species to colonize burned areas by sprouting or from off-site seed (Rickard and Rogers 1983). Sprouts originate from adventitious buds located on the stem and root crown (Daubenmire 1975). This species reproduces abundantly from heavily seed crops (Young 1983). Seeds are easily dispersed to burned sites over long distances by wind.

Burrobrush is top-killed by fire but is a prolific seeder and can quickly colonize burned sites (Tesky 1992). O'Leary and Minnich (1981) found that where burrobrush was abundant pre-fire, it became dominant after fire.

Desert almond is also fire-adapted, with the ability to resprout from its roots after low-intensity fires, though high-intensity fires can damage its root system, making regeneration more difficult (Borchert 2022).

Indian ricegrass is fairly fire tolerant (Wright 1985), which is likely due to its low culm density and below-ground plant crowns. Vallentine (1989) cites several studies in the sagebrush zone that classified Indian ricegrass as being slightly damaged from late summer burning. Indian ricegrass has also been found to reestablish on burned sites through seeds dispersed from adjacent unburned areas (Young 1983, West 1994). Thus, the presence of surviving, seed-producing plants facilitates the reestablishment of Indian ricegrass. Grazing management following fire to promote seed production and establishment of seedlings is important. When properly planted and managed, Indian ricegrass can be a key factor in a community recovering from disturbance because it can grow in rough, rocky, coarse soils (Booth et al. 1980).

Livestock/Wildlife Grazing Interpretations:

Plant communities associated with ephemeral stream channels provide structural elements of food, cover, nesting and breeding habitat, and movement/migration corridors for several wildlife species. Typically, faunal diversity is higher relative to uplands (Levick et al. 2007). Migrating song birds use ephemeral stream corridors for cover and food sources. Mammals, amphibians and reptiles utilize temporary pools for water and seek cover especially during the heat of the day.

Basin big sagebrush provides food and cover for several wildlife species and is considered emergency feed for livestock and wildlife during severe winter weather. Big sagebrush is browsed in the winter by native ungulates. Personius et al. (1987) found Wyoming big sagebrush and basin big sagebrush to be intermediately palatable to mule deer (*Odocoileus hemionus*) when compared to mountain big sagebrush (most palatable) and black sagebrush (least palatable). Pygmy rabbits (*Sylvilagus idahoensis*) and the greater sage grouse also forage on basin big sagebrush and it provides valuable winter cover.

Fourwing saltbush is one of the most important forage shrubs in arid sites. Its importance is due to its abundance, accessibility, size, large volume of forage, evergreen habit, high palatability, and nutritive value (USFS 1937, Crofts and Epps 1975). The palatability rates from fairly good to good for cattle, and as good for domestic sheep and goats. Mule deer usually consume it as a winter browse (USFS 1937). It has similar protein, fat, and carbohydrate levels as alfalfa (*Medicago sativa*) (Catlin 1925). Fourwing saltbush is especially valuable as winter forage. Otsyina et al. (1982) noted that domestic sheep readily grazed fourwing saltbush when introduced into a new pasture. Saltbush species are vital sources of non-protein nitrogen and essential nutrients; however, most are sensitive to browsing, with the exception of shadscale saltbush, which may be preferentially grazed under favorable conditions (Cibils et al. 1998). Defoliation typically impairs root growth, crown cover, and seed production in saltbush, thereby disrupting the photosynthetic processes that regulate biomass accumulation and carbohydrate synthesis (Mohebby et al. 2012).

Indian ricegrass is a deep-rooted, cool-season perennial bunchgrass that is adapted primarily to coarse-textured soils. Indian ricegrass is a preferred forage species for livestock and wildlife (Cook 1962, Booth et al. 2006). This species is often heavily utilized in winter because it cures well (Booth et al. 2006). It is also readily utilized in early spring, being a source of green feed before most other perennial grasses have produced new growth (Quinones 1981). Booth et al. (2006) noted that the plant does well when utilized in winter and spring. Cook and Child (1971), however, found that repeated heavy grazing reduced crown cover, which may reduce seed production, density, and basal area of these plants. Additionally, heavy early spring grazing reduces plant vigor and stand density (Stubbendieck et al. 1985). In eastern Idaho, productivity of Indian ricegrass was at least 10 times greater in undisturbed plots than in heavily grazed ones (Pearson 1965). Cook and Child (1971) found significant reduction in plant cover after 7 years of rest from heavy (90%) and moderate (60%) spring use. The seed crop may be reduced where grazing is heavy (Bich et al. 1995). Tolerance to grazing increases after May, thus spring deferment may be necessary for stand enhancement (Pearson 1964, Cook and Child 1971); however, utilization of less than 60% is recommended. In summary, adaptive management is required to manage this bunchgrass well.

Other species that provide browse and cover for wildlife and livestock include rubber rabbitbrush, burrobrush, and desert almond. Rubber rabbitbrush is considered an important browse species on degraded rangelands for wildlife and livestock especially during winter months. Burrobrush seeds are commonly eaten by domestic sheep. Desert almond is rated low palatability but may be browsed by mule deer in the winter. Small mammals may also utilize the fruits.

State and Transition Model Narrative for Group 9:

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 29 Disturbance Response Group 9.

Reference State 1.0:

The Reference State 1.0 is representative of the natural range of variability under pristine conditions. The reference state has two general community phases; a shrub-grass dominant phase and a shrub dominant phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. This site is inherently unstable, with shrubs dominating the plant community composition. Plant community changes would occur in response to precipitation, flooding, long-term drought, or abusive grazing and would be reflected in annual production. Wet years will increase grass production, while dry conditions will reduce grass production and shrubs will dominate. Intense, natural flooding and infrequent fire events shape the landscape and contribute to the increase in rabbitbrush, burrobrush, and horsebrush (*Tetradymia spp.*) following disturbance.

Community Phase 1.1:

This community is dominated by rubber rabbitbrush, fourwing saltbush, and Indian ricegrass. Burrobrush may be a co-dominant or subdominant component. Littleleaf horsebrush (*Tetradymia glabrata*), Bailey's greasewood (*Sarcobatus baileyi*), Nevada ephedra (*Ephedra nevadensis*), and Anderson wolfberry (*Lycium andersonii*). make up minor components. Other common perennial bunchgrasses include needle-and-thread (*Hesperostipa comata*), desert needlegrass (*Achnatherum speciosum*), basin wildrye (*Leymus cinereus*), bottlebrush squirreltail (*Elymus elymoides*), sand dropseed (*Sporobolus* cryptandrus) and purple threeawn (*Aristida purpurea*). Potential vegetative composition (by air-dry weight) is approximately 20% grasses, 10% forbs and 70% shrubs. Annual air-dry production ranges from 100 to 500 lb/ac.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
Severe seasonal flooding, wildfire, prolonged drought, disease and/or insect attack.

Community Phase 1.2:
After flooding, this plant community is dominated by rubber rabbitbrush, burrobrush, and littleleaf horsebrush. Fourwing saltbush has limited tolerance to flooding so this species may decrease in the community. Indian ricegrass is reduced after flooding or drought. After wildfire, sprouting species such as rubber rabbitbrush, burrobrush, littleleaf horsebrush and fourwing saltbush will dominate. The stream channel may become braided and extensive channel erosion may occur after flooding.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
A combination of time and lack of disturbances such as fire, flooding, drought, or herbivory will allow for natural shrub and perennial bunchgrass regeneration.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0:

Trigger: This transition is caused by the introduction of non-native annual plants such as cheatgrass, Russian thistle or mustards.

Slow variables: Over time the annual non-native species will increase within the community.

Threshold: The presence of introduced non-native annual species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

This state is similar to the Reference State 1.0 with two similar community phases. Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of invasive weeds. Non-natives may increase in abundance but will not become dominant within this state. These non-natives can be highly flammable and can promote fire where historically fire had been infrequent. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These feedbacks include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Positive feedbacks reduce ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal.

Community Phase 2.1:
This community is dominated by rubber rabbitbrush, fourwing saltbush, and Indian ricegrass. Burrobrush may be a co-dominant or subdominant component. Littleleaf

horsebrush, Bailey's greasewood, Nevada ephedra, and wolfberry make up minor components. Other common perennial bunchgrasses include needleandthread, desert needlegrass, basin wildrye, sand dropseed, purple threeawn, and bottlebrush squirreltail. Annual non-native species such as cheatgrass, mustards, and Russian thistle are present and may be increasing within the community.

Dry Wash (R029XY041NV), Current Potential 2.1, T. Stringham June 2023

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
Severe seasonal flooding, wildfire, prolonged drought, off-road vehicle use, disease and/or insect attack.

Community Phase 2.2:
After flooding, this plant community is dominated by rubber rabbitbrush, burrobrush, and littleleaf horsebrush. Fourwing saltbush has limited tolerance to flooding so this species may decrease in the community. Indian ricegrass is reduced after flooding or drought. After wildfire, sprouting species such as rubber rabbitbrush, burrobrush, horsebrush and fourwing saltbush will dominate. The stream channel may become braided and extensive channel erosion may occur after flooding or off-road vehicle use. Annual non-native species such as cheatgrass, mustards, and Russian thistle are present and may be increasing within the community.

Valley Wash (R029XY072NV), Current Potential 2.2, T. Stringham, August 2021

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:

A combination of time and lack of disturbances such as fire, flooding, drought, off-road vehicle use, or herbivory will allow for natural shrub and perennial bunchgrass regeneration.

T2A: Transition from Current Potential State 2.0 to Shrub State 3.0:

Trigger: This transition is caused by prolonged drought, wildfire, off-road vehicle use, or inappropriate, long-term grazing.

Slow variables: Long-term reduction in cover of shrubs, deep-rooted perennial grasses and forbs results in a decrease in organic matter inputs and subsequent soil water decline.

Threshold: Loss of shrubs, deep-rooted perennial bunchgrasses and forbs spatially and temporally changes nutrient cycling and redistribution, and reduces soil organic matter.

Shrub State 3.0:

This state has two community phases in which the overstory is dominated by sprouting shrubs such as rubber rabbitbrush, burrobrush and fourwing saltbush. Indian ricegrass and other perennial bunchgrasses and forbs are sparse in the understory. A site in this state has crossed a biotic threshold and soil erosion may be increasing, especially after a recent flash flood. Annual production has been reduced. Site resources such as soil water, nutrient capture, nutrient cycling, and soil organic matter are temporally and spatially redistributed by the vegetation composition. Bare ground has increased.

Community Phase 3.1:
Rubber rabbitbrush, fourwing saltbush and burrobrush dominate the overstory. Deep-rooted perennial bunchgrasses have significantly declined. Palatable shrubs may be heavily grazed. Perennial forbs are sparse. Annual non-native species may be present. Bare ground and soil redistribution may be increasing.

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:
Severe seasonal flooding, wildfire or off-road vehicle use.

Community Phase 3.2:
Rabbitbrush, burrobrush and other sprouting shrubs dominate the overstory. Annual non-native species may be increasing and bare ground is significant. The stream channel may become braided and channel erosion may increase. This site is at risk of channel entrenchment but was not observed during field studies.

Dry Wash (R029XY041NV), Shrub State 3.2, T. Stringham, June 2021

Upland Wash (R029XY009NV), Shrub State 3.2, T. Stringham, May 2022

Community Phase Pathway 3.2a, from Phase 3.2 to 3.1:
Time and lack of disturbance, release from drought, and/or grazing management that favors the establishment and growth of palatable shrubs and perennial bunchgrasses. Deposition of sandy sediments and deep infiltration favors vigorous plant growth and production enhancing infiltration by further retarding sheet flow.

Potential Resilience Differences with Other Ecological Sites in this Group:

Upland Wash (R029XY009NV):

This site occurs on intermountain valley fans and active ephemeral stream channels of hills, mountains and upper piedmont slopes. Slope gradients of 4 to 8% are typical. Elevations range from 3,800 to 6,200 ft. The soils are formed in deep alluvium from mixed sources. Textures are quite variable as they continue to be reworked by water. The soils typically have high amounts of gravels and cobbles throughout the profile. The plant community is dominated by big sagebrush (basin, Wyoming and mountain – depending on elevation), desert almond and rubber rabbitbrush. Sandberg bluegrass and Indian ricegrass are the important grasses on this site. Production on a normal year is approximately 700 lb/ac. This site differences from the modal site in having an Annual State at higher elevations after wildfire.

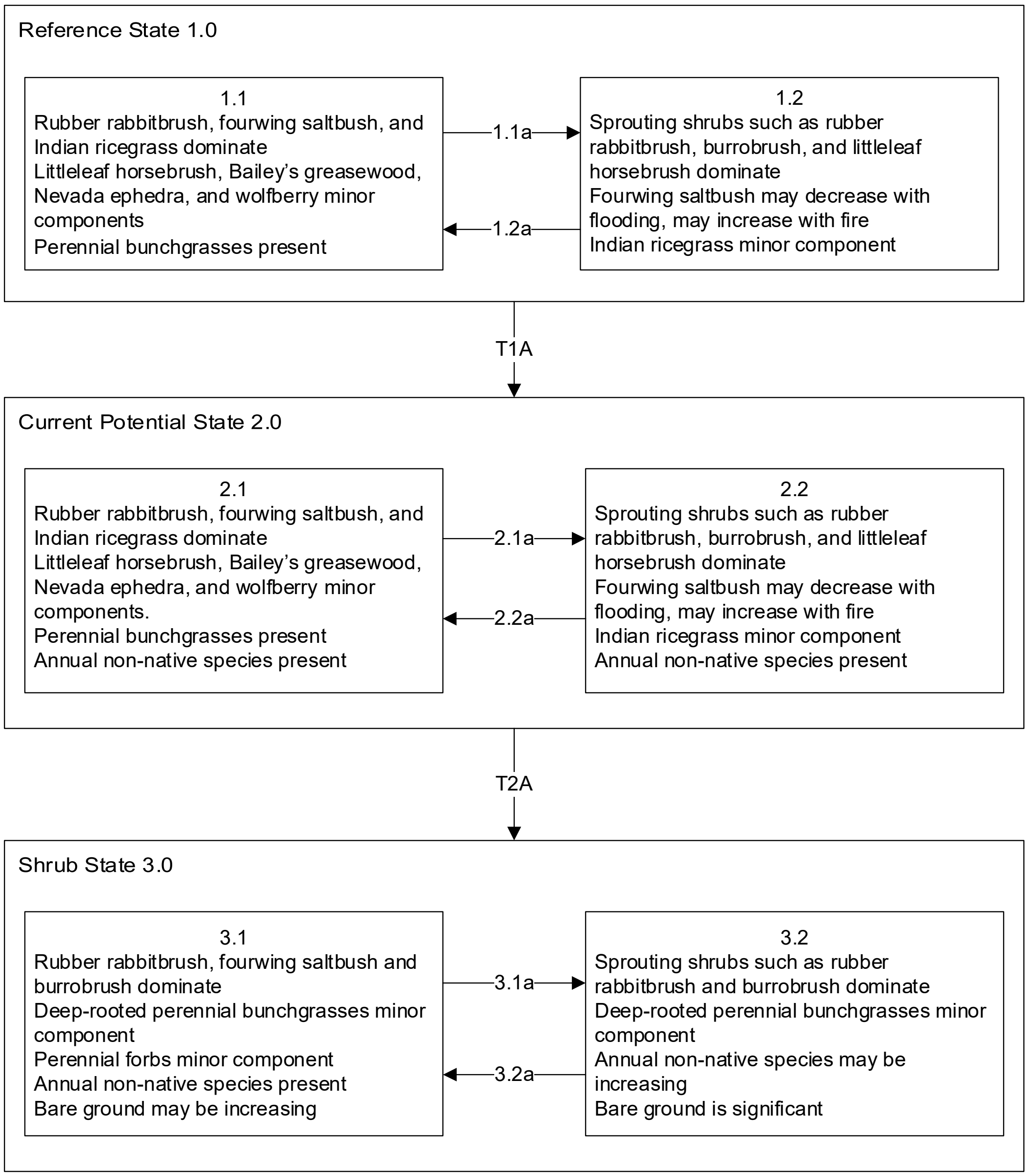
Upland Wash (R029XY009NV), Annual State, T. Stringham, May 2020

Valley Wash (R029XY072NV):

This site occurs in ephemeral stream channels of inset fans and axial stream terraces. Slope gradients of 2 to 8% are typical. Elevations range from 4,000 to 5,500 ft. The soils are formed in deep alluvium from mixed rock sources. Soil textures are variable as they continue to be re-worked by water. These soils typically have high amounts of gravels and cobbles throughout the soil profile. The plant community is dominated by fourwing saltbush and wooly fruit bur ragweed. Other important species include yellow rabbitbrush (*Chrysothamnus* viscidiflorus) and Nevada ephedra. Perennial grasses include Indian ricegrass, needleandthread, bottlebrush squirreltail, sand dropseed and purple threeawn. This site has a three-state model similar to the modal site (Dry Wash).

Modal State and Transition Model for Group 9 in MLRA 29:

MLRA 29
Group 9
Dry Wash
R029XY041NV



MLRA 29
Group 9
Dry Wash
R029XY041NV

Reference State 1.0 Community Phase Pathways
1.1a: Severe seasonal flooding, wildfire, prolonged drought, disease and/or insect attack.
1.2a: A combination of time and lack of disturbances such as fire, flooding, drought, or herbivory will allow for natural shrub and perennial bunchgrass regeneration.

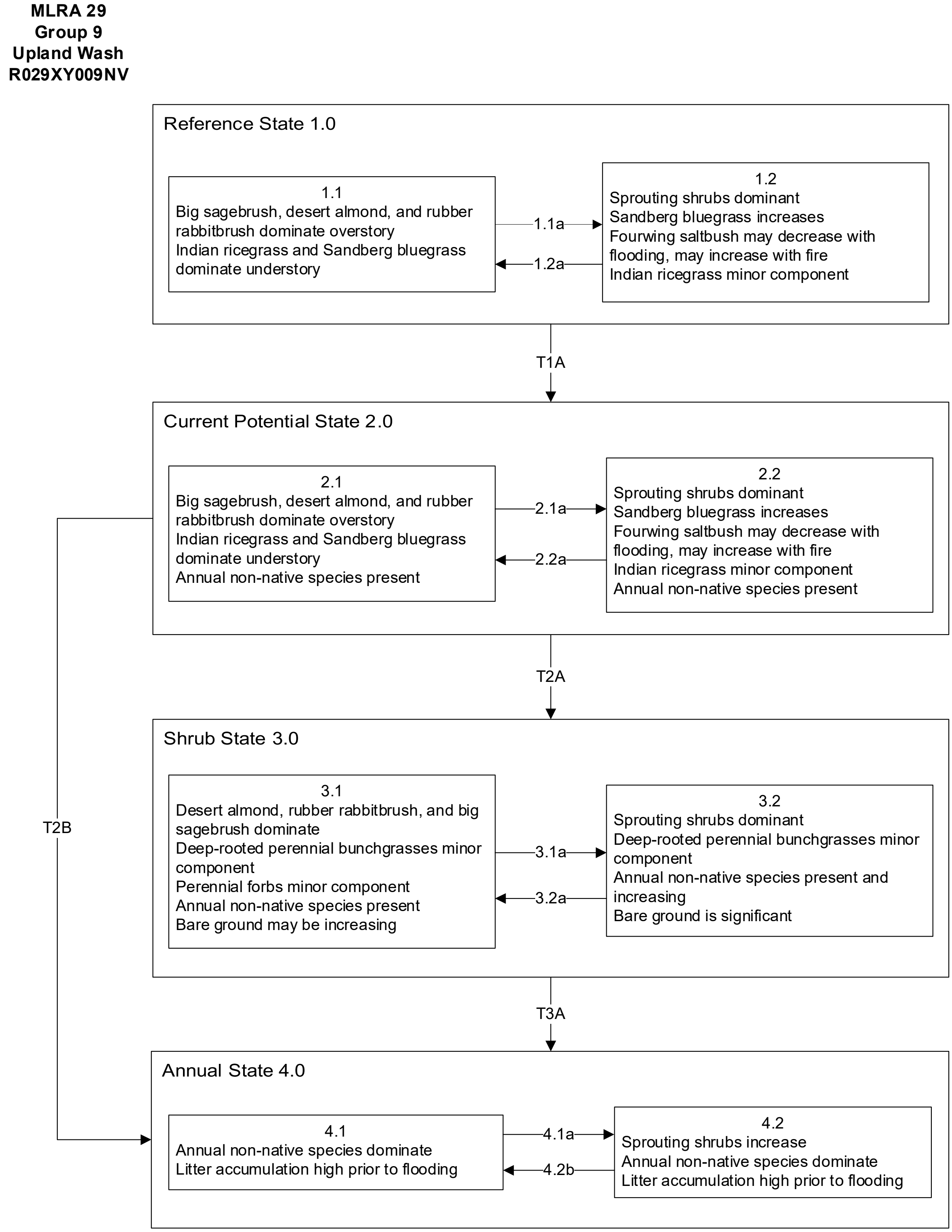
Transition T1A: Introduction of non-native species such as cheatgrass, mustards, or Russian thistle.

Current Potential State 2.0 Community Phase Pathways
2.1a: Severe seasonal flooding, wildfire, prolonged drought, off-road vehicle use, disease, and/or insect attack.
2.2a: A combination of time and lack of disturbances such as fire, flooding, drought, off-road vehicle use, or herbivory will allow for natural shrub and perennial bunchgrass regeneration.

Transition T2A: Prolonged drought, wildfire, off-road vehicle use, and/or inappropriate, long-term grazing reduces shrub and deep-rooted perennial grass cover.

Shrub State 3.0 Community Phase Pathways
3.1a: Severe seasonal flooding, wildfire, and/or off-road vehicle use.
3.2a: Time and lack of disturbance, release from drought, and/or grazing management that favors the establishment and growth of palatable shrubs and perennial bunchgrasses. Deposition of sandy sediments and deep infiltration favors vigorous plant growth and production enhancing infiltration by further retarding sheet flow.

Additional State and Transition Models for Group 9 in MLRA 29:



MLRA 29
Group 9
Upland Wash
R029XY009NV

Reference State 1.0 Community Phase Pathways
1.1a: Severe seasonal flooding, wildfire, prolonged drought, disease and/or insect attack.
1.2a: Time and lack of disturbance such as fire, drought, herbivory, or combinations of these will allow for natural shrub regeneration.

Transition T1A: Introduction of non-native annual species such as cheatgrass or mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Severe seasonal flooding, wildfire, prolonged drought, off-road vehicle use, disease, and/or insect attack.
2.2a: Time and lack of disturbances such as flooding, fire, drought, off-road vehicle use, herbivory, or combinations of these will allow for natural shrub and perennial grass regeneration.

Transition T2A: Prolonged drought, wildfire, off-road vehicle use, and/or inappropriate long-term grazing reduces shrub and deep-rooted perennial grass cover.

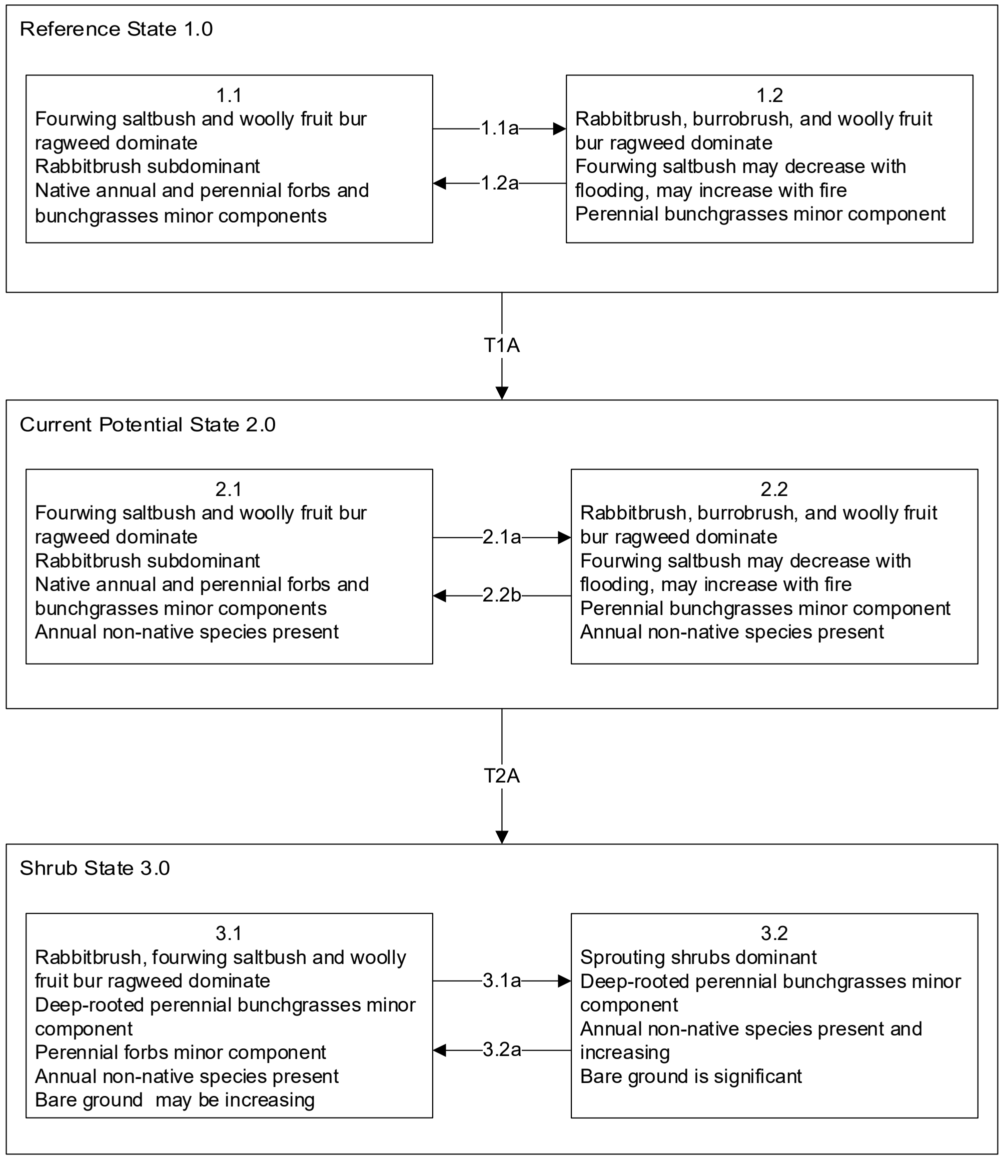
Transition T2B: Wildfire decreases deep-rooted perennial grasses and non-sprouting shrubs, favoring an increase in non-native annual species and/or sprouting shrubs.

Shrub State 3.0 Community Phase Pathways
3.1a: Severe seasonal flooding, wildfire, and/or off-road vehicle use.
3.2a: Time and lack of disturbance, release from drought, and/or grazing management that favors the growth of palatable shrubs and perennial bunchgrasses.

Transition T3A: Wildfire decreases deep-rooted perennial grasses and shrubs, favoring an increase in non-native annual species and/or sprouting shrubs.

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of disturbance allows establishment of sprouting shrubs.
4.2a: Wildfire and/or drought reduces sprouting shrubs, allowing non-native annual species to dominate.

MLRA 29
Group 9
Valley Wash
R029XY072NV



MLRA 29
Group 9
Valley Wash
R029XY072NV

Reference State 1.0 Community Phase Pathways
1.1a: Severe seasonal flooding, wildfire, prolonged drought, disease and/or insect attack.
1.2a: Time and lack of disturbance such as fire, drought, herbivory, or combinations of these will allow for natural shrub regeneration.

Transition T1A: Introduction of non-native annual species such as cheatgrass, mustards, or Russian thistle.

Current Potential State 2.0 Community Phase Pathways
2.1a: Severe seasonal flooding, wildfire, prolonged drought, off-road vehicle use, disease, and/or insect attack.
2.2a: Time and lack of disturbances such as flooding, fire, drought, off-road vehicle use, herbivory, or combinations of these will allow for natural shrub and perennial grass regeneration.

Transition T2A: Prolonged drought, wildfire, off-road vehicle use, and/or inappropriate, long-term grazing reduces shrub and deep-rooted perennial grass cover.

Shrub State 3.0 Community Phase Pathways
3.1a: Severe seasonal flooding, wildfire, and/or off-road vehicle use.
3.2a: Time and lack of disturbance, release from drought, and/or grazing management that favors the growth of palatable shrubs and perennial bunchgrasses.

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<u>MLRA 29 Group 10: Loamy soils with basin big sagebrush and basin wildrye</u>

Description of MLRA 29 Disturbance Response Group 10

Disturbance Response Group (DRG) 10 consists of one ecological site, Loamy Bottom 8-12" P.Z. (R029XY003NV). This site occurs on inset fans, lake plains, and axial stream floodplains. Slopes range from 0 to about 4%. Elevations are 5,000 to about 7,500 ft. Average annual precipitation is 8 to 12 in. The soils in this site are deep to very deep and well to somewhat poorly drained. Surface soils are thick, fertile, and moderately fine to medium textured. The available water capacity is moderate to high. Some soils have a seasonally high water table at depths of 30 to 60 in., which allows for significant fluctuations in herbage production. Additional moisture is received on this site as overflow from adjacent streams or as run-in off higher landscapes. The soil moisture regime is xeric and the soil temperature regime is mesic. The plant community is dominated by basin big sagebrush (*Artemisia tridentata ssp. tridentata*) and basin wildrye (*Leymus cinereus*). Western wheatgrass (*Pascopyrum smithii*) and beardless wildrye (*Leymus triticoides*) may be a sub-dominant component. Average production in a normal year is 2,000 lb/ac.

Disturbance Response Group 10 Ecological Sites:

Loamy Bottom 8-12" P.Z. – Modal R029XY003NV

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasives. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans a unique area in Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area. Flashy, summer storm events contribute significantly to annual precipitation as well. Air and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

The ecological site in this DRG is dominated by deep-rooted cool-season, perennial grasses, and long-lived shrubs (50+ years) with high root-to-shoot ratios. The dominant shrubs usually root to the full depth of the winter-spring soil moisture recharge, which ranges from 1 to over 3 m (3 to 9 ft) (Comstock and Ehleringer 1992). Root length of mature sagebrush plants was measured to a depth of 2 m (6.5 ft) in alluvial soils in Utah (Richards and Caldwell 1987). These shrubs have a flexible generalized root system with development of both deep taproots and laterals near the surface (Comstock and Ehleringer 1992). The Great Basin sagebrush communities have high spatial and temporal variability in precipitation both over years and within growing seasons. Nutrient availability is typically low but increases with elevation and closely follows moisture availability. The moisture resource supporting the greatest amount of plant growth is usually the water stored in the soil profile during the winter. The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and depressed competition or can increase resource pools by the decomposition of dead plant material following disturbance. The invasion of sagebrush communities by cheatgrass (*Bromus tectorum*) has been linked to disturbances (fire, abusive grazing) that have resulted in fluctuations in resources (Chambers et al. 2007).

A primary disturbance on this ecological site is channel incision leading to a lowered seasonal water table which facilitates an increase in shrubs and a decrease in perennial bunchgrasses (Chambers et al. 2004). With continued site degradation, rubber rabbitbrush (*Ericameria nauseosa*) becomes the dominant plant. There is some evidence that many Loamy Bottom ecological sites are degraded Wet Meadow ecological sites created through channel incision processes. Additionally, the encroachment of singleleaf pinyon (*Pinus monophylla*) and Utah juniper (*Juniperus osteosperma*) into associated upland sites has the potential to modify the hydrology of this site through changes to the watershed's overall water budget. Research indicates pinyon and juniper canopies intercept, on average, 44% of incoming rainfall (Lossing 2012), and a 10 to 12 in. diameter basal height tree consumes approximately 10 to 68 liters per day (2.6 to 18 gallons) (Snyder et al. 2013). Further investigation and updating of ecological site concepts for this site is warranted.

Basin big sagebrush, a common species in the Great Basin, is widely distributed throughout the western United States, particularly in arid and semi-arid environments (Weber and Wittmann 2012). This perennial, native shrub is adapted to a variety of soil types, including sandy, loamy, and clayey soils, and is commonly found in foothills, basins, and along montane slopes (Stubbendieck et al. 2017). Basin big sagebrush is highly drought-tolerant and can thrive in areas with low precipitation, though it prefers areas with moderate winter moisture (Tilley et al. 2002). This species typically grows to heights of 1 to 2 m (3 to 6.5 ft) and exhibits a robust root system, including a deep taproot that can exceed 3 m (9 ft) deep, allowing it to access water in dry conditions. Basin big sagebrush is considered a phreatophyte, with the ability to tap into shallow groundwater sources (Klepper et al. 1985). Physiologically, it is well-adapted to drought stress, using C3 photosynthesis and producing resinous compounds that help reduce water loss and deter herbivores (Bates et al. 2006). Basin big sagebrush also plays an important ecological role, providing crucial habitat for a variety of wildlife species, including sage grouse (*Centrocercus urophasianus*) (Davies et al. 2011).

Basin wildrye is a long-lived cool-season perennial bunchgrass with an extensive deep, coarse fibrous root system, reaching depths of 100 cm (39 in.) and a lateral spread of 90 cm (35 in.) and long leaf blades that reach lengths of 15 to 25 in. (Abbott et al. 1991, Ogle 2000a). It can be found at elevations from 2,000 to 9,000 ft elevation and grows best in areas with average annual precipitation of 8 in. to above 20 in. (Ogle 2000a). Additionally, it is adapted to a wide range of soils from clay and silty soils to coarse-textured, gravelly, and stony soils, and has been shown to do well in moderately saline soils (Bowns et al. 2025a). Basin wildrye is considered intolerant of heavy growing season grazing due to its placement of growing points 4 to 6 in. above the soil (Banner et al. 2011). However, when managed correctly, it is considered especially useful as winter forage, due to its large forage production and position above snowline (Bowns et al. 2025a), for cattle and elk (Banner et al. 2011), and horses (Ogle et al. 2012b). Similarly, basin wildrye has been shown to be a desirable forage source for horses (Ogle et al. 2012b), and abundant forage for cattle, elk, and deer (Banner et al. 2011, Bowns et al. 2025a) during the spring months. Furthermore, a study by Cruz-Guerra (1994) demonstrated that basin wildrye was the second most preferable forage species, after crested wheatgrass, by cattle during spring. The same pattern was reported from mid-May to late June, and an increase to the most preferable species by cattle between July and September. This preference was supported by Ogle et al. (2012b) who reported basin wildrye as a desirable species for cattle and horses during early summer, but conflicts with reports by Banner et al. (2011) and Bowns et al. (2025a), who stated basin wildrye was less preferred during the summer months. Basin wildrye is also extensively used to stabilize disturbed soils, help mitigate soil erosion, and as a restoration species wherever moisture is adequate. For instance, being used as a grass barrier for wind erosion or blowing snow control and as a vegetative terrace to control water erosion on hilly croplands (Ogle 2000a). However it can be hard to establish due to lack of highly germinable seed (Banner et al. 2011, Bowns et al. 2025a).

The perennial bunchgrasses generally have somewhat shallower root systems than the shrubs, but root densities are often as high as or higher than those of shrubs in the upper 0.5 m (1.6 ft) but taper off more rapidly than shrubs. However, basin wildrye is weakly rhizomatous and has been found to root to depths of 1 m (3.2 ft) or more and to exhibit greater lateral root spread than many other grass species (Abbott et al. 1991). Similarly, western wheatgrass possesses spreading rhizomes that make it an excellent and widely used species for range seeding, revegetation of saline and alkaline areas, and in crucial areas for erosion control (NRCS 2002).

Its relative drought tolerance combined with strong rhizomatous root systems and adaptation to a variety of soils make this species ideal for reclamation in areas receiving 12 to 20 in. annual precipitation (Ogle 2000b).

Periodic drought regularly influences sagebrush ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West. Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006).

The ecological site in this DRG has moderate resilience to disturbance and resistance to invasion. A primary disturbance on these ecological sites is channel incision or other disturbances leading to a lowered water table. This facilitates an increase in shrubs and a decrease in basin wildrye. This can be caused by inappropriate grazing practices, drought, groundwater pumping, singleleaf pinyon or Utah juniper encroachment in the watershed, and/or fire. Annual non-native species invade these sites where competition from perennial species is decreased.

Annual Invasive Species:

The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and depressed competition or can increase resource pools by the decomposition of dead plant material following disturbance. Excessive grazing pressure during settlement and into the 20th century has increased the overall presence of cheatgrass, halogeton (*Halogeton glomeratus*), Russian thistle (*Salsola tragus*) and weedy mustard species (*Brassicaceae* family) (Peters and Bunting 1994). Lambsquarters (*Chenopodium album*), and whitetop (*Cardaria draba*) have also been shown to invade this site. The presence of exotic annual plants within these ecosystems decreases ecosystem resilience and resistance to disturbance through competition for limited resources. (Dobrowolski et al. 1990) cite multiple factors on the extent of the soil profile exploited by the competitive exotic annual cheatgrass. Specifically, the depth of rooting is dependent on the size the plant achieves, and in competitive environments, cheatgrass roots were found to penetrate only 15 cm (6 in.) whereas isolated plants and pure stands were found to root at least 1 m (3.2 ft) in depth with some plants rooting as deep as 1.5 to 1.7 m (5 to 5.5 ft). Encroachment by native annual species, with weedy characteristics, such as western tansymustard (*Descurainia pinnata*) and aridland goosefoot (*Chenopodium desiccatum*) is also possible, and may lead to further degradation of site and dominance of annual species.

Cheatgrass is a cool-season annual grass that maintains an advantage over native plants in part because it is a prolific seed producer, can germinate in the autumn or spring, tolerates grazing, and increases with frequent fire (Klemmedson and Smith 1964, Miller 1999). Cheatgrass originated from Eurasia and was first reported in North America in the late 1800s (Furbush 1953, Mack and Pyke 1983). Pellant and Hall (1994) found 3.3 million acres of public lands dominated by cheatgrass and suggested that another 76 million acres were susceptible to invasion by winter annuals including cheatgrass and medusahead (*Taeniatherum caput-medusae*).

Halogeton is a poisonous noxious annual weed introduced to the United Stated from Eurasia in the early 20th century (Tilley et al. 2008). It inhabits disturbed sites, road sides, and arid lands in poor ecological conditions and is uniquely adapted to basic and saline soil (Stubbendieck et al. 2017). Halogeton possesses a taproot that can reach depths of 20 in. with lateral roots spreading 18 in. in all directions. It is particularly detrimental since it accumulates salt from the soil within its plant tissue which is then leaches out of dead plants and roots increasing the overall salinity of the soil and favoring the establishment of halogeton over other species. In addition, halogeton is a prolific seed generator, producing as many as 75 seeds per inch of stem or about 400 lb of seed per acre. This poses a threat to livestock as halogeton accumulates soluble oxalates within its plant tissue which is highly toxic to sheep and cattle, requiring the consumption of less than 1.5 lb to be fatal. Proper management of site disturbance is crucial to reducing risk of halogeton invasion, however mechanical and chemical methods can be implemented if an infestation is detected early (Tilley et al. 2008).

Russian thistle is a tap-rooted, C4 photosynthesis (warm-season) annual forb, introduced from southeast Europe and central Asia. The seeds have a remarkable capability to germinate in a variety of soil temperatures and in areas with very little precipitation, and even move back into dormancy after initial germination (Wallace et al. 1968). The seeds however, are not persistent and generally remain viable in the seedbank for less than two years (Boerboom 1993, Young et al. 1995). Russian thistle has been observed to provide initial establishment in completely de-vegetated sites and create microsite habitat which may allow increased establishment of other species (Allen and Allen 1988). The successful establishment of other species, particularly later seral species which forms mycorrhizal associations may reduce cover of Russian thistle as mycorrhizal inoculation has been observed to reduce the size and vigor of Russian thistle, while encouraging later seral species such as perennial bunchgrasses (Johnson 1998a).

Hydrology:

The typical seasonal high water table occurs at depths of 30 to 60 in. which allows for significant production of basin wildrye. In many areas, this site occurs where a channel has become entrenched lowering the water table required to support a meadow plant community. However, with further channel incising and associated water table lowering site degradation occurs. Most Great Basin streams have been prone to incision for the past two thousand years, thus separating changes attributable to ongoing stream incision from those caused by human impact can be difficult (Chambers et al. 2004). Rosgen (1997) characterizes channel incision as a response to altered base level and anthropogenic modifications (e.g. channelization, confinement, and riparian vegetation conversion) and notes that incision lowers the water table, accelerates bank erosion, causes land loss, and degrades aquatic and terrestrial habitat conditions that restoration seeks to reverse by reestablishing stable reference-channel form and reconnecting floodplains. The most direct evidence that anthropogenic disturbance has attributed to stream incision in the central Great Basin is derived from research on the effects of roads on riparian areas (Forman and Deblinger 2000, Trombulak and Frissell 2000). Germanoski and Miller (2004) state that while many Great Basin streams have a natural tendency toward incision due to climatic and geomorphic factors, anthropogenic activities such as historical overgrazing have contributed to incision in some basins by removing stabilizing vegetation and increasing surface runoff. In general, overuse of the riparian area by livestock can negatively affect stream bank and channel stability, and localized changes in stream morphology have been associated with heavy livestock use in the western United States (see reviews in Trimble and Mendel (1995), Belsky et al. (1999)). However, data that clearly demonstrate the relationship between regional stream incision and overuse by livestock have not been collected for the Great Basin (Chambers et al. 2004). Although a direct link between livestock use and widespread channel incision in the Great Basin has not been demonstrated, livestock grazing has been associated with localized stream bank destabilization and morphological changes, including channel widening and sloughing (Monsen et al. 2004b). The impact of feral horse use on riparian systems is also in need of documentation. In regard to restoration and management, it is important to recognize that particular streams have a greater sensitivity to both natural and management disturbances. For further guidance see Chambers et al. (2004), Rosgen (2006), Brisbin (2024), or Newton et al. (1998).

Hydrologic modification of this site may occur through channel incision or gully formation with post-fire rain events. Channel incision or gully formation has the potential to lower the site water table, drying out the site and favoring the dominance of sagebrush and rabbitbrush over the herbaceous component. In addition, pinyon-juniper encroachment into the surrounding sagebrush dominated sagebrush dominated areas and the associated change in understory species cover and soil moisture, has been well documented (Miller et al. 2005, Miller and Heyerdahl 2008, Roundy et al. 2020). Increased tree dominance has been documented to cause increased bare ground, accelerated hillslope runoff, increased erosion and substantial soil loss (Pierson et al. 2010, Pierson et al. 2013). In addition, pinyon-juniper encroachment has been shown to reduce groundwater recharge to associated meadow areas (Cornachione 2021). The hydrologic modification of the watershed to associated meadow sites has had a significant impact on the localized meadow hydrology and is a primary driver in the conversion of meadow areas into plant communities dominated by upland vegetation.

Although not a component of this site, field observations indicate as the site degrades hydrologically, Wyoming big sagebrush (*Artemisia tridentata ssp. wyomingensis*) may become co-dominant with basin big sagebrush. The dominance of big sagebrush within the Loamy Bottom ecological site is a strong indicator of modified hydrology and the co-dominance of Wyoming big sagebrush, the most drought tolerant of the big sagebrush species, strongly indicates the historical hydrology of the site has been lost and active management will be required for restoration.

Fire Ecology:

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The initial condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species' response. For most forbs and grasses the growing points are located at or below the soil surface providing relative protection from disturbances that decrease above-ground biomass, such as grazing or fire. Thus, fire mortality is more correlated to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant, and abundance of old growth (Wright 1971, Young 1983). In addition, season and severity of the fire will influence plant response as will post-fire soil moisture availability.

Basin wildrye, a major component on this site, is relatively resistant to fire, particularly dormant season fire, as plants sprout from surviving root crowns and rhizomes (Zschaechner 1985). Miller et al. (2013) reports fall and spring burning increased total shoot and reproductive shoot densities in the first year, although live basal areas were similar between burn and unburned plants. By year two, there was little difference between burned and control treatments.

In many basin big sagebrush communities, changes in fire occurrence have occurred along with fire suppression, livestock grazing, and OHV use. Few if any fire history studies have been conducted on basin big sagebrush; however, Sapsis and Kauffman (1991) suggests that fire return intervals in basin big sagebrush are intermediate between mountain big sagebrush (5 to 15 years) and Wyoming big sagebrush (10 to 70 years). It is likely the fire return interval for this site with an average production of 2,000 lb/ac was greater than those reported for mountain big sagebrush communities. Fire severity in big sagebrush communities is described as "variable" depending on weather, fuels, and topography. However, fire in basin big sagebrush communities is typically stand-replacing (Sapsis and Kauffman 1991). Basin big sagebrush does not sprout after fire and is often eliminated from the site by frequent or stand-replacing fires (Bunting et al. 1987). Basin big sagebrush re-establishes primarily by off-site seed or seed from plants that survive in unburned patches. Approximately 90% of big sagebrush seed is dispersed within 30 ft (9 m) of the parent shrub (Goodrich et al. 1985) with maximum seed dispersal at approximately 108 ft (33 m) from the parent shrub (Shumar and Anderson 1986). Therefore, regeneration of basin big sagebrush after stand-replacing fires is difficult and dependent upon proximity of residual mature plants and favorable moisture conditions (Johnson and Payne 1968, Humphrey 1984). Reestablishment after fire may require 50 to 120 or more years (Baker 2006). However, the introduction and expansion of cheatgrass have dramatically altered the fire regime (Balch et al. 2013), therefore altering the restoration potential of big sagebrush communities (Evans and Young 1978). Sites with low abundances of native perennial grasses and forbs typically have reduced resiliency following disturbance and are less resistant to invasion or increases in cheatgrass (Miller et al. 2013).

Hydrologic modification of this site may occur through channel incision or gully formation with post-fire rain events. Channel incision or gully formation has the potential to lower the site water table, drying out the site and favoring the dominance of sagebrush and rabbitbrush over the herbaceous component.

Livestock/Wildlife Grazing Interpretations:

Inappropriate grazing management leads to an increase in big sagebrush and a decline in understory plants like basin wildrye. Reduced bunchgrass vigor or density provides an opportunity for beardless wildrye or western wheatgrass expansion and/or cheatgrass and other invasive species to occupy interspaces. Beardless wildrye has a rhizomatous rooting system, and is tolerant of grazing and increases under grazing pressure (USFS 1937).

Western wheatgrass is considered high quality forage for pasture or range seedings and is described as palatable to all classes of livestock and wildlife and highly nutritious (Hafenrichter et al. 1968, Tirmenstein 1999, Ogle 2000b, NRCS 2002). It is considered moderately palatable to elk and cattle year-round and is a desirable feed for cattle, horses, and elk during summer, fall, and winter (Ogle 2000b, NRCS 2002). Hafenrichter et al. (1968) also showed it to be good winter forage for livestock due to fall re-growth, however, Hart et al. (1993) concluded it produced little re-growth after mid-July regardless of grazing strategy. Western wheatgrass is considered desirable forage for sheep and antelope and only palatable to deer in the spring when its protein content is highest (Ogle 2000b, NRCS 2002). Ogle (2000b) considered it a preferred feed for cattle, horses, deer, and elk in the spring, however a study by Hafenrichter et al. (1968) found that livestock will graze native bunchgrasses first and more frequently if they are available. Irrigation has been shown to improve western wheatgrass establishment and maintenance. Stands should not be grazed until they are firmly established, however, once established they can tolerate heavy grazing, though 40 to 60% of the annual growth should be left intact to ensure plant viability and establishment (Ogle 2000b, NRCS 2002).

Beardless wildrye is considered valuable forage, particularly on meadows that become dry, wet alkaline soils in low-precipitation zones, saline areas, and areas that are flooded in the spring (Monsen et al. 2004a, Dyer and O’Beck 2006a). It can be effectively seeded forming highly persistent stands that are resistant to trampling and recover well from grazing once established. A notable cultivar of this species is known as ‘Shoshone’ and was first collected in 1958 from a stand in Riverton, WY. It is a high forage producer and is used primarily for forage, stabilization, or cover on wet or wet-saline-alkaline soils (Dyer and O’Beck 2006a).

Basin wildrye is a commonly grazed species due to its high palatability to domestic livestock and wildlife. Basin wildrye reaches peak production in protein per acre from mid-June through August (Ogle 2000a). New stands should not be grazed until plants are at least 10 in. tall, and to best maintain stands, grazing should occur during the late fall and winter, when plants are dormant (Ogle 2000a, Bowns et al. 2025a). Spring defoliation of basin wildrye should be light, however consistent heavy grazing during the growing season has been found to significantly reduce basin wildrye production and density (Krall et al. 1971, Bowns et al. 2025a). A stubble of at least 10 in. should remain following grazing of established stands to protect plant health (Ogle 2000a).

If the site is dependent upon a water table supported by an associated stream channel, excessive livestock or wildlife trampling of the streamside vegetation could lead to channel morphology changes and eventual headcutting, incision, or other channel instability processes. Any lowering of the water table associated with channel degradation has potential negative impacts on the associated Loamy Bottom plant community. The sagebrush component will expand with a lowering of the seasonal water table. The root length of mature sagebrush was measured to a depth of 2 m (6.5 ft) in alluvial soils in Utah (Richards and Caldwell 1987).

State and Transition Model Narrative for Group 10:

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 29 Disturbance Response Group 10.

Reference State 1.0:

The Reference State 1.0 is a representative of the natural range of variability under pristine conditions. The Reference State has three general community phases; a shrub-grass dominant phase, a perennial grass dominant phase, and a shrub dominant phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire, periodic drought, and/or insect or disease attack.

Community Phase 1.1**:**
The reference plant community is dominated by basin wildrye and the subdominants of western wheatgrass and/or beardless wildrye. Basin big sagebrush and rubber rabbitbrush may or may not be present. Potential vegetative composition by air-dry weight is approximately 80% grasses, 5% forbs and 15% shrubs. Approximate ground cover (basal and canopy) is 40 to 65%. Total annual air-dry production ranges from 800 to 3,000 lb/ac.

Community Phase Pathway 1.1a, from 1.1 to 1.2:
Fire and/or an Aroga moth (*Aroga websteri*) infestation would decrease or eliminate the big sagebrush component. Basin wildrye would expand and sprouting shrubs, such as rabbitbrush, may temporarily increase.

Community Phase Pathway 1.1b, from 1.1 to 1.3:
Time and lack of disturbance such as fire, and/or long-term drought, and/or Aroga moth will facilitate an increase in basin big sagebrush and a decline in basin wildrye.

Community Phase 1.2:
This community phase is characteristic of a post-disturbance, early-seral community. Basin wildrye, western wheatgrass and/or beardless wildrye, and other perennial grasses and grass-likes dominate. Rabbitbrush may be sprouting. Depending on fire severity or intensity of Aroga moth infestations, patches of intact sagebrush may remain.

Community Phase Pathway 1.2a, from 1.2 to 1.1:
Time and lack of disturbance will allow sagebrush to increase.

Community Phase 1.3:
Basin big sagebrush increases in the absence of fire and/or Aroga moth, becoming co-dominant with basin wildrye.

Community Phase Pathway 1.3a, from Phase 1.3 to 1.1:
A low severity fire, Aroga moth or combination would reduce the sagebrush overstory and create a basin wildrye dominant community with a small component of basin big sagebrush.

Community Phase Pathway 1.3b, from 1.3 to 1.2:
Fire and/or a severe Aroga moth infestation will decrease or eliminate the overstory of sagebrush and allow for basin wildrye to dominate the site.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0:

Trigger: This transition is caused by the introduction of non-native annual and perennial plants, such as cheatgrass, non-native mustards, halogeton, and Russian thistle.

Slow variables: Over time the non-native species will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

This state is similar to the Reference State 1.0 with three similar community phases. Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of invasive weeds. Non-natives may increase in abundance but will not become dominant within this State. These non-natives can be highly flammable and can promote fire where historically fire had been infrequent. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These feedbacks include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross-pollinate, and adaptations for seed dispersal.

Community Phase 2.1:
This community is dominated by basin wildrye and basin big sagebrush. Western wheatgrass and beardless wildrye are subdominant. Other perennial grasses and forbs make up a minor component of understory. Non-native annual species are present.

Community Phase Pathway 2.1a, from 2.1 to 2.2:
Fire will decrease or eliminate the sparse stand of sagebrush and perennial bunchgrasses and grass-likes remain dominant on the site resulting in mosaic. Fire will typically remove most of the sagebrush overstory and rabbitbrush will likely resprout. A severe infestation of Aroga moth could also cause a large decrease in sagebrush giving a competitive advantage to the perennial grasses and forbs. Non-native species are likely to increase after fire.

Community Phase Pathway 2.1b, from 2.1 to 2.3:
Time and lack of disturbance such as fire or Aroga moth allow for sagebrush and rabbitbrush to increase and become decadent. Long-term drought, inappropriate herbivory, or combinations of these will cause a decline in perennial bunchgrasses and fine fuels leading to a reduced fire frequency and allowing big sagebrush and rabbitbrush to dominate the site. Inappropriate grazing management reduces the perennial bunchgrass understory.

Community Phase 2.2:
This community phase is characteristic of a post-disturbance, early-seral community. Basin wildrye, western wheatgrass, beardless wildrye, and other perennial grasses and grass-likes dominate. Rabbitbrush may be sprouting. Depending on fire severity or intensity of Aroga moth infestations, patches of intact sagebrush may remain. Non-native annual species are present.

Community Phase Pathway 2.2a, from 2.2 to 2.1:
Time and lack of disturbance and/or grazing management that favors the establishment and growth of sagebrush and rabbitbrush allows the shrub component to recover. The establishment of basin big sagebrush can take many years.

Community Phase 2.3:
This community is at risk of crossing a threshold to another state. Basin big sagebrush dominates the overstory and perennial bunchgrasses in the understory are reduced,

either from competition with shrubs, inappropriate grazing, lowered water table, or a combination of the three. Rabbitbrush may be a significant component. Utah juniper and/or singleleaf pinyon may be present and without management will likely increase. Non-native species may be stable or increasing due to lack of competition with perennial bunchgrasses. This site is susceptible to further degradation from grazing, drought, and fire.

Community Phase Pathway 2.3a, from 2.3 to 2.1:
A change in grazing management that decreases shrubs would allow for the perennial bunchgrasses in the understory to increase. Heavy late-fall/winter grazing may cause mechanical damage and subsequent death to sagebrush, facilitating an increase in the herbaceous understory. An infestation of Aroga moth or a low severity fire would reduce some sagebrush overstory and allow perennial grasses to increase in the community. Brush treatments with minimal soil disturbance would also decrease sagebrush and release the perennial understory. Annual non-native species are present and may increase in the community.

Community Phase Pathway 2.3b, from 2.3 to 2.2:
Fire and/or a severe Aroga moth infestation will decrease or eliminate the overstory of sagebrush and allow for basin wildrye to dominate the site. Non-native annual species are present and may increase in response to fire.

T2A: Transition from Current Potential State 2.0 to Shrub State 3.0:

Trigger: To Community Phase 3.1: Chronic growing season grazing and/or hydrologic modification facilitates an increase in shrub cover and a significant decline in basin wildrye density and production. To Community Phase 3.2: Fire removes basin big sagebrush, favoring sprouting shrubs like rabbitbrush, which become dominant. Over time, and in the absence of further disturbance, sagebrush can gradually reestablish.

Slow variables: Long-term decrease in deep-rooted perennial grass density.

Threshold: Loss of deep-rooted perennial bunchgrasses changes nutrient cycling, nutrient redistribution, and reduces soil organic matter.

Shrub State 3.0:

This state has two community phases a decadent shrub phase and a sprouting shrub phase. This state is a product of chronic growing season grazing and/or hydrologic modification resulting in a lowered water table. Big sagebrush dominates the overstory and rabbitbrush may be a significant component. Big sagebrush cover exceeds site concept and may be decadent, reflecting stand maturity and lack of seedling establishment due to competition with mature plants. The shrub overstory dominates site resources such that soil water, nutrient capture, nutrient cycling and soil organic matter are temporally and spatially redistributed. Bare ground may be significant with soil redistribution occurring between interspace and canopy locations.

Community Phase 3.1:
Basin big sagebrush dominates the overstory. Rabbitbrush may be a significant component. Basin wildrye and other perennial grasses may be present in trace amounts or absent from the community. Annual non-natives forbs and grass may increase. Bare ground is significant. Utah juniper and/or singleleaf pinyon pine may be present.

Loamy Bottom 8-12" P.Z. (R029XY003NV), Shrub State 3.1, T. Stringham, June 2022

Community Phase Pathway 3.1a, from 3.1 to 3.2:
Fire, heavy fall grazing causing mechanical damage to shrubs, Aroga moth, and/or brush treatments with minimal soil disturbance, will greatly reduce the sagebrush overstory and facilitate an increase in sprouting shrubs. Basin wildrye may be trace amount to non-existent. Annual invasive grass and forbs may be increasing.

Community Phase 3.2:
Basin big sagebrush reduced to trace or absent. Perennial grass is trace to absent. Rabbitbrush is sprouting and may be a significant component. Annual native and non-native species are increasing. Bare ground cover is significant.

Community Phase Pathway 3.2a, from 3.2 to 3.1:
Time and lack of disturbance and/or grazing management that favor the establishment and growth of basin big sagebrush allows the shrub component to recover.

T3A: Transition from Shrub State 3.0 to Tree State 4.0:

Trigger: Time and a lack of disturbance or management action allows for Utah Juniper to dominate site. Singleleaf pinyon may be present or increasing. This may be coupled with grazing management that favors tree establishment by reducing understory herbaceous competition for site resources.

Slow variables: Over time the abundance and size of trees will increase.

Threshold: Trees dominate ecological processes and number of shrub skeletons exceed number of live shrubs.

T3B: Transition from Shrub State 3.0 to Annual State 5.0:

Trigger: To Community Phase 5.1: Lowering of the water table due to flow path incision and long-term drought results in an increase in dead basin bag sagebrush stands, allowing native and non-native annuals to increase and become dominant.

Slow variables: Development of flow path incisions and persistence of drought.

Threshold: Non-native annual forbs account for the majority of site productivity, while dead shrub stands outweigh live ones. Shrub cover has been reduced to a sub-dominant component, and sagebrush presence is greatly diminished across the site.

R3A: Restoration Pathway from Shrub State 3.0 to Current Potential 2.0:

Brush management and/or slow intensity fire decreases shrub cover, allowing for perennial grasses to increase in density.

R3B: Restoration Pathway from Shrub State 3.0 to Seeded State 6.0:

Brush management such as mowing, coupled with seeding of native or non-native deep-rooted perennial bunchgrasses.

Tree State 4.0:

This state is characterized by a dominance of Utah juniper and singleleaf pinyon in the overstory. Basin big sagebrush and perennial bunchgrasses may still be present, but they are no longer controlling site resources. Soil moisture, soil nutrients and soil organic matter distribution and cycling have been spatially and temporally altered.

Community Phase 4.1:

Utah juniper and/or singleleaf pinyon dominates the overstory and site resources. Trees are actively growing with noticeable leader growth. Trace amounts of bunchgrasses may be found under tree canopies with trace amounts of forbs in the interspaces. Sagebrush is stressed and dying. Recruitment of sagebrush cohorts is minimal. Annual non-native species are present under tree canopies. Bare ground interspaces are large and connected.

Loamy Bottom 8-12" P.Z. (R029XY003NV), Tree State 4.2, T. Stringham, May 2020

Community Phase Pathway 4.1a, from 4.1 to 4.2:
Time and lack of disturbance or management action allows for tree cover and density to further increase and trees to out-compete the herbaceous understory species for sunlight and water.

Community Phase 4.2:
Utah juniper and/or singleleaf pinyon dominates the site and tree leader growth is minimal; annual non-native species may be the dominant understory species and will typically be found under the tree canopies. Trace amounts of sagebrush may be present however dead skeletons will be more numerous than living sagebrush. Bunchgrasses may or may not be present. Bare ground interspaces are large and connected. Soil redistribution is evident.

Community Phase Pathway 4.2a, from 4.2 to 4.1:
Fire and/or brush management reduces tree cover and density allows increase in sagebrush cover. Perennial grasses increase with lesser presence of non-native and native annual species.

R4A: Restoration Pathway from Tree State 4.0 to Seeded State 6.0:

Tree removal with minimal soil disturbance strategies and seeding of desired species decreases tree cover and allows for increase of shrub and perennial grass productivity.

Annual State 5.0

This state has one community phase, a post-hydrologic degradation site, dominated by native and non- native annuals with shrubs reduced to minor component and an increase in dead stands.

Trigger: Hydrologic modification leading to a lowered water table and chronic growing season grazing facilitates an increase in big sagebrush and annual species.

Community Phase 5.1:
Non-native annual forbs and/or grasses or native annual forbs such as western tansymustard dominate. Basin big sagebrush and Wyoming big sagebrush may be the dominant overstory. Rabbitbrush may be a significant component. Basin wildrye and/or other perennial grasses trace to non-existent.

Community Phase Pathway 5.1a, from 5.1 to 5.2:
Severe fire or failed brush/seeding treatment reduces sagebrush cover to trace levels, promoting dominance of sprouting shrubs in the overstory and allowing non-native annual forbs and grasses, and/or native annual forbs such as western tansymustard to dominate the understory.

Community Phase 5.2:
Rabbitbrush and other sprouting shrubs are actively resprouting and dominate the overstory, while non-native annual forbs and grasses, and/or native annual forbs such as western tansymustard dominate the understory. Sagebrush is reduced to trace amounts or absent.

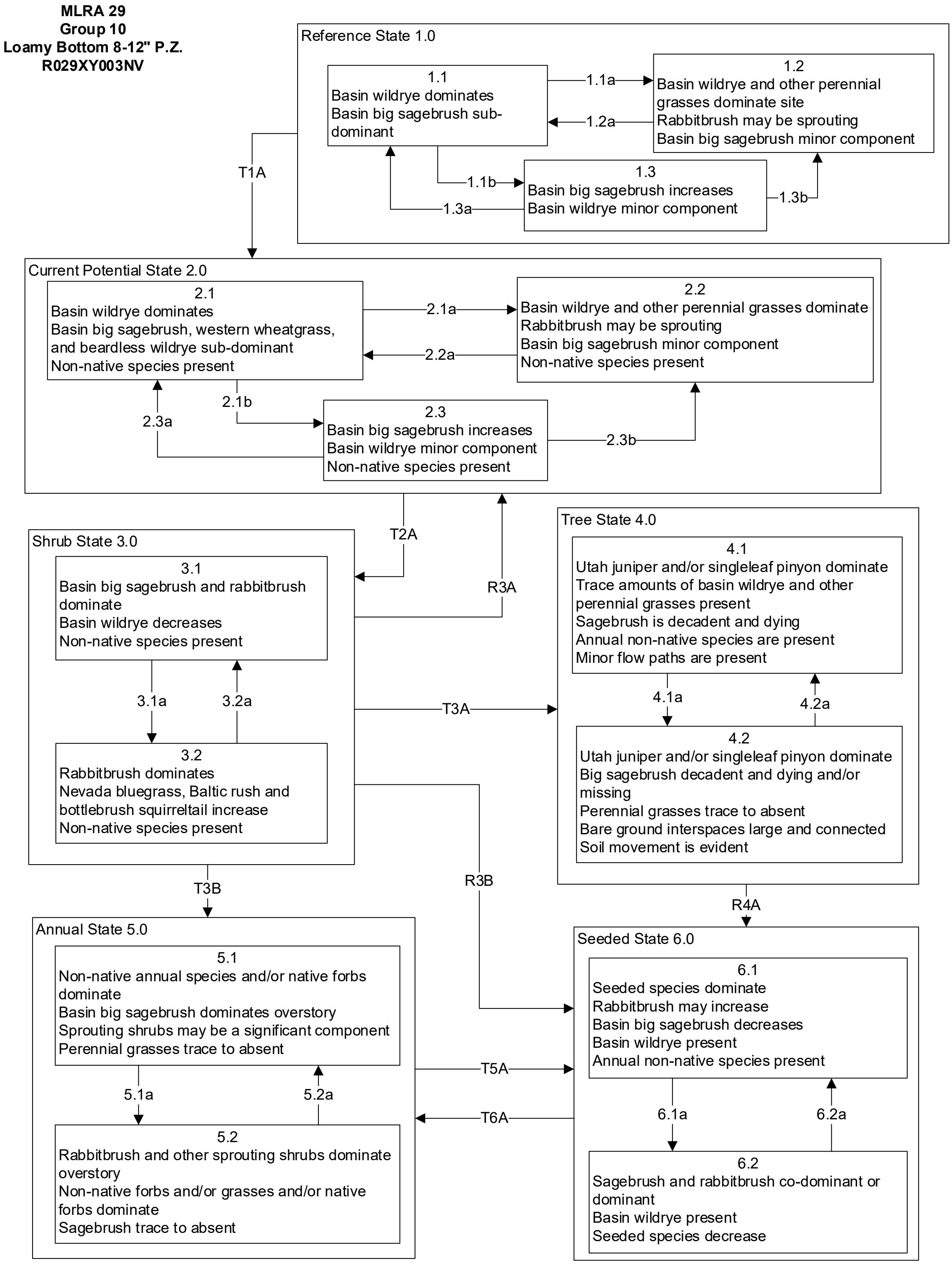
Community Phase Pathway 5.2a, from 5.2 to 5.1:
Time and lack of disturbance allows sagebrush component to recover and dominate the overstory. Non-native annual forbs and grasses, and/or native annual forbs such as western tansymustard continue to dominate the understory.


Loamy Bottom 8-12" P.Z. (R029XY003NV), Annual State 5.0, T. Stringham, June 2023

States Not Observed in Group 10:

Seeded State: While a Seeded State was not seen for this group, a similar ecological site Loamy Bottom 10-14" P.Z. (R028BY003NV) in MLRA 28 Group 9 (Stringham et al. 2015a) contains a Seeded State with two community phases: (1) a non-native perennial bunchgrass-dominated phase; (2) and a basin big sagebrush, rubber rabbitbrush-perennial bunchgrass, which are possible in this group.

Modal State and Transition Model for Group 10 in MLRA 29:



MLRA 29
Group 10
Loamy Bottom 8-12" P.Z.
R029XY003NV

Reference State 1.0 Community Phase Pathways
1.1a: Fire and/or Aroga moth significantly reduces sagebrush cover. Basin wildrye expands. Rabbitbrush and/or other sprouting shrubs may increase.
1.1b: Time and lack of disturbance such as fire, and/or long-term drought, and/or excessive herbivory will facilitate an increase in basin big sagebrush and a decline in basin wildrye.
1.2a: Time and lack of disturbance allows for shrub regeneration.
1.3a: A low severity fire, Aroga moth or combination would reduce the sagebrush overstory and create a basin wildrye dominate community with a small component of basin big sagebrush.
1.3b: Fire and/or a severe Aroga moth infestation will decrease or eliminate the overstory of sagebrush and allow for basin wildrye to dominate the site.

Transition T1A: Introduction of non-native species such as cheatgrass, mustards, halogeton and Russian thistle.

Current Potential State 2.0 Community Phase Pathways
2.1a: Fire creates grass/sagebrush mosaic. Aroga moth may also cause a large die-off in sagebrush; Basin wildrye expands; non-native annual species present.
2.1b: Time and lack of disturbance such as fire, and/or long-term drought, and/or excessive herbivory / grazing will facilitate an increase in basin big sagebrush and a decline in basin wildrye. Non-native species present.
2.2a: Time and lack of disturbance allows for regeneration of sagebrush
2.3a: Fire reduces sagebrush. Aroga moth infestation may create a sagebrush/grass mosaic. Brush management with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: A low severity fire, Aroga moth or combination would reduce the sagebrush overstory and create a basin wildrye dominate community with a small component of basin big sagebrush.

Transition T2A: Hydrologic alteration (lowering of water table i.e. gullying of associated channel), inappropriate grazing management or combinations (3.1). Fire (3.2).

Shrub State 3.0 Community Phase Pathways
3.1a: Fire and/or brush management with minimal soil disturbance.
3.2a: Time and lack of disturbance (not likely to occur).

Transition T3A: Time and lack of disturbance leads to encroachment of Pinyon and Juniper.
Transition T3B:Continual inappropriate grazing management and/or hydrologic alteration (i.e. gullying of associated channel). Severe fire, and/or failed brush management and seeding.

Restoration R3A: Brush management, such as mowing coupled with seeding of native or nonnative deep-rooted perennial bunchgrasses.
Restoration R3B: Brush management with minimal soil disturbance coupled with seeding of desired species (6.1).

Tree State 4.0 Community Phase Pathways
4.1a: Time and lack of disturbance allows for increase in tree cover.
4.2a: Fire and/or invasive species management increase sagebrush cover.

Restoration R4A: Tree removal with minimal soil disturbance coupled with seeding of desired species.

Annual State 5.0 Community Phase Pathways
5.1a: Severe fire or failed brush treatment and seeding.
5.2a: Time and lack of disturbance allows sagebrush to recover and dominate overstory.

Restoration R5A: Invasive species management with minimal soil disturbance coupled with seeding of desired species (6.1).

Seeded State 6.0 Community Phase Pathways (Not Observed, seen in similar site in MLRA 28B)
6.1a: Time and lack of disturbance; inappropriate grazing management may also reduce perennial understory.
6.2a: Fire, brush management, and/or Aroga moth infestation.

Transition T6A: Failed seeding and/or severe fire allows annual species to increase density.

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MLRA 29 Group 11: Calcareous soils with black sagebrush and needlegrasses

Description of MLRA 29 Disturbance Response Group 11

Disturbance Response Group (DRG) 11 consists of eleven ecological sites. The precipitation ranges from 6 in. to 14 in. Slopes range from 2 to 75% with less than 30% being typical. Elevation ranges from 4,500 to about 7,500 ft. Annual production for a normal year ranges from 125 to 600 lb/ac. Soils are formed from a variety of sources, including quartzite, limestone, lacustrine, travertine, volcanic rock, welded tuffs, and altered granitic rocks. These soils are typically calcareous or carbonatic and are often modified with high amounts of gravels, cobbles, or stones on the surface and throughout the profile. The available water holding capacity is very low to moderate. Soils are well-drained; runoff is slow to very high and the potential for sheet and rill erosion is moderate to high. The soil moisture regime is aridic and the soil temperature regime is mesic. The reference plant community for these sites varies depending on precipitation, elevation, and landform. The reference plant communities are dominated by black sagebrush (*Artemisia nova*), with sub-dominants of ephedra (*Ephedra nevadensis* and/or *Ephedra viridis*) or Stansbury's cliffrose (*Purshia stansburiana*). The perennial grass understory is dominated by Indian ricegrass (*Achnatherum hymenoides*), needle-and-thread grass (*Hesperostipa comata*), and desert needlegrass (*Achnatherum speciosum*). Other grasses important to these sites include galleta (*Pleuraphis jamesii*), sand dropseed (*Sporobolus cryptandrus*), and threeawn (*Aristida spp*.). Other shrub species include winterfat (*Krascheninnikovia lanata*), Fremont's mahonia (*Mahonia fremontii*), and broom snakeweed *(Gutierrezia sarothrae).* These sites also all carry a small amount of Utah juniper (*Juniperus osteosperma*) and/or singleleaf pinyon (*Pinus monophylla*).

Disturbance Response Group 11 Ecological Sites:

Shallow Calcareous Loam 8-12" P.Z. – Modal	R029XY008NV
Shallow Calcareous Slope 8-12" P.Z.	R029XY014NV
Shallow Calcareous Hill 10-14" P.Z.	R029XY081NV
Shallow Clay Loam 8-12" P.Z.	R029XY104NV
Shallow Calcareous Hill 8-10" P.Z.	R029XY015NV
Shallow Eroded Slope 8-10" P.Z.	R029XY168NV
Shallow Calcareous Loam 10-12" P.Z.	R029XY170NV
Stony Calcareous Hill 8-12" P.Z.	R029XY099NV
Stony Calcareous Slope 8-12" P.Z.	R029XY045NV
Travertine Bar	R029XY047NV
Limestone Slope 8-10" P.Z.	R029XY160NV

Modal Site:

The Shallow Calcareous Loam 8-12" P.Z. ecological site is the modal site that represents this DRG, as it has the most acres mapped. This site occurs on summits and sideslopes of fan piedmonts, hills, and lower mountains on all exposures. Slopes range from 2 to 50%, but slope gradients of 4 to 30% are most typical. Elevations range from 5,200 to 7,000 ft. Annual production ranges from 250 lb/ac in an unfavorable year to 700 lb/ac in a favorable year and is about 500 lb/ac in a normal year. Soils are often modified with high amounts of gravels, cobbles, or stones on the surface. These soils are moderately to strongly calcareous and soil reaction increases with soil depth. Some soils accumulate variable concentrations of salts and sodium in their lower substratum. Available water holding capacity is low to moderate. The shrub component is dominated by black sagebrush. Fourwing saltbush (*Atriplex canescens*), winterfat, and Nevada ephedra may also be present. The herbaceous component is dominated by Indian ricegrass and needle-and-thread. Galleta and Sandberg bluegrass are also present in minor amounts.

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasive species. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans a unique area in Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area. Flashy, summer storm events contribute significantly to annual precipitation as well. Air and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

Periodic drought regularly influences sagebrush ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West (Miller et al. 2008a). Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006).

Native insect outbreaks are also important drivers of ecosystem dynamics in sagebrush communities. Climate is generally believed to influence the timing of insect outbreaks especially a sagebrush defoliator, Aroga moth (*Aroga websteri*). Aroga moth infestations have occurred in the Great Basin in the 1960s, early 1970s, and is ongoing in Nevada since 2004 (Bentz et al. 2008). Thousands of acres of big sagebrush have been impacted, with partial to complete die-off observed. Aroga moth can partially or entirely kill individual plants or entire stands of big sagebrush (Furniss and Barr 1975), but the research is inconclusive of the damage sustained by black sagebrush populations.

The black sagebrush communities that dominate this DRG are characterized by high spatial and temporal variability in precipitation, both over years and within growing seasons. Nutrient availability is typically low but increases with elevation and closely follows moisture availability. The resource supporting the greatest amount of plant growth is usually water stored in the soil profile during the winter (Comstock and Ehleringer 1992). The invasibility of plant communities is often linked to resource availability. Disturbance can increase resources for invasive species through native species mortality or damage. Soil water and nutrient availability can increase with native species mortality and decomposition further aiding invasive species establishment. The invasion of sagebrush communities by cheatgrass (*Bromus tectorum*) has been linked to disturbances (fire, abusive grazing) that have resulted in fluctuations in resources (Chambers et al. 2007). The introduction of annual non-native species, like cheatgrass, may cause an increase in fire frequency. Conversely, increased fire return intervals, driven by inappropriate grazing management and fire suppression, facilitates an increase in woody species cover.

The ecological sites in this DRG are dominated by black sagebrush and cool-season, perennial bunchgrasses. Black sagebrush, the dominant shrub of this group, is a low growing, evergreen shrub with a flat-topped crown. It reaches heights of 4 to 20 in. tall and its leaves can be grayish to dark green. Black sagebrush is found primarily on shallow soils that are well drained, gravelly and often calcareous (Thatcher 1959, Hironaka 1963, Zamora and Tueller 1973). Community types with black sagebrush as the dominant shrub were found to have soil depths and available rooting depths of 77 to 81 cm (30 to 32 in.) in a study in northeast Nevada (Jensen 1990). As a generally long-lived species, it is not necessary for new individuals to recruit every year for perpetuation of the stand. Infrequent large recruitment events and simultaneous low, continuous recruitment is the foundation of population maintenance (Noy-Meir 1973). Survival of the seedlings is dependent on adequate moisture conditions. Black sagebrush usually inhabits sites intolerable for other sagebrush species, forming unique communities (Tilley and St. John 2012a). The species is also a tetraploid meaning that it contains four homologous sets of chromosomes. This causes the smaller stature and slow growth rate of black sagebrush and increases its resistance to drought (Mahalovich and McArthur 2004).

The primary deep-rooted, perennial grasses that are found on these sites include Indian ricegrass, needle-and-thread, and desert needlegrass. Galleta, a warm-season, shallow-rooted, rhizomatous, species occurs frequently. These species generally have somewhat shallower root systems than the shrubs, but root densities are often as high as or higher than those of shrubs in the upper 0.5 m of the soil profile. General differences in root depth distributions between grasses and shrubs result in resource partitioning in these shrub/grass systems.

Indian ricegrass, the dominant understory species of this group, is a long-lived, cool-season perennial bunchgrass that grows from 4 to 24 inches in height (Blaisdell and Holmgren 1984). Primarily adapted to coarse-textured soils, its deep, fibrous root system makes Indian ricegrass one of the most drought-tolerant native species (Booth et al. 1980). Unlike other cool-season species, Indian ricegrass does not require vernalization (exposure to cold) in order to produce flowers and flowering can continue into late fall with favorable environmental conditions. This allows the seeds in each panicle to ripen over a longer period of time than most other species thus providing a greater opportunity for successful seed production (Jones 1990).

Needle-and-thread is a cool-season, perennial bunchgrass most commonly found on well-drained soils (Miller et al. 2013). It ranges in height from 12 to 36 in. tall (Stubbendieck et al. 2003) and produces a widely-spreading, deep, and fibrous root system that allows it to capture moisture and nutrients effectively (Weaver 1958).

Desert needlegrass is a cool-season, perennial bunchgrass that grows 12 to 24 in. tall in large dense clumps (Sampson et al. 1951, Harrington 1954). It reproduces both sexually and asexually. This grass is pollinated by wind, and is capable of producing large amounts of seeds (Sampson et al. 1951). Reproduction is highly dependent on water availability; seed will not set if soil moisture is too low and temperatures are too high (Bertiller et al. 1991). Vegetative reproduction occurs with the annual growth of new tillers (Evert 2006). Awns catch on animal fur, which disseminates seeds (Kearney et al. 1960).

Galleta is a mat-forming, rhizomatous, native grass that is 11 to 19 in. tall (Stubbendieck et al. 2003). This warm-season, perennial species is more water efficient than its cool-season counterparts. This allows galleta grass to survive in low precipitation zones where a significant portion of rainfall occurs during summer months (Banner et al. 2011). Everett et al. (1980) found that galleta grass initiated more than one phenological cycle with the presence of summer precipitation, allowing the species to grow and set seed more than once. This plant is typical of southern Nevada and the transition zone between the Great Basin and the Mojave Desert. It is most common in fine-textured soils (Stubbendieck et al. 2003).

Infilling and expansion by singleleaf pinyon and Utah juniper has been occurring since the late 1800s due to changes in climate, grazing and fire (Miller et al. 2019). Without disturbance, singleleaf pinyon and Utah juniper will dominate the site and out-compete other species for resources severely reducing both the shrub and herbaceous understory (Lett and Knapp 2005, Miller et al. 2019). However, bluegrasses may remain underneath trees on north-facing slopes. The potential for soil erosion increases as tree cover increases and the understory plant community cover declines (Pierson et al. 2010).

Annual Invasive Species:

The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species resulting in reduced competition while simultaneously increasing resource pools through the decomposition of dead plant material. Historically, black sagebrush communities were free of exotic invaders; however, excessive grazing pressure during settlement and into the 20th century has increased the overall presence of cheatgrass, red brome (*Bromus rubens*), halogeton (*Halogeton glomeratus*), Russian thistle (*Salsola tragus*) and weedy mustard species (Brassicaceae family) (Peters and Bunting 1994). The presence of non-native annual plants within these ecosystems decreases ecosystem resilience and resistance to disturbance through competition for limited resources.

Russian thistle is a tap-rooted, C4 photosynthesis (warm-season) annual forb, introduced from southeastern Europe and central Asia. The seeds have a remarkable capability to germinate in a variety of soil temperatures and very little precipitation and even move back into dormancy after initial germination (Wallace et al. 1968). The seeds, however, are not persistent and generally remain viable in the seed bank for less than two years (Boerboom 1993, Young et al. 1995). Russian thistle has been observed to provide initial establishment in completely de-vegetated sites and create a microsite habitat that may allow increased establishment of other species (Allen and Allen 1988). The successful establishment of other species, particularly later seral species that form mycorrhizal associations, may reduce the cover of Russian thistle as mycorrhizal inoculation has been observed to reduce the size and vigor of Russian thistle while encouraging later seral species such as perennial bunchgrasses (Johnson 1998a).

Halogeton is an introduced, succulent annual, native to semi-desert lands in the Altai region of central Asia (Tisdale and Zappetini 1953). It possesses a strong tap root that penetrates 4 to 5 in. and an extensive root system spanning up to 2 ft in lateral spread and depth (Tisdale and Zappetini 1953). Halogeton is characterized by its small fleshy leaves that can appear slightly red or purple as the plant matures. This plant can produce as many as 25,000 seeds, while typical plant sizes of about 3 in. can produce up to 800 seeds. These seeds are spread primarily through fruit ingestion and fruit movement, but can also be spread through wind (Tisdale and Zappetini 1953). Halogeton is well adapted to alkaline and saline soils and is prevalent on disturbed and overgrazed sites. The plants accumulate salt that can leach from dead plant materials, increasing the soil salinity in topsoil, which favors continued germination and spread in invaded sites (Cronin and Williams 1966).

Cheatgrass is a cool-season annual grass that maintains an advantage over native plants, in part, because it is a prolific seed producer, can germinate in the autumn or spring, tolerates grazing, and increases with frequent fire (Klemmedson and Smith 1964, Miller et al. 1994). Cheatgrass originated from Eurasia and was first reported in North America in the late 1800s (Furbush 1953, Mack and Pyke 1983). Bradley et al. (2018) found that cheatgrass has expanded to greater than 15% cover over 210,000 km^2 (over 50 million acres), which is roughly 31% of the Intermountain West. In the Great Basin, cheatgrass is expanding at a rate of expansion of 3,700 km^2 (roughly 914,000 ac) annually and is a land management issue that will require creative solutions (Smith et al. 2022).

Mapping potential or current invasion vectors is a management method designed to increase the cost-effectiveness of control methods. Recent modeling and empirical work by Bradford and Lauenroth (2006) suggest that seasonal patterns of precipitation input and temperature are also key factors determining regional variation in the growth, seed production, and spread of invasive annual grasses. The phenomenon of cheatgrass "die-off" provides opportunities for restoration of perennial native species (Baughman et al. 2016, Baughman et al. 2017). The causes of these events are not fully understood, but there is ongoing work to try to predict where they occur, in the hopes of aiding conservation planning (Weisberg et al. 2017, Brehm 2019).

Methods to control cheatgrass include herbicide, targeted grazing, and seeding. Spraying with herbicide (imazapic or imazapic + glyphosate) and seeding with crested wheatgrass (*Agropyron cristatum*) and Sandberg bluegrass (*Poa secunda*) has been found to be more successful at combating cheatgrass and medusahead (*Taeniatherum caput-medusae*) than spraying alone (Sheley et al. 2012). To date, most seeding success has occurred with non-native wheatgrass species. Perennial grasses, especially crested wheatgrass, are able to suppress cheatgrass growth when mature (Blank et al. 2020). Butler et al. (2011) tested four herbicides (imazapic, imazapic + glyphosate, rimsulfuron, and sulfometuron + chlorsulfuron) for suppression of cheatgrass, medusahead, and ventenata (*Ventenata dubia*) within residual stands of native bunchgrass. Additionally, they tested the same four herbicides followed by seeding of six bunchgrasses (native and non-native) with varying success (Butler et al. 2011). Herbicide-only treatments appeared to remove competition for established bluebunch wheatgrass (*Pseudoroegneria spicata*) by providing 100% control of ventenata and medusahead and greater than 95% control of cheatgrass (Butler et al. 2011). Clements et al. (2022) found that imazapic successfully reduced cheatgrass on study plots by 95% and subsequent seeding efforts with native and non-native species produced an average of 4.8 perennial grasses per square meter (0.45 perennial grasses per square foot)

Indaziflam, a relatively new herbicide for rangeland applications, is showing promise in its ability to control cheatgrass, red brome, medusahead, ventenata, and halogeton. Approved for rangelands in 2016, this pre-emergent herbicide works by inhibiting cell wall biosynthesis and therefore seed germination and root elongation (Kaapro and Hall 2012, Clark et al. 2019). Indaziflam effectively reduces the seed bank of invasive annuals with little to no effect on aboveground plant communities (Courkamp et al. 2022). It also has been proven to control invasive annuals longer than other herbicides, providing 3 or more years of control (Sebastian et al. 2017b). Sebastian et al. (2017b) found that indaziflam selectively controlled cheatgrass without impacting perennial grass and forb biomass as well. This led to significant increases in biomass of desirable species due to reductions in cheatgrass presence and competition (Sebastian et al. 2017b). Clark et al. (2019) found a similar result on plots in Colorado suggesting that indaziflam may be the best new herbicide on the market for invasive annual control.

Targeted cattle grazing during the fall and winter can also control cheatgrass on invaded sites. Fall and winter grazing decreases standing dead biomass and reduces fuel continuity with minimal risk to native perennial herbaceous plants (Davies et al. 2016). This alters fire risk and severity by reducing fuel loads, flame height, rate of spread and area burned in Great Basin sagebrush systems (Davies et al. 2015a). Repetitive fall grazing can also reduce cheatgrass seed banks, however, the seed bank can rapidly recover if fall grazing efforts cease (Perryman et al. 2020).

Fire Ecology:

Historically, black sagebrush plants have no morphological adaptations for surviving fire and must reestablish from seed (Wright et al. 1979). Fire return intervals in black sagebrush ecosystems have been estimated at 100 to 200 years (Kitchen and McArthur 2007); however, fires were probably patchy and very infrequent due to the low productivity of these sites. The ability of black sagebrush to establish after fire is mostly dependent on the amount of seed deposited in the seed bank the year before the fire. Seeds typically do not persist in the soil for more than one growing season (Beetle 1960). A few seeds may remain viable in soil for two years (Meyer 2008a); however, even in dry storage, black sagebrush seed viability has been found to drop rapidly over time, from 1% to 81% viability after 2 and 10 years of storage, respectively (Stevens et al. 1981). Thus, repeated frequent fires can eliminate black sagebrush from a site, however black sagebrush in zones receiving 12 to 16 in. of annual precipitation has been found to have greater fire survival (Boltz 1994). In lower precipitation zones, broom snakeweed, Stansbury cliffrose, yellow rabbitbrush (*Chrysothamnus viscidiflorus*), and/or ephedra may become the dominant shrub species following fire often with an understory of galleta, sand dropseed, Sandberg bluegrass, and/or invasive annual forbs or grasses.

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The condition of bunchgrasses along with seasonality and intensity of the fire all factor into the individual species' response. Thus, fire mortality is correlated to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant, and abundance of old growth (Wright 1971, Young 1983). Boyd et al. (2015) found soil color and depth of burn to be accurate predictors of bunchgrass mortality in post fire landscapes. They also found that bunchgrasses in close proximity of shrubs had up to five-fold higher mortality than bunchgrasses located in the interspaces (Boyd et al. 2015). The two dominant grasses on this site, Indian ricegrass and needle-and-thread grass, have different responses to fire.

Indian ricegrass is fairly fire tolerant (Wright 1985), which is likely due to its low culm density and below-ground plant crowns. Vallentine (1989) cites several studies in the sagebrush zone that classified Indian ricegrass as being slightly damaged from late summer burning. Indian ricegrass has also been found to reestablish on burned sites through seeds dispersed from adjacent unburned areas (Young 1983, West 1994). Thus, the presence of surviving, seed-producing plants facilitates the reestablishment of Indian ricegrass. Grazing management following fire to promote seed production and establishment of seedlings is important. When properly managed, Indian ricegrass can be a key factor in a community recovering from disturbance because it can grow in rough, rocky, coarse, and otherwise unproductive soils (Booth et al. 1980).

Needle-and-thread, contrary to Indian ricegrass, is considered sensitive to fire (Akinsoji 1988, Bradley et al. 1992, Miller et al. 2013). Needle-and-thread is top-killed by fire but is likely to resprout if fire does not consume above-ground stems (Akinsoji 1988, Bradley et al. 1992). In a study by Wright and Klemmedson (1965), season of burn rather than fire intensity seemed to be the crucial factor in mortality for needle-and-thread. Early summer season burning was observed to kill the plants while August burning had no effect. Thus, under late season wildfire scenarios, needle-and-thread is often present in the post-burn community.

Galleta grass, a minor component of these ecological sites, has been found to increase following fire likely due to its rhizomatous root structure and ability to resprout (Jameson 1962). Sandberg bluegrass, another minor component of these ecological sites, has also been found to increase following fire likely due to its low stature, early dormancy, and low productivity (Daubenmire 1975). Both grass species may retard reestablishment of deeper-rooted bunchgrasses. Repeated frequent fire in this community will eliminate black sagebrush, significantly decrease deep-rooted bunchgrass density and facilitate the establishment of an annual weed community with varying amounts of galleta, Sandberg bluegrass, and sprouting shrubs.

Utah juniper and singleleaf pinyon mortality in burned stands is a function of fire weather, fuel structure, and continuity (Miller et al. 2019). Both species are most vulnerable to fire when under 4 ft tall, however, mortality of trees over 6 ft tall is unlikely except under extreme fire weather conditions or when sufficient ladder fuels are present (Dwyer and Pieper 1967, Wright et al. 1979, Bradley et al. 1992, Miller et al. 2013). Larger juniper trees, because they have foliage farther from the ground and thicker bark, can survive low severity fires but mortality does occur when 60% or more of the crown is scorched (Bradley et al. 1992). Singleleaf pinyon mature trees do not self-prune their dead branches allowing for accumulated fuel in the crowns. This characteristic and the relative flammability of the foliage make individual mature trees more susceptible to fire than juniper (Bradley et al. 1992). However, high severity fires were not likely in this community in its reference condition due to low production of understory vegetation and low density of trees per acre (Bradley et al. 1992, Miller and Tausch 2001).

Infilling and expansion by singleleaf pinyon and Utah juniper has been occurring since the late 1800s due to changes in climate, grazing and fire (Miller et al. 2019). Without disturbance, singleleaf pinyon and Utah juniper will dominate the site and out-compete other species for resources severely reducing both the shrub and herbaceous understory (Lett and Knapp 2005, Miller et al. 2019). However, grasses may remain underneath trees on north-facing slopes. The potential for soil erosion increases as tree cover increases and the understory plant community cover declines (Pierson et al. 2010).

Livestock/Wildlife Grazing Interpretations:

Black sagebrush palatability has been rated as moderate to high depending on the ungulate and the season of use (Horton 1989, Wambolt 1996). Pronghorn utilize black sagebrush heavily (Beale and Smith 1970). On the Desert Experiment Range, black sagebrush was found to comprise 68% of pronghorn diet even though it was only the third most common plant. Fawns were found to prefer black sagebrush utilizing it more than all other forage species combined (Beale and Smith 1970). Domestic livestock will also utilize black sagebrush. The domestic sheep industry that emerged in the Great Basin in the early 1900s was largely based on wintering domestic sheep in black sagebrush communities (Mozingo 1987c). Domestic sheep will browse black sagebrush during all seasons of the year depending on the availability of other forage species, with greater amounts being consumed in fall and winter. Black sagebrush is generally less palatable to domestic cattle than to domestic sheep and wild ungulates (McArthur et al. 1979). However, cattle use of black sagebrush has also been shown to be greatest in fall and winter (Schultz and McAdoo 2002), with only trace amounts being consumed in summer (Van Vuren 1984). Dormant season use of black sagebrush can reduce sagebrush density and increase the density of bunchgrasses such as Indian ricegrass. Heavy use of black sagebrush can reduce the density of the shrub while increasing winterfat and/or rabbitbrush. Following wildfire, surviving black sagebrush plants may experience increased herbivory with potential negative impacts (Wambolt 1996).

Indian ricegrass is a preferred forage species for livestock and wildlife and cures well, providing nutritious winter feed (Cook et al. 1962, Booth et al. 1980). It is also readily utilized in early spring, being a source of green feed before most other perennial grasses have produced new growth (Quinones 1981). Booth et al. (1980) note that the plant does well when utilized in winter and spring. In eastern Idaho, productivity of Indian ricegrass was at least 10 times greater in undisturbed plots than in heavily (60% utilization) grazed ones (Pearson 1965). Cook and Child (1971) found significant reduction in crown cover, plant vigor and herbage yield of Indian ricegrass when the species was utilized at 90% during any season. However, they found minimal reductions at 30% utilization during any season and at 60% utilization during winter and early spring grazing (Cook and Child 1971). The seed crop may be reduced where grazing is heavy (Bich et al. 1995). Tolerance to grazing increases after May, thus spring deferment may be necessary for stand enhancement (Pearson 1964, Cook and Child 1971); however, utilization of less than 60% is recommended. In summary, adaptive management is required to manage this bunchgrass well.

Needle-and-thread grass is not grazing tolerant and will be one of the first grasses to decrease under heavy grazing pressure during the growing season (Smoliak et al. 1972, Tueller and Blackburn 1974). Heavy grazing (greater than 60% utilization) is likely to reduce basal area of these plants (Smoliak et al. 1972). With the reduction in competition from deep-rooted perennial bunchgrasses, the rhizomatous galleta grass and short-statured Sandberg bluegrass will likely increase (Jameson 1962, Smoliak et al. 1972). However, needle-and-thread cures well and provides good forage to livestock during fall and winter months if overgrazing does not occur (Stubbendieck et al. 2003).

Galleta, a warm-season grass, is a highly palatable forage species for cattle, sheep, deer, antelope, and horses during late spring and summer while it is green (Stubbendieck et al. 2017). Once the plant cures and its palatability declines to poor domestic livestock will not utilize it unless more palatable species are unavailable (USFS 1937). Due to its rhizomatous characteristics, galleta is particularly tolerant of heavy grazing and trampling (Pratt et al. 2002). This species will also initiate more than one phenological cycle if summer precipitation is present (Everett et al. 1980), allowing galleta to regrow and propagate after defoliation.

Inappropriate grazing management during the spring growing season will cause a decline in understory plants such as Indian ricegrass and needle-and-thread. Growing season grazing by cattle several years in a row causes a decrease in the bunchgrass component and gives a competitive advantage to shrub species including black sagebrush (Eckert et al. 1972). Reduced bunchgrass vigor or density provides an opportunity for galleta and/or Sandberg bluegrass expansion and/or cheatgrass and other invasive species such as halogeton or Russian thistle to occupy interspaces. Galleta and/or Sandberg bluegrass increases under grazing pressure (Jameson 1962, Tisdale and Hironaka 1981) and is capable of co-existing with cheatgrass. Increased cheatgrass cover leads to increased fire frequency and potentially an annual plant community. Thus, depending on the season of use, the type of grazing animal, and site conditions, either galleta, Sandberg bluegrass or invasive annual grass or forbs may become the dominant understory with inappropriate grazing management.

State and Transition Model Narrative for Group 11:

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 29 Disturbance Response Group 11.

Reference State 1.0:

The Reference State is a representative of the natural range of variability under pristine conditions. The Reference State has three general community phases; a shrub-grass dominant phase, a shrub dominant phase and a grass dominant phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire, periodic drought and/or insect or disease attack. Due to the nature and extent of disturbance in this site, all three plant community phases would likely occur in a mosaic across the landscape. Utah juniper or singleleaf pinyon may be present on the site, but will only occur as scattered trees and will not dominate the site.

Community Phase 1.1:
Black sagebrush dominates the overstory with Indian ricegrass and needle-and-thread grass dominant in the understory. Galleta, Sandberg bluegrass and other perennial grasses may be present. Forbs are a minor component. Utah juniper or singleleaf pinyon may be present. Approximate vegetative composition by air-dry weight is 50% grasses, 5% forbs and 45% shrubs. Approximate ground cover (basal and crown) is 20 to 30%. Total annual air-dry production ranges from 250 to 700 lb/ac.

Shallow Calcareous Loam 8-12" P.Z. (R029XY008NV), Reference State 1.1, T. Stringham, May 2021

Shallow Calcareous Slope 8-12" P.Z. (R029XY014NV), Reference State 1.1, T. Stringham, May 2020

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
A low severity fire would decrease the sagebrush overstory and allow for understory perennial grasses to increase. Fires are infrequent and typically low severity resulting in a mosaic pattern due to low fuel loads. A fire following an unusually wet spring, facilitating an increase in fine fuels, may be more severe and reduce sagebrush cover to trace amounts creating an early-seral community, dominated by grass.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.3:
Time and lack of disturbance such as fire allows black sagebrush to increase and become decadent. Long-term drought, herbivory, or combinations of these will cause a decline in perennial bunchgrasses and fine fuels leading to a reduced fire frequency and allowing sagebrush to dominate the site.

Community Phase 1.2:
This community phase is characteristic of a post-disturbance, early seral community phase. Indian ricegrass, needle-and-thread and other perennial bunchgrasses dominate. Sprouting shrubs such as yellow rabbitbrush and ephedra may increase. Black sagebrush could still be present in unburned patches. Forbs may increase post-fire but will likely return to pre-burn levels within a few years. Galleta will generally increase following fire.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
Time and lack of disturbance will allow sagebrush to re-establish.

Community Phase 1.3:
Black sagebrush increases in the absence of disturbance. Decadent sagebrush dominates the overstory and the deep-rooted perennial bunchgrasses in the understory are reduced either from competition with shrubs and/or herbivory. Sandberg bluegrass

and/or galleta may increase in the understory and become the co-dominant with deep rooted bunchgrasses. Scattered Utah juniper and singleleaf pinyon may be present on the site.

Shallow Calcareous Slope 8-12" P.Z. (R029XY014NV), Reference State 1.3, T. Stringham, May 2021

Community Phase Pathway 1.3a, from Phase 1.3 to 1.1:
A low severity fire, herbivory, or combinations will reduce the sagebrush overstory and create a sagebrush/grass mosaic.

Community Phase Pathway 1.3b, from Phase 1.3 to 1.2:
Fire will decrease or eliminate the overstory of sagebrush and allow for the perennial bunchgrasses to dominate the site. Fires will typically be high intensity, driven by severe fire weather and the dominance of sagebrush resulting in removal of the overstory shrub community.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0

Trigger: Introduction of non-native annual plants.

Slow variables: Over time the annual non-native plants will increase within the community.

Threshold: Any amount of invasive non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

This state is similar to the Reference State 1.0 with the same three community phases. Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of invasive non-native annuals. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal. Additionally, the presence of highly flammable, non-native species reduces State resilience because these species can promote fire where historically fire has been infrequent, leading to positive feedbacks that further the degradation of the system.

Community Phase 2.1:
This community phase is compositionally similar to the Reference State Community Phase 1.1 with the presence of non-native species in trace amounts. This community is dominated by black sagebrush in the overstory with Indian ricegrass and needle-and-thread grass dominant in the understory. Annual non-native species are present and Utah juniper, singleleaf pinyon and seeded species may be present.

Stony Calcareous Hill 8-12" P.Z. (R029XY099NV), Current Potential 2.1, T. Stringham, May 2020

Stony Calcareous Slope 8-12" P.Z. (R029XY045NV), Current Potential 2.1, T. Stringham, May 2020

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
A low severity fire would decrease the overstory of sagebrush and allow for the understory perennial grasses to increase. Fires are typically low severity resulting in a mosaic pattern due to low fuel loads. A fire following an unusually wet spring or a change in management favoring an increase in fine fuels may be more severe and reduce sagebrush cover to trace amounts. Inappropriate sheep grazing may also reduce the black sagebrush component. Annual non-native species are likely to increase after fire.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.3:
Absence of disturbance over time, chronic drought, inappropriate grazing by cattle or horse's or combinations of these would allow black sagebrush to dominate. Inappropriate grazing management reduces the perennial bunchgrass understory; conversely galleta and/or Sandberg bluegrass may increase.

Community Phase 2.2:
This community phase is characteristic of a post-disturbance, early seral community where annual non-native species are present. Sagebrush is present in trace amounts; perennial bunchgrasses and sprouting shrubs dominate the site. Depending on fire severity patches of intact sagebrush may remain. Rabbitbrush or other sprouting shrubs may be increasing. Annual non-native species are stable or increasing within the community. Galleta will generally increase following fire as well. Seeded species may be present.

Shallow Calcareous Loam 8-12" P.Z. (R029XY008NV), Current Potential 2.2, T. Stringham, May 2020

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Absence of disturbance over time and/or grazing management that favors the establishment and growth of black sagebrush allows the shrub component to recover. The establishment of black sagebrush can take many years.

Community Phase 2.3 (At Risk):
Black sagebrush dominates the overstory and perennial bunchgrasses in the understory are reduced, either from competition with shrubs or from inappropriate grazing, or from both. Rabbitbrush may be a significant component. Galleta and/or Sandberg bluegrass may increase and become co-dominant with deep-rooted bunchgrasses. Utah juniper and singleleaf pinyon may be present and without management will likely increase. Annual non-natives species may be stable or increasing due to lack of competition with perennial bunchgrasses. Seeded species may be present. This site is susceptible to further degradation from grazing, drought, and fire. This community is at risk of crossing a threshold to either a Shrub State 3.0 (grazing or fire) or an Annual State 4.0 (fire).

Shallow Calcareous Loam 8-12" P.Z. (R029XY008NV), Current Potential 2.3, T. Stringham, May 2020

Shallow Calcareous Hill 10-14" P.Z. (R029XY081NV), Current Potential 2.3, T. Stringham, May 2020

Shallow Eroded Slope 8-10" P.Z. (R029XY168NV), Current Potential 2.3, T. Stringham, May 2021

Community Phase Pathway 2.3a, from Phase 2.3 to 2.1:
Grazing management that reduces shrubs will allow for the perennial bunchgrasses in the understory to increase. Heavy late-fall/winter grazing by cattle that causes mechanical damage to sagebrush, or spring grazing by sheep of black sagebrush promotes the perennial bunchgrass understory. Brush treatments with minimal soil disturbance will also decrease sagebrush and release the perennial understory. Annual non-native species are present and may increase in the community. A low severity fire would decrease the overstory of sagebrush and allow for the understory perennial grasses to increase.

Community Phase Pathway 2.3b, from Phase 2.3 to 2.2:
Fire will decrease or eliminate the overstory of black sagebrush and allow for the perennial bunchgrasses to dominate the site. Severe fire weather combined with the dominance of black sagebrush results in a high intensity fire leading to the removal of the overstory shrub community. Annual non-native species respond well to fire and may increase post-burn.

T2A: Transition from Current Potential State 2.0 to Shrub State 3.0

Trigger: To Community Phase 3.1: Inappropriate cattle/horse grazing will decrease or eliminate deep-rooted perennial bunchgrasses, increase bottlebrush squirreltail, Sandberg bluegrass and/or galleta and favor shrub growth and establishment. To Community Phase 3.2: Severe fire will remove black sagebrush overstory, decrease perennial bunchgrasses and enhance squirreltail (*Elymus elymoides*), galleta and/or Sandberg bluegrass. Soil disturbing brush treatments and/or inappropriate sheep grazing will reduce black sagebrush and potentially increase sprouting shrubs and bottlebrush squirreltail, Sandberg bluegrass and/or galleta grass.

Slow variables: Long term decrease in deep-rooted perennial grass density and/or black sagebrush.

Threshold: Loss of deep-rooted perennial bunchgrasses changes nutrient cycling, nutrient redistribution, and reduces soil organic matter. Loss of long-lived, black sagebrush changes the temporal distribution, and depending on the replacement shrub, the spatial distribution of nutrient cycling.

T2B: Transition from Current Potential State 2.0 to Tree State 5.0

Trigger: Absence of disturbance over time allows for Utah juniper or singleleaf pinyon dominance.

Feedbacks and ecological processes: Trees increasingly dominate use of soil water resulting in decreasing herbaceous and shrub production and decreasing organic matter inputs, contributing to reductions in soil water availability to grasses and shrubs and increased soil erodibility.

Slow variables: Long term increase in Utah juniper and/or singleleaf pinyon density.

Threshold: Trees overtop black sagebrush and out-compete shrubs for water and sunlight. Shrub skeletons exceed live shrubs in number. There is minimal recruitment of new shrub cohorts. Litter builds up underneath trees while bare ground increases in interspaces; this changes nutrient cycling and levels of organic matter in the soil. Redistribution of soil, organic matter and nutrients may occur with water and wind erosion.

T2C: Transition from Current Potential State 2.0 to Annual State 4.0

Trigger: Catastrophic fire and/or severe soil surface disturbance.

Slow variables: Increased production and cover of non-native annual species.

Threshold: Loss of deep-rooted perennial bunchgrasses and shrubs changes energy and nutrient capture and cycling both spatially and temporally within the community. Increased, continuous fine fuels modify the fire regime by changing intensity, size and spatial variability of fires.

Shrub State 3.0:

This state has two community phases in which the overstory is dominated by either black sagebrush or sprouting shrubs such as rabbitbrush, broom snakeweed, and/or ephedra. Squirreltail, Sandberg bluegrass or galleta dominates the understory. A site in this state has crossed a biotic threshold and site processes are being controlled by shrubs. Site resources such as soil water, nutrient capture, nutrient cycling, and soil organic matter are temporally and spatially redistributed by the vegetation composition. Bare ground has increased and pedestalling of grasses may be excessive.

Community Phase 3.1 (At Risk):
Black sagebrush dominates overstory while bottlebrush squirreltail, Sandberg bluegrass or galleta dominates the understory. Deep-rooted perennial bunchgrasses have significantly declined. Annual non-native species may be present. Bare ground and soil redistribution may be increasing. If present on the site, Utah juniper and/or singleleaf pinyon is increasing. The community phase may be at risk of transitioning into a Tree State 5.0 or Annual State 4.0.

Shallow Calcareous Loam 8-12" P.Z. (R029XY008NV), Shrub State 3.1, T. Stringham, May 2020

Shallow Calcareous Hill 10-14" P.Z. (R029XY081NV), Shrub State 3.1 at Risk of Tree State, T. Stringham, May 2020

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:
Fire or brush treatments that reduces black sagebrush to trace amounts and allows for sprouting shrubs such as rabbitbrush, broom snakeweed, and/or ephedra to dominate. Inappropriate or excessive sheep grazing could also reduce cover of black sagebrush and allow for sprouting shrubs to dominate the community.

Community Phase 3.2 (At Risk):
Rabbitbrush, broom snakeweed, and/or ephedra dominate the overstory while bottlebrush squirreltail, galleta, Sandberg bluegrass and/or sand dropseed dominate the understory. Annual non-native species may be increasing and bare ground is significant. This site is at risk for an increase in invasive annual weeds. This community phase is at risk of transitioning to an Annual State 4.0.

Shallow Calcareous Loam 8-12" P.Z. (R029XY008NV), Shrub State 3.2, T. Stringham, June 2020

Shallow Calcareous Slope 8-12" P.Z. (R029XY014NV), Shrub State 3.2, T. Stringham, May 2021

Community Phase Pathway 3.2a, from Phase 3.2 to 3.1:
Time and lack of disturbance and/or grazing management that favors the establishment and growth of black sagebrush allows for the shrub component to recover. The establishment of black sagebrush may not occur or may take many years.

T3A: Transition from Shrub State 3.0 to Tree State 5.0

Trigger: Absence of disturbance over time allows for Utah juniper and/or singleleaf pinyon dominance.

Feedbacks and ecological processes: Trees increasingly dominate use of soil water resulting in decreasing herbaceous and shrub production and decreasing organic matter inputs, contributing to reductions in soil water availability to grasses and shrubs and increased soil erodibility.

Slow variables: Long-term increase in juniper and/or singleleaf pinyon density.

Threshold: Trees overtop black sagebrush and out-compete shrubs for water and sunlight. Shrub skeletons exceed live shrubs in number. There is minimal recruitment of new shrub cohorts. Litter builds up underneath trees while bare ground increases in interspaces; this changes nutrient cycling and levels of organic matter in the soil.

R3A: Restoration from Shrub State 3.0 to Seeded State 6.0:

Seeding of deep-rooted introduced bunchgrasses and other desired species; may be coupled with brush management and/or herbicide. Probability of success is low.

T3B: Transition from Shrub State 3.0 to Annual State 4.0

Trigger: Fire or treatments that disturb the soil and existing plant community (ex: failed restoration attempts).

Slow variables: Increased seed production and cover of annual non-native species.

Threshold: Increased, continuous fine fuels modify the fire regime by changing intensity, size and spatial variability of fires. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and sagebrush truncate energy capture and impact the nutrient cycling and distribution.

Annual State 4.0:

This state has two community phases, one is dominated by annual non-native species and the other is co-dominated by annual non-natives and sprouting shrubs. In this state, a biotic threshold has been crossed and state dynamics are driven by the dominance and persistence of the invasive annual grass community which is perpetuated by a shortened fire return interval fire. The herbaceous understory is dominated by annual non-native species such as cheatgrass, red brome, halogeton, Russian thistle, and mustards. Resiliency has declined and further degradation from fire facilitates a cheatgrass, weedy forb, and sprouting shrub plant community. Fire return interval has shortened due to the dominance of cheatgrass in the understory and is a driver in site dynamics.

Community Phase 4.1:
Cheatgrass, Russian thistle, halogeton and other annuals dominate the site. Sprouting shrubs may be present and soil redistribution may be significant. Seeded species may also be present if resulting from a failed seeding attempt.

Shallow Calcareous Loam 8-12" P.Z. (R029XY008NV), Annual State 4.1, D. Snyder, September 2020

Stony Calcareous Slope 8-12" P.Z. (R029XY045NV), Annual State 4.1, D. Snyder, September 2020

Community Phase Pathway 4.1a, from Phase 4.1 to 4.2:
Time and lack of fire allows for sprouting shrubs to become co-dominate with the annual non-native species. Probability of black sagebrush establishment is extremely low.

Community Phase 4.2
Sprouting shrubs such as rabbitbrush, broom snakeweed, and/or ephedra are co-dominate with annual non-native species. Soil redistribution may be significant and seeded grass and forb species may be present in trace amounts.

Shallow Calcareous Loam 8-12" P.Z. (R029XY008NV), Annual State 4.2, T. Stringham, May 2020

Shallow Calcareous Slope 8-12" P.Z. (R029XY014NV), Annual State 4.2, T. Stringham, May 2021

Community Phase Pathway 4.2a, from Phase 4.2 to 4.1:
Fire reduces/eliminates overstory brush component and allows for annual non-native species to dominate the site.

Tree State 5.0:

This state has two community phases that are characterized by a dominance of Utah juniper and/or singleleaf pinyon in the overstory. Singleleaf pinyon may play a significant role in the higher elevation ranges within this site. Black sagebrush and perennial bunchgrasses may still be present, but they are no longer controlling site resources. Soil moisture, soil nutrients and soil organic matter distribution and cycling have been spatially and temporally altered.

Community Phase 5.1:
Utah juniper and/or singleleaf pinyon dominate overstory. Black sagebrush is decadent and dying and deep-rooted perennial bunchgrasses are significantly decreased. Recruitment of black sagebrush cohorts is minimal. Annual non-natives may be present or increasing. Bare ground interspaces are large and connected.

Shallow Calcareous Hill 10-14" P.Z. (R029XY081NV), Tree State 5.1, T. Stringham, May 2020

Shallow Clay Loam 8-12" P.Z. (R029XY104NV), Tree State 5.1, T. Stringham, May 2021

Stony Calcareous Slope 8-12" P.Z. (R029XY045NV), Tree State 5.1, D. Snyder, September 2020

Shallow Calcareous Loam 10-12" P.Z. (R029XY170NV), Tree State 5.1, T. Stringham, June 2020

Community Phase Pathway 5.1a, from Phase 5.1 to 5.2:
Absence of disturbance over time allows for tree cover and density to further increase and trees to out-compete the herbaceous understory species for sunlight and water.

Community Phase 5.2:
Utah juniper and/or singleleaf pinyon trees dominate overstory. Black sagebrush is decadent and dying with numerous skeletons present or sagebrush may be missing from the system. Bunchgrasses present in trace amounts and annual non-native species may dominate understory. Herbaceous species may be located primarily under the canopy or near the drip line of trees. Bare ground interspaces are large and connected. Soil redistribution is evident.

R5A: Restoration Pathway from Tree State 5.0 to Seeded State 6.0:

Removal of trees in community phase 5.1 and seeding of introduced species. If restoration efforts fail, this site could transition to Annual State 4.0.

T5A: Transition from Tree State 5.0 to Annual State 4.0

Trigger: Catastrophic fire causing a stand replacement event. Inappropriate tree removal practices with soil disturbance will also cause a transition to Annual State 4.0.

Slow variables: Increased production and cover of non-native annual species under tree canopies.

Threshold: Closed tree canopy with non-native annual species dominant in the understory changes the intensity, size and spatial variability of fires. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and sagebrush truncate energy capture and impacts nutrient cycling and distribution.

Seeded State 6.0:

This state is characterized by the dominance of seeded, non-native grass species. Other desired seeded species including black sagebrush and native and non-native grasses and forbs may be present.

Community Phase 6.1:
Seeded grass species such as crested wheatgrass are dominant. Native and non-native seeded grasses and forbs may also be present. Trace amounts of black sagebrush may be present along with native bunchgrasses. Annual non-native species present.

Community Phase Pathway 6.1a, from Phase 6.1 to 6.2:
Inappropriate grazing management particularly during the growing season reduces perennial bunchgrass vigor and density and facilitates shrub establishment.

Community Phase 6.2:
Seeded grass species such as crested wheatgrass are dominant. Native and non-native seeded grasses and forbs may also be present. Trace amounts of black sagebrush may be present along with native bunchgrasses. Annual non-native species present.


Shallow Calcareous Loam 8-12" P.Z. (R029XY008NV), Seeded State 6.1, T. Stringham, May 2020


Shallow Calcareous Loam 10-12" P.Z. (R029XY170NV), Seeded State 6.1, T. Stringham, May 2022

Community Phase Pathway 6.2a, from Phase 6.2 to 6.1:
Low severity fire or brush management with minimal soil disturbance will reduce the shrub/tree overstory and may allow seeded grasses to become dominant. Native bunchgrasses may be present in trace amounts.

T6A: Transition from Seeded State 6.0 to Tree State 5.0

Trigger: Absence of disturbance over time and/or inappropriate grazing management facilitates the establishment and eventual dominance of Utah juniper and/or singleleaf pinyon.

Slow variables: Long-term increase in Utah juniper and/or singleleaf pinyon density.

Threshold: Trees out-compete understory species for water and sunlight. There is minimal recruitment of new shrub cohorts. Litter builds up underneath trees while bare ground increases in interspaces; this changes nutrient cycling and levels of organic matter in the soil. Redistribution of soil, organic matter and nutrients may occur with water and wind erosion.

T6B: Transition from Seeded State 6.0 to Annual State 4.0

Trigger: Fire, inappropriate grazing management or treatments that disturb the soil and existing plant community (ex: failed restoration attempts).

Slow variables: Increased seed production and cover of annual non-native species.

Threshold: Increased, continuous fine fuels modify the fire regime by changing intensity, size and spatial variability of fires. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and sagebrush truncate energy capture and impact the nutrient cycling and distribution.

Potential Resilience Differences with Other Ecological Sites in this Group:

Limestone Slope 8-10" P.Z. R029XY160NV:

This is a burned phase of Shallow Calcareous Hill 8-12" (R029XY014NV) occurring in the eastern side of MLRA 29. It occurs on steep sideslopes of hills and lower mountains with slopes ranging from 30 to 75%. Elevations range from 4,700 to 6,800 ft. This burned phase is dominated by Stansbury cliffrose, black sagebrush, green ephedra and spiny greasebush (*Glossopetalon spinescens*). Desert needlegrass and galleta are the dominant grasses.

Shallow Calcareous Slope 8-12" P.Z. R029XY014NV:

Black sagebrush and Indian ricegrass dominate this ecological site, but it is less productive than the modal site (Shallow Calcareous Loam 8-12" R029XY008NV). It occurs on slope gradients typically steeper than the modal and therefore are more susceptible to soil erosion. Soils are high in lime content with a shallow rooting depth. Shadscale (*Atriplex confertifolia*) is recognized as a seral community phase following wildfire or other major disturbance to the black sagebrush community, especially at the lower elevations of this site’s occurrence. This site will have the same states as the modal site.

Shallow Calcareous Hill 10-14" P.Z. R029XY081NV:

Utah juniper readily increases while singleleaf pinyon readily invades this site, making it highly susceptible to a Tree State 5.0. Black sagebrush, Stansbury's cliffrose, and Indian ricegrass dominate the understory. This site occurs at higher elevations and receives more precipitation that the modal ecological site, however the soils are very shallow and well drained. After fire, Stansbury's cliffrose will often sprout and dominate the overstory. This site will have the same states as the modal site.

Shallow Clay Loam 8-12" P.Z. R029XY104NV:

Black sagebrush, Indian ricegrass and Thurber's needlegrass (*Achnatherum thurberianum*) dominate this ecological site. Thurber's needlegrass is significantly more susceptible to fire damage than other common bunchgrasses in this group. Soils are shallow and are derived from volcanic parent material making the site more likely to be invaded by non-native annual grasses, and Utah juniper and singleleaf pinyon. Overall, this site is less resilient than the modal.

Shallow Calcareous Hill 8-10" P.Z. R029XY015NV:

Utah juniper readily increases while singleleaf pinyon readily invades this site, making it highly susceptible to a Tree State 5.0. Stansbury cliffrose, black sagebrush, and Indian ricegrass dominate the understory. However, this site is less productive than the modal. After fire, Stansbury cliffrose will often sprout and dominate the overstory on this site.

Shallow Eroded Slope 8-10" P.Z. R029XY168NV:

Broom snakeweed, black sagebrush and galleta dominate this ecological site. It occurs on slope gradients typically steeper than the modal and is therefore more susceptible to soil erosion. Due to constant soil movement, non-native annual grass invasion on this site is unlikely. This site is also less productive than the modal and occurs at lower elevations. This site is unlikely to have a Tree State due to the surface soil instability and loss of the rooting zone due to erosion.

Shallow Calcareous Loam 10-12" P.Z. R029XY170NV:

Black sagebrush, Indian ricegrass and needle-and-thread dominate this ecological site. It occurs at a slightly higher elevation than the modal and is more productive. Following fire, Stansbury cliffrose and wild crab apple (*Peraphyllum ramosissimum*) will likely sprout. This site will have the same states as the modal site.

Stony Calcareous Hill 8-12" P.Z. R029XY099NV:

Black sagebrush, Fremont's mahonia and Indian ricegrass dominate this ecological site. It is slightly less productive than the modal, however this and the presence of Fremont's mahonia are the only major differences. Fremont’s mahonia is unpalatable to domestic livestock and will increase under grazing pressure. Fremont’s mahonia is rhizomatous and sprouting should be expected following disturbance. This site will have the same states as the modal site.

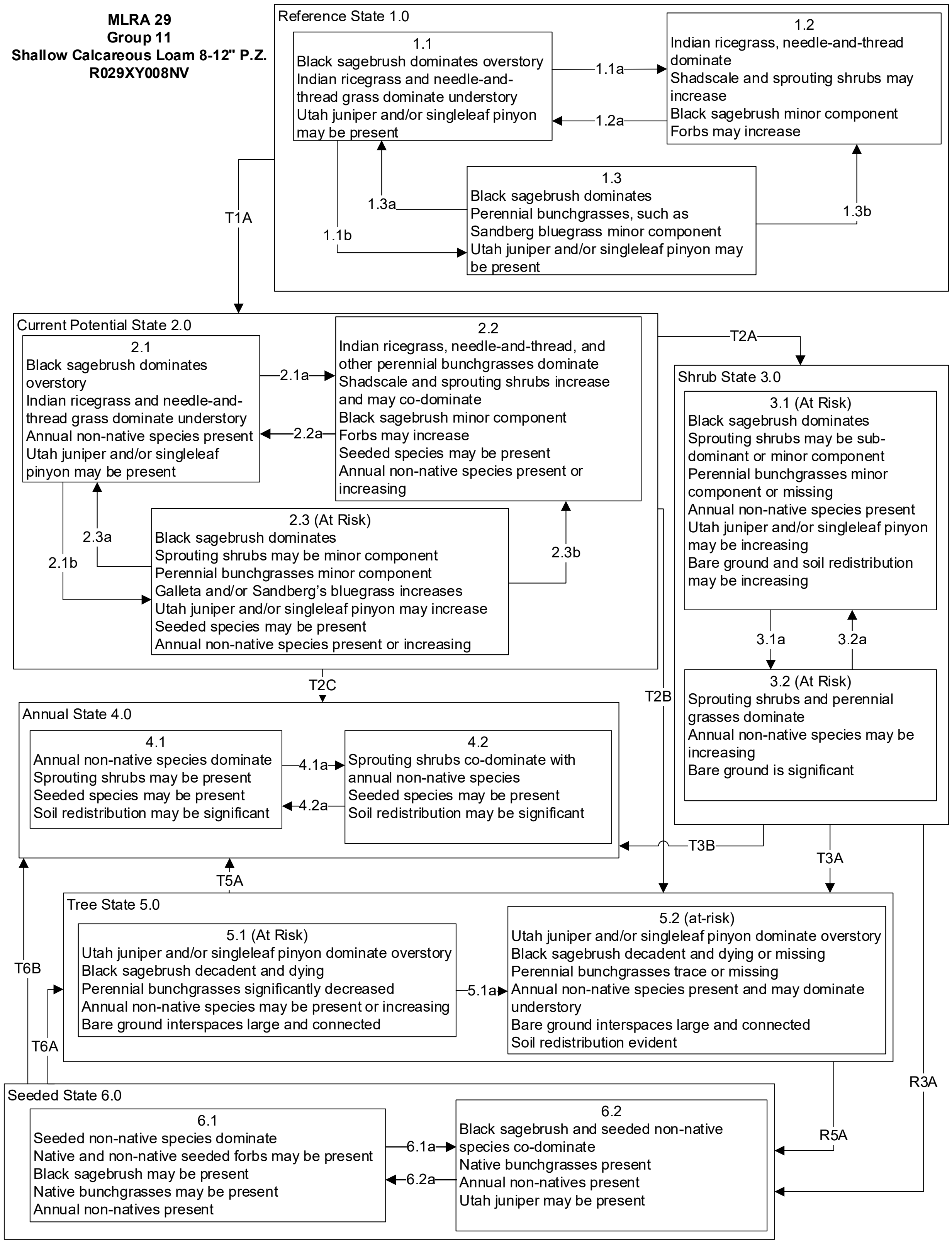
Stony Calcareous Slope 8-12" P.Z. R029XY045NV:

Black sagebrush, desert needlegrass and Indian ricegrass dominate this ecological site. It occurs on slope gradients that are typically steeper than the modal which makes this site more susceptible to soil erosion. This site will have the same states as the modal site.

Travertine Bar R029XY047NV:

Fremont’s mahonia, black sagebrush and Indian ricegrass dominate this site. It occurs on calcium carbonate deposits within stream terrace remnants and at lower elevations that the modal. Travertine Bar is also less productive than the modal site. This site will have the same states as the modal site.

Modal State and Transition Model for Group 11 in MLRA 29:



MLRA 29
Group 11
Shallow Calcareous Loam 8-12" P.Z.
R029XY008NV

Reference State 1.0 Community Pathways
1.1a: Low severity fire, herbivory, Aroga moth infestation or combinations creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by perennial grasses, shadscale and sprouting shrubs.
1.1b: Time and lack of disturbance such as fire allows black sagebrush to increase. Excessive herbivory and/ or drought may also reduce perennial understory.
1.2a: Time and lack of disturbance allows for shrub re-establishment.
1.3a: Low severity fire, herbivory, Aroga moth infestation or combinations will reduce sagebrush and create a sagebrush/grass mosaic.
1.3b: High severity fire significantly reduces sagebrush cover allowing perennial bunchgrasses to dominate.

Transition T1A: Introduction of non-native plants.

Current Potential State 2.0 Community Pathways
2.1a: Low severity fire, herbivory, Aroga moth infestation or combinations creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by perennial grasses and forb, shadscale and sprouting shrubs: non-native annual species are likely to increase after fire.
2.1b: Time and lack of disturbance, chronic drought, inappropriate grazing management or combinations of these reduces perennial bunchgrass understory, allowing sagebrush overstory to increase and dominate the site; Sandberg blue grass may increase.
2.2a: Time and lack of disturbance and/or grazing management that favors shrub establishment.
2.3a: Low severity fire, late fall/winter grazing, spring sheep grazing, and/or brush treatment with minimal soil disturbance reduces shrub cover allowing perennial bunchgrasses to increase.
2.3b: High severity fire significantly reduces sagebrush and leads to early/mid-seral community. Annual non-native species increase post-burn.

Transition T2A: Inappropriate cattle/horse grazing management that favors shrub dominance and reduces perennial bunchgrasses will lead to Shrub State 3.1. Severe fire, soil disturbing brush treatments, and/or inappropriate sheep grazing will reduce black sagebrush, decrease perennial bunchgrasses, enhance galleta and/or Sandberg blue grass, and potentially increase sprouting shrubs leading to Shrub State 3.2.
Transition T2B: Time and lack of disturbance allows for maturation of the tree community.
Transition T2C: Catastrophic fire and/or severe soil surface disturbance.

Shrub State 3.0 Community Pathways
3.1a: Fire, inappropriate sheep grazing, and/or brush treatments reduce black sagebrush and allow sprouting shrubs such as rabbitbrush, broom snakeweed, and/or ephedra to dominate.
3.2a: Time and lack of disturbance and/or grazing management that favors shrub establishment allows black sagebrush to recover.

Transition T3A: Time and lack of disturbance allows for maturation of the tree community.
Transition T3B: Fire and/or soil/plant disturbing treatments.

Restoration Pathway R3A: Seeding of deep-rooted bunchgrasses and other desired species, potentially coupled with brush management and/ or herbicide.

Annual State 4.0 Community Pathways
4.1a: Time and lack of fire allows sprouting shrubs to become co-dominant.
4.2a: Fire reduces overstory allowing for annual non-native species to dominate.

Tree State 5.0 Community Pathways
5.1a: Time and lack of disturbance allows for maturation of the tree community, out-competing herbaceous understory.

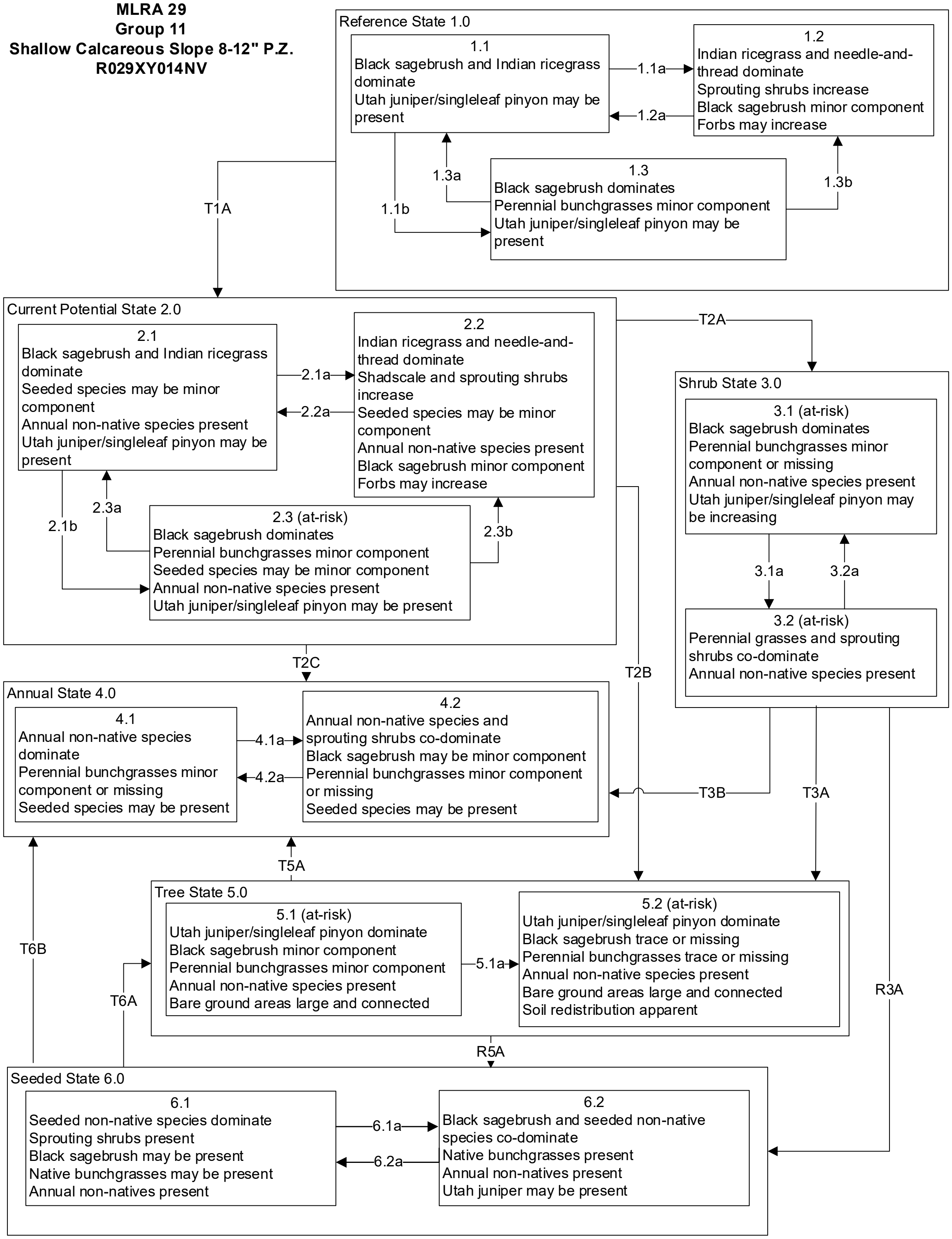
Transition T5A: Catastrophic fire that significantly reduces or eliminates tree and any remaining shrub overstory or inappropriate tree removal practices with soil disturbance.

Restoration Pathway R5A: Removal of trees and seeding of desired species.

Seeded State 6.0 Community Pathways
6.1a: Inappropriate grazing management during the growing season facilitates shrub establishment and dominance.
6.2a: Fire and brush treatments with minimal soil disturbance.

Transition T6A: Time and lack of disturbance and/or inappropriate grazing management facilitates establishment and dominance of Utah juniper and/or singleleaf pinyon.
Transition T6B: Fire, inappropriate grazing management, and/or soil/plant disturbing treatments.

Additional State and Transition Models for Group 11 in MLRA 29:



MLRA 29
Group 11
Shallow Calcareous Slope 8-12" P.Z.
R029XY014NV

Reference State 1.0 Community Pathways
1.1a: Low severity fire, herbivory, Aroga moth infestation or combinations creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush and leads to early/mid-seral community dominated by perennial grasses and sprouting shrubs..
1.1b: Time and lack of disturbance such as fire. Excessive herbivory and/ or drought may also reduce perennial understory.
1.2a: Time and lack of disturbance allows for shrub reestablishment.
1.3a: Low severity fire, herbivory, Aroga moth infestation or combinations will reduce sagebrush and create a sagebrush/grass mosaic.
1.3b: High severity fire significantly reduces sagebrush cover leading to early/mid-seral community dominated by perennial grasses and sprouting shrubs.

Transition T1A: Introduction of non-native plants.

Current Potential State 2.0 Community Pathways:
2.1a: Low severity fire, herbivory, Aroga moth infestation or combinations creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by perennial grasses and forbs. Non-native annual species present.
2.1b: Time and lack of disturbance such as fire; chronic drought, inappropriate grazing management or combinations of these would allow the sagebrush overstory to increase and dominate the site.
2.2a: Time and lack of disturbance and/or grazing management that favors shrub establishment.
2.3a: Low severity fire, late fall/winter grazing, Aroga moth infestation or brush treatment with minimal soil disturbance creates sagebrush/ grass mosaic.
2.3b: High severity fire significantly reduces sagebrush and leads to early/mid-seral community. Non-natives increase post-fire.

Transition T2A: Inappropriate cattle/horse grazing management favoring shrub dominance and reducing perennial bunchgrasses will lead to phase 3.1. Soil disturbing treatments and/or inappropriate sheep grazing management will lead to phase 3.2.
Transition T2B: Time and lack of disturbance allows for maturation of the tree community.
Transition T2C: Catastrophic fire or soil disturbing treatments.

Shrub State 3.0 Community Pathways
3.1a: Fire and/or chronic inappropriate sheep grazing. Brush treatments (i.e. mowing) with minimal soil disturbance.
3.2a: Time, lack of fire and/or fall and early winter sheep grazing that allows shrubs to reestablish.

Transition T3A: Time and lack of disturbance allows for maturation of the tree community. Heavy sheep grazing will expedite this transition.
Transition T3B: Fire and/or soil disturbing treatments.

Restoration Pathway R3A: Drill or aerial seeding of native and non-native grasses, forbs, and other species.

Annual State 4.0 Community Pathways
4.1a: Time and lack of fire.
4.2a: Fire.

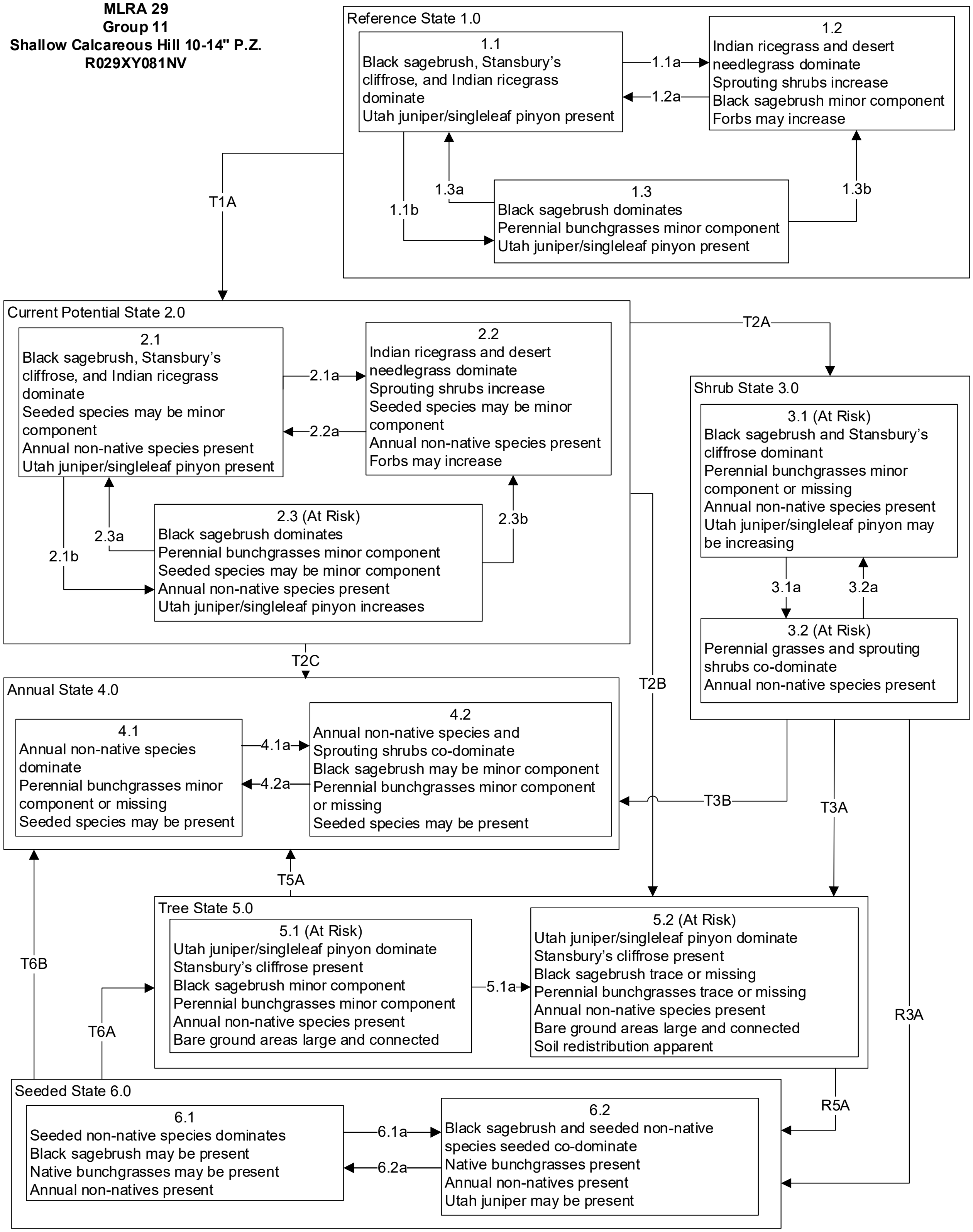
Tree State 5.0 Community Pathways
5.1a: Time and lack of disturbance allows for maturation of the tree community.

Transition T5A: Catastrophic fire that significantly reduces or eliminates tree and any remaining shrub overstory. Tree removal practices may also contribute to this transition.
Restoration Pathway R5A: Removal of trees and seeding of desired species.

Seeded State 6.0 Community Pathways
6.1a: Inappropriate grazing management during the growing season facilitates shrub establishment and dominance.
6.2a: Fire or brush treatments with minimal soil disturbance.

Transition T6A:Time without disturbance allows trees to establish and dominate the site; may be coupled with grazing management that favors reduced perennial grass density and increased tree establishment.
Transition T6B: High severity fire and/or inappropriate grazing management. Soil disturbing brush treatments may also lead to the annual state.

MLRA 29
Group 11
Shallow Calcareous Hill 10-14" P.Z.
R029XY081NV



MLRA 29
Group 11
Shallow Calcareous Hill 10-14" P.Z.
R029XY081NV

Reference State 1.0 Community Pathways
1.1a: Low severity fire, herbivory, Aroga moth infestation or combinations creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by perennial grasses and sprouting shrubs.
1.1b: Time and lack of disturbance such as fire. Excessive herbivory and/ or drought may also reduce perennial understory.
1.2a: Time and lack of disturbance allows for shrub reestablishment.
1.3a: Low severity fire, herbivory, Aroga moth infestation or combinations will reduce sagebrush and create a sagebrush/grass mosaic.
1.3b: High severity fire significantly reduces sagebrush cover leading to early/mid-seral community dominated by perennial grasses and sprouting shrubs.

Transition T1A: Introduction of non-native plants.

Current Potential State 2.0 Community Pathways
2.1a: Low severity fire, herbivory, Aroga moth infestation or combinations creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by perennial grasses and forbs: non-native annual species present.
2.1b: Time and lack of disturbance such as fire; chronic drought, inappropriate grazing management or combinations of these would allow the sagebrush overstory to increase and dominate the site.
2.2a: Time and lack of disturbance and/or grazing management that favors shrub establishment.
2.3a: Low severity fire, late fall/winter grazing, Aroga moth infestation or brush treatment with minimal soil disturbance creates sagebrush/ grass mosaic.
2.3b: High severity fire significantly reduces sagebrush and leads to early/mid-seral community.

Transition T2A: Inappropriate cattle/horse grazing management favoring shrub dominance and reducing perennial bunchgrasses will lead to phase 3.1. Soil disturbing treatments and/or inappropriate sheep grazing management will lead to phase 3.2.
Transition T2B: Time and lack of disturbance allows for maturation of the tree community.
Transition T2C: Catastrophic fire or soil disturbing treatments.

Shrub State 3.0 Community Pathways
3.1a: Fire and/or chronic inappropriate sheep grazing. Brush treatments (i.e. mowing) with minimal soil disturbance.
3.2a: Time, lack of fire and/or early winter sheep grazing that allows shrubs to reestablish.

Transition T3A: Time and lack of disturbance allows for maturation of the tree community. Heavy sheep grazing will expedite this transition.
Transition T3B: Fire and/or soil disturbing treatments.

Restoration Pathway R3A: Drill or aerial seeding of native and non-native grasses, forbs, and other species.

Annual State 4.0 Community Pathways
4.1a: Time and lack of fire.
4.2a: Fire.

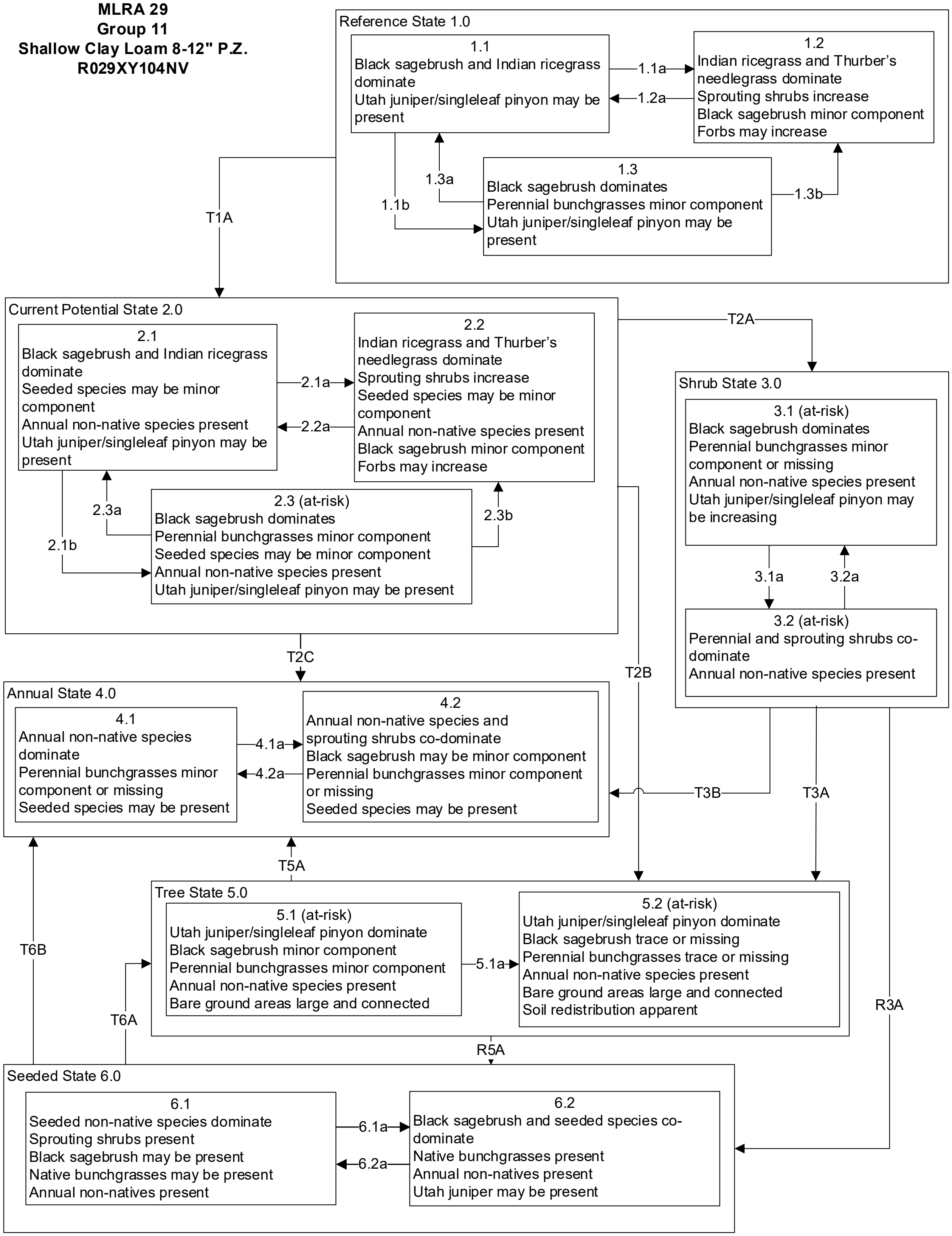
Tree State 5.0 Community Pathways
5.1a: Time and lack of disturbance allows for maturation of the tree community.

Transition T5A: Catastrophic fire that significantly reduces or eliminates tree and any remaining shrub overstory. Tree removal practices may also contribute to this transition.
Restoration Pathway R5A: Removal of trees and seeding of desired species.

Seeded State 6.0 Community Pathways
6.1a: Inappropriate grazing management during the growing season facilitates shrub establishment and dominance.
6.2a: Fire or brush treatments with minimal soil disturbance.

Transition T6A:Time without disturbance allows trees to establish and dominate the site; may be coupled with grazing management that favors reduced perennial grass density and increased tree establishment.
Transition T6B: High severity fire and/or inappropriate grazing management. Soil disturbing brush treatments may also lead to the annual state.

MLRA 29
Group 11
Shallow Clay Loam 8-12" P.Z.
R029XY104NV



MLRA 29
Group 11
Shallow Clay Loam 8-12" P.Z.
R029XY104NV

Reference State 1.0 Community Pathways
1.1a: Low severity fire, herbivory, Aroga moth or combinations creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by perennial grasses and sprouting shrubs..
1.1b: Time and lack of disturbance such as fire. Excessive herbivory and/ or drought may also reduce perennial understory.
1.2a: Time and lack of disturbance allows for shrub reestablishment.
1.3a: Low severity fire, herbivory, Aroga moth infestation or combinations will reduce sagebrush and create a sagebrush/grass mosaic.
1.3b: High severity fire significantly reduces sagebrush cover leading to early/mid-seral community.

Transition T1A: Introduction of non-native plants.

Current Potential State 2.0 Community Pathways:
2.1a: Low severity fire, herbivory, Aroga moth or combinations creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by perennial grasses and sprouting shrubs: non-native annual species present.
2.1b: Time and lack of disturbance such as fire; chronic drought, inappropriate grazing management or combinations of these would allow the sagebrush overstory to increase and dominate the site.
2.2a: Time and lack of disturbance and/or grazing management that favors shrub establishment.
2.3a: Low severity fire, late fall/winter grazing, Aroga moth infestation or brush treatment with minimal soil disturbance creates sagebrush/ grass mosaic.
2.3b: High severity fire significantly reduces sagebrush and leads to early/mid-seral community.

Transition T2A: Inappropriate cattle/horse grazing management favoring shrub dominance and reducing perennial bunchgrasses will lead to phase 3.1. Soil disturbing treatments and/or inappropriate sheep grazing management will lead to phase 3.2.
Transition T2B: Time and lack of disturbance allows for maturation of the tree community.
Transition T2C: Catastrophic fire or soil disturbing treatments.

Shrub State 3.0 Community Pathways
3.1a: Fire and/or chronic inappropriate sheep grazing. Brush treatments (i.e. mowing) with minimal soil disturbance.
3.2a: Time, lack of fire and/or fall or early winter sheep grazing that allows shrubs to reestablish.

Transition T3A: Time and lack of disturbance allows for maturation of the tree community. Heavy sheep grazing will expedite this transition.
Transition T3B: Fire and/or soil disturbing treatments.

Restoration Pathway R3A: Drill or aerial seeding of native and non-native grasses, forbs, and other species.

Annual State 4.0 Community Pathways
4.1a: Time and lack of fire.
4.2a: Fire.

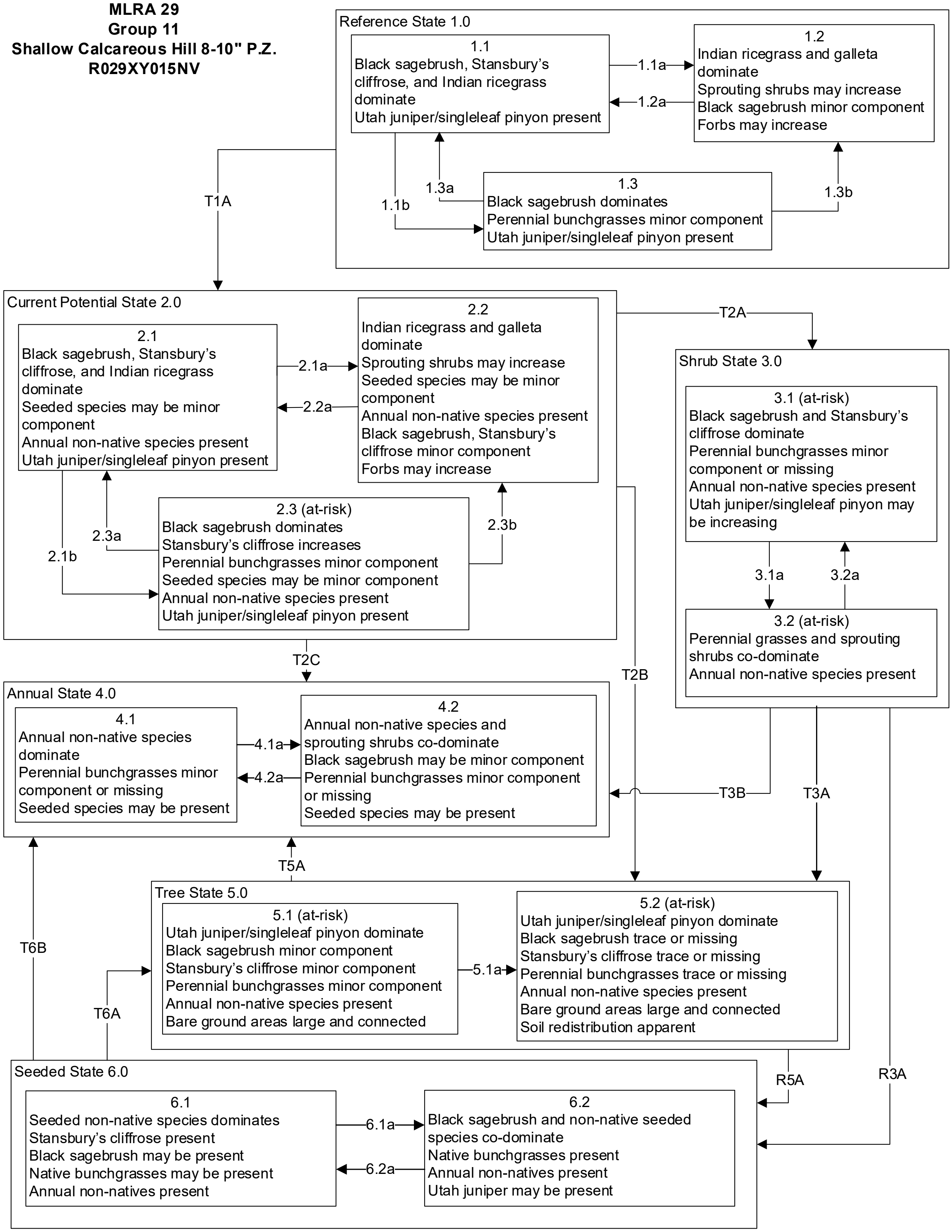
Tree State 5.0 Community Pathways
5.1a: Time and lack of disturbance allows for maturation of the tree community.

Transition T5A: Catastrophic fire that significantly reduces or eliminates tree and any remaining shrub overstory. Tree removal practices may also contribute to this transition.
Restoration Pathway R5A: Removal of trees and seeding of desired species.

Seeded State 6.0 Community Pathways
6.1a: Inappropriate grazing management during the growing season facilitates shrub establishment and dominance.
6.2a: Fire or brush treatments with minimal soil disturbance.

Transition T6A:Time without disturbance allows trees to establish and dominate the site; may be coupled with grazing management that favors reduced perennial grass density and increased tree establishment.
Transition T6B: High severity fire and/or inappropriate grazing management. Soil disturbing brush treatments may also lead to the annual state.

MLRA 29
Group 11
Shallow Calcareous Hill 8-10" P.Z.
R029XY015NV



MLRA 29
Group 11
Shallow Calcareous Hill 8-10" P.Z.
R029XY015NV

Reference State 1.0 Community Pathways
1.1a: Low severity fire, herbivory, Aroga moth infestation or combinations creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by perennial grasses.
1.1b: Time and lack of disturbance such as fire. Excessive herbivory and/ or drought may also reduce perennial understory.
1.2a: Time and lack of disturbance allows for shrub reestablishment.
1.3a: Low severity fire, herbivory, Aroga moth infestation or combinations will reduce sagebrush and create a sagebrush/grass mosaic.
1.3b: High severity fire significantly reduces sagebrush cover leading to early/mid-seral community.

Transition T1A: Introduction of non-native plants.

Current Potential State 2.0 Community Pathways
2.1a: Low severity fire, herbivory, Aroga moth infestation or combinations creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by perennial grasses and forbs: non-native annual species present.
2.1b: Time and lack of disturbance such as fire; chronic drought, inappropriate grazing management or combinations of these would allow the sagebrush overstory to increase and dominate the site.
2.2a: Time and lack of disturbance and/or grazing management that favors shrub establishment.
2.3a: Low severity fire, late fall/winter grazing, Aroga moth infestation or brush treatment with minimal soil disturbance creates sagebrush/grass mosaic.
2.3b: High severity fire significantly reduces sagebrush and leads to early/mid-seral community. Non-native species increase post-fire.

Transition T2A: Inappropriate cattle/horse grazing management favoring shrub dominance and reducing perennial bunchgrasses will lead to phase 3.1. Soil disturbing treatments and/or inappropriate sheep grazing management will lead to phase 3.2.
Transition T2B: Time and lack of disturbance allows for maturation of the tree community.
Transition T2C: Catastrophic fire or soil disturbing treatments.

Shrub State 3.0 Community Pathways
3.1a: Fire and/or chronic inappropriate sheep grazing. Brush treatments (i.e. mowing) with minimal soil disturbance.
3.2a: Time, lack of fire and/or early winter sheep grazing that allows shrubs to reestablish.

Transition T3A: Time and lack of disturbance allows for maturation of the tree community. Heavy sheep grazing will expedite this transition.
Transition T3B: Fire and/or soil disturbing treatments.

Restoration Pathway R3A: Drill or aerial seeding of native and non-native grasses, forbs, and other species.

Annual State 4.0 Community Pathways
4.1a: Time and lack of fire.
4.2a: Fire.

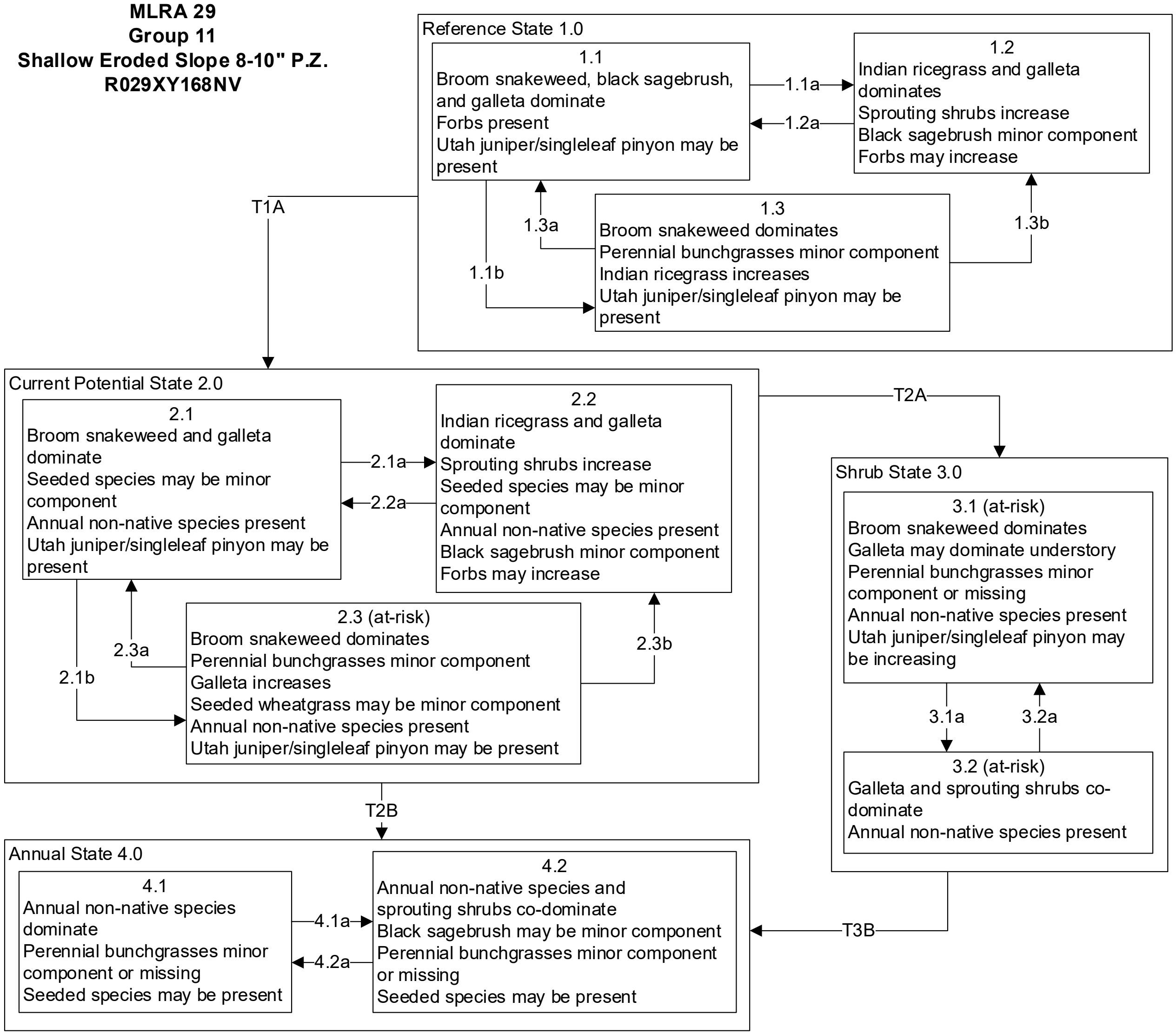
Tree State 5.0 Community Pathways
5.1a: Time and lack of disturbance allows for maturation of the tree community.

Transition T5A: Catastrophic fire that significantly reduces or eliminates tree and any remaining shrub overstory. Tree removal practices may also contribute to this transition.
Restoration Pathway R5A: Removal of trees and seeding of desired species.

Seeded State 6.0 Community Pathways
6.1a: Inappropriate grazing management during the growing season facilitates shrub establishment and dominance.
6.2a: Fire or brush treatments with minimal soil disturbance.

Transition T6A: Time without disturbance allows trees to establish and dominate the site; may be coupled with grazing management that favors reduced perennial grass density and increased tree establishment.
Transition T6B: High severity fire and/or inappropriate grazing management. Soil disturbing brush treatments may also lead to the annual state.

MLRA 29
Group 11
Shallow Eroded Slope 8-10" P.Z.
R029XY168NV



MLRA 29
Group 11
Shallow Eroded Slope 8-10" P.Z.
R029XY168NV

Reference State 1.0 Community Pathways
1.1a: Low severity fire, herbivory, Aroga moth or combinations creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by perennial grasses and sprouting shrubs.
1.1b: Time and lack of disturbance such as fire. Excessive herbivory and/ or drought may also reduce perennial understory.
1.2a: Time and lack of disturbance allows for shrub reestablishment.
1.3a: Low severity fire, herbivory, Aroga moth infestation or combinations will reduce sagebrush and create a sagebrush/grass mosaic.
1.3b: High severity fire significantly reduces sagebrush cover leading to early/mid-seral community.

Transition T1A: Introduction of non-native plants.

Current Potential State 2.0 Community Pathways:
2.1a: Low severity fire, herbivory, Aroga moth or combinations creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by perennial grasses and forbs: non-native annual species present.
2.1b: Time and lack of disturbance such as fire; chronic drought, inappropriate grazing management or combinations of these would allow the sagebrush overstory to increase and dominate the site.
2.2a: Time and lack of disturbance and/or grazing management that favors shrub establishment.
2.3a: Low severity fire, late fall/winter grazing, Aroga moth infestation or brush treatment with minimal soil disturbance creates sagebrush/ grass mosaic.
2.3b: High severity fire significantly reduces sagebrush and leads to early/mid-seral community.

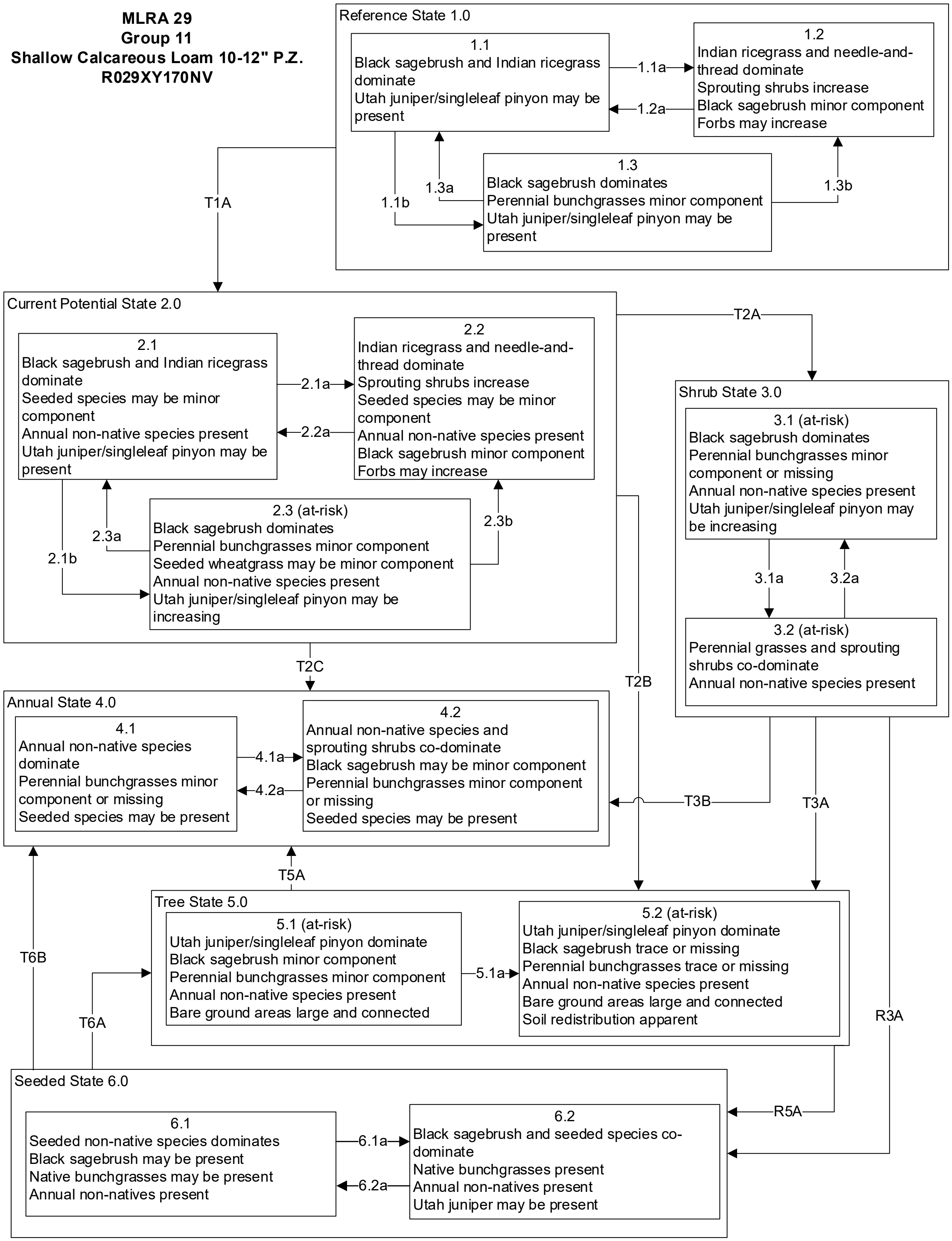
Transition T2A: Inappropriate cattle/horse grazing management favoring shrub dominance and reducing perennial bunchgrasses will lead to phase 3.1. Soil disturbing treatments and/or inappropriate sheep grazing management will lead to phase 3.2.
Transition T2B: Catastrophic fire or soil disturbing treatments.

Shrub State 3.0 Community Pathways
3.1a: Fire and/or chronic inappropriate sheep grazing. Brush treatments (i.e. mowing) with minimal soil disturbance.
3.2a: Time, lack of fire and/or early winter sheep grazing that allows shrubs to reestablish.

Transition T3B: Fire and/or soil disturbing treatments.

Annual State 4.0 Community Pathways
4.1a: Time and lack of fire.
4.2a: Fire.

MLRA 29
Group 11
Shallow Calcareous Loam 10-12" P.Z.
R029XY170NV



MLRA 29
Group 11
Shallow Calcareous Loam 10-12" P.Z.
R029XY170NV

Reference State 1.0 Community Pathways
1.1a: Low severity fire, herbivory, Aroga moth infestation or combinations creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by perennial grasses and sprouting shrubs.
1.1b: Time and lack of disturbance such as fire. Excessive herbivory and/or drought may also reduce perennial understory.
1.2a: Time and lack of disturbance allows for shrub reestablishment.
1.3a: Low severity fire, herbivory, Aroga moth infestation or combinations will reduce sagebrush and create a sagebrush/grass mosaic.
1.3b: High severity fire significantly reduces sagebrush cover leading to early/mid-seral community dominated by perennial grasses and sprouting shrubs.

Transition T1A: Introduction of non-native plants.

Current Potential State 2.0 Community Pathways
2.1a: Low severity fire, herbivory, Aroga moth infestation or combinations creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by perennial grasses and forbs and sprouting shrubs. Non-native annual species present.
2.1b: Time and lack of disturbance such as fire; chronic drought, inappropriate grazing management or combinations of these would allow the sagebrush overstory to increase and dominate the site.
2.2a: Time and lack of disturbance and/or grazing management that favors shrub establishment.
2.3a: Low severity fire, late fall/winter grazing, Aroga moth infestation or brush treatment with minimal soil disturbance creates sagebrush/ grass mosaic.
2.3b: High severity fire significantly reduces sagebrush and leads to early/mid-seral community. Annual non-native species increase.

Transition T2A: Inappropriate cattle/horse grazing management favoring shrub dominance and reducing perennial bunchgrasses will lead to phase 3.1. Soil disturbing treatments and/or inappropriate sheep grazing management will lead to phase 3.2.
Transition T2B: Time and lack of disturbance allows for maturation of the tree community.
Transition T2C: Catastrophic fire or soil disturbing treatments.

Shrub State 3.0 Community Pathways
3.1a: Fire and/or chronic inappropriate sheep grazing. Brush treatments (i.e. mowing) with minimal soil disturbance.
3.2a: Time, lack of fire and/or early winter sheep grazing that allows shrubs to reestablish.

Transition T3A: Time and lack of disturbance allows for maturation of the tree community. Heavy sheep grazing will expedite this transition.
Transition T3B: Fire and/or soil disturbing treatments.

Restoration Pathway R3A: Drill or aerial seeding of native and non-native grasses, forbs, and other species.

Annual State 4.0 Community Pathways
4.1a: Time and lack of fire.
4.2a: Fire.

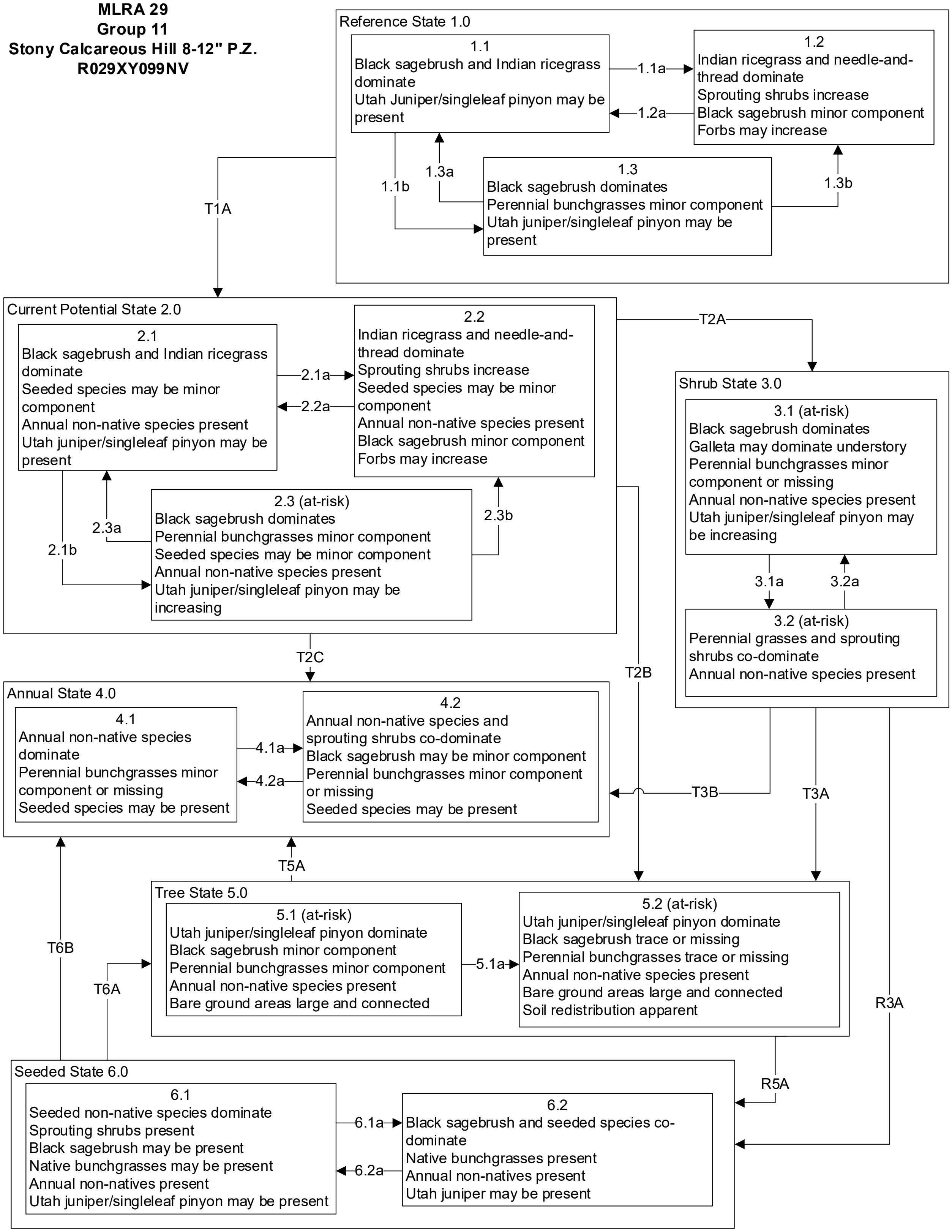
Tree State 5.0 Community Pathways
5.1a: Time and lack of disturbance allows for maturation of the tree community.

Transition T5A: Catastrophic fire that significantly reduces or eliminates tree and any remaining shrub overstory. Tree removal practices may also contribute to this transition.
Restoration Pathway R5A: Removal of trees and seeding of desired species.

Seeded State 6.0 Community Pathways
6.1a: Inappropriate grazing management during the growing season facilitates shrub establishment and dominance.
6.2a: Fire or brush treatments with minimal soil disturbance.

Transition T6A:Time without disturbance allows trees to establish and dominate the site; may be coupled with grazing management that favors reduced perennial grass density and increased tree establishment.
Transition T6B: High severity fire and/or inappropriate grazing management. Soil disturbing brush treatments may also lead to the annual state.

MLRA 29
Group 11
Stony Calcareous Hill 8-12" P.Z.
R029XY099NV



MLRA 29
Group 11
Stony Calcareous Hill 8-12" P.Z.
R029XY099NV

Reference State 1.0 Community Pathways
1.1a: Low severity fire, herbivory, Aroga moth or combinations creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by perennial grasses and sprouting shrubs.
1.1b: Time and lack of disturbance such as fire. Excessive herbivory and/ or drought may also reduce perennial understory.
1.2a: Time and lack of disturbance allows for shrub reestablishment.
1.3a: Low severity fire, herbivory, Aroga moth infestation or combinations will reduce sagebrush and create a sagebrush/grass mosaic.
1.3b: High severity fire significantly reduces sagebrush cover leading to early/mid-seral community.

Transition T1A: Introduction of non-native plants.

Current Potential State 2.0 Community Pathways:
2.1a: Low severity fire, herbivory, Aroga moth or combinations creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by perennial grasses and sprouting shrubs: non-native annual species present.
2.1b: Time and lack of disturbance such as fire; chronic drought, inappropriate grazing management or combinations of these would allow the sagebrush overstory to increase and dominate the site.
2.2a: Time and lack of disturbance and/or grazing management that favors shrub establishment.
2.3a: Low severity fire, late fall/winter grazing, Aroga moth infestation or brush treatment with minimal soil disturbance creates sagebrush/ grass mosaic.
2.3b: High severity fire significantly reduces sagebrush and leads to early/mid-seral community.

Transition T2A: Inappropriate cattle/horse grazing management favoring shrub dominance and reducing perennial bunchgrasses will lead to phase 3.1. Soil disturbing treatments and/or inappropriate sheep grazing management will lead to phase 3.2.
Transition T2B: Time and lack of disturbance allows for maturation of the tree community.
Transition T2C: Catastrophic fire or soil disturbing treatments.

Shrub State 3.0 Community Pathways
3.1a: Fire and/or chronic inappropriate sheep grazing. Brush treatments (i.e. mowing) with minimal soil disturbance.
3.2a: Time, lack of fire and/or fall or early winter sheep grazing that allows shrubs to reestablish.

Transition T3A: Time and lack of disturbance allows for maturation of the tree community. Heavy sheep grazing will expedite this transition.
Transition T3B: Fire and/or soil disturbing treatments.

Restoration Pathway R3A: Drill or aerial seeding of native and non-native grasses, forbs, and other species.

Annual State 4.0 Community Pathways
4.1a: Time and lack of fire.
4.2a: Fire.

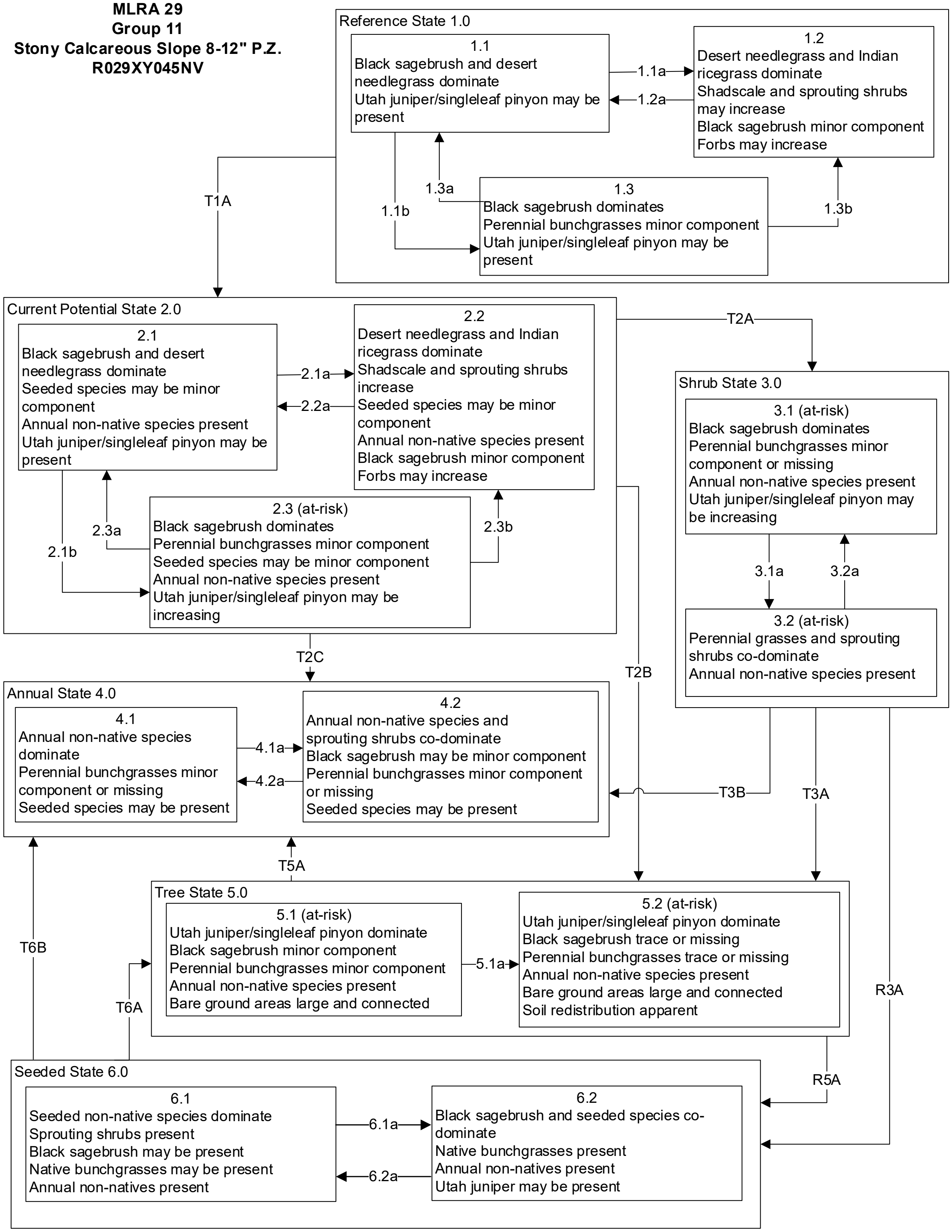
Tree State 5.0 Community Pathways
5.1a: Time and lack of disturbance allows for maturation of the tree community.

Transition T5A: Catastrophic fire that significantly reduces or eliminates tree and any remaining shrub overstory. Tree removal practices may also contribute to this transition.
Restoration Pathway R5A: Removal of trees and seeding of desired species.

Seeded State 6.0 Community Pathways
6.1a: Inappropriate grazing management during the growing season facilitates shrub establishment and dominance.
6.2a: Fire or brush treatments with minimal soil disturbance.

Transition T6A:Time without disturbance allows trees to establish and dominate the site; may be coupled with grazing management that favors reduced perennial grass density and increased tree establishment.
Transition T6B: High severity fire and/or inappropriate grazing management. Soil disturbing brush treatments may also lead to the annual state.

MLRA 29
Group 11
Stony Calcareous Slope 8-12" P.Z.
R029XY045NV



MLRA 29
Group 11
Stony Calcareous Slope 8-12" P.Z.
R029XY045NV

Reference State 1.0 Community Pathways
1.1a: Low severity fire, herbivory, Aroga moth infestation or combinations creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by perennial grasses and sprouting shrubs.
1.1b: Time and lack of disturbance such as fire. Excessive herbivory and/or drought may also reduce perennial understory.
1.2a: Time and lack of disturbance allows for shrub reestablishment.
1.3a: Low severity fire, herbivory, Aroga moth infestation or combinations will reduce sagebrush and create a sagebrush/grass mosaic.
1.3b: High severity fire significantly reduces sagebrush cover leading to early/mid-seral community.

Transition T1A: Introduction of non-native plants.

Current Potential State 2.0 Community Pathways
2.1a: Low severity fire, herbivory, Aroga moth infestation or combinations creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by perennial grasses and sprouting shrubs: non-native annual species present.
2.1b: Time and lack of disturbance such as fire; chronic drought, inappropriate grazing management or combinations of these would allow the sagebrush overstory to increase and dominate the site.
2.2a: Time and lack of disturbance and/or grazing management that favors shrub establishment.
2.3a: Low severity fire, late fall/winter grazing, Aroga moth infestation or brush treatment with minimal soil disturbance creates sagebrush/ grass mosaic.
2.3b: High severity fire significantly reduces sagebrush and leads to early/mid-seral community.

Transition T2A: Inappropriate cattle/horse grazing management favoring shrub dominance and reducing perennial bunchgrasses will lead to phase 3.1. Soil disturbing treatments and/or inappropriate sheep grazing management will lead to phase 3.2.
Transition T2B: Time and lack of disturbance allows for maturation of the tree community.
Transition T2C: Catastrophic fire or soil disturbing treatments.

Shrub State 3.0 Community Pathways
3.1a: Fire and/or chronic inappropriate sheep grazing. Brush treatments (i.e. mowing) with minimal soil disturbance.
3.2a: Time, lack of fire and/or fall or early winter sheep grazing that allows shrubs to reestablish.

Transition T3A: Time and lack of disturbance allows for maturation of the tree community. Heavy sheep grazing will expedite this transition.
Transition T3B: Fire and/or soil disturbing treatments.

Restoration Pathway R3A: Drill or aerial seeding of native and non-native grasses, forbs, and other species.

Annual State 4.0 Community Pathways
4.1a: Time and lack of fire.
4.2a: Fire.

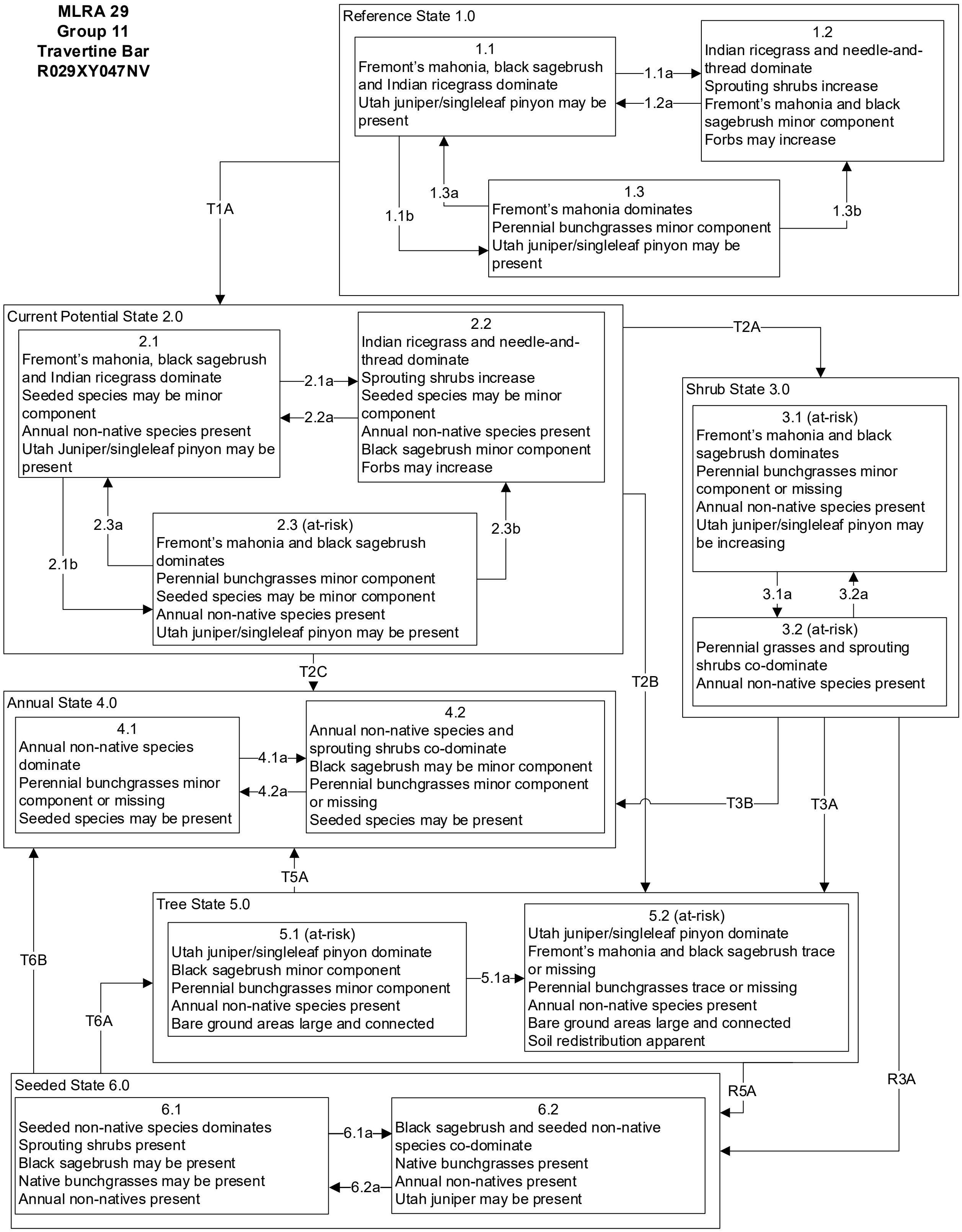
Tree State 5.0 Community Pathways
5.1a: Time and lack of disturbance allows for maturation of the tree community.

Transition T5A: Catastrophic fire that significantly reduces or eliminates tree and any remaining shrub overstory. Tree removal practices may also contribute to this transition.
Restoration Pathway R5A: Removal of trees and seeding of desired species.

Seeded State 6.0 Community Pathways
6.1a: Inappropriate grazing management during the growing season facilitates shrub establishment and dominance.
6.2a: Fire or brush treatments with minimal soil disturbance.

Transition T6A:Time without disturbance allows trees to establish and dominate the site; may be coupled with grazing management that favors reduced perennial grass density and increased tree establishment.
Transition T6B: High severity fire and/or inappropriate grazing management. Soil disturbing brush treatments may also lead to the annual state.

MLRA 29
Group 11
Travertine Bar
R029XY047NV



MLRA 29
Group 11
Travertine Bar
R029XY047NV

Reference State 1.0 Community Pathways
1.1a: Low severity fire, herbivory, Aroga moth infestation or combinations creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by perennial grasses and sprouting shrubs.
1.1b: Time and lack of disturbance such as fire. Excessive herbivory and/ or drought may also reduce perennial understory.
1.2a: Time and lack of disturbance allows for shrub reestablishment.
1.3a: Low severity fire, herbivory, Aroga moth infestation or combinations will reduce sagebrush and create a sagebrush/grass mosaic.
1.3b: High severity fire significantly reduces sagebrush cover leading to early/mid-seral community.

Transition T1A: Introduction of non-native plants.

Current Potential State 2.0 Community Pathways
2.1a: Low severity fire, herbivory, Aroga moth infestation or combinations creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by perennial grasses and sprouting shrubs: non-native annual species present.
2.1b: Time and lack of disturbance such as fire; chronic drought, inappropriate grazing management or combinations of these would allow the sagebrush overstory to increase and dominate the site.
2.2a: Time and lack of disturbance and/or grazing management that favors shrub establishment.
2.3a: Low severity fire, late fall/winter grazing, Aroga moth infestation or brush treatment with minimal soil disturbance creates sagebrush/ grass mosaic.
2.3b: High severity fire significantly reduces sagebrush and leads to early/mid-seral community. Non-native species increase post-fire.

Transition T2A: Inappropriate cattle/horse grazing management favoring shrub dominance and reducing perennial bunchgrasses will lead to phase 3.1. Soil disturbing treatments and/or inappropriate sheep grazing management will lead to phase 3.2.
Transition T2B: Time and lack of disturbance allows for maturation of the tree community.
Transition T2C: Catastrophic fire or soil disturbing treatments.

Shrub State 3.0 Community Pathways
3.1a: Fire and/or chronic inappropriate sheep grazing. Brush treatments (i.e. mowing) with minimal soil disturbance.
3.2a: Time, lack of fire and/or early winter sheep grazing that allows shrubs to reestablish.

Transition T3A: Time and lack of disturbance allows for maturation of the tree community. Heavy sheep grazing will expedite this transition.
Transition T3B: Fire and/or soil disturbing treatments.

Restoration Pathway R3A: Drill or aerial seeding of native and non-native grasses, forbs, and other species.

Annual State 4.0 Community Pathways
4.1a: Time and lack of fire.
4.2a: Fire.

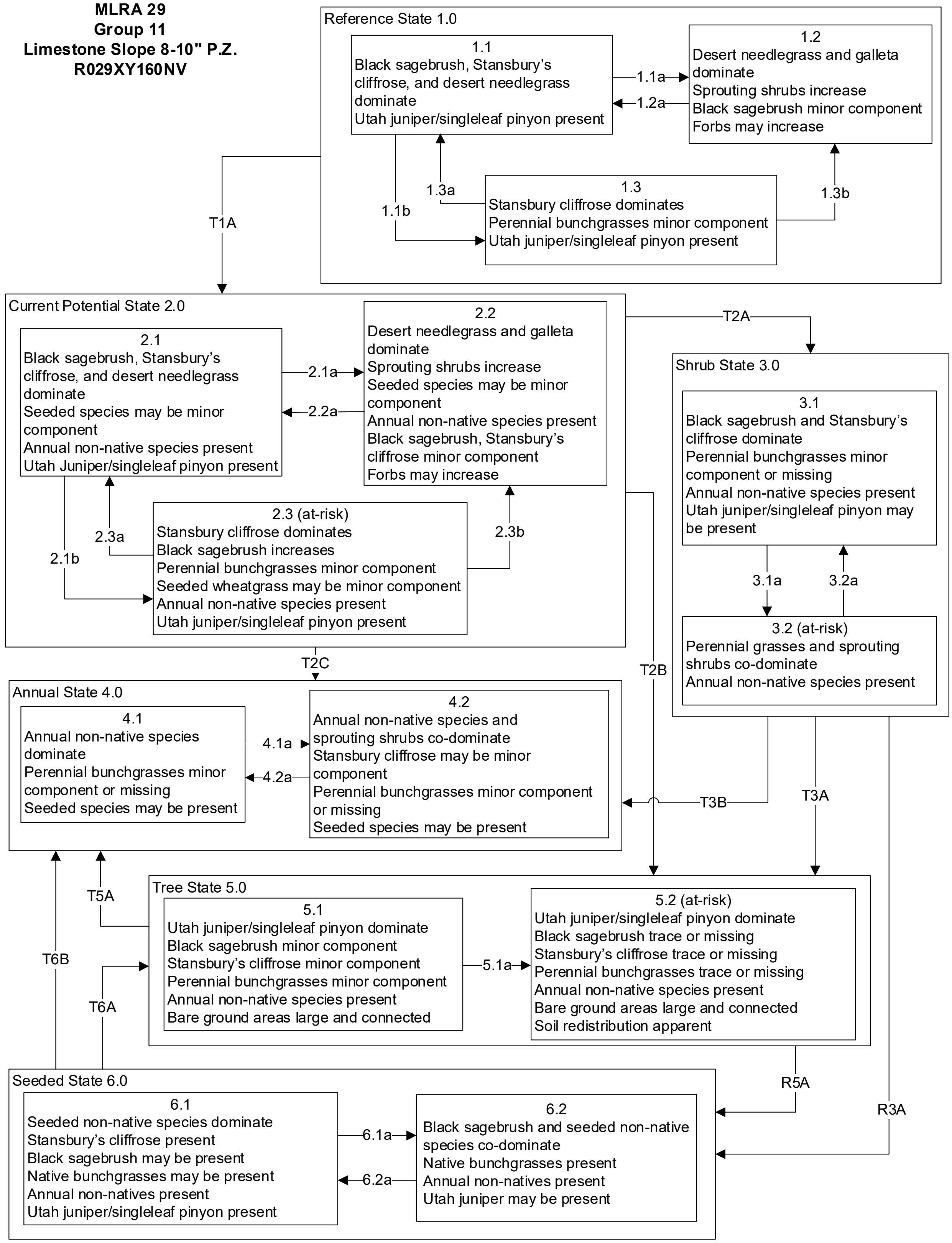
Tree State 5.0 Community Pathways
5.1a: Time and lack of disturbance allows for maturation of the tree community.

Transition T5A: Catastrophic fire that significantly reduces or eliminates tree and any remaining shrub overstory. Tree removal practices may also contribute to this transition.
Restoration Pathway R5A: Removal of trees and seeding of desired species.

Seeded State 6.0 Community Pathways
6.1a: Inappropriate grazing management during the growing season facilitates shrub establishment and dominance.
6.2a: Fire or brush treatments with minimal soil disturbance.

Transition T6A:Time without disturbance allows trees to establish and dominate the site; may be coupled with grazing management that favors reduced perennial grass density and increased tree establishment.
Transition T6B: High severity fire and/or inappropriate grazing management. Soil disturbing brush treatments may also lead to the annual state.

MLRA 29
Group 11
Limestone Slope 8-10" P.Z.
R029XY160NV



MLRA 29
Group 11
Limestone Slope 8-10" P.Z.
R029XY160NV

Reference State 1.0 Community Pathways
1.1a: Low severity fire, herbivory, Aroga moth infestation or combinations creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by perennial grasses and sprouting shrubs.
1.1b: Time and lack of disturbance such as fire. Excessive herbivory and/ or drought may also reduce perennial understory.
1.2a: Time and lack of disturbance allows for shrub reestablishment.
1.3a: Low severity fire, herbivory, Aroga moth infestation or combinations will reduce sagebrush and create a sagebrush/grass mosaic.
1.3b: High severity fire significantly reduces sagebrush cover leading to early/mid-seral community.

Transition T1A: Introduction of non-native plants.

Current Potential State 2.0 Community Pathways
2.1a: Low severity fire, herbivory, Aroga moth infestation or combinations creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by grasses and forbs: non-native annual species present.
2.1b: Time and lack of disturbance such as fire; chronic drought, inappropriate grazing management or combinations of these would allow the sagebrush overstory to increase and dominate the site.
2.2a: Time and lack of disturbance and/or grazing management that favors shrub establishment.
2.3a: Low severity fire, late fall/winter grazing, Aroga moth infestation or brush treatment with minimal soil disturbance creates sagebrush/ grass mosaic.
2.3b: High severity fire significantly reduces sagebrush and leads to early/mid-seral community.

Transition T2A: Inappropriate cattle/horse grazing management favoring shrub dominance and reducing perennial bunchgrasses will lead to phase 3.1. Soil disturbing treatments and/or inappropriate sheep grazing management will lead to phase 3.2.
Transition T2B: Time and lack of disturbance allows for maturation of the tree community.
Transition T2C: Catastrophic fire or soil disturbing treatments.

Shrub State 3.0 Community Pathways
3.1a: Fire and/or chronic inappropriate sheep grazing. Brush treatments (i.e. mowing) with minimal soil disturbance.
3.2a: Time, lack of fire and/or fall or early winter sheep grazing that allows shrubs to reestablish.

Transition T3A: Time and lack of disturbance allows for maturation of the tree community. Heavy sheep grazing will expedite this transition.
Transition T3B: Fire and/or soil disturbing treatments.

Restoration Pathway R3A: Drill or aerial seeding of native and non-native wheatgrasses, forbs, and other species.

Annual State 4.0 Community Pathways
4.1a: Time and lack of disturbance.
4.2a: Fire.

Tree State 5.0 Community Pathways
5.1a: Time and lack of disturbance allows for maturation of the tree community.

Transition T5A: Catastrophic fire that significantly reduces or eliminates tree and any remaining shrub overstory. Tree removal practices may also contribute to this transition.
Restoration Pathway R5A: Removal of trees and seeding of desired species.

Seeded State 6.0 Community Pathways
6.1a: Inappropriate grazing management during the growing season facilitates shrub establishment and dominance.
6.2a: Fire or brush treatments with minimal soil disturbance.

Transition T6A:Time without disturbance allows trees to establish and dominate the site; may be coupled with grazing management that favors reduced perennial grass density and increased tree establishment.
Transition T6B: High severity fire and/or inappropriate grazing management. Soil disturbing brush treatments may also lead to the annual state.

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MLRA 29 Group 12: Calcareous soils at higher precipitation zone with black sagebrush and cool-season grasses

Description of MLRA 29 Disturbance Response Group 12

Disturbance Response Group (DRG) 12 is made up of two ecological sites. The precipitation zone ranges from 12 to 16 in. (30–41 cm). Slopes range from 4 to 75%. Elevations range from 6,000 to about 9,000 ft (1,829–2,743 m). The soils temperature regime is typically mesic and the moisture regime is aridic. The soils on these sites are typically very shallow to shallow and well drained. Soil surfaces are modified with a high percentage of gravel, cobbles and stones and available water holding capacity is low. Total annual production is 500 lb/ac for a normal year. The reference plant community of the modal site is dominated by black sagebrush (*Artemisia nova*) and beardless wheatgrass (*Pseudoroegneria spicata ssp. inermis)*. Other important species include Indian ricegrass (*Achnatherum hymenoides*), Sandberg bluegrass (*Poa secunda*) and ephedra (*Ephedra* spp.). Black sagebrush and muttongrass (*Poa fendleriana*) are dominant species on the non-modal site, while Stansbury cliffrose (*Purshia stansburiana*) is a sub-dominant.

Disturbance Response Group 12 Ecological Sites:

Shallow Calcareous Slope 12-14" P.Z – Modal	R029XY028NV
Shallow Gravelly Fan 12-14" P.Z.	R029XY173NV

Modal Site:

The Shallow Calcareous Slope 12-14" P.Z. ecological site is the modal site that represents this DRG, as it has the most acres mapped. This site occurs on mountain sideslopes and summits at elevations from 6,500 to about 9,000 ft (1,981–2,743 m). At lower elevations this site is restricted to cooler, northerly aspects. Slopes range from 4 to 75%, but slope gradients of 15 to 50% are most typical. The soils are generally shallow and modified with high amounts of gravels and/or cobbles on the surface which provide a stabilizing effect on surface erosion. The soils are well drained, and available water holding capacity is low. The shrub component of the plant community is dominated by black sagebrush. The herbaceous component is dominated by beardless wheatgrass.

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasives. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans a unique area in Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area. Flashy, summer storm events contribute significantly to annual precipitation as well. Air and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

Periodic drought regularly influences sagebrush ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West (Miller et al. 2008a). Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006).

Native insect outbreaks are also important drivers of ecosystem dynamics in sagebrush communities. Climate is generally believed to influence the timing of insect outbreaks especially a sagebrush defoliator, Aroga moth (*Aroga websteri*). Aroga moth infestations have occurred in the Great Basin in the 1960s, early 1970s, and is ongoing in Nevada since 2004 (Bentz et al. 2008). Thousands of acres of big sagebrush have been impacted, with partial to complete die-off observed. Aroga moth can partially or entirely kill individual plants or entire stands of big sagebrush (Furniss and Barr 1975), but the research is inconclusive of the damage sustained by black sagebrush populations.

The Great Basin sagebrush communities have high spatial and temporal variability in precipitation both among years and within growing seasons. Nutrient availability is typically low but increases with elevation and closely follows moisture availability. The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and depressed competition or can increase resource pools by the decomposition of dead plant material following disturbance. The invasion of sagebrush communities by cheatgrass (*Bromus tectorum*) has been linked to disturbances (fire, abusive grazing) that have resulted in fluctuations in resources (Chambers et al. 2007).

The ecological sites in this DRG are dominated by deep-rooted cool season, perennial bunchgrasses and long-lived shrubs (50+ years) with high root to shoot ratios. The dominant shrubs usually root to the full depth of the winter-spring soil moisture recharge, which ranges from 1 to over 3 m (3 to 10 ft) (Dobrowolski et al. 1990). Root length of mature sagebrush plants was measured to a depth of 2 m (6.5 ft) in alluvial soils in Utah (Richards and Caldwell 1987). However, community types with black sagebrush as the dominant shrub were found to have shallow soil depths and thus available rooting depths of 77 to 81 cm (30 to 32 in.) in a study in northeast Nevada (Jensen 1990). These shrubs have a flexible generalized root system with development of both deep taproots and laterals near the surface (Comstock and Ehleringer 1992).

Black sagebrush is an evergreen, aromatic shrub that is low-growing and decumbent. Black sagebrush is drought tolerant, highly light tolerant and shade intolerant. Mature plants are slightly salt tolerant and flood intolerant. The root system of black sagebrush consists of a taproot that's often restricted by shallow soils, and shallow branching roots. Black sagebrush typically has more fibrous roots compared to big sagebrush. Black sagebrush flowers from midsummer to mid-fall. Seeds commonly fall close to the parent plant, since seeds are light and unable to be carried by wind, making it difficult for sagebrush to spread. Seeds typically maintain viability over winter, and germinate in the spring, although germination rates are highly variable. Survival of sagebrush seedlings is highly dependent on adequate moisture and light conditions (Fryer 2009).

Stansbury cliffrose (*Purshia stansburiana*) is a semi-evergreen shrub native to the southwestern United States, typically occurring at elevations between 3,000 and 7,000 ft (914–2,134 m). It grows in a variety of habitats, including canyons, mesas, rocky slopes, and open woodlands, often alongside juniper species (*Juniperus spp.) pinyon* (*Pinus spp.)*, sagebrush species, and saltbush species (*Atriplex* spp.) (Welsh et al. 1987). This species has an extensive root system and exhibits nitrogen-fixing capability through symbiosis with *Frankia actinomycetes*, which enables it to thrive in nutrient-poor soils (Van Devender et al. 1987). *Cliffrose* produces small, fragrant cream-colored flowers in early spring, which are pollinated by a variety of native insects. Its seeds are dispersed primarily by gravity and wind, although successful germination may require dormancy-breaking treatments such as scarification or stratification (Stubbendieck et al. 2017). The plant plays an important role in native plant communities of the Intermountain and southwestern regions due to its longevity and structural contribution to shrublands.

Perennial bunchgrasses generally have somewhat shallower root systems than shrubs, but root densities are often as high as or higher than those of shrubs in the upper 0.5 m. General differences in root depth distributions between grasses and shrubs result in resource partitioning in these shrub/grass systems. The perennial bunchgrasses that are sub-dominant with the shrubs include beardless wheatgrass, Indian ricegrass, Sandberg bluegrass, and muttongrass.

Beardless wheatgrass, a subspecies of bluebunch wheatgrass (*Pseudoroegneria spicata*) is the perennial grass species dominating the understory on the modal site. It is a common bunchgrass in the Intermountain regions of the western United States. It is a long-lived, cool-season native grass with an extensive root system exhibiting strong tillering. It is highly variable and grows from 0.5 to 3 ft (<1 m) tall with seed spikes under an inch long (Stubbendieck et al. 2017). Beardless wheatgrass is cold tolerant, moderately shade tolerant, and exhibits high tolerance to wildfire (Ogle 1996). Daubenmire (1939) notes that the only notable difference between beardless wheatgrass and its parent species, bluebunch wheatgrass, is the absence of awns. Aside from this primary distinction, the two subspecies exhibit nearly identical ecological and physiological processes, thus they will be considered the same species throughout this document.

Indian ricegrass (*Achnatherum hymenoides*) can be found in low deserts associated with fourwing saltbush, shadscale and winterfat and in elevations up to 10,000 ft (3,048 m). It can be found throughout MLRA 29, including on ridges, canyons, dunes, hills, plains, and mountains. Indian ricegrass is a key plant in recovering communities disturbed by grazing, mining, and fire because it is a hardy grass that is able to grow in rough, rocky, and coarse soils and still provides very valuable forage. When successfully planted or recovered and managed, Indian ricegrass can help rehabilitate disturbed areas by competing with invasive plants and providing cover and forage (Booth et al. 1980). Indian ricegrass germination and establishment appears to occur in strong pulses, with the plant preferring spring conditions, characterized by slightly higher than normal early soil temperatures, followed by below average temperatures later in the growing season (Pearson 1979).

Sandberg bluegrass (*Poa secunda*) is a cool-season, perennial bunchgrass widely distributed across western North America, from lowland sagebrush steppe to subalpine zones, occurring at elevations ranging from 2,000 to over 10,000 ft (610–3,480 m) (NRCS 2009). It is common throughout MLRA 29 and is often found on dry hillsides, rocky ridges, plains, and disturbed rangelands and it has the capacity to grow in compacted, shallow, and gravelly soils (Stubbendieck et al. 2017). Sandberg bluegrass exhibits high drought tolerance and is competitive with invasive species such as *Bromus tectorum*, especially when established early in restoration seedings (Pellant and Hall 1994). Successful establishment is most likely under cool, moist conditions, especially in early spring or fall, and benefits from shallow seeding (<0.25 in. or 0.6 cm) and low soil crusting (Monsen et al. 2004b).

Muttongrass (*Poa fendleriana*), is a tufted, multi-flowered, perennial bunchgrass that can grow between 8 and 30 in. (20–76 cm) tall and has narrow leaves, which range from 1 to 3 m (<1 in.) wide (Stubbendieck et al. 2017). Muttongrass has a fibrous root system that reaches a depth of approximately 10 in. (25 cm), which provides good surface erosion control (Tilley et al. 2007). Muttongrass is one of the most drought-tolerant bluegrasses and is useful for restoring communities disturbed by fire, grazing, or mining, but is limited in its use due to low seed viability (Forsling and Dayton 1931). Muttongrass plants are most frequently pistillate, but staminate plants do occasionally occur, which are able to hybridize and crossbreed with other bluegrasses.

The ecological sites in this DRG have low to moderate resilience to disturbance and resistance to invasion. Increased resilience increases with elevation, aspect, increased precipitation and increased nutrient availability. Five possible stable states have been identified for the Shallow Calcareous Slope 12-14” P.Z ecological site. Differences in resilience to disturbance for the remaining ecological site in this DRG is described at the end of this document.

Annual Invasive Species:

The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and depressed competition or can increase resource pools by the decomposition of dead plant material following disturbance. The presence of exotic annual plants within these ecosystems decreases ecosystem resilience and resistance to disturbance through competition for limited resources. Peters and Bunting (1994) cites multiple authors on the extent of the soil profile exploited by the competitive exotic annual cheatgrass. Specifically, the depth of rooting is dependent on the size the plant achieves, and in competitive environments, cheatgrass roots were found to penetrate only 15 cm (6 in.) whereas isolated plants and pure stands were found to root at least 1 m in depth (3.2 ft) with some plants rooting as deep as 1.5 to 1.7 m (5 to 5.5 ft).

The species most likely to invade these sites is cheatgrass. Cheatgrass is a cool-season annual grass that maintains an advantage over native plants in part because it is a prolific seed producer, can germinate in the autumn or spring, tolerates grazing, and increases with frequent fire (Klemmedson and Smith 1964, Miller 1999). Cheatgrass originated from Eurasia and was first reported in North America in the late 1800s. Pellant and Hall (1994) found 3.3 million acres of public lands dominated by cheatgrass and suggested that another 76 million acres were susceptible to invasion by winter annuals including cheatgrass and medusahead (*Taeniatherum caput-medusae*).

Recent modeling and empirical work by Bradford and Lauenroth (2006) suggest that seasonal patterns of precipitation input and temperature are also key factors determining regional variation in the growth, seed production, and spread of invasive annual grasses. The phenomenon of cheatgrass “die-off” provides opportunities for restoration of perennial and native species (Baughman et al. 2016, Baughman et al. 2017). The causes of these events are not fully understood, but there is ongoing work to try to predict where they occur, in the hopes of aiding conservation planning (Weisberg et al. 2017, Brehm 2019).

Methods to control cheatgrass include herbicide application, prescribed fire, targeted grazing, and rangeland seeding. Mapping potential or current invasion vectors is a management method designed to increase the cost-effectiveness of control methods. Spraying with herbicide (imazapic or imazapic + glyphosate) and seeding with crested wheatgrass and Sandberg bluegrass has been found to be more successful at combating cheatgrass than spraying alone (Sheley et al. 2012). To date, most seeding success has occurred with non-native wheatgrass species. Perennial grasses, especially crested wheatgrass, are able to suppress cheatgrass growth when mature (Blank et al. 2020). Where native bunchgrasses are missing from the site, revegetation of annual grass-invaded rangelands has been shown to have a higher likelihood of success when using introduced perennial bunchgrasses such as crested wheatgrass Butler et al. (2011), (Davies et al. 2015b, Clements et al. 2017) tested four herbicides (imazapic, imazapic + glyphosate, rimsulfuron, and sulfometuron + chlorsulfuron) for suppression of cheatgrass, medusahead (*Taeniatherum caput-medusae*), and North Africa grass (*Ventenata dubia*) within residual stands of native bunchgrass. Additionally, they tested the same four herbicides followed by seeding of six bunchgrasses (native and non-native) with varying success (Butler et al. 2011). Herbicide-only treatments appeared to remove competition for established bluebunch wheatgrass by providing 100% control of North Africa grass and medusahead and greater than 95% control of cheatgrass (Butler et al. 2011). Caution in using these results is advised, as only 1 year of data was reported.

In considering the combination of pre-emergent herbicide and prescribed fire for invasive annual grass control, it is important to assess the tolerance of desirable brush species to the herbicide being applied. Vollmer and Vollmer (2008) tested the tolerance of alderleaf mountain mahogany (*Cercocarpus montanus*), antelope bitterbrush, and multiple sagebrush species to three rates of imazapic with and without methylated seed oil as a surfactant. They found that a cheatgrass control program in an antelope bitterbrush community should not exceed imazapic at 8 oz/ac with or without surfactant. Sagebrush, regardless of species or rate of application, was not affected. However, many environmental variables were not reported in this study and managers should install test plots before broad-scale herbicide application is initiated.

Fire Ecology:

Fire is not a major ecological component of these community types (Winward 2001), and would be infrequent. Fire return intervals have been estimated at 100 to 200 years (Kitchen and McArthur 2007); however, fires were probably patchy and very infrequent due to the low productivity of these sites. Black sagebrush plants have no morphological adaptations for surviving fire and must reestablish from seed following fire (Wright et al. 1979). The ability of black sagebrush to establish after fire is mostly dependent on the amount of seed deposited in the seed bank the year before the fire. Seeds typically do not persist in the soil for more than one growing season (Beetle 1960). A few seeds may remain viable in soil for two years (Meyer 2008a); however, even in dry storage, black sagebrush seed viability has been found to drop rapidly over time, from 81% to 1% viability after two and 10 years of storage, respectively (Stevens et al. 1981). Thus, repeated frequent fires can eliminate black sagebrush from a site, however black sagebrush in zones receiving 12 to 16 in. (30–41 cm) of annual precipitation have been found to have greater fire survival (Boltz 1994). In lower precipitation zones, rabbitbrush may become the dominant shrub species following fire, often with an understory of Sandberg bluegrass and/or cheatgrass and other weedy species.

Stansbury cliffrose is moderately fire tolerant (McConnell and Smith 1977). These shrubs regenerate primarily by seed and may resprout (Blaisdell and Mueggler 1956, McArthur and Welch 1982), however, sprouting ability is highly variable and has been attributed to genetics, plant age, phenology, soil moisture and texture, and fire severity (Blaisdell and Mueggler 1956, Blaisdell et al. 1982, Clark et al. 1982, Cook et al. 1994). Cliffrose sprouts from a region on the stem approximately 1.5 in. (3.8 cm) above and below the soil surface; the plant rarely sprouts if the root crown is killed by fire (Blaisdell and Mueggler 1956). It may resprout following a low-intensity fire however, sprouting response also depends on soil moisture levels at the time of fire (Murray 1983). Lower soil moisture allows more charring of the stem below ground level (Blaisdell and Mueggler 1956), thus sprouting will usually be more successful after a spring fire than after a fire in summer or fall (Murray 1983, Busse et al. 2000, Kerns et al. 2006). If cheatgrass is present, cliffrose seedling success is much lower. The factor that most limits the establishment of these seedlings is competition for water resources with the invasive species cheatgrass (Clements and Young 2002).

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The initial condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species response. For most forbs and grasses, the growing points are located at or below the soil surface providing relative protection from disturbances which decrease above ground biomass, such as grazing or fire. Thus, fire mortality is more correlated to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant and abundance of old growth (Wright 1971, Young 1983). However, season and severity of the fire will influence plant response. Plant response will vary depending on post-fire soil moisture availability.

Fire will remove aboveground biomass from beardless wheatgrass but plant mortality is generally low (Robberecht and Defossé 1995) because the buds are underground (Conrad and Poulton 1966) or protected by foliage. Uresk et al. (1976) reported burning increased vegetative and reproductive vigor of beardless wheatgrass. Thus, beardless wheatgrass is considered to experience slight damage to fire but is more susceptible in drought years (Young 1983). Plant response will vary depending on season, fire severity, fire intensity and post-fire soil moisture availability.

Indian ricegrass is fairly fire tolerant (Wright 1985), which is likely due to its low culm density and below-ground plant crowns. Vallentine (1989) cites several studies in the sagebrush zone that classified Indian ricegrass as being slightly damaged from late summer burning. Indian ricegrass has also been found to reestablish on burned sites through seeds dispersed from adjacent unburned areas (Young 1983, West 1994). Thus, the presence of surviving, seed-producing plants facilitates the reestablishment of Indian ricegrass. Grazing management following fire to promote seed production and establishment of seedlings is important. When properly managed, Indian ricegrass can be a key factor in a community recovering from disturbance because it can grow in rough, rocky, coarse, and otherwise unproductive soils (Booth et al. 1980).

Sandberg bluegrass is relatively fire tolerant due to its early seasonal dormancy and small stature, which result in low fuel accumulation and limited heat damage to meristematic tissues (NRCS 2009, Halvorson 2011). The species often survives wildfires with minimal mortality and may increase in post-fire environments where competition is reduced. Although seed dispersal is limited, *Sandberg bluegrass* can reestablish burned areas when unburned seed sources are nearby, particularly if grazing is managed to protect recovering plants (NRCS 2009). Its ability to persist on disturbed, nutrient-poor soils and stabilize interspaces makes it an important component of early-successional vegetation following fire. As with other native bunchgrasses, post-fire management should prioritize light or deferred grazing to promote recovery and maintain its ecological role (Monsen et al. 2004b, Halvorson 2011).

Muttongrass is top killed by fire but will regrow after low to moderate severity fires (Monsen et al. 2004b). Research by Vose and White (1991) found minimal difference in density and number of plants following fall fire in muttongrass communities. However, high severity fire has been shown to kill muttongrass with little to no recovery (Erdman 1970).

Livestock/ Wildlife Grazing Interpretations:

Black sagebrush palatability has been rated as moderate to high depending on the ungulate and the season of use (Horton 1989, Wambolt 1996). The palatability of black sagebrush increases the potential negative impacts on remaining black sagebrush plants from grazing or browsing pressure following fire (Wambolt 1996). Pronghorn utilize black sagebrush heavily (Beale and Smith 1970). On the Desert Experiment Range, black sagebrush was found to comprise 68% of pronghorn diet even though it was only the third most common plant. Fawns were found to prefer black sagebrush utilizing it more than all other forage species combined (Beale and Smith 1970). Domestic livestock will also utilize black sagebrush. The domestic sheep industry that emerged in the Great Basin in the early 1900s was largely based on wintering domestic sheep in black sagebrush communities (Mozingo 1987c). Domestic sheep will browse black sagebrush during all seasons of the year depending on the availability of other forage species with greater amounts being consumed in fall and winter. Black sagebrush is generally less palatable to cattle than to domestic sheep and wild ungulates (McArthur et al. 1979); however, cattle use of black sagebrush has also been shown to be greatest in fall and winter (Schultz and McAdoo 2002), with only trace amounts being consumed in summer (Van Vuren 1984). Frye et al. (2013) found that greater sage-grouse preferentially selected black sagebrush over other sagebrush species, likely due to its more favorable nutritional profile and lower concentrations of plant secondary metabolites.

Stansbury cliffrose is a regionally important browse species in the southwestern United States, especially valued by wildlife. It is a preferred winter forage for mule deer, elk, pronghorn, and desert bighorn sheep, particularly in areas like the Kaibab Plateau, where it is often heavily browsed during cold seasons (Tiedemann and Johnson 1983, Monsen et al. 2004b). While livestock may utilize it in spring and summer when alternative forage is scarce, palatability varies geographically and among species. For instance, it is rated as good forage for cattle in Arizona, but only fair to poor in California and Utah; sheep rank it from fair to good depending on location, while horses rarely use it (Tiedemann and Johnson 1983). Preference by mule deer appears more consistent, with *P. stansburiana* ranked third out of 10 browse species in one Utah palatability trial, though other studies ranked it fifteenth out of thirty-two (Smith and Hubbard 1954). Despite some regional and ecological variation in palatability, *P. stansburiana* plays a significant nutritional and ecological role in desert and pinyon-juniper shrublands throughout its range (Monsen et al. 2004b).

Inappropriate grazing management during the growing season will cause a decline in beardless wheatgrass. It is moderately grazing tolerant, however is sensitive to defoliation during the active growth period (Blaisdell and Pechanec 1949, Laycock 1967, Anderson and Scherzinger 1975, Britton et al. 1990). Herbage and flower stalk production was reduced with clipping at all times during the growing season; however, clipping was most harmful during the boot stage (Blaisdell and Pechanec 1949). Tiller production and growth of beardless wheatgrass was greatly reduced when clipping was coupled with drought (Busso and Richards 1995). Mueggler (1975) estimated that low vigor beardless wheatgrass may need up to 8 years rest to recover. Although an important forage species, it is not always the preferred species by livestock and wildlife (Zlatnik 1999b).

Indian ricegrass is a preferred forage species for livestock and wildlife (Cook 1962, Booth et al. 1980). This species is often heavily utilized in winter because it cures well (Booth et al. 1980). It is also readily utilized in early spring, being a source of green feed before most other perennial grasses have produced new growth (Quinones 1981). Booth et al. (1980) note that the plant does well when utilized in winter and spring. However, it has been found that repeated heavy grazing, particularly in early spring, reduced crown cover, stand density, and plant vigor, which may reduce seed production, density, and basal area of these plants (Cook and Child 1971). In eastern Idaho, productivity of Indian ricegrass was at least 10 times greater in undisturbed plots than in heavily grazed ones (Pearson 1979), however, Cook and Child (1971) found a significant reduction in plant cover after 7 years of rest from heavy (90%) and moderate (60%) spring use. Tolerance to grazing increases after May, thus spring deferment may be necessary for stand enhancement (Pearson 1964, Cook and Child 1971); however, utilization of less than 60% is recommended. In summary, adaptive management is required to manage this or any other bunchgrass well.

Sandberg bluegrass is one of the first grasses to green up in spring, providing critical early forage for livestock and wildlife (NRCS 2009, Halvorson 2011). While palatable when young, its value declines as it cures by early summer. Although it contributes modestly to total forage biomass, it plays an important ecological role by stabilizing soil in interspaces and limiting invasive species establishment (Monsen et al. 2004b). Grazing tolerance is moderate, thus light spring grazing is acceptable, but repeated heavy use can reduce vigor and reproduction (Monsen et al. 2004b, Halvorson 2011).

Muttongrass is very palatable for wildlife and livestock and is rated as excellent forage for cattle and horses, and good for sheep. Muttongrass starts growth in late winter or early spring and provides excellent early feed. Muttongrass foliage cures well and is good fall forage, but not as good as spring or summer (Humphrey et al. 1952).

State and Transition Model Narrative for Group 12:

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 29 disturbance response group 12.

Reference State 1.0:

The Reference State 1.0 is a representative of the natural range of variability under pristine conditions. The Reference State has three general community phases; a shrub-grass dominant phase, a perennial grass dominant phase and a shrub dominant phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire, periodic drought and/or insect or disease attack. Due to the nature and extent of disturbance in this site, all three plant community phases would likely occur in a mosaic across the landscape. Utah juniper and/or singleleaf pinyon may be present on the site, but will only occur as scattered trees.

Community Phase 1.1:

The reference plant community is dominated by black sagebrush and beardless wheatgrass. Forbs and other perennial grasses make up smaller components. Utah juniper and singleleaf pinyon are described in the site concept and may or may not be present. Potential vegetative composition is approximately 60% grasses, 5% forbs and 35% shrubs and trees. Approximate ground cover (basal and crown) is approximately 15 to 35%. Total annual air-dry production ranges from 250 to 700 lb/ac.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:

A low severity fire will decrease or eliminate the overstory of sagebrush and allow for the perennial bunchgrasses to dominate the site. Fires will typically be low severity resulting in a mosaic pattern due to low fuel loads. A fire following an unusually wet spring facilitating an increase in fine fuels may be more severe and reduce sagebrush cover to trace amounts.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.3:

Time and lack of disturbance such as fire allows for sagebrush to increase and become decadent. Chronic drought, herbivory, or combinations of these will generally cause a reduction in perennial bunchgrasses and fine fuels leading to a reduced fire frequency and allowing black sagebrush to dominate the site. Utah juniper and/or singleleaf pinyon will increase where this site occurs next to woodlands.

Community Phase 1.2:

This community phase is characteristic of a post-disturbance, early-seral community. Beardless wheatgrass, Indian ricegrass, and other perennial bunchgrasses dominate. Sprouting shrubs such as yellow rabbitbrush (*Chrysothamnus viscidiflorus*) may increase. Depending on fire severity patches of intact sagebrush may remain.

Community Phase Pathway 1.2a, from 1.2 to 1.1:

Time and lack of disturbance will allow sagebrush to increase.

Community Phase 1.3:

Sagebrush increases in the absence of disturbance. Decadent sagebrush dominates the overstory and the deep-rooted perennial bunchgrasses in the understory are reduced either from competition with shrubs and/or from herbivory. Sandberg bluegrass may increase in the understory and become the dominant grass on the site. Scattered Utah juniper or singleleaf pinyon may be present on the site.

Community Phase Pathway 1.3a, from Phase 1.3 to 1.1:

A low severity fire, fall/winter herbivory causing mechanical damage to shrubs, or combinations will reduce the sagebrush overstory and create a sagebrush/grass mosaic.

Community Phase Pathway 1.3b, from Phase 1.3 to 1.2:

Fire will decrease or eliminate the overstory of sagebrush and allow for the perennial bunchgrasses to dominate the site. Fires will typically be high intensity due to the dominance of sagebrush in this community phase, resulting in removal of the overstory shrub community.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0

Trigger: This transition is caused by the introduction of non-native annual plants, such as cheatgrass and mustards.

Slow variables: Over time the annual non-native species will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

This state is similar to the Reference State 1.0 however with the addition of a fourth community phase. Ecological function of community phases 2.1, 2.2 and 2.3 has not changed, however the resiliency of the state has been reduced by the presence of non-native annual species. Non-native annuals may increase in abundance on a temporal basis as described in community phase 2.4 but will not become dominant within this State. These non-natives can be highly flammable and can promote fire where historically fire had been infrequent. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These feedbacks include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal.

Community Phase 2.1:

This community phase is similar to the Reference State Community Phase 1.1, with the presence of non-native species in trace amounts. Black sagebrush and beardless wheatgrass dominate the site. Forbs and other shrubs and perennial grasses make up smaller components of this site.

Shallow Calcareous Slope 12-14" P.Z. (R029XY028NV), Current Potential 2.1, T. Stringham, June 2023

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:

Fire reduces the shrub overstory and allows for perennial bunchgrasses to dominate the site. Fires are typically low severity resulting in a mosaic pattern due to low fuel loads. A fire following an unusually wet spring or a change in management favoring an increase in fine fuels may be more severe and reduce sagebrush cover to trace amounts. Annual non-native species are likely to increase after fire.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.3:

Time and lack of disturbance allows for sagebrush to increase and become decadent. Chronic drought reduces fine fuels and leads to a reduced fire frequency, allowing black sagebrush to dominate the site. Inappropriate grazing management reduces the perennial bunchgrass understory; conversely Sandberg bluegrass may increase in the understory depending on grazing management. Utah juniper and/or singleleaf pinyon may increase where site occurs near woodlands.

Community Phase 2.2:

This community phase is characteristic of a post-disturbance, early seral community where annual non-native species are present. Sagebrush is present in trace amounts; perennial bunchgrasses dominate the site. Depending on fire severity patches of intact sagebrush may remain. Rabbitbrush may be sprouting. Annual non-native species are stable or increasing within the community.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:

Time and lack of disturbance and/or grazing management that favors the establishment and growth of sagebrush allows the shrub component to recover. The establishment of black sagebrush can take many years.

Community Phase 2.3 (At Risk):

Black sagebrush dominates the overstory and perennial bunchgrasses in the understory are reduced, either from competition with shrubs or from inappropriate grazing, or from both. Yellow rabbitbrush may be a significant component. Sandberg bluegrass may increase and become co-dominant with deep rooted bunchgrasses. Utah juniper and/or singleleaf pinyon may be present and without management will likely increase. Annual non-natives species may be stable or increasing due to lack of competition with perennial bunchgrasses. This community phase is susceptible to further degradation from grazing, drought, and fire. This community is at risk of crossing a threshold to either State 3.0 (grazing or fire) or State 4.0 (fire).

Community Phase Pathway 2.3a, from Phase 2.3 to 2.1:

Grazing management that reduces shrubs will allow for the perennial bunchgrasses in the understory to increase. Heavy late-fall/winter grazing may cause mechanical damage to sagebrush thus promoting the perennial bunchgrass understory. Brush treatments with minimal soil disturbance will also decrease sagebrush and release the perennial understory. Annual non-native species are present and may increase in the community. A low severity fire would decrease the overstory of sagebrush and allow for the understory perennial grasses to increase. Due to low fuel loads in this state, fires will likely be small creating a mosaic pattern.

Community Phase Pathways 2.3b, from Phase 2.3 to 2.2:
Fire will decrease or eliminate the overstory of sagebrush and allow for the perennial bunchgrasses to dominate the site. Fires will typically be high intensity due to the dominance of sagebrush in this community phase resulting in removal of the overstory shrub community. Annual non-native species respond well to fire and may increase post-burn. Brush treatment would reduce black sagebrush overstory and allow for perennial bunchgrasses to increase.

T2A: Transition from Current Potential State 2.0 to Shrub State 3.0

Trigger: To Community Phase 3.1: Inappropriate cattle/horse/sheep grazing will decrease or eliminate deep-rooted perennial bunchgrasses, increase Sandberg bluegrass and favor shrub growth and establishment. To Community Phase 3.2: Severe fire will remove sagebrush overstory, decrease perennial bunchgrasses and enhance Sandberg bluegrass. Soil disturbing brush treatments and/or inappropriate domestic sheep grazing will reduce sagebrush and potentially increase sprouting shrubs and Sandberg bluegrass and/or galleta grass.

Slow variables: Long-term decrease in deep-rooted perennial bunchgrass density and/or black sagebrush.

Threshold: Loss of deep-rooted perennial bunchgrasses changes nutrient cycling, nutrient redistribution, and reduces soil organic matter. Loss of long-lived, black sagebrush changes the temporal and depending on the replacement shrub, the spatial distribution of nutrient cycling.

T2B: Transition from Current Potential State 2.0 to Tree State 4.0

Trigger: Time and lack of disturbance (fire) or management action allows for Utah Juniper and/or singleleaf pinyon to dominate. This may be coupled with grazing management that favors tree establishment by reducing understory herbaceous competition for site resources.

Feedbacks and ecological processes: Trees increasingly dominate use of soil water resulting in decreasing herbaceous and shrub production and decreasing organic matter inputs, contributing to reductions in soil water availability to grasses and shrubs and increased soil erodibility.

Slow variables: Over time the abundance and size of trees will increase.

Threshold: Trees dominate ecological processes and sagebrush is decadent and dying.

T2C: Transition from Current Potential State 2.0 to Annual State 5.0

Trigger: Catastrophic fire or soil surface disturbance.

Slow variables: Increased production and cover of non-native annual species.

Threshold: Loss of deep-rooted perennial bunchgrasses and shrubs changes energy and nutrient capture and cycling both spatially and temporally within the community. Increased, continuous fine fuels modify the fire regime by changing intensity, size and spatial variability of fires.

Shrub State 3.0:

This state has two community phases, one that is characterized by a decadent black sagebrush overstory and one with a post-fire sprouting shrub overstory. Sandberg bluegrass and/or galleta may dominate the understory. Sagebrush cover exceeds site concept and may be decadent, reflecting stand maturity and lack of seedling establishment due to competition with mature plants. The shrub overstory dominates site resources such that soil water, nutrient capture, nutrient cycling and soil organic matter are temporally and spatially redistributed. Bare ground has increased and soil redistribution may be increasing.

Community Phase 3.1

Decadent black sagebrush dominates the overstory. Rabbitbrush may be a significant component. Deep-rooted perennial bunchgrasses may be present in trace amounts or absent from the community. Sandberg bluegrass and/or galleta may be dominate understory. Annual non-native species increase. Bare ground is significant and soil redistribution may be occurring. If present on the site, Utah juniper and/or singleleaf pinyon is increasing. This community phase may be at risk of transitioning to either the Tree State or Annual State.

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:

Fire reduces black sagebrush to trace amounts and allows for sprouting shrubs such as rabbitbrush to dominate. Brush treatments with minimal soil disturbance would facilitate sprouting shrubs and Sandberg bluegrass and/or galleta.

Community Phase 3.2

Sprouting shrubs such as yellow rabbitbrush dominate the overstory. Sandberg bluegrass and/or galleta may be reduced. Annual non-native species may be increasing and bare ground is significant. This site is at risk for an increase in non-native annuals.

Community Phase 3.2a, from Phase 3.2 to 3.1:

Time and lack of disturbance and/or grazing management that favors the establishment and growth of sagebrush allows for the shrub component to recover. The establishment of black sagebrush may take many years.

T3A: Transition from Shrub State 3.0 to Tree State 4.0

Trigger: Absence of disturbance (fire) over time allows for Utah juniper or singleleaf pinyon dominance. This may be coupled with grazing management that favors tree establishment by reducing understory herbaceous competition for site resources.

Slow variables: Long-term increase in Utah juniper and/or singleleaf pinyon density and size.

Threshold: Trees overtop black sagebrush and out-compete shrubs for water and sunlight. Shrub skeletons exceed live shrubs in number. There is minimal recruitment of new shrub cohorts. Litter builds up underneath trees while bare ground increases in interspaces; this changes nutrient cycling and levels of organic matter in the soil.

T3B: Transition from Shrub State 3.0 to Annual State 5.0

Trigger: Severe fire.

Slow variables: Increased production and cover of non-native annual species.

Threshold: Increased, continuous fine fuels modify the fire regime by changing intensity, size and spatial variability of fires. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and sagebrush truncate energy capture spatially and temporally thus impacting nutrient cycling and distribution.

Tree State 4.0:

This state has two community phases that are characterized by a dominance of Utah juniper and/or singleleaf pinyon in the overstory. Black sagebrush and perennial bunchgrasses may still be present, but they are no longer controlling site resources. Soil moisture, soil nutrients and soil organic matter distribution and cycling have been spatially and temporally altered.

Community Phase 4.1

Utah juniper and/or singleleaf pinyon dominates the overstory and site resources. Trees are actively growing with noticeable leader growth. Trace amounts of bunchgrasses may be found under tree canopies with trace amounts of Sandberg bluegrass and mat-forming forbs in the interspaces. Sagebrush is stressed and dying. Recruitment of sagebrush cohorts is minimal. Annual non-native species are present under tree canopies. Bare ground interspaces are large and connected.

Community Phase Pathway 4.1a, from Phase 4.1 to 4.2:

Time and lack of disturbance (fire) or management action allows for tree cover and density to further increase, and trees to out-compete the herbaceous understory species for sunlight and water.

Community Phase 4.2 (at risk)

Utah juniper and/or singleleaf pinyon dominates the site and tree leader growth is minimal; annual non-native species may be the dominant understory species and will typically be found under the tree canopies. Trace amounts of sagebrush may be present however dead skeletons will be more numerous than living sagebrush. Bunchgrasses may be present. Sandberg bluegrass or mat forming forbs may be present in trace amounts. Bare ground interspaces are large and connected. Soil redistribution is evident.

R4A: Restoration from Tree State 4.0 to Current Potential 2.0:

Tree removal with minimum soil disturbance such as hand-felling or mastication within community phase 4.1. This is usually coupled with seeding of desired species.

T4A: Transition from Tree State 4.0 to Annual State 5.0

Trigger: Catastrophic fire causing a stand replacement event. Inappropriate tree removal practices with soil disturbance will also cause a transition to Annual State 5.0.

Slow variables: Increased production and cover of non-native annual species under tree canopies.

Threshold: Closed tree canopy with non-native annual species dominant in the understory changes the intensity, size and spatial variability of fires. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and sagebrush truncate energy capture and impact nutrient cycling and distribution.

Annual State 5.0:

This state has one community phase dominated by an annual grass community. In this state, a biotic threshold has been crossed and state dynamics are driven by the dominance and persistence of the annual grass community which is perpetuated by a shortened fire return interval. The herbaceous understory is dominated by annual non-native species such as cheatgrass and mustards. Resiliency has declined and further degradation from fire facilitates a cheatgrass and sprouting shrub plant community. The fire return interval has shortened due to the dominance of cheatgrass in the understory and is a driver in site dynamics.

Community Phase 5.1:

Annual non-native plants such as Russian thistle (*Salsola tragus*) and cheatgrass dominate this site.

Shallow Calcareous Slope 12-14" P.Z. (R029XY028NV), Annual State, T. Stringham, June 2023

Community Phase Pathway 5.1a, from Phase 5.1 to 5.2:

Time and lack of disturbance (fire) or management action allows for black sagebrush and perennial grasses to reestablish or increase. Sprouting shrubs will be the first to appear after fire.

Community Phase 5.2:

Sprouting shrubs remain in the overstory with annual non-native species dominating the understory. Trace amounts of perennial bunchgrasses may be present.

Community Phase Pathway 5.2a, from Phase 5.2 to 5.1:

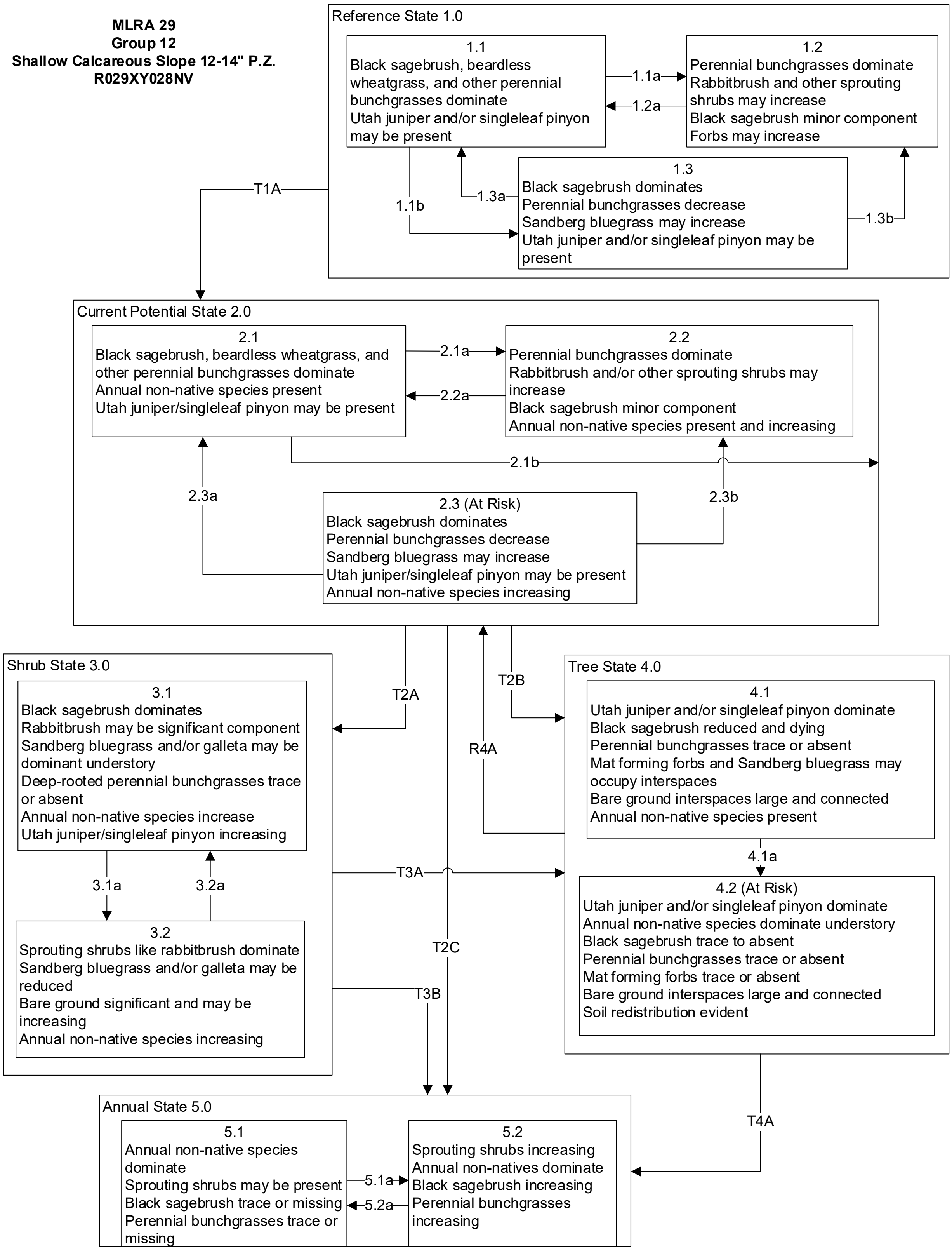
Wildfire allows for annual non-native species to dominate the site.

Potential Resilience Differences with Other Ecological Sites in this Group:

Shallow Gravelly Fan 12-14" P.Z. (R029XY173NV)

The reference plant community is dominated by black sagebrush and muttongrass. This site occurs on fan remnants at elevations from 6,000 to 7,500 ft (1,829–2,286 m). Slopes typically range from 4% to 75%. Soils on these sites have formed in alluvium derived from limestone. They are moderately alkaline from the soil surface to the petrocalcic horizon. The surface is covered with approximately 70% rock fragments, mostly gravels, providing a stabilizing effect on surface erosion conditions. Potential vegetative composition by air-dry weight of this site is 25% grasses, 15% forbs, 60% shrubs, and ≤1% trees. The annual air-dry production on a normal year for the site is 500 lb/ac. This site has similar resilience as the modal site because of similar elevations, precipitation and production.

Modal State and Transition Model for Group 12 in MLRA 29:



MLRA 29
Group 12
Shallow Calcareous Slope 12-14" P.Z.
R029XY028NV

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community, dominated by grasses and forbs.
1.1b: Time and lack of disturbance such as fire or drought allows sagebrush to increase and become decadent. Excessive herbivory or drought would also reduce perennial understory.
1.2a: Time and lack of disturbance allows for sagebrush regeneration.
1.3a: Low severity fire results in a grass/sagebrush mosaic. Fall/winter herbivory may cause mechanical damage to shrubs and reduce shrub density.
1.3b: High severity fire significantly reduces sagebrush cover and leads to early/mid-seral community, dominated by perennial grasses and forbs

Transition T1A: Introduction of non-native species such as cheatgrass and mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community dominated by grasses and forbs; non-native annual species present.
2.1b: Time and lack of disturbance such fire or drought allows sagebrush to increase and become decadent. Inappropriate grazing management may also reduce perennial understory.
2.2a: Time and lack of disturbance allows for sagebrush regeneration.
2.3a: Low severity fire results in a grass/sagebrush mosaic pattern. Brush management with minimal soil disturbance or late-fall/winter grazing causing mechanical damage to sagebrush promotes growth in the perennial bunchgrass understory.
2.3b: High severity fire significantly reduces sagebrush cover and leads to early/mid-seral community dominated by grasses and forbs; non-native annual species present.

Transition T2A: Inappropriate grazing management from cattle/wild horses/burrows decreases or eliminates deep-rooted perennial bunchgrasses(3.1). Fire or brush treatment that may be coupled with inappropriate grazing management reduces sagebrush and perennial bunchgrasses but increases Sandberg bluegrass (3.2).
Transition T2B: Time and lack of disturbance allows for maturation of trees, may be coupled with grazing management that favors tree establishment by reducing herbaceous understory.
Transition T2C: High severity fire or soil surface disturbance.

Shrub State 3.0 Community Phase Pathways
3.1a: Fire or brush management (i.e. mowing) with minimal soil disturbance.
3.2a: Time and lack of disturbance.

Transition T3A: Time and lack of disturbance allows for tree maturation; may be coupled with grazing management that favors tree establishment by removing competitive herbaceous understory.
Transition T3B: Catastrophic fire.

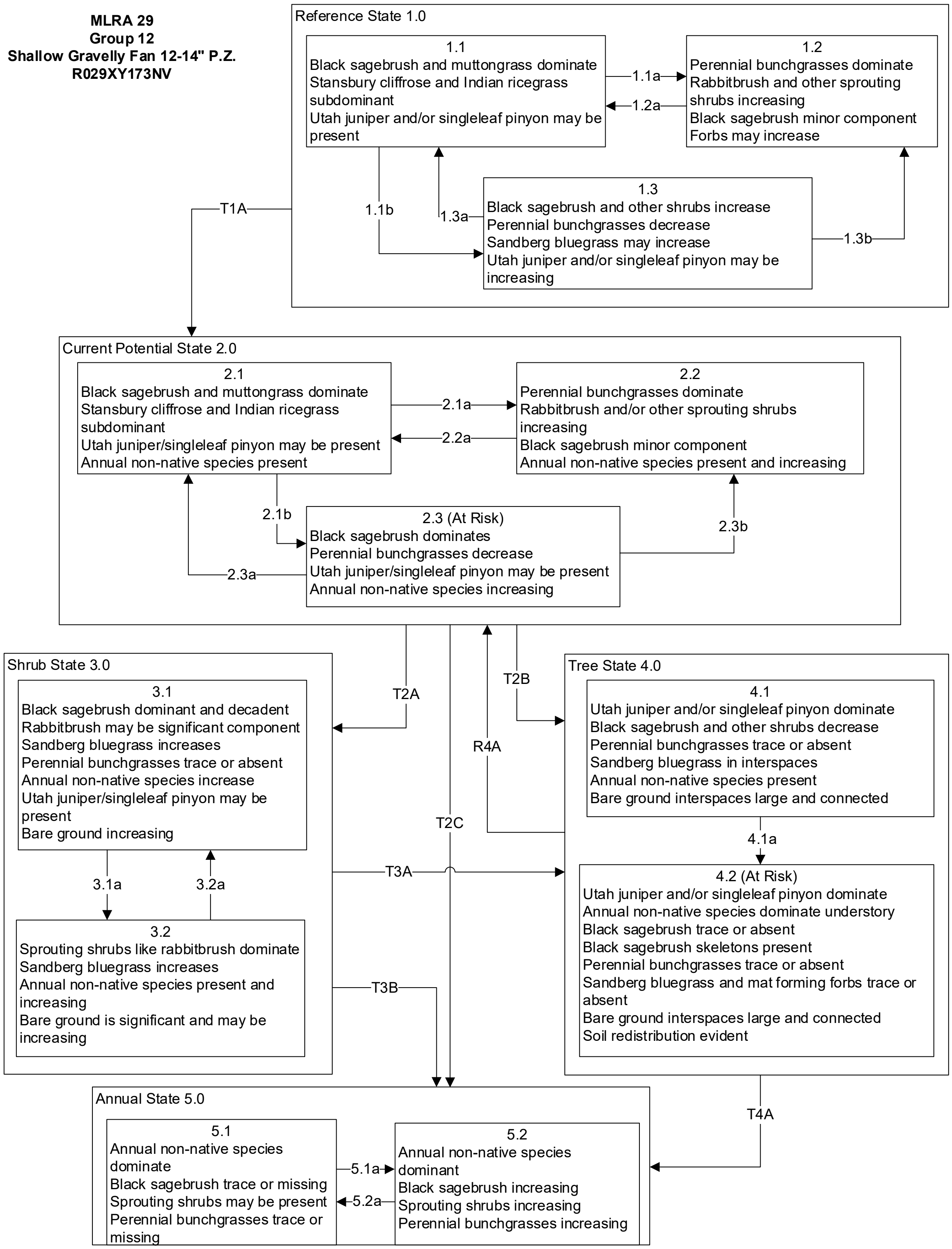
Tree State 4.0 Community Phase Pathways
4.1a: Time and lack of disturbance allows maturation of tree community.

Restoration R4A: Tree removal with minimal soil disturbance. Usually coupled with seeding of desired species.

Transition T4A: Catastrophic fire and/or inappropriate tree removal practices.

Annual State 5.0 Community Phase Pathways
5.1a: Time and lack of disturbance (fire) allows for shrubs and perennial bunchgrasses to increase.
5.2b: Wildfire

Additional State and Transition Models for Group 12 in MLRA 29:



MLRA 29
Group 12
Shallow Gravelly Fan 12-14" P.Z.
R029XY173NV

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community, dominated by grasses and forbs.
1.1b: Time and lack of disturbance such as fire or drought allows sagebrush to increase and become decadent. Excessive herbivory or drought would also reduce perennial understory.
1.2a: Time and lack of disturbance allows for sagebrush regeneration.
1.3a: Low severity fire results in a grass/sagebrush mosaic. Fall/winter herbivory may cause mechanical damage to shrubs and reduce shrub density.
1.3b: High severity fire significantly reduces sagebrush cover and leads to early/mid-seral community, dominated by perennial grasses and forbs

Transition T1A: Introduction of non-native species such as cheatgrass and mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community dominated by grasses and forbs; non-native annual species present.
2.1b: Time and lack of disturbance such fire or drought allows sagebrush to increase and become decadent. Inappropriate grazing management may also reduce perennial understory.
2.2a: Time and lack of disturbance allows for sagebrush regeneration.
2.3a: Low severity fire results in a grass/sagebrush mosaic pattern. Brush management with minimal soil disturbance or late-fall/winter grazing causing mechanical damage to sagebrush promotes growth in the perennial bunchgrass understory.
2.3b: High severity fire significantly reduces sagebrush cover and leads to early/mid-seral community dominated by grasses and forbs; non-native annual species present.

Transition T2A: Inappropriate grazing management from cattle/wild horses/burrows decreases or eliminates deep-rooted perennial bunchgrasses(3.1). Fire or brush treatment that may be coupled with inappropriate grazing management reduces sagebrush and perennial bunchgrasses but increases Sandberg bluegrass (3.2).
Transition T2B: Time and lack of disturbance allows for maturation of trees, may be coupled with grazing management that favors tree establishment by reducing herbaceous understory.
Transition T2C: High severity fire or soil surface disturbance.

Shrub State 3.0 Community Phase Pathways
3.1a: Fire or brush management (i.e. mowing) with minimal soil disturbance.
3.2a: Time and lack of disturbance.

Transition T3A: Time and lack of disturbance allows for tree maturation; may be coupled with grazing management that favors tree establishment by removing competitive herbaceous understory.
Transition T3B: Catastrophic fire.

Tree State 4.0 Community Phase Pathways
4.1a: Time and lack of disturbance allows maturation of tree community.

Restoration R4A: Tree removal with minimal soil disturbance. Usually coupled with seeding of desired species.

Transition T4A: Catastrophic fire and/or inappropriate tree removal practices.

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MLRA 29 Group 13: Loamy soils with Wyoming big sagebrush and cool-season grasses

Description of MLRA 29 Disturbance Response Group 13

Disturbance Response Group (DRG) 14 consists of thirteen ecological sites. These sites range in precipitation from 8 to 14 in. (20–36 cm). Sites within this disturbance response group are characterized by a dominance of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*), or a mix of Wyoming big sagebrush and mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*). Indian ricegrass (*Achnatherum hymenoides*) is the dominant understory grass species. The elevation range of this group is approximately 4,800 to about 8,000 ft (1,463–2,438 m). Slopes range from 0 to 75%. Annual production for a normal year ranges from 350 to 1,200 lb/ac. The soils are primarily formed in alluvium and there is typically a slight or moderate concentration of salts and sodium in the subsoil. Surface soils for these sites are varied and can be fine-textured or coarse-textured with gravel and/or rock fragments throughout the profile. The majority of the soils correlated to the ecological sites in this group have a mesic soil temperature, and a frigid soil temperature at the higher elevations. The soil moisture regime is xeric or aridic. Additional important plant species found on these sites include needle-and-thread grass (*Hesperostipa comata*), desert needlegrass (*Achnatherum speciosum*), beardless wheatgrass (*Pseudoroegneria spicata* ssp. *inermis*), galleta (*Pleuraphis jamesii*), Stansbury's cliffrose (*Purshia stansburiana*), bitterbrush (*Purshia* spp.), ephedra (*Ephedra* spp.) and fourwing saltbush (*Atriplex canescens*).

The Natural Resource Conservation Service (NRCS) describes the shrub component of some of the ecological sites in this DRG as being dominated by mountain big sagebrush or containing a mix of big sagebrush species. However, investigation during field visits revealed a potential misidentification of the sagebrush subspecies. Through careful examination of morphological characteristics and ultraviolet (UV) light testing, a technique developed by Stevens and McArthur (1974), Wyoming big sagebrush, instead of mountain big sagebrush, was confirmed on many of these sites occurring within the 12–14 in. (30–36 cm) precipitation zone. Utilizing this methodology, it was determined that in MLRA 29, mountain big sagebrush occurs primarily above 7,500 ft (2,286 m) in elevation and occasionally between 6,500 and 7,500 ft (1,981–2,286 m) on north-facing aspects. Identification of sagebrush using the UV light testing is recommended for confirmation of subspecies.

Disturbance Response Group 13 Ecological Sites:

Loamy Slope 8-10" P.Z. – Modal	R029XY010NV
Loamy 8-10" P.Z.	R029XY006NV
Sandy Loam 8-12" P.Z.	R029XY049NV
Loamy 10-12" P.Z.	R029XY029NV
Loamy Slope 10-12" P.Z.	R029XY075NV

Gravelly Clay Slope 12-14" P.Z.	R029XY164NV
Loamy Fan 8-12" P.Z.	R029XY114NV
Gravelly Loam 8-10" P.Z.	R029XY167NV
Bouldery Slope 8-12" P.Z.	R029XY073NV
Gravelly Clay Slope 10-12" P.Z.	R029XY106NV
Loamy 12-14" P.Z.	R029XY030NV
Loamy Slope 12-14" P.Z.	R029XY057NV
Fan Collar 12-16" P.Z.	R029XY061NV
Coarse Loamy 8-10" P.Z.	R029XY158NV

Modal Site:

The Loamy Slope 8-10" P.Z. ecological site is the modal site for this DRG, as it has the most acres mapped. This site occurs on piedmont slopes, rock pediments, hills, and lower mountain sideslopes on all exposures. Slopes range from 15 to 75%, but slope gradients of 30 to 50% are typical. Elevations are 4,800 to about 6,500 ft (1,463–1,981 m). Soils of this site are very shallow to moderately deep and are formed in a variety of parent materials. Runoff is rapid and the soils are well drained. The surface may be stony, cobbly, or gravelly. The soils typically have low to moderate available water capacity. The soil temperature regime is mesic and the moisture regime is xeric. The reference plant community is dominated by Wyoming big sagebrush, and Indian ricegrass. Other important species occurring on this site are fourwing saltbush and ephedra. The average production for a normal year is 350 lb/ac.

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasives. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans a unique area in Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area. Flashy, summer storm events contribute significantly to annual precipitation as well. Air and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992).

Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

Periodic drought regularly influences sagebrush ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West (Miller and Heyerdahl 2008). Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006).

Native insect outbreaks are also important drivers of ecosystem dynamics in sagebrush communities. Climate is generally believed to influence the timing of insect outbreaks especially a sagebrush defoliator, Aroga moth (*Aroga websteri*). Documented Aroga moth infestations have occurred in the Great Basin in the 1960s, early 1970s, and is ongoing in Nevada since 2004 (Bentz et al. 2008). Thousands of acres of big sagebrush have been impacted, with partial to complete die-off observed. Aroga moth can partially or entirely kill individual plants or entire stands of big sagebrush (Furniss and Barr 1975), but the research is inconclusive of the damage sustained by black sagebrush populations.

The sagebrush communities that dominate this DRG are characterized by high spatial and temporal variability in precipitation, both over years and within growing seasons. Nutrient availability is typically low but increases with elevation and closely follows moisture availability. The resource supporting the greatest amount of plant growth is usually water stored in the soil profile during the winter (Comstock and Ehleringer 1992). The invasibility of plant communities is often linked to resource availability. Disturbance can increase resources for invasive species through native species mortality or damage. Soil water and nutrient availability can increase with native species mortality and decomposition further aiding invasive species establishment. The invasion of sagebrush communities by cheatgrass (*Bromus tectorum*) has been linked to disturbances (fire, abusive grazing) that have resulted in fluctuations in resources (Chambers et al. 2007). The introduction of annual non-native species, like cheatgrass, may cause an increase in fire frequency. Conversely, increased fire return intervals, driven by inappropriate grazing management and fire suppression, facilitates an increase in woody species cover.

The ecological sites in this DRG are dominated by big sagebrush and cool-season, perennial bunchgrasses. Wyoming big sagebrush and mountain big sagebrush are generally long lived (50+ years); therefore, it is not necessary for new individuals to recruit every year for perpetuation of the stand. Infrequent large recruitment events and simultaneous low, continuous recruitment is the foundation of population maintenance (Noy-Meir 1973). Survival of the seedlings is dependent on adequate moisture conditions. These shrubs usually root to the full depth of the winter-spring soil moisture recharge, which ranges from 1 to over 3 m (Comstock and Ehleringer 1992). Root length of mature sagebrush plants was measured to a depth of 2 m in alluvial soils in Utah (Richards and Caldwell 1987). These shrubs have a flexible generalized root system with development of both deep taproots and laterals near the surface (Dobrowolski et al. 1990).

The primary perennial grasses that are found on these sites include Indian ricegrass, needle-and-thread, beardless wheatgrass and galleta. These species generally have somewhat shallower root systems than the shrubs, but root densities are often as high as or higher than those of shrubs in the upper 0.5 m (1.6 ft) of the soil profile. General differences in root depth distributions between grasses and shrubs result in resource partitioning in these shrub/grass systems.

Indian ricegrass, the dominant understory species of the ecological sites within the 8 to 12 in. precipitation zone, is a long-lived, cool-season perennial bunchgrass that grows from 4 to 24 inches in height (Blaisdell and Holmgren 1984). Primarily adapted to coarse-textured soils, its deep, fibrous root system makes Indian ricegrass one of the most drought-tolerant native species (Booth et al. 1980). Unlike other cool-season species, Indian ricegrass does not require vernalization (exposure to cold) in order to produce flowers and flowering can continue into late fall with favorable environmental conditions. This allows the seeds in each panicle to ripen over a longer period of time than most other species thus providing a greater opportunity for successful seed production (Jones 1990).

Needle-and-thread is a cool-season, perennial bunchgrass most commonly found on well-drained soils (Miller et al. 2013). It ranges in height from 12 to 36 in. (30–91 cm) tall (Stubbendieck et al. 2003) and produces a widely-spreading, deep, and fibrous root system that allows it to capture moisture and nutrients effectively (Weaver 1958).

Beardless wheatgrass, an awnless variety of bluebunch wheatgrass (*Pseudoroegneria spicata*), is a native, long-lived, cool-season, perennial bunchgrass. It is highly variable and grows to 1.5 to 4 ft (46–122 cm) tall with seed spikes 3 to 8 in. (8–20 cm) long. It has an extensive root system with strong tillers and its leaves are considered coarse. It is common to the Intermountain regions of the western United States and is typically found in 12 to 16 in. (30–41 cm) precipitation zone in MLRA 29.

Galleta is a mat-forming, rhizomatous, native grass that is 11 to 19 in. (28–48 cm) tall (Stubbendieck et al. 2003). This warm-season, perennial species is more water efficient than its cool-season counterparts. This allows galleta grass to survive in low precipitation zones where a significant portion of rainfall occurs during summer months (Banner et al. 2011). Everett et al. (1980) found that galleta grass initiated more than one phenological cycle with the presence of summer precipitation, allowing the species to grow and set seed more than once. This plant is typical of southern Nevada and the transition zone between the Great Basin and the Mojave Desert. It is most common in areas with fine-textured soils (Stubbendieck et al. 2003).

The ecological sites in this DRG have low resilience to disturbance and low resistance to invasion. Resilience increases with elevation, aspect, increased precipitation, and increased nutrient availability. Six possible alternative stable states have been identified for this DRG.

Annual Invasive Species:

The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species resulting in reduced competition while simultaneously increasing resource pools through the decomposition of dead plant material. Historically, Wyoming big sagebrush communities were free of non-native invasive species; however, excessive grazing pressure during settlement and into the 20th century has increased the overall presence of cheatgrass, red brome (*Bromus rubens*), halogeton (*Halogeton glomeratus*), Russian thistle (*Salsola tragus*) and weedy mustard species (Brassicaceae family) (Peters and Bunting 1994). The presence of non-native annual plants within these ecosystems decreases ecosystem resilience and resistance to disturbance through competition for limited resources.

The species most likely to invade the ecological sites in this DRG is cheatgrass. Cheatgrass is a cool-season annual grass that maintains an advantage over native plants, in part, because it is a prolific seed producer, can germinate in the autumn or spring, tolerates grazing, and increases with frequent fire (Klemmedson and Smith 1964, Miller et al. 1999). Cheatgrass originated from Eurasia and was first reported in North America in the late 1800s (Furbush 1953, Mack and Pyke 1983). Bradley et al. (2018) found that cheatgrass has expanded to greater than 15% cover over 210,000 km^2, roughly 31% of the Intermountain West. In the Great Basin, cheatgrass is expanding at a rate of expansion of 3,700 km^2 annually and is a land management issue that will require creative solutions (Smith et al. 2022).

Mapping potential or current invasion vectors is a management method designed to increase the cost-effectiveness of control methods. Recent modeling and empirical work by Lauenroth and Bradford (2006) suggest that seasonal patterns of precipitation input and temperature are also key factors determining regional variation in the growth, seed production, and spread of invasive annual grasses. The phenomenon of cheatgrass “die-off” provides opportunities for restoration of perennial native species (Baughman et al. 2016, Baughman et al. 2017). The causes of these events are not fully understood, but there is ongoing work to try to predict where they occur, in the hopes of aiding conservation planning (Weisberg et al. 2017, Brehm 2019).

Methods to control cheatgrass include herbicide application, prescribed fire, targeted grazing, and rangeland seeding. Spraying with herbicide (imazapic or imazapic + glyphosate) and seeding with crested wheatgrass (*Agropyron cristatum*) and Sandberg bluegrass (*Poa secunda*) has been found to be more successful at combating cheatgrass than spraying alone (Sheley et al. 2012). To date, most seeding success has occurred with non-native wheatgrass species. Perennial grasses, especially crested wheatgrass, are able to suppress cheatgrass growth when mature (Blank et al. 2020). Butler et al. (2011) tested four herbicides (imazapic, imazapic + glyphosate, rimsulfuron, and sulfometuron + chlorsulfuron) for suppression of cheatgrass, medusahead (*Taeniatherum caput-medusae*), and ventenata (North Africa grass, *Ventenata dubia*) within residual stands of native bunchgrass. Additionally, they tested the same four herbicides followed by seeding of six bunchgrasses (native and non-native) with varying success (Butler et al. 2011). Herbicide-only treatments appeared to remove competition for established bluebunch wheatgrass (*Pseudoroegneria spicata*) by providing 100% control of ventenata and medusahead and greater than 95% control of cheatgrass (Butler et al. 2011). Clements et al. (2022) found that imazapic successfully reduced cheatgrass on study plots by 95% and subsequent seeding efforts with native and non-native species produced an average of 4.8 perennial grasses per meter squared.

Indaziflam, a relatively new herbicide for rangeland applications, is showing promise in its ability to control cheatgrass, red brome, medusahead, ventenata, and halogeton. Approved for rangelands in 2016, this pre-emergent herbicide works by inhibiting cell wall biosynthesis and therefore seed germination and root elongation (Kaapro and Hall 2012, Clark et al. 2019). Indaziflam effectively reduces the seed bank of invasive annuals with little to no effect on aboveground plant communities (Courkamp et al. 2022). It also has been proven to control invasive annuals longer than other herbicides, providing three or more years of control (Sebastian et al. 2017a). Sebastian et al. (2017a) found that indaziflam selectively controlled cheatgrass without impacting perennial grass and forb biomass as well. This led to significant increases in biomass of desirable species due to reductions in cheatgrass presence and competition (Sebastian et al. 2017a). Clark et al. (2019) found a similar result on plots in Colorado suggesting that indaziflam may be the best new herbicide on the market for invasive annual control.

Targeted cattle grazing during the fall and winter can also control cheatgrass on invaded sites. Fall and winter grazing decreases standing dead biomass and reduces fuel continuity with minimal risk to native perennial herbaceous plants (Davies et al. 2016). This alters fire risk and severity by reducing fuel loads, flame height, rate of spread and area burned in Great Basin sagebrush systems (Davies et al. 2015a). Repetitive fall grazing can also reduce cheatgrass seed banks, however, the seed bank can rapidly recover if fall grazing efforts cease (Perryman et al. 2020).

Fire Ecology:

Fire is a dominant disturbance force in big sagebrush communities. Wyoming big sagebrush communities historically had low fuel loads, and patchy fires that burned in a mosaic pattern were common at 10 to 70-year return intervals (West and Hassan 1985, Bunting et al. 1987). Davies et al. (2007) suggest fire return intervals in Wyoming big sagebrush communities were around 50 to 100 years. More recently, Baker (2011) estimates fire rotation to be 200 to 350 years in Wyoming big sagebrush communities.

Wyoming big sagebrush and mountain big sagebrush are killed by fire and only regenerate from seed. Recovery time for Wyoming big sagebrush may require 50 to 120 or more years (Baker 2006). Mountain big sagebrush seedlings, on the other hand, can grow rapidly and may reach reproductive maturity within 3 to 5 years (Bunting et al. 1987). Mountain big sagebrush may return to pre-burn density and cover within 15 to 20 years following fire, but establishment after severe fires may proceed more slowly (Bunting et al. 1987). Post-fire regeneration for both varieties of sagebrush will vary depending on site characteristics, seed source, and fire characteristics.

Mountain big sagebrush is killed by fire (Neuenschwander 1980, Blaisdell et al. 1982) and does not resprout (Blaisdell 1953). Post-fire regeneration occurs from seed and will vary depending on site characteristics, seed source, and fire characteristics. Mountain big sagebrush seedlings can grow rapidly and may reach reproductive maturity within 3 to 5 years (Bunting et al. 1987). Mountain big sagebrush may return to pre-burn density and cover within 15 to 20 years following fire, but establishment after severe fires may proceed more slowly (Bunting et al. 1987). Fire is believed to be the dominant disturbance force in natural big sagebrush communities. Several authors suggest pre-settlement fire return intervals in mountain big sagebrush communities varied from 15 to 25 years (Burkhardt and Tisdale 1969, Houston 1973, Miller and Eddleman 2000). Kitchen and McArthur (2007) suggest a mean fire-return interval of 40 to 80 years for mountain big sagebrush communities. The range from 15 to 80 years is probably more accurate and reflects the differences in elevation and precipitation where mountain big sagebrush communities occur.

On a landscape scale, multiple seral stages were represented in a mosaic reflecting periodic reoccurrence of fire and other disturbances (Crawford et al. 2004). Post-fire hydrologic recovery and resilience are primarily influenced by pre-fire site conditions, fire severity, and post-fire weather and land use that relate to vegetation recovery. Fire adaptation by herbaceous species is generally superior to the dominant shrubs, which are typically killed by fire. Sites with low abundances of native perennial grasses and forbs typically have reduced resiliency following disturbance and are less resistant to invasion or increases in cheatgrass (Miller et al. 2013). However, the introduction and expansion of cheatgrass has dramatically altered the fire regime (Balch et al. 2013) and restoration potential of Wyoming and mountain big sagebrush communities.

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The initial condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species' response. For most forbs and grasses the growing points are located at or below the soil surface providing relative protection from disturbances which decrease above-ground biomass, such as grazing or fire. Thus, fire mortality is more correlated to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant, and abundance of old growth (Wright 1971, Young 1983). The two dominant grasses on this site, Indian ricegrass and needle-and-thread grass, have different responses to fire.

Indian ricegrass is fairly fire tolerant (Wright 1985), which is likely due to its low culm density and below-ground plant crowns. Vallentine (1989) cites several studies in the sagebrush zone that classified Indian ricegrass as being slightly damaged from late summer burning. Indian ricegrass has also been found to reestablish on burned sites through seeds dispersed from adjacent unburned areas (Young 1983, West 1994). Thus, the presence of surviving, seed-producing plants facilitates the reestablishment of Indian ricegrass. Grazing management following fire to promote seed production and establishment of seedlings is important. When properly managed, Indian ricegrass can be a key factor in a community recovering from disturbance because it can grow in rough, rocky, coarse, and otherwise unproductive soils (Booth et al. 1980).

Needle-and-thread, contrary to Indian ricegrass, is a fine leaf grass and is considered sensitive to fire (Akinsoji 1988, Bradley et al. 1992, Miller et al. 2013). Needle-and-thread is top-killed by fire but is likely to resprout if fire does not consume above-ground stems (Akinsoji 1988, Bradley et al. 1992). In a study by Wright and Klemmedson (1965), season of burn rather than fire intensity seemed to be the crucial factor in mortality for needle-and-thread grass. Early spring season burning was seen to kill the plants while August burning had no effect. Thus, under wildfire scenarios, needle-and-thread is often present in the post-burn community.

Fire will remove aboveground biomass from bluebunch wheatgrass but plant mortality is generally low (Robberecht and Defossé 1995) because the buds are underground (Conrad and Poulton 1966) or protected by foliage. Uresk and Cline (1976) reported that burning increased vegetative and reproductive vigor of bluebunch wheatgrass. Thus, bluebunch wheatgrass is considered to experience slight damage to fire but is more susceptible in drought years (Young 1983). Plant response will vary depending on the season, fire severity, fire intensity, and post-fire soil moisture availability.

Galleta grass, a minor component of these ecological sites, has been found to increase following fire likely due to its rhizomatous root structure and ability to resprout (Jameson 1962). Sandberg bluegrass, another minor component of these ecological sites, has also been found to increase following fire likely due to its low stature and productivity (Daubenmire 1975). Both grass species may retard reestablishment of deeper-rooted bunchgrasses. Repeated frequent fire in this community will eliminate Wyoming big sagebrush, significantly decrease bunchgrass density on the site and facilitate the establishment of a non-native annual community with varying amounts of galleta, ephedra, fourwing saltbush, and rabbitbrush (*Chrysothamnus* spp.).

Utah juniper (*Juniperus osteosperma*) and singleleaf pinyon (*Pinus monophylla*) mortality in burned stands is a function of fire weather, fuel structure, and continuity (Miller et al. 2019).

Both species are most vulnerable to fire when under 4 ft (1.2 m) tall, however, mortality of trees over 6 ft (1.8 m) tall is unlikely except under extreme fire weather conditions or when sufficient ladder fuels are present (Dwyer and Pieper 1967, Wright et al. 1979, Bradley et al. 1992, Miller et al. 2013). Larger trees, because they have foliage farther from the ground and thicker bark, can survive low severity fires but mortality does occur when 60% or more of the crown is scorched (Bradley et al. 1992). Singleleaf pinyon mature trees do not self-prune their dead branches allowing for accumulated fuel in the crowns. This characteristic and the relative flammability of the foliage make individual mature trees susceptible to fire than juniper (Bradley et al. 1992). However, high severity fires were not likely in this community in its reference condition due to low production of understory vegetation and low density of trees per acre (Bradley et al. 1992, Miller and Tausch 2001).

Infilling and expansion by singleleaf pinyon and Utah juniper has been occurring since the late 1800s due to changes in climate, grazing and fire (Miller et al. 2019). Without disturbance, singleleaf pinyon and Utah juniper will dominate the site and out-compete other species for resources severely reducing both the shrub and herbaceous understory (Lett and Knapp 2005, Miller et al. 2019). However, bluegrasses may remain underneath trees on north-facing slopes. The potential for soil erosion increases as tree cover increases and the understory plant community cover declines (Pierson et al. 2010).

Livestock/Wildlife Grazing Interpretations:

Wyoming big sagebrush communities are important winter ranges for big game (Tweit and Houston 1980, Allen et al. 1984). The literature is unclear as to the palatability of Wyoming big sagebrush. Generally, Wyoming big sagebrush is the least palatable of the big sagebrush taxa (Sheehy and Winward 1981, Bray et al. 1991), however it may receive light or moderate use depending upon the amount of understory herbaceous cover (Tweit and Houston 1980). Personius et al. (1987) found Wyoming big sagebrush and basin big sagebrush to be intermediately palatable to mule deer (*Odocoileus hemionus*) when compared to mountain big sagebrush (most palatable) and black sagebrush (least palatable).

Despite low palatability, mountain big sagebrush is eaten by domestic sheep, cattle, goats, and horses. Chemical analysis indicates that the leaves of big sagebrush equal alfalfa meal (*Medicago sativa*) in protein, have a higher carbohydrate content, and yield twelvefold more fat (USFS 1937). Many wildlife species are dependent on the sagebrush ecosystem including the greater sage grouse (*Centrocercus urophasianus*), sage sparrow (*Artemisiospiza nevadensis*), pygmy rabbit (*Brachylagus idahoensis*), and the sagebrush vole (*Lemmiscus curtatus*). Dobkin and Sauder (2004) identified 61 species, including 24 mammals and 37 birds, associated with the shrub-steppe habitats of the Intermountain West.

Indian ricegrass is a preferred forage species for livestock and wildlife and cures well, providing nutritious winter feed (Cook 1962, Booth et al. 1980). It is also readily utilized in early spring, being a source of green feed before most other perennial grasses have produced new growth

(Quinones 1981). Booth et al. (1980) note that the plant does well when utilized in winter and spring. In eastern Idaho, productivity of Indian ricegrass was at least 10 times greater in undisturbed plots than in heavily (60% utilization) grazed ones (Pearson 1965). (Cook and Child 1971) found significant reduction in crown cover, plant vigor and herbage yield of Indian ricegrass when the species was utilized at 90% during any season. However, they found no reductions at 30% utilization during any season and no reductions at 60% utilization during winter and early spring grazing (Cook and Child 1971). The seed crop may be reduced where grazing is heavy (Bich et al. 1995). Tolerance to grazing increases after May, thus spring deferment may be necessary for stand enhancement (Pearson 1964, Cook and Child 1971); however, utilization of less than 60% is recommended. In summary, adaptive management is required to manage this bunchgrass well.

Needle-and-thread grass is not grazing tolerant and will be one of the first grasses to decrease under heavy grazing pressure during the growing season (Smoliak et al. 1972, Tueller and Blackburn 1974). Heavy grazing (greater than 60% utilization) is likely to reduce basal area of these plants (Smoliak et al. 1972). With the reduction in competition from deep-rooted perennial bunchgrasses, the rhizomatous galleta grass and short-statured Sandberg bluegrass will likely increase (Jameson 1962, Smoliak et al. 1972). However, needle-and-thread cures well and provides good forage to livestock during fall and winter months if overgrazing does not occur (Stubbendieck et al. 2003).

Beardless wheatgrass (bluebunch wheatgrass) is moderately grazing tolerant and is very sensitive to defoliation during the active growth period (Blaisdell and Pechanec 1949, Laycock 1967, Anderson and Scherzinger 1975). Herbage and flower stalk production was reduced with clipping at all times during the growing season; however, clipping was most harmful during the boot stage (Blaisdell and Pechanec 1949, Britton et al. 1990). Tiller production and growth of bluebunch was greatly reduced when clipping was coupled with drought (Busso and Richards 1995). Mueggler (1975) estimated that low vigor bluebunch wheatgrass may need up to 8 years rest to recover. Although an important forage species, it is not always the preferred species by livestock and wildlife.

Galleta is a highly palatable forage species for cattle, sheep, deer (*Odocoileus spp.*), pronghorn (*Antilocapra americana*), and horses during late spring and summer while it is green (Stubbendieck et al. 2017). Due to its rhizomatous characteristics, galleta grass is particularly tolerant of heavy grazing and trampling (Pratt et al. 2002). This species will also initiate more than one phenological cycle if summer precipitation is present (Everett et al. 1980), allowing galleta to grow and propagate after defoliation.

Inappropriate grazing management during the spring growing season will cause a decline in understory plants such as Indian ricegrass and needle-and-thread. Growing season grazing by cattle several years in a row causes a decrease in the bunchgrass component and gives a competitive advantage to shrub species including Wyoming and mountain big sagebrush (Eckert et al. 1972). Reduced bunchgrass vigor or density provides an opportunity for galleta and/or

Sandberg bluegrass expansion and/or cheatgrass and other invasive species such as halogeton to occupy interspaces. Galleta and/or Sandberg bluegrass increases under grazing pressure (Jameson 1962, Tisdale and Hironaka 1981) and is capable of co-existing with cheatgrass. Increased cheatgrass cover leads to increased fire frequency and potentially an annual plant community. Thus, depending on the season of use, the type of grazing animal, and site conditions, either galleta, Sandberg bluegrass or cheatgrass may become the dominant understory with inappropriate grazing management.

State and Transition Model Narrative for Group 13:

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 29 Disturbance Response Group 13.

Reference State 1.0:

The Reference State 1.0 is a representative of the natural range of variability under pristine conditions. The reference state has three general community phases; a shrub-grass dominant phase, a perennial grass dominant phase and a shrub dominant phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire, periodic drought and/or insect or disease attack.

Community Phase 1.1:
Wyoming big sagebrush and Indian ricegrass dominate the site. Needle-and-thread grass is a sub-dominant plant in the understory. Sandberg bluegrass, galleta grass, squirreltail, and perennial forbs are also common. Scattered Utah juniper and singleleaf pinyon may be present. Potential vegetative composition by air-dry weight is approximately 45% grasses, 5% forbs and 50% shrubs. Approximate ground cover (basal and crown) is 15 to 20%. Total annual air-dry production ranges from 250 to 500 lb/ac.

Loamy 10-12" P.Z. (R029XY029NV), Reference State 1.1, T. Stringham, May 2021

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
Fire and/or Aroga moth infestation would decrease or eliminate the overstory of sagebrush and allow for the perennial bunchgrasses to dominate the site. Fires would typically be small and patchy due to low fuel loads. A fire following an unusually wet spring or a change in management may be more severe and reduce sagebrush cover to trace amounts. A severe infestation of Aroga moth could also cause a large decrease in sagebrush within the community, giving a competitive advantage to the perennial grasses and forbs.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.3:
Time and lack of disturbance such as fire allows Wyoming big sagebrush to increase and become decadent. Long-term drought, herbivory, or combinations of these will cause a decline in perennial bunchgrasses and fine fuels leading to a reduced fire frequency and allowing sagebrush to dominate the site.

Community Phase 1.2:
This community phase is characteristic of a post-disturbance, early seral community phase. Indian ricegrass, needle-and-thread and other perennial bunchgrasses dominate. Sprouting shrubs such as yellow rabbitbrush (*Chrysothamnus viscidiflorus*) and ephedra may increase. Wyoming big sagebrush could still be present in unburned patches. Perennial forbs may increase post-fire but will likely return to pre-burn levels within a few years. Galleta will generally increase following fire.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
Time and lack of disturbance will allow sagebrush to re-establish.

Community Phase 1.3:

Wyoming big sagebrush increases in the absence of disturbance. Decadent sagebrush dominates the overstory and the deep-rooted perennial bunchgrasses in the understory are reduced either from competition with shrubs and/or herbivory. Sandberg's bluegrass and/or galleta may increase in the understory and become co-dominant with deep-rooted bunchgrasses. Scattered Utah juniper and/or singleleaf pinyon may be present on the site.

Community Phase Pathway 1.3a, from Phase 1.3 to 1.1:
A low severity fire, herbivory, Aroga moth infestation or combinations will reduce the sagebrush overstory and create a sagebrush/grass mosaic.

Community Phase Pathway 1.3b, from Phase 1.3 to 1.2:
High intensity fire will decrease or eliminate the overstory of sagebrush and allow for perennial bunchgrasses to dominate the site.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0:

Trigger: Introduction of non-native annual plants.

Slow variables: Over time the annual non-native plants will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

This state is similar to the Reference State 1.0. Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of invasive weeds. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal. Additionally, the presence of highly flammable, non-native species reduces State resilience because these species can promote fire where historically fire has been infrequent, leading to positive feedbacks that further the degradation of the system**.**

Community Phase 2.1:
This community phase is compositionally similar to the Reference State Community Phase 1.1 with the presence of non-native species in trace amounts. This community is dominated by Wyoming big sagebrush in the overstory with Indian ricegrass and needle-

and-thread grass dominant in the understory. Utah juniper and singleleaf pinyon may be present.

Loamy Slope 8-10" P.Z. (R029XY010NV), Current Potential State 2.1, P. Novak-Echenique, June 2021

Sandy Loam 8-12" P.Z. (R029XY049NV), Current Potential State 2.1, T. Stringham, May 2020

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:

Fire and/or Aroga moth infestation would decrease or eliminate the overstory of sagebrush and allow for the perennial bunchgrasses to dominate the site. Fires would typically be small and patchy due to low fuel loads. A fire following an unusually wet spring or a change in management may be more severe and reduce sagebrush cover to trace amounts. Annual non-native species are likely to increase after fire.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.3:
Absence of disturbance over time, chronic drought, inappropriate cattle or horse grazing management or combinations of these would allow sagebrush to dominate the site. Inappropriate grazing management reduces the perennial bunchgrass understory; conversely galleta grass and/or Sandberg bluegrass may increase.

Community Phase 2.2:
This community phase is characteristic of a post-disturbance, early seral community where annual non-native species are present. Sagebrush is present in trace amounts; perennial bunchgrasses and sprouting shrubs dominate the site. Depending on fire severity patches of intact sagebrush may remain. Rabbitbrush or other sprouting shrubs may be increasing. Annual non-native species are present within the community. Galleta will generally increase following fire as well. Seeded species may be present.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Absence of disturbance over time and/or grazing management that favors the establishment and growth of sagebrush allows the shrub component to recover. The establishment of Wyoming big sagebrush can take many years.

Community Phase 2.3 (At Risk):
Wyoming big sagebrush dominates the overstory and perennial bunchgrasses in the understory are reduced, either from competition with shrubs or from inappropriate grazing, or from both. Rabbitbrush may be a significant component. Galleta and/or Sandberg bluegrass may increase and become co-dominant with deep-rooted bunchgrasses. Utah juniper and singleleaf pinyon may be present and without management will likely increase. Annual non-natives species may be stable or increasing due to lack of competition with perennial bunchgrasses. This site is susceptible to further degradation from grazing, drought, and fire. This community is at risk of crossing a threshold to either a Shrub State 3.0 (grazing or fire) or an Annual State 4.0 (fire).


Loamy 8-10" P.Z. (R029XY006NV), Current Potential State 2.3, T. Stringham, June 2021

Community Phase Pathway 2.3a, from Phase 2.3 to 2.1:
Grazing management that reduces shrubs will allow for the perennial bunchgrasses in the understory to increase. Heavy late-fall/winter grazing by cattle that causes mechanical damage to sagebrush, or brush treatments with minimal soil disturbance will also decrease sagebrush and release the perennial understory. Aroga moth infestation may also reduce the shrub overstory. Annual non-native species are present. A low-severity fire would decrease the overstory of sagebrush and allow for the understory perennial grasses to increase.

Community Phase Pathway 2.3b from Phase 2.3 to 2.2:
High intensity fire will decrease or eliminate the overstory of sagebrush and allow for the perennial bunchgrasses to dominate the site. Annual non-native species respond well to fire and may temporarily increase post-burn.

T2A: Transition from Current Potential State 2.0 to Shrub State 3.0:

Trigger: To Community Phase 3.1: Inappropriate cattle/horse grazing will decrease or eliminate deep-rooted perennial bunchgrasses, increase Sandberg bluegrass and/ or galleta grass and favor shrub growth and establishment. To Community Phase 3.2: Severe fire will remove sagebrush overstory, decrease perennial bunchgrasses, enhance galleta and/or Sandberg's bluegrass and potentially increase sprouting shrubs. Soil-disturbing brush treatments will reduce sagebrush and increase sprouting shrubs and Sandberg's bluegrass and/or galleta grass.

Slow variables: Long-term decrease in deep-rooted perennial bunchgrass density and/or Wyoming big sagebrush.

Threshold: Loss of deep-rooted perennial bunchgrasses changes nutrient cycling, nutrient redistribution, and reduces soil organic matter. Loss of long-lived, Wyoming big sagebrush changes the temporal distribution, and depending on the replacement shrub, the spatial distribution of nutrient cycling.

T2B: Transition from Current Potential State 2.0 to Annual State 4.0

Trigger: Catastrophic fire or soil surface disturbance.

Slow variables: Increased production and cover of non-native annual species.

Threshold: Loss of deep-rooted perennial bunchgrasses and shrubs changes energy and nutrient capture and cycling both spatially and temporally within the community. Increased, continuous fine fuels modify the fire regime by changing frequency, intensity, and size of fires.

T2C: Transition from Current Potential State 2.0 to Tree State 5.0:

Trigger: Absence of disturbance over time allows for Utah juniper or singleleaf pinyon dominance.

Feedbacks and ecological processes: Trees increasingly dominate use of soil water resulting in decreasing herbaceous and shrub production and decreasing organic matter inputs, contributing to reductions in soil water availability to grasses and shrubs and increased soil erodibility.

Slow variables: Long-term increase in juniper and/or singleleaf pinyon density.

Threshold: Trees overtop sagebrush and out-compete shrubs for water and sunlight. Shrub skeletons exceed live shrubs in number. There is minimal recruitment of new shrub cohorts. Litter builds up underneath trees while bare ground increases in interspaces; this changes nutrient cycling and levels of organic matter in the soil. Redistribution of soil, organic matter and nutrients may occur with water and wind erosion.

Shrub State 3.0:

This state has two community phases in which the overstory is dominated by either Wyoming big sagebrush or sprouting shrubs such as rabbitbrush and/or ephedra. Sandberg's bluegrass or galleta grass dominates the understory. A site in this state has crossed a biotic threshold and site processes are being controlled by shrubs. Site resources such as soil water, nutrient capture, nutrient cycling, and soil organic matter are temporally and spatially redistributed by the vegetation composition. Bare ground has increased and pedestalling of grasses may be excessive.

Community Phase 3.1 (At Risk):
Wyoming big sagebrush dominates overstory while Sandberg's bluegrass or galleta grass dominates the understory. Deep-rooted perennial bunchgrasses have significantly declined. Annual non-native species may be present. Bare ground and soil redistribution may be increasing. If present on the site, Utah juniper and/or singleleaf pinyon is increasing. The community phase may be at risk of transitioning into a Tree State 5.0 or Annual State 4.0.

Loamy Slope 8-10" P.Z. (R029XY010NV), Shrub State, D. Snyder, September 2020

Loamy 8-10" P.Z. (R029XY006NV), Shrub State 3.1, T. Stringham, June 2020

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:
Fire, Aroga moth infestation, or brush treatments that reduces the Wyoming big sagebrush to trace amounts and allows for sprouting shrubs such as rabbitbrush and/or ephedra to dominate.

Community Phase 3.2 (At Risk):
Rabbitbrush, desert bitterbrush, and/or ephedra dominate the overstory while squirreltail, Sandberg's bluegrass and/or galleta dominate the understory. Annual non-native species may be increasing and bare ground is significant. This community phase is at risk of transitioning to an Annual State 4.0.

Loamy Slope 8-10" P.Z. (R029XY010NV), Shrub State 3.2, T. Stringham, May 2021

Gravelly Clay Slope 12-14" P.Z. (R029XY164NV), Shrub State 3.2, T. Stringham, June 2022

Community Phase Pathway 3.2a, from Phase 3.2 to 3.1:
Time and lack of disturbance and/or grazing management that favors the establishment and growth of sagebrush allows for the shrub component to recover. The establishment of Wyoming big sagebrush may take many years.

T3A: Transition from Shrub State 3.0 to Annual State 4.0:

Trigger: Fire or treatments that disturb the soil and existing plant community (ex: failed restoration attempts).

Slow variables: Increased seed production and cover of annual non-native species.

Threshold: Increased, continuous fine fuels modify the fire regime by changing intensity, size and spatial variability of fires. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and sagebrush truncate energy capture and impact the nutrient cycling and distribution.

R3A: Restoration from Shrub State 3.0 to Seeded State 6.0:

Seeding of deep-rooted introduced bunchgrasses and other desired species; may be coupled with brush management and/or herbicide. Probability of success is low.

T3B: Transition from Shrub State 3.0 to Tree State 5.0:

Trigger: Absence of disturbance over time allows for Utah juniper and/or singleleaf pinyon dominance.

Feedbacks and ecological processes: Trees increasingly dominate use of soil water resulting in decreasing herbaceous and shrub production and decreasing organic matter inputs, contributing to reductions in soil water availability to grasses and shrubs and increased soil erodibility.

Slow variables: Long-term increase in Utah juniper and/or singleleaf pinyon density.

Threshold: Trees overtop sagebrush and out-compete shrubs for water and sunlight. Shrub skeletons exceed live shrubs in number. There is minimal recruitment of new shrub cohorts. Litter builds up underneath trees while bare ground increases in interspaces; this changes nutrient cycling and levels of organic matter in the soil.

Annual State 4.0:

This state has two community phases, one is dominated by annual non-native species and the other is co-dominated by annual non-natives and sprouting shrubs. In this state, a biotic threshold has been crossed and state dynamics are driven by the dominance and persistence of the invasive annual grass community which is perpetuated by a shortened fire return interval fire. The herbaceous understory is dominated by annual non-native species such as cheatgrass, red brome, halogeton, and mustards. Resiliency has declined and further degradation from fire facilitates a cheatgrass and sprouting shrub plant community. Fire return interval has shortened due to the dominance of cheatgrass in the understory and is a driver in site dynamics.

Community Phase 4.1:
Annual non-native plants such as cheatgrass, red brome, and/or western tansy mustard (*Descurainia pinnata*) dominate the site. This phase may have seeded species present if resulting from a failed seeding attempt.

Sandy Loam 8-12" P.Z. (R029XY049NV), Annual State 4.1, T. Stringham, May 2020

Community Phase Pathway 4.1a, from Phase 4.1 to 4.2:
Time and lack of fire allows for sprouting shrubs to become co-dominate with the annual non-native species. Probability of sagebrush establishment is extremely low.

Community Phase 4.2:
Sprouting shrubs such as rabbitbrush, Stansbury's cliffrose and/or ephedra remain in the overstory with annual non-native species, likely cheatgrass, dominating the understory. Wyoming big sagebrush may be present in trace amounts. Trace amounts of desirable bunchgrasses may be present.

Loamy Slope 8-10" P.Z. (R029XY010NV), Annual State 4.2, T. Stringham, May 2020

Loamy 10-12" P.Z. (R029XY029NV), Annual State 4.2, T. Stringham, September 2021

Community Phase Pathway 4.2a, from Phase 4.2 to 4.1:
Fire reduces/eliminates overstory brush component and allows for annual non-native species to dominate the site.

R4A: Restoration from Annual State 4.0 to Seeded State 6.0:

Seeding of deep-rooted introduced bunchgrasses and other desired species; may be coupled herbicide; probability of success very low (6.1).

Tree State 5.0:

This state is characterized by a dominance of Utah juniper and/or singleleaf pinyon in the overstory. Wyoming big sagebrush and perennial bunchgrasses may still be present, but they are no longer controlling site resources. Soil moisture, soil nutrients and soil organic matter distribution and cycling have been spatially and temporally altered.

Community Phase 5.1:
Utah juniper and/or singleleaf pinyon trees dominate overstory. Wyoming big sagebrush is decadent and dying and deep-rooted perennial bunchgrasses are decreasing. Recruitment of sagebrush cohorts is minimal. Annual non-natives may be present or increasing. Bare ground interspaces are large and connected.

Loamy 8-10" P.Z. (R029XY006NV), Tree State 5.1, T. Stringham, May 2020

Loamy Slope 10-12" P.Z. (R029XY075NV), Tree State 5.1, D. Snyder, June 2019

Community Phase Pathway 5.1a, from Phase 5.1 to 5.2:
Absence of disturbance over time allows for tree cover and density to further increase and out-compete the herbaceous understory species for sunlight and water.

Community Phase 5.2:
Utah juniper and/or singleleaf pinyon trees dominate the overstory. Annual non-native species may be the dominant understory species and will typically be found under the tree canopies. Trace amounts of Wyoming big sagebrush may be present however dead skeletons will be more numerous than living sagebrush. Bunchgrasses may or may not be present. Sandberg bluegrass, galleta or mat forming forbs may be present in trace amounts. Bare ground interspaces are large and connected. Soil redistribution is evident.

Loamy 10-12" P.Z. (R029XY029NV), Tree State 5.2, T. Stringham, August 2021

Gravelly Clay Slope 12-14" P.Z. (R029XY164NV), Tree State 5.2, T. Stringham, May 2022

T5A: Transition from Tree State 5.0 to Annual State 4.0:

Trigger: Catastrophic fire causing a stand replacement event. Inappropriate tree removal practices with soil disturbance will also cause a transition to the Annual State 4.0.

Slow variables: Increased production and cover of non-native annual species under tree canopies.

Threshold: Closed tree canopy with non-native annual species dominant in the understory changes the intensity, size and spatial variability of fires. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and sagebrush truncate energy capture and impacts nutrient cycling and distribution.

R5A: Restoration from Tree 5.0 to Seeded State 6.0:

Removal of trees in community phase 5.1 and seeding of introduced species. If restoration efforts fail, this site could transition to Annual State 4.0.

Seeded State 6.0:

This state is characterized by the dominance of seeded, introduced wheatgrass species. Forage kochia and other desired seeded species including Wyoming big sagebrush and native and non-native forbs may be present. This state was not observed in the modal site (Loamy Slope 8-10" P.Z.), but was observed in other ecological sites within this group.

Community Phase 6.1:
Seeded wheatgrass species and other non-native species dominate the community. Native and non-native seeded forbs may be present. Trace amounts of Wyoming big sagebrush may be present along with native bunchgrasses. Annual non-native species present.

Community Phase Pathway 6.1a, from Phase 6.1 to 6.2:
Time and lack of disturbance may be coupled with inappropriate grazing management.

Community Phase 6.2:
Wyoming big sagebrush increases and may become the dominant overstory species. Seeded wheatgrass species dominate understory. Annual non-native species present. Utah juniper and/or singleleaf pinyon may be present.

Sandy Loam 8-12" P.Z. (R029XY049NV), Seeded State 6.2, T. Stringham, June 2022

Community Phase Pathway 6.2a, from Phase 6.2 to 6.1:
Low severity fire would reduce sagebrush and increase seeded, deep-rooted perennial bunchgrasses.

Community Phase Pathway 6.2b, from Phase 6.2 to 6.3:
Continued inappropriate grazing reduces bunchgrasses and increases density of sagebrush; usually a slow transition.

Community Phase 6.3 (At Risk):
Wyoming big sagebrush dominates the overstory. Perennial bunchgrasses are significantly reduced. Annual non-native species may be increasing. Utah juniper and/or singleleaf pinyon may be present. This community phase is at risk of transitioning to Annual State 4.0 or Tree State 5.0.

Community Phase Pathway 6.3a, from Phase 6.3 to 6.1:
Fire or brush management with minimal soil disturbance would reduce Wyoming big sagebrush to trace amounts and allow for the perennial understory to increase.

T6A: Transition from Seeded State 6.0 to Annual State 4.0:

Trigger: Fire, inappropriate grazing management or treatments that disturb the soil and existing plant community (ex: failed restoration attempts).

Slow variables: Increased seed production and cover of annual non-native species.

Threshold: Increased, continuous fine fuels modify the fire regime by changing intensity, size and spatial variability of fires. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and sagebrush truncate energy capture and impact the nutrient cycling and distribution.

T6B: Transition from Seeded State 6.0 to Tree State 5.0:

Trigger: Absence of disturbance over time and/or inappropriate grazing management facilitates the establishment and eventual dominance of Utah juniper and/or singleleaf pinyon.

Slow variables: Long-term increase in Utah juniper and/or singleleaf pinyon density.

Threshold: Trees out-compete understory species for water and sunlight. There is minimal recruitment of new shrub cohorts. Litter builds up underneath trees while bare ground increases in interspaces; this changes nutrient cycling and levels of organic matter in the soil. Redistribution of soil, organic matter and nutrients may occur with water and wind erosion.

Potential Resilience Differences with Other Ecological Sites in this Group:

Loamy 8-10" P.Z. (R029XY006NV):

This site occurs on piedmont slopes, rock pediments, and low rolling hills on all exposures. Slope gradients are typically less than the modal ecological site. Production is 600 lb/ac in a normal year. This site is more likely to transition to an Annual State than a Tree State. A Seeded State was not observed on this site. Historic range seedings (1950–1960s) were documented but success of those seedings is unknown.

Sandy Loam 8-12" P.Z. (R029XY049NV):

This site occurs on inset fans and fan piedmonts on all exposures at a slightly higher elevation that the modal site. Significantly more productive than the modal, the predominant herbaceous species is Indian ricegrass due to the sandy, well drained soils on this site. Total annual air-dry production ranges from 500 to 1,100 lb/ac. A Tree State is highly unlikely.

Loamy 10-12" P.Z (R029XY029NV):

This site is more productive than the modal and carries both Wyoming big sagebrush and mountain big sagebrush as described in the ecological site description. Total annual air-dry production ranges from 600 to 1,100 lb/ac. The dominant herbaceous species on this site are needle-and-thread grass and Indian ricegrass. Singleleaf pinyon and Utah juniper readily invade this ecological site where it occurs adjacent to woodlands. This site is equally likely to transition to an Annual State or Tree State. Mastication and seeding of the Tree State were documented.

Loamy Slope 10-12" P.Z. (R029XY075NV):

This site is slightly more productive than the modal and carries both Wyoming big sagebrush and mountain big sagebrush as described in the ecological site description. Total annual air-dry production ranges from 300 to 1,100 lb/ac. It also occurs at higher elevations than the modal. The dominant herbaceous species on this site are needle-and-thread and Indian ricegrass. Singleleaf pinyon and Utah juniper readily invade this site where it occurs adjacent to woodlands. This site is equally likely to transition to an Annual State or Tree State. A Seeded State was not observed on this site.

Gravelly Clay Slope 12-14" P.Z. (R029XY164NV):

This site occurs at higher elevations and significantly more productive than the modal ecological site. Total annual air-dry production ranges from 800 to 1,200 lb/ac. The dominant shrubs are mountain big sagebrush and Utah serviceberry (*Amelanchier utahensis*) as described in the ecological site description. Following fire, Gambel oak (*Quercus gambelii*) and Sonoran scrub oak (*Quercus turbinella*) will likely be the most abundant sprouting shrubs. This site is more likely to transition to a Tree State than an Annual State. A Seeded State was not observed on this site.

Loamy Fan 8-12" P.Z. (R029XY114NV):

This site occurs on inset fans and adjacent fan skirts at a similar elevation to the modal site. Significantly more productive than the modal, the predominant herbaceous species is basin wildrye, with Indian ricegrass being a close second. Total annual air-dry production ranges from 600 to 1,000 lb/ac. This site is equally likely to transition to an Annual State or Tree State. A Seeded State was not observed on this site.

Gravelly Loam 8-10" P.Z. (R029XY167NV):

This site is slightly more productive than the modal ecological site. Total annual air-dry production ranges from 300 to 800 lb/ac. The predominant herbaceous species are blue grama and galleta. These grasses are rhizomatous and therefore withstand disturbance and grazing better than deep-rooted perennial bunchgrasses. This site is more likely to transition to an Annual State than a Tree State. A Seeded State was not observed on this site.

Bouldery Slope 8-12" P.Z. (R029XY073NV):

This site occurs on very boulder and/or stony mountains, hill summits, and sideslopes. It is slightly more productive than the modal site and carries both Wyoming big sagebrush and mountain big sagebrush as described in the ecological site description. Total annual air-dry production ranges from 400 to 800 lb/ac. It also occurs at higher elevations than the modal. The dominant herbaceous species on this site is desert needlegrass. Field observations indicate that this species survives and increases after most wildfires. This site is more likely to transition to an Annual State than a Tree State. A Seeded State was not observed on this site.

Gravelly Clay Slope 10-12" P.Z. (R029XY106NV):

This site occurs on rolling hills and lower mountain sideslopes on all exposures. It carries both Wyoming big sagebrush and mountain big sagebrush and the understory is dominated by Thurber's needlegrass (*Achnatherum thurberianum*) and Indian ricegrass as described in the ecological site description. It is slightly more productive than the modal. Total annual air-dry production ranges from 250 to 700 lb/ac. Antelope bitterbrush (*Purshia tridentata*) may be a dominant overstory species after fire. This site is equally likely to transition to an Annual State or Tree State. A Seeded State was not observed on this site.

Loamy Slope 12-14" P.Z. (R029XY057NV):

This site is slightly more productive than the modal and carries both Wyoming big sagebrush and mountain big sagebrush as described in the ecological site description. Total annual air-dry production ranges from 350 to 700 lb/ac. It also occurs at higher elevations than the modal. The dominant herbaceous species on this site are beardless wheatgrass and Thurber's needlegrass. Singleleaf pinyon and Utah juniper readily invade this site where it occurs adjacent to woodlands. Annual State is highly unlikely. A Seeded State was not observed on this site.

Loamy 12-14" P.Z. (R029XY030NV):

This site occurs at higher elevations and significantly more productive than the modal ecological site. Total annual air-dry production ranges from 800 to 1,200 lb/ac. The dominant shrubs are mountain big sagebrush and Stansbury cliffrose while the dominant grasses are beardless wheatgrass and needle-and-thread as described in the ecological site description. A transition pathway from Reference State directly to Shrub State has been observed and included in the STM for this ecological site. Singleleaf pinyon and Utah juniper readily invade this site where it occurs adjacent to woodlands. An Annual State is highly unlikely. Historic range seedings (1950–1960s) were documented near the Cucomungo Mountains, Esmeralda County, but success of those seedings is unknown.

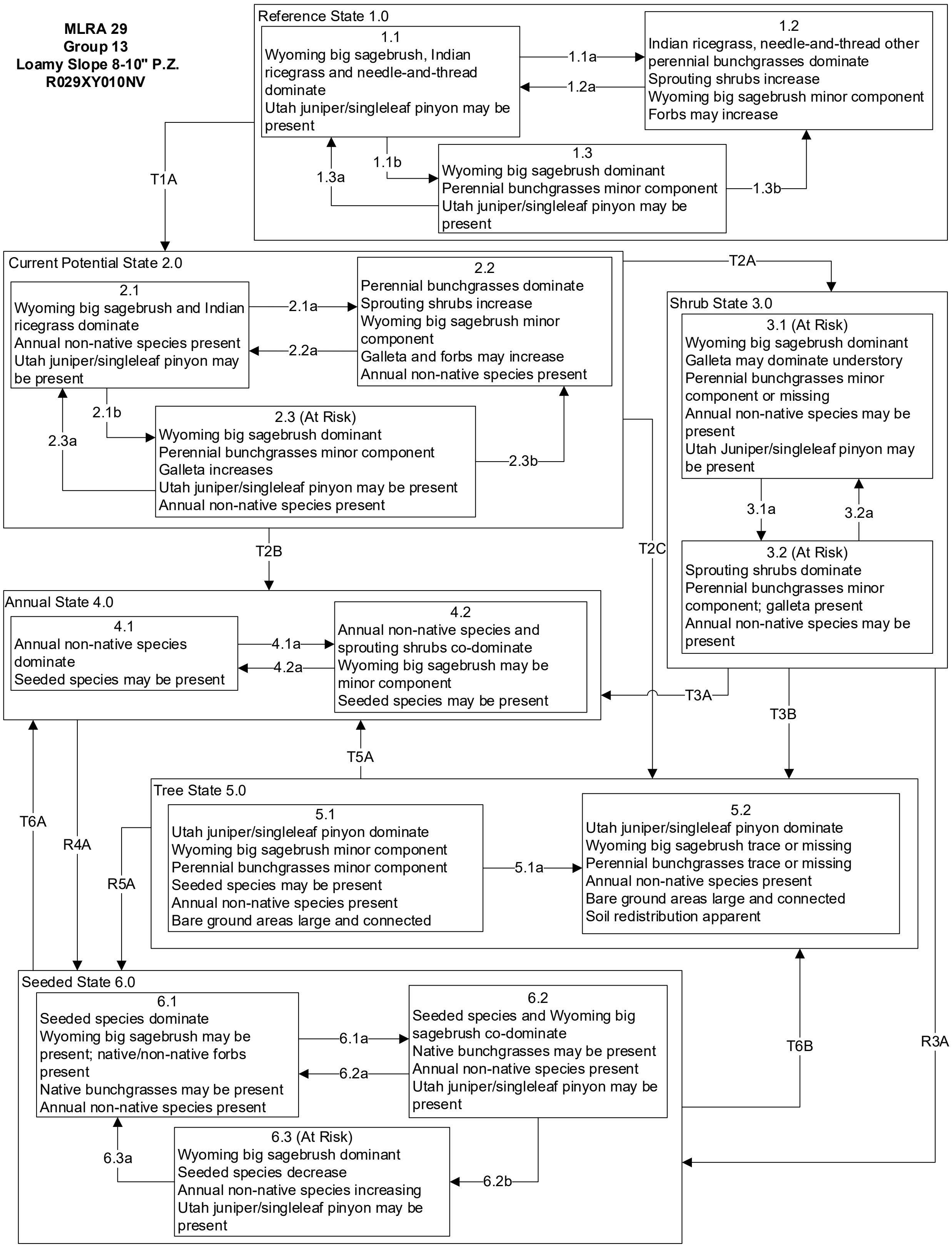
Fan Collar 12-16" P.Z. (R029XY061NV):

This site occurs on alluvial fan collars and recently deposited torrent flows. This site is significantly more productive than the modal ecological site with 1,200 lb/ac being produced in a normal year. Mountain big sagebrush, desert bitterbrush, and basin wildrye dominate the site. Singleleaf pinyon and Utah juniper readily invade this site where it occurs adjacent to woodlands. Tree State and Annual State are both likely. A Seeded State was not observed on this site.

Coarse Loamy 8-10" P.Z. (R029XY158NV):

This site occurs on inset fans and adjacent fan skirts. This site receives runoff from adjacent landscapes and is more productive than the modal site. Total annual air-dry production is approximately 800 lb/ac in a normal year. The dominant shrubs are Wyoming big sagebrush and fourwing saltbush. Dominant grasses include Indian ricegrass and basin wildrye. An Annual State is likely to occur after wildfire. A Seeded State was not observed on this site.

Modal State and Transition Model for Group 13 in MLRA 29:



MLRA 29
Group 13
Loamy Slope 8-10" P.Z.
R029XY010NV

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire and/or Aroga moth infestation creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community, dominated by sprouting shrubs, perennial grasses and forbs.
1.1b: Time and lack of disturbance such as fire or drought. Excessive herbivory may also decrease perennial bunchgrass understory.
1.2a: Time and lack of disturbance allows for shrub regeneration.
1.3a: Low severity fire, herbivory and/or Aroga moth infestation resulting in a mosaic pattern.
1.3b: High severity fire significantly reduces sagebrush cover and allows for sprouting shrubs, perennial grasses and forbs to dominate the site.

Transition T1A: Introduction of non-native species such as cheatgrass and mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire and/or Aroga moth infestation creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community dominated by sprouting shrubs, grasses and forbs; non-native annual species present.
2.1b: Time and lack of disturbance such as fire or drought. Inappropriate grazing management may also reduce perennial grasses.
2.2a: Time and lack of disturbance allows for regeneration of sagebrush.
2.3a: Low severity fire, herbivory and/or Aroga moth infestation creates sagebrush/grass mosaic. Brush management with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire significantly reduces sagebrush cover and allows for sprouting shrubs, perennial grasses and forbs to dominate the site.

Transition T2A: Time and lack of disturbance and/or inappropriate grazing management (3.1).
Transition T2B: High severity fire and/or soil disturbance (4.1). Inappropriate grazing that favors shrubs in the presence of non-native annual species (4.2).
Transition T2C: Time and lack of disturbance allows for an increase in tree cover; inappropriate grazing management and/or chronic drought can reduce fine fuels and lead to increased tree establishment and dominance (5.1).

Shrub State 3.0 Community Phase Pathways
3.1a: Fire, Aroga moth infestation or brush treatments (i.e. mowing) with minimal soil disturbance.
3.2a: Time, lack of disturbance and/or grazing management that favors the establishment of shrubs, especially sagebrush.

Transition T3A: Catastrophic fire and/or treatments that cause soil disturbance (4.1). Inappropriate grazing management in the presence of non-native annual species (4.2).
Transition T3B: Time and a lack of fire allows for trees to dominate site.

Restoration R3A: Brush management with minimal soil disturbance and/or herbicide treatment, coupled with seeding of desired species. Probability of success very low (6.1).

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of fire.
4.2a: Fire.

Restoration R4A: Seeding of desired species; may be coupled with herbicide; probability of success very low (6.1).

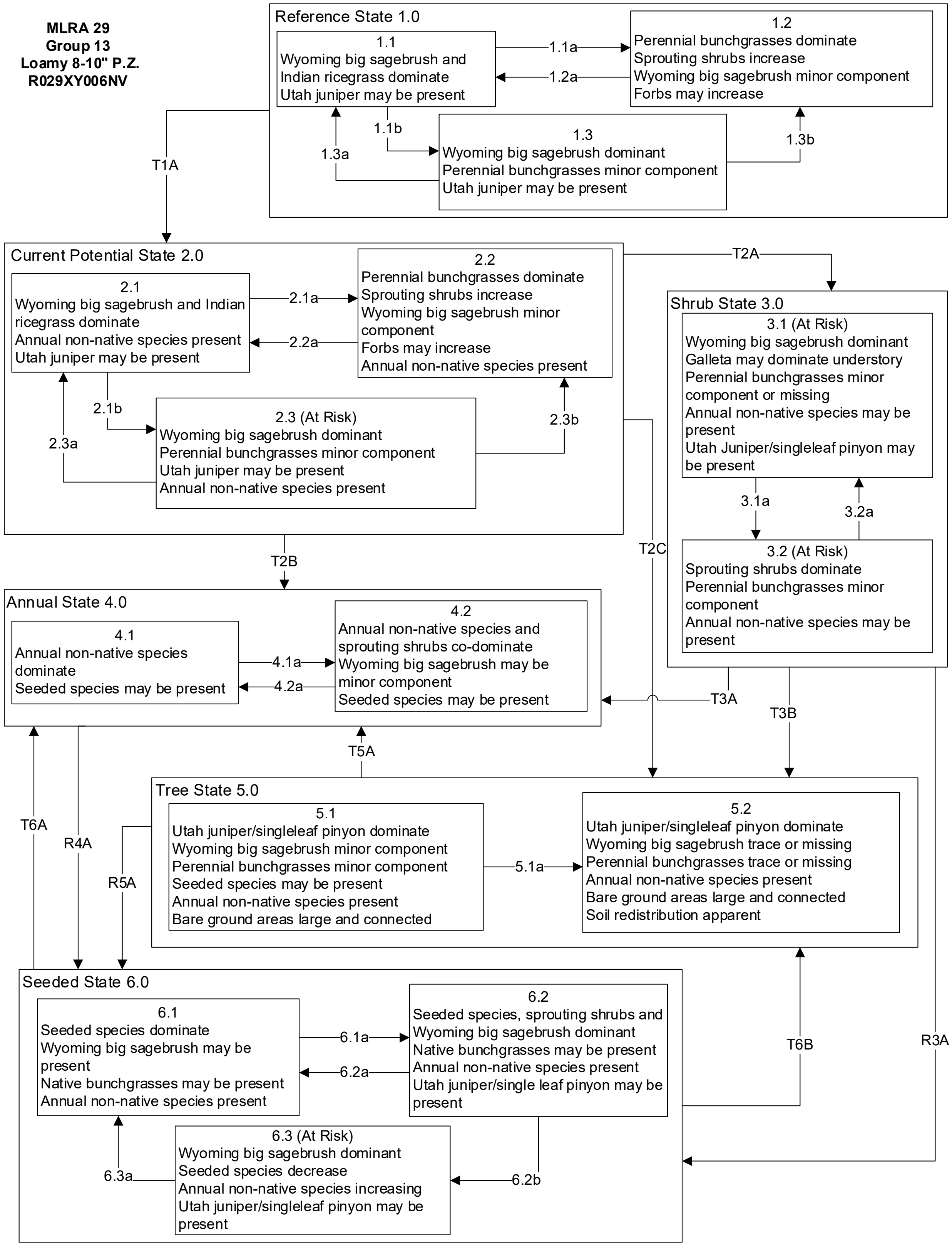
Tree State 5.0 Community Phase Pathways
5.1a: Time and lack of disturbance allows for tree maturation.

Transition T5A: Catastrophic fire, inappropriate tree removal practices with soil disturbance will cause a transition to the Annual State (4.0).
Restoration R5A: Tree removal and seeding of non-native desirable species such as crested wheatgrass.

Seeded State 6.0 Community Phase Pathways
6.1a: Time and lack of disturbance may be coupled with inappropriate grazing management.
6.2a: Low severity fire.
6.2b: Inappropriate grazing management reduces bunchgrasses and increases density of sagebrush; usually a slow transition.
6.3a: Fire or brush treatment with minimal soil disturbance.

Transition T6A: Catastrophic fire and/or inappropriate grazing management or treatments with soil disturbance.
Transition T6B: Time and a lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management (5.1).

Additional State and Transition Models for Group 13 in MLRA 29:



MLRA 29
Group 13
Loamy 8-10" P.Z.
R029XY006NV

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire and/or Aroga moth infestation creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community, dominated by sprouting shrubs, grasses and forbs.
1.1b: Time and lack of disturbance such as fire or drought. Excessive herbivory may also decrease perennial grasses.
1.2a: Time and lack of disturbance allows for shrub regeneration.
1.3a: Low severity fire and/or Aroga moth infestation resulting in a mosaic pattern.
1.3b: High severity fire significantly reduces sagebrush cover leading to early/mid-seral community dominated by sprouting shrubs, grasses and forbs.

Transition T1A: Introduction of non-native species such as cheatgrass and mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire and/or Aroga moth infestation creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community dominated by grasses and forbs; non-native annual species present.
2.1b: Time and lack of disturbance such as fire or drought. Inappropriate grazing management may also reduce perennial understory.
2.2a: Time and lack of disturbance allows for regeneration of sagebrush.
2.3a: Low severity fire and/or Aroga moth infestation creates sagebrush/grass mosaic. Brush management with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire significantly reduces sagebrush cover leading to early mid-seral community dominated by sprouting shrubs, grasses and forbs.

Transition T2A: Time and lack of disturbance and/or inappropriate grazing management (3.1).
Transition T2B: High severity fire and/or soil disturbance (4.1). Inappropriate grazing that favors shrubs in the presence of non-native annual species (4.2).
Transition T2C: Time and lack of disturbance allows for an increase in tree cover; inappropriate grazing management and/or chronic drought can reduce fine fuels and lead to increased tree establishment and dominance (5.1).

Shrub State 3.0 Community Phase Pathways
3.1a: Fire or brush treatments (i.e. mowing) with minimal soil disturbance.
3.2a: Time and lack of fire allows some shrubs to reestablish.

Transition T3A: Catastrophic fire and/or soil disturbance (4.1). Inappropriate grazing management in the presence of non-native annual species (4.2).
Transition T3B: Time and a lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management (5.1).

Restoration R3A: Brush management with minimal soil disturbance, coupled with seeding of desired species. Probability of success very low (6.1).

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of fire.
4.2a: Fire.

Restoration R4A: Seeding of desired species; may be coupled with herbicide; probability of success very low (6.1).

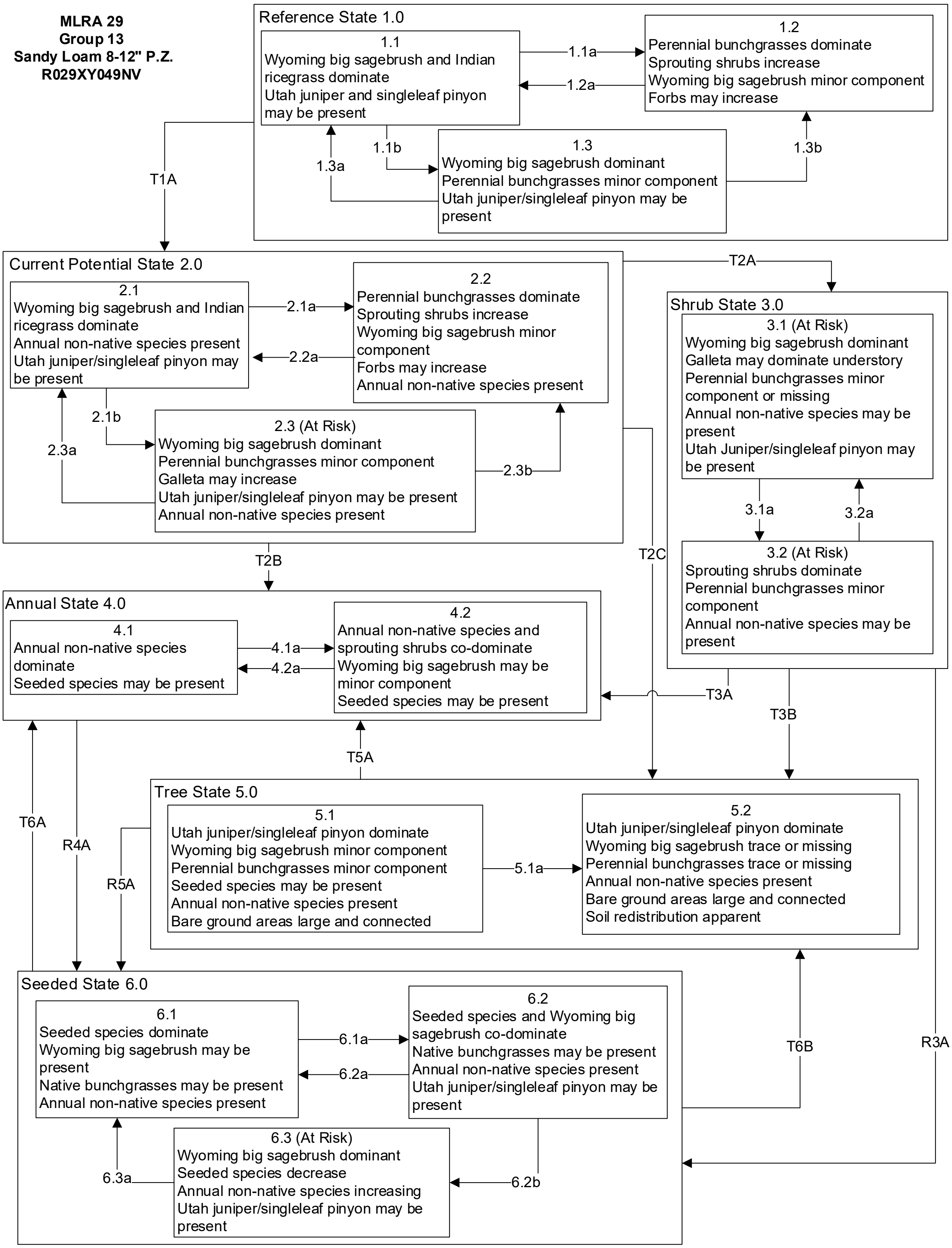
Tree State 5.0 Community Phase Pathways
5.1a: Time and lack of disturbance allows for tree maturation.

Restoration R5A: Tree removal and seeding of native and non-native species.

Transition T5A: Catastrophic fire, inappropriate tree removal practices (5.1).

Seeded State 6.0 Community Phase Pathways
6.1a: Time and lack of disturbance may be coupled with inappropriate grazing management.
6.2a: Low severity fire.
6.2b: Inappropriate grazing management reduces bunchgrasses and increases density of sagebrush; usually a slow transition.
6.3a: Fire or brush treatment with minimal soil disturbance.

Transition T6A: Catastrophic fire and/or inappropriate grazing management.
Transition T6B: Time and a lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management (5.1).


MLRA 29
Group 13
Sandy Loam 8-12" P.Z.
R029XY049NV
Reference State 1.0
1.1
Wyoming big sagebrush and Indian ricegrass dominate
Utah juniper and singleleaf pinyon may be present
1.1a
1.2a
1.2
Perennial bunchgrasses dominate
Sprouting shrubs increase
Wyoming big sagebrush minor component
Forbs may increase
1.1b
1.3a
1.3b
1.3
Wyoming big sagebrush dominant
Perennial bunchgrasses minor component
Utah juniper/singleleaf pinyon may be present
T1A
Current Potential State 2.0
2.1
Wyoming big sagebrush and Indian ricegrass dominate
Annual non-native species present
Utah juniper/singleleaf pinyon may be present
2.1a
2.2a
2.2
Perennial bunchgrasses dominate
Sprouting shrubs increase
Wyoming big sagebrush minor component
Forbs may increase
Annual non-native species present
2.1b
2.3a
2.3 (At Risk)
Wyoming big sagebrush dominant
Perennial bunchgrasses minor component
Galleta may increase
Utah juniper/singleleaf pinyon may be present
Annual non-native species present
2.3b
T2A
Shrub State 3.0
3.1 (At Risk)
Wyoming big sagebrush dominant
Galleta may dominate understory
Perennial bunchgrasses minor component or missing
Annual non-native species may be present
Utah Juniper/singleleaf pinyon may be present
3.1a
3.2a
3.2 (At Risk)
Sprouting shrubs dominate
Perennial bunchgrasses minor component
Annual non-native species may be present
T2B
T2C
Annual State 4.0
4.1
Annual non-native species dominate
Seeded species may be present
4.1a
4.2a
4.2
Annual non-native species and sprouting shrubs co-dominate
Wyoming big sagebrush may be minor component
Seeded species may be present
T3A
T3B
T5A
Tree State 5.0
5.1
Utah juniper/singleleaf pinyon dominate
Wyoming big sagebrush minor component
Perennial bunchgrasses minor component
Seeded species may be present
Annual non-native species present
Bare ground areas large and connected
5.1a
5.2
Utah juniper/singleleaf pinyon dominate
Wyoming big sagebrush trace or missing
Perennial bunchgrasses trace or missing
Annual non-native species present
Bare ground areas large and connected
Soil redistribution apparent
T6A
R4A
R5A
Seeded State 6.0
6.1
Seeded species dominate
Wyoming big sagebrush may be present
Native bunchgrasses may be present
Annual non-native species present
6.1a
6.2a
6.2
Seeded species and Wyoming big sagebrush co-dominate
Native bunchgrasses may be present
Annual non-native species present
Utah juniper/singleleaf pinyon may be present
T6B
R3A
6.3a
6.3 (At Risk)
Wyoming big sagebrush dominant
Seeded species decrease
Annual non-native species increasing
Utah juniper/singleleaf pinyon may be present
6.2b

MLRA 29
Group 13
Sandy Loam 8-12" P.Z.
R029XY049NV

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire and/or Aroga moth creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community, dominated by sprouting shrubs, grasses and forbs.
1.1b: Time and lack of disturbance such as fire or drought. Excessive herbivory may also decrease perennial grasses.
1.2a: Time and lack of disturbance allows for shrub regeneration.
1.3a: Low severity fire and/or Aroga moth infestation resulting in a mosaic pattern.
1.3b: High severity fire significantly reduces sagebrush cover leading to early/mid-seral community dominated by sprouting shrubs, grasses and forbs.

Transition T1A: Introduction of non-native species such as cheatgrass and mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community dominated by sprouting shrubs, grasses and forbs; non-native annual species present.
2.1b: Time and lack of disturbance such as fire or drought. Inappropriate grazing management may also reduce perennial understory.
2.2a: Time and lack of disturbance allows for regeneration of sagebrush.
2.3a: Low severity fire or Aroga moth infestation creates sagebrush/grass mosaic. Brush management with minimal soil disturbance; late-fall/ winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire significantly reduces sagebrush cover leading to early mid-seral community dominated by sprouting shrubs, grasses and forbs.

Transition T2A: Time and lack of disturbance and/or inappropriate grazing management (3.1).
Transition T2B: High severity fire and/or soil disturbance (4.1). Inappropriate grazing that favors shrubs in the presence of non-native annual species (4.2).
Transition T2C: Time and lack of disturbance allows for an increase in tree cover; inappropriate grazing management and/or chronic drought can reduce fine fuels and lead to increased tree establishment and dominance (5.1).

Shrub State 3.0 Community Phase Pathways
3.1a: Fire or brush treatments (i.e. mowing) with minimal soil disturbance.
3.2a: Time and lack of fire allows some shrubs to reestablish.

Transition T3A: Catastrophic fire and/or soil disturbance (4.1). Inappropriate grazing management in the presence of non-native annual species (4.2).
Transition T3B: Time and a lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management (5.1).

Restoration R3A: Brush management with minimal soil disturbance, coupled with seeding of desired species. Probability of success is very low (6.1).

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of fire.
4.2a: Fire.

Restoration R4A: Seeding of desired species; may be coupled with herbicide; probability of success is very low (6.1).

Tree State 5.0 Community Phase Pathways
5.1a: Time and lack of disturbance allows for tree maturation.

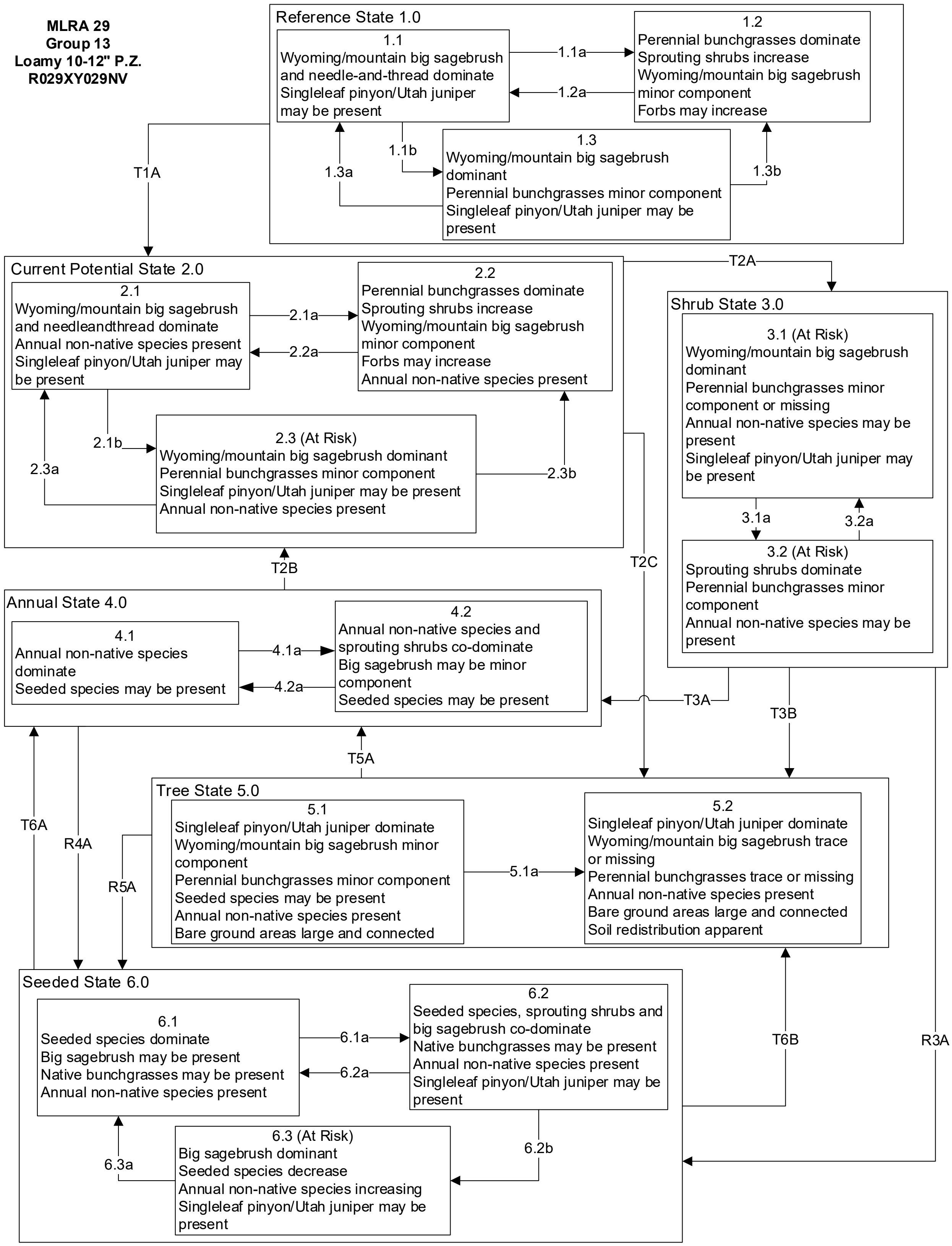
Restoration R5A: Tree removal and seeding of native and non-native species.

Transition T5A: Catastrophic fire, inappropriate tree removal practices (5.1).

Seeded State 6.0 Community Phase Pathways
6.1a: Time and lack of disturbance may be coupled with inappropriate grazing management.
6.2a: Low severity fire.
6.2b: Inappropriate grazing management reduces bunchgrasses and increases density of sagebrush; usually a slow transition.
6.3a: Fire or brush treatment with minimal soil disturbance.

Transition T6A: Catastrophic fire and/or inappropriate grazing management.
Transition T6B: Time and a lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management (5.1).

MLRA 29
Group 13
Loamy 10-12" P.Z.
R029XY029NV



MLRA 29
Group 13
Loamy 10-12" P.Z.
R029XY029NV

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire and/or Aroga moth infestation creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community, dominated by grasses and forbs.
1.1b: Time and lack of disturbance such as fire or drought. Excessive herbivory may also decrease perennial grasses.
1.2a: Time and lack of disturbance allows for shrub regeneration.
1.3a: Low severity fire and/or Aroga moth infestation resulting in a mosaic pattern.
1.3b: High severity fire significantly reduces sagebrush cover leading to early/mid-seral community.

Transition T1A: Introduction of non-native species such as cheatgrass and thistles.

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire and/or Aroga moth infestation creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community dominated by grasses and forbs; non-native annual species present.
2.1b: Time and lack of disturbance such as fire or drought. Inappropriate grazing management may also reduce perennial grasses.
2.2a: Time and lack of disturbance allows for regeneration of sagebrush.
2.3a: Low severity fire and/or Aroga moth infestation creates sagebrush/grass mosaic. Brush management with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire significantly reduces sagebrush cover leading to early mid-seral community.

Transition T2A: Time and lack of disturbance and/or inappropriate grazing management (3.1).
Transition T2B: High severity fire and/or soil disturbance (4.1). Inappropriate grazing that favors shrubs in the presence of non-native annual species (4.2).
Transition T2C: Time and lack of disturbance allows for an increase in tree cover; inappropriate grazing management and/or chronic drought can reduce fine fuels and lead to increased tree establishment and dominance (5.1).

Shrub State 3.0 Community Phase Pathways
3.1a: Fire or brush treatments (i.e. mowing) with minimal soil disturbance.
3.2a: Time and lack of fire allows some shrubs to reestablish.

Transition T3A: Catastrophic fire and/or soil disturbance (4.1). Inappropriate grazing management in the presence of non-native annual species (4.2).
Transition T3B: Time and a lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management (5.1).

Restoration R3A: Brush management with minimal soil disturbance, coupled with seeding of desired species. Probability of success is moderate (6.1).

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of fire.
4.2a: Fire.

Restoration R4A: Seeding of desired species; may be coupled with herbicide; probability of success is moderate (6.1).

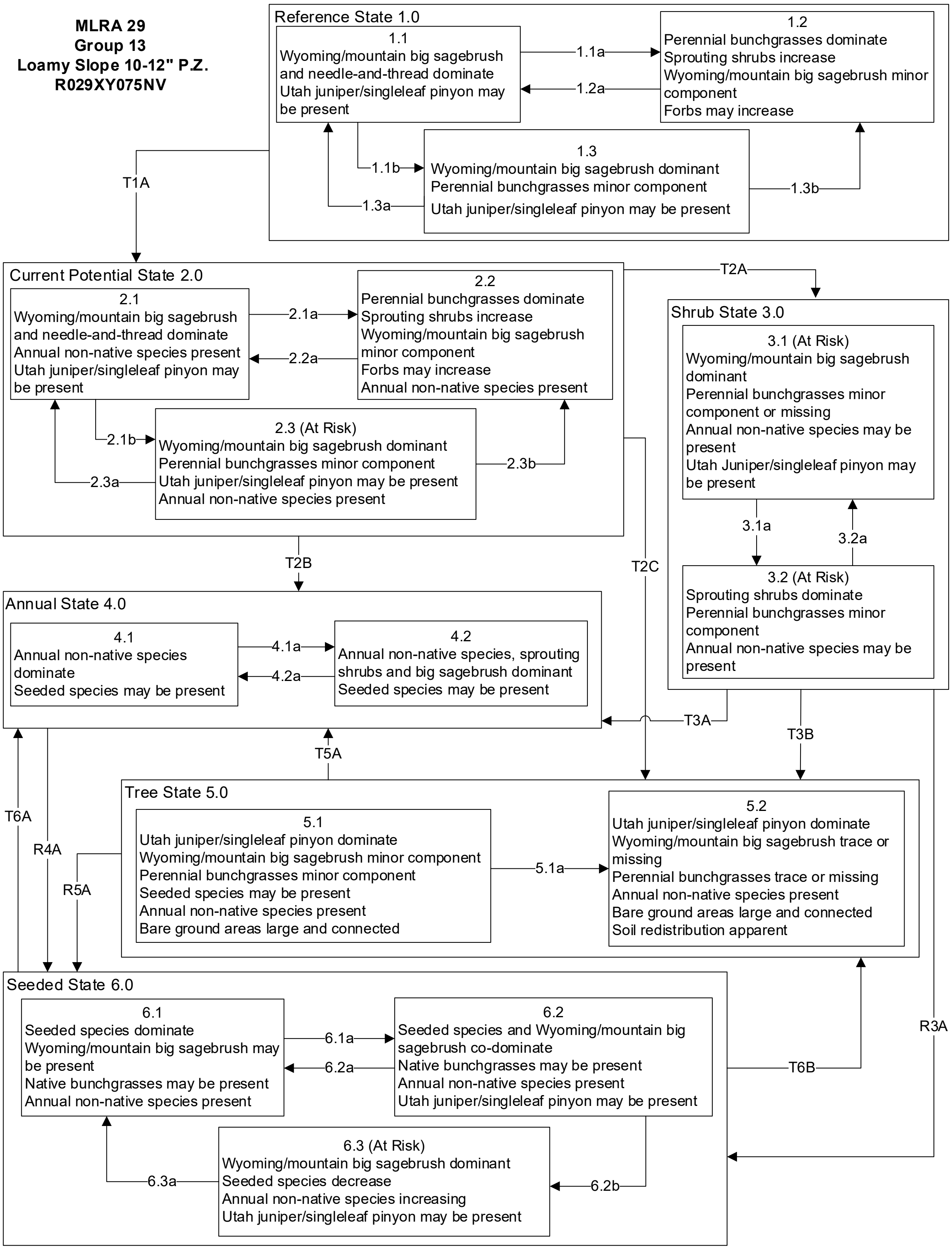
Tree State 5.0 Community Phase Pathways
5.1a: Time and lack of disturbance allows for tree maturation.

Restoration R5A: Tree removal and seeding of native and non-native desirable species.

Transition T5A: Catastrophic fire, inappropriate tree removal practices (5.1).

Seeded State 6.0 Community Phase Pathways
6.1a: Time and lack of disturbance may be coupled with inappropriate grazing management.
6.2a: Low severity fire.
6.2b: Inappropriate grazing management reduces bunchgrasses and increases density of sagebrush; usually a slow transition.
6.3a: Fire or brush treatment with minimal soil disturbance.

Transition T6A: Catastrophic fire and/or inappropriate grazing management.
Transition T6B: Time and a lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management (5.1).



MLRA 29
Group 13
Loamy Slope 10-12" P.Z.
R029XY075NV
Reference State 1.0
1.1
Wyoming/mountain big sagebrush and needle-and-thread dominate
Utah juniper/singleleaf pinyon may be present
1.1a
1.2a
1.2
Perennial bunchgrasses dominate
Sprouting shrubs increase
Wyoming/mountain big sagebrush minor component
Forbs may increase
1.1b
1.3a
1.3
Wyoming/mountain big sagebrush dominant
Perennial bunchgrasses minor component
Utah juniper/singleleaf pinyon may be present
1.3b
T1A
Current Potential State 2.0
2.1
Wyoming/mountain big sagebrush and needle-and-thread dominate
Annual non-native species present
Utah juniper/singleleaf pinyon may be present
2.1a
2.2a
2.2
Perennial bunchgrasses dominate
Sprouting shrubs increase
Wyoming/mountain big sagebrush minor component
Forbs may increase
Annual non-native species present
2.1b
2.3a
2.3 (At Risk)
Wyoming/mountain big sagebrush dominant
Perennial bunchgrasses minor component
Utah juniper/singleleaf pinyon may be present
Annual non-native species present
2.3b
T2A
Shrub State 3.0
3.1 (At Risk)
Wyoming/mountain big sagebrush dominant
Perennial bunchgrasses minor component or missing
Annual non-native species may be present
Utah Juniper/singleleaf pinyon may be present
3.1a
3.2a
3.2 (At Risk)
Sprouting shrubs dominate
Perennial bunchgrasses minor component
Annual non-native species may be present
T2B
T2C
Annual State 4.0
4.1
Annual non-native species dominate
Seeded species may be present
4.1a
4.2a
4.2
Annual non-native species, sprouting shrubs and big sagebrush dominant
Seeded species may be present
T3A
T3B
T5A
T6A
R4A
R5A
Tree State 5.0
5.1
Utah juniper/singleleaf pinyon dominate
Wyoming/mountain big sagebrush minor component
Perennial bunchgrasses minor component
Seeded species may be present
Annual non-native species present
Bare ground areas large and connected
5.1a
5.2
Utah juniper/singleleaf pinyon dominate
Wyoming/mountain big sagebrush trace or missing
Perennial bunchgrasses trace or missing
Annual non-native species present
Bare ground areas large and connected
Soil redistribution apparent
R3A
Seeded State 6.0
6.1
Seeded species dominate
Wyoming/mountain big sagebrush may be present
Native bunchgrasses may be present
Annual non-native species present
6.1a
6.2a
6.2
Seeded species and Wyoming/mountain big sagebrush co-dominate
Native bunchgrasses may be present
Annual non-native species present
Utah juniper/singleleaf pinyon may be present
T6B
6.3a
6.3 (At Risk)
Wyoming/mountain big sagebrush dominant
Seeded species decrease
Annual non-native species increasing
Utah juniper/singleleaf pinyon may be present
6.2b

MLRA 29
Group 13
Loamy Slope 10-12" P.Z.
R029XY075NV

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community, dominated by grasses and forbs.
1.1b: Time and lack of disturbance such as fire or drought. Excessive herbivory may also decrease perennial understory.
1.2a: Time and lack of disturbance allows for shrub regeneration.
1.3a: Low severity fire or Aroga moth infestation resulting in a mosaic pattern.
1.3b: High severity fire significantly reduces sagebrush cover leading to early/mid-seral community.

Transition T1A: Introduction of non-native species such as cheatgrass and mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire and/or Aroga moth infestation creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community dominated by sprouting shrubs, grasses and forbs; non-native annual species present.
2.1b: Time and lack of disturbance such as fire or drought. Inappropriate grazing management may also reduce perennial grasses.
2.2a: Time and lack of disturbance allows for regeneration of sagebrush.
2.3a: Low severity fire and/or Aroga moth infestation creates sagebrush/grass mosaic. Brush management with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire significantly reduces sagebrush cover leading to early mid-seral community dominated by sprouting shrubs, grasses and forbs.

Transition T2A: Time and lack of disturbance and/or inappropriate grazing management (3.1).
Transition T2B: High severity fire and/or soil disturbance (4.1). Inappropriate grazing that favors shrubs in the presence of non-native annual species (4.2).
Transition T2C: Time and lack of disturbance allows for an increase in tree cover; inappropriate grazing management and/or chronic drought can reduce fine fuels and lead to increased tree establishment and dominance (5.1).

Shrub State 3.0 Community Phase Pathways
3.1a: Fire or brush treatments (i.e. mowing) with minimal soil disturbance.
3.2a: Time and lack of fire allows some shrubs to reestablish.

Transition T3A: Catastrophic fire and/or soil disturbance (4.1). Inappropriate grazing management in the presence of non-native annual species (4.2).
Transition T3B: Time and a lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management (5.1).

Restoration R3A: Brush management with minimal soil disturbance, coupled with seeding of desired species. Probability of success is low (6.1).

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of fire.
4.2a: Fire.

Restoration R4A: Seeding of desired species; may be coupled with herbicide; probability of success is low (6.1).

Tree State 5.0 Community Phase Pathways
5.1a: Time and lack of disturbance allows for tree maturation.

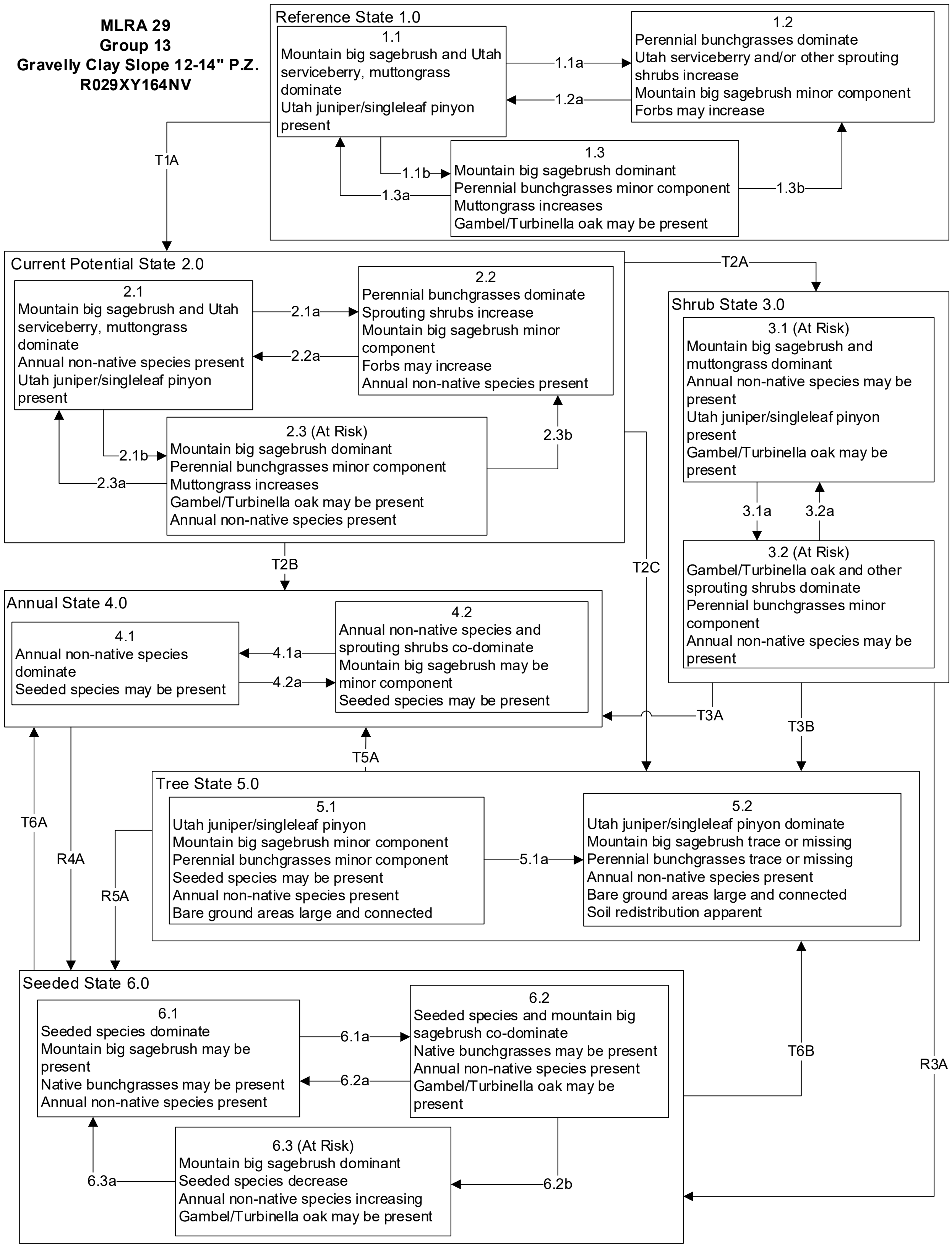
Restoration R5A: Tree removal and seeding of native and non-native species.

Transition T5A: Catastrophic fire, inappropriate tree removal practices (5.1).

Seeded State 6.0 Community Phase Pathways
6.1a: Time and lack of disturbance may be coupled with inappropriate grazing management.
6.2a: Low severity fire.
6.2b: Inappropriate grazing management reduces bunchgrasses and increases density of sagebrush; usually a slow transition.
6.3a: Fire or brush treatment with minimal soil disturbance.

Transition T6A: Catastrophic fire and/or inappropriate grazing management.
Transition T6B: Time and a lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management (5.1).

MLRA 29
Group 13
Gravelly Clay Slope 12-14" P.Z.
R029XY164NV



MLRA 29
Group 13
Gravelly Clay Slope 12-14" P.Z.
R029XY164NV

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community, dominated by sprouting shrubs, grasses and forbs.
1.1b: Time and lack of disturbance such as fire or drought. Excessive herbivory may also decrease perennial bunchgrasses.
1.2a: Time and lack of disturbance allows for sagebrush regeneration.
1.3a: Low severity fire resulting in a mosaic pattern of sprouting shrubs, grasses and forbs..
1.3b: High severity fire significantly reduces sagebrush cover leading to early/mid-seral community dominated by sprouting shrubs, grasses and forbs.

Transition T1A: Introduction of non-native species such as cheatgrass and red brome.

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community dominated by sprouting shrubs, grasses and forbs; non-native annual species present.
2.1b: Time and lack of disturbance such as fire or drought. Inappropriate grazing management may also reduce perennial bunchgrasses.
2.2a: Time and lack of disturbance allows for regeneration of sagebrush.
2.3a: Low severity fire creates sagebrush/grass mosaic. Brush management with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire significantly reduces sagebrush cover leading to early mid-seral community dominated by sprouting shrubs, grasses and forbs.

Transition T2A: Time and lack of disturbance and/or inappropriate grazing management (3.1).
Transition T2B: High severity fire and/or soil disturbance (4.1). Inappropriate grazing that favors shrubs in the presence of non-native annual species (4.2).
Transition T2C: Time and lack of disturbance allows for an increase in tree cover; inappropriate grazing management and/or chronic drought can reduce fine fuels and lead to increased tree establishment and dominance (5.1).

Shrub State 3.0 Community Phase Pathways
3.1a: Fire or brush treatments (i.e. mowing) with minimal soil disturbance.
3.2a: Time and lack of fire allows some shrubs to reestablish.

Transition T3A: Catastrophic fire and/or soil disturbance (4.1). Inappropriate grazing management in the presence of non-native annual species (4.2).
Transition T3B: Time and a lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management (5.1).

Restoration R3A: Brush management with minimal soil disturbance, coupled with seeding of desired species. Probability of success is moderate (6.1).

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of fire.
4.2a: Fire.

Restoration R4A: Seeding of desired species; may be coupled with herbicide; probability of success is moderate (6.1).

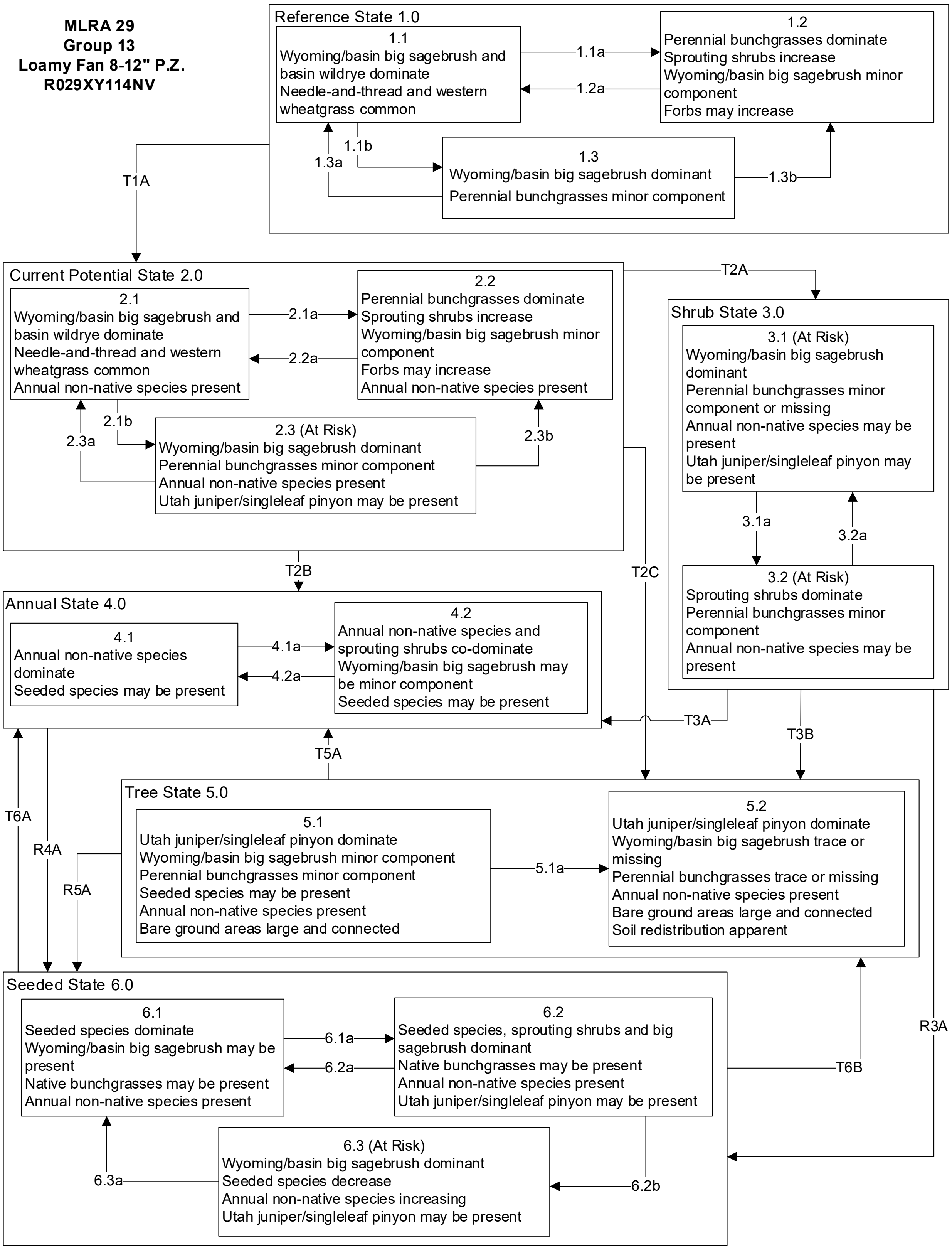
Tree State 5.0 Community Phase Pathways
5.1a: Time and lack of disturbance allows for tree maturation.

Restoration R5A: Tree removal and seeding of native and non-native species.

Transition T5A: Catastrophic fire, inappropriate tree removal practices (5.1).

Seeded State 6.0 Community Phase Pathways
6.1a: Time and lack of disturbance may be coupled with inappropriate grazing management.
6.2a: Low severity fire.
6.2b: Inappropriate grazing management reduces bunchgrasses and increases density of shrubs; usually a slow transition.
6.3a: Fire or brush treatment with minimal soil disturbance.

Transition T6A: Catastrophic fire and/or inappropriate grazing management.
Transition T6B: Time and a lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management (5.1).


MLRA 29
Group 13
Loamy Fan 8-12" P.Z.
R029XY114NV
Reference State 1.0
1.1
Wyoming/basin big sagebrush and basin wildrye dominate
Needle-and-thread and western wheatgrass common
1.1a
1.2a
1.2
Perennial bunchgrasses dominate
Sprouting shrubs increase
Wyoming/basin big sagebrush minor component
Forbs may increase
1.1b
1.3a
1.3
Wyoming/basin big sagebrush dominant
Perennial bunchgrasses minor component
1.3b
T1A
Current Potential State 2.0
2.1
Wyoming/basin big sagebrush and basin wildrye dominate
Needle-and-thread and western wheatgrass common
Annual non-native species present
2.1a
2.2a
2.2
Perennial bunchgrasses dominate
Sprouting shrubs increase
Wyoming/basin big sagebrush minor component
Forbs may increase
Annual non-native species present
2.1b
2.3a
2.3 (At Risk)
Wyoming/basin big sagebrush dominant
Perennial bunchgrasses minor component
Annual non-native species present
Utah juniper/singleleaf pinyon may be present
2.3b
T2A
Shrub State 3.0
3.1 (At Risk)
Wyoming/basin big sagebrush dominant
Perennial bunchgrasses minor component or missing
Annual non-native species may be present
Utah juniper/singleleaf pinyon may be present
3.1a
3.2a
3.2 (At Risk)
Sprouting shrubs dominate
Perennial bunchgrasses minor component
Annual non-native species may be present
T2B
T2C
Annual State 4.0
4.1
Annual non-native species dominate
Seeded species may be present
4.1a
4.2a
4.2
Annual non-native species and sprouting shrubs co-dominate
Wyoming/basin big sagebrush may be minor component
Seeded species may be present
T3A
T3B
T5A
T6A
R4A
R5A
Tree State 5.0
5.1
Utah juniper/singleleaf pinyon dominate
Wyoming/basin big sagebrush minor component
Perennial bunchgrasses minor component
Seeded species may be present
Annual non-native species present
Bare ground areas large and connected
5.1a
5.2
Utah juniper/singleleaf pinyon dominate
Wyoming/basin big sagebrush trace or missing
Perennial bunchgrasses trace or missing
Annual non-native species present
Bare ground areas large and connected
Soil redistribution apparent
R3A
Seeded State 6.0
6.1
Seeded species dominate
Wyoming/basin big sagebrush may be present
Native bunchgrasses may be present
Annual non-native species present
6.1a
6.2a
6.2
Seeded species, sprouting shrubs and big sagebrush dominant
Native bunchgrasses may be present
Annual non-native species present
Utah juniper/singleleaf pinyon may be present
T6B
6.3 (At Risk)
Wyoming/basin big sagebrush dominant
Seeded species decrease
Annual non-native species increasing
Utah juniper/singleleaf pinyon may be present
6.3a
6.2b

MLRA 29
Group 13
Loamy Fan 8-12" P.Z.
R029XY114NV

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire and/or Aroga moth infestation creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community, dominated by sprouting shrubs, grasses and forbs.
1.1b: Time and lack of disturbance such as fire or drought. Excessive herbivory may also decrease perennial grasses..
1.2a: Time and lack of disturbance allows for shrub regeneration.
1.3a: Low severity fire or Aroga moth infestation resulting in a mosaic pattern.
1.3b: High severity fire significantly reduces sagebrush cover leading to early/mid-seral community dominated by sprouting shrubs, grasses and forbs..

Transition T1A: Introduction of non-native species such as cheatgrass and mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire and/or creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community dominated by sprouting shrubs, grasses and forbs; non-native annual species present.
2.1b: Time and lack of disturbance such as fire or drought. Inappropriate grazing management may also reduce perennial understory.
2.2a: Time and lack of disturbance allows for regeneration of sagebrush.
2.3a: Low severity fire and/or Aroga moth infestation creates sagebrush/grass mosaic. Brush management with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire significantly reduces sagebrush cover leading to early to mid-seral community dominated by sprouting shrubs, grasses and forbs.

Transition T2A: Time and lack of disturbance and/or inappropriate grazing management (3.1).
Transition T2B: High severity fire and/or soil disturbance (4.1). Inappropriate grazing that favors shrubs in the presence of non-native annual species (4.2).
Transition T2C: Time and lack of disturbance allows for an increase in tree cover; inappropriate grazing management and/or chronic drought can reduce fine fuels and lead to increased tree establishment and dominance (5.1).

Shrub State 3.0 Community Phase Pathways
3.1a: Fire or brush treatments (i.e. mowing) with minimal soil disturbance.
3.2a: Time and lack of fire allows some shrubs to reestablish.

Transition T3A: Catastrophic fire and/or soil disturbance (4.1). Inappropriate grazing management in the presence of non-native annual species (4.2).
Transition T3B: Time and a lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management (5.1).

Restoration R3A: Brush management with minimal soil disturbance, coupled with seeding of desired species. Probability of success is low (6.1).

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of fire.
4.2a: Fire.

Restoration R4A: Seeding of desired species; may be coupled with herbicide; probability of success is low (6.1).

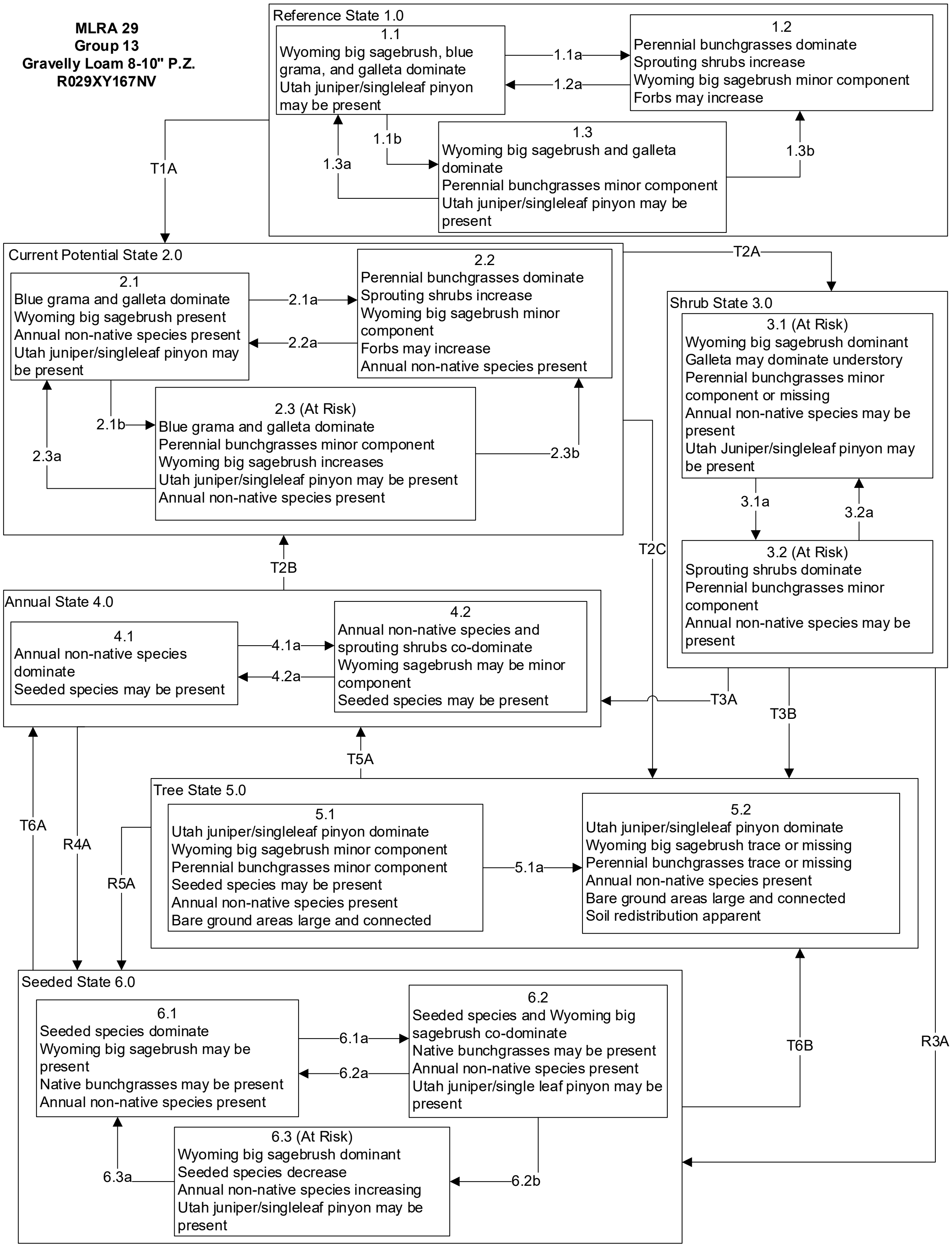
Tree State 5.0 Community Phase Pathways
5.1a: Time and lack of disturbance allows for tree maturation.

Restoration R5A: Tree removal and seeding of non-native desirable species such as crested wheatgrass.

Transition T5A: Catastrophic fire, inappropriate tree removal practices (5.1).

Seeded State 6.0 Community Phase Pathways
6.1a: Time and lack of disturbance may be coupled with inappropriate grazing management.
6.2a: Low severity fire.
6.2b: Inappropriate grazing management reduces bunchgrasses and increases density of sagebrush; usually a slow transition.
6.3a: Fire or brush treatment with minimal soil disturbance.

Transition T6A: Catastrophic fire and/or inappropriate grazing management.
Transition T6B: Time and a lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management (5.1).


MLRA 29
Group 13
Gravelly Loam 8-10" P.Z.
R029XY167NV
Reference State 1.0
1.1
Wyoming big sagebrush, blue grama, and galleta dominate
Utah juniper/singleleaf pinyon may be present
1.2
Perennial bunchgrasses dominate
Sprouting shrubs increase
Wyoming big sagebrush minor component
Forbs may increase
1.3
Wyoming big sagebrush and galleta dominate
Perennial bunchgrasses minor component
Utah juniper/singleleaf pinyon may be present
1.1a
1.2a
1.1b
1.3a
1.3b
T1A
Current Potential State 2.0
2.1
Blue grama and galleta dominate
Wyoming big sagebrush present
Annual non-native species present
Utah juniper/singleleaf pinyon may be present
2.2
Perennial bunchgrasses dominate
Sprouting shrubs increase
Wyoming big sagebrush minor component
Forbs may increase
Annual non-native species present
2.3 (At Risk)
Blue grama and galleta dominate
Perennial bunchgrasses minor component
Wyoming big sagebrush increases
Utah juniper/singleleaf pinyon may be present
Annual non-native species present
2.1a
2.2a
2.1b
2.3a
2.3b
T2A
Shrub State 3.0
3.1 (At Risk)
Wyoming big sagebrush dominant
Galleta may dominate understory
Perennial bunchgrasses minor component or missing
Annual non-native species may be present
Utah Juniper/singleleaf pinyon may be present
3.2 (At Risk)
Sprouting shrubs dominate
Perennial bunchgrasses minor component
Annual non-native species may be present
3.1a
3.2a
T2C
T2B
Annual State 4.0
4.1
Annual non-native species dominate
Seeded species may be present
4.2
Annual non-native species and sprouting shrubs co-dominate
Wyoming sagebrush may be minor component
Seeded species may be present
4.1a
4.2a
T3A
T3B
T5A
Tree State 5.0
5.1
Utah juniper/singleleaf pinyon dominate
Wyoming big sagebrush minor component
Perennial bunchgrasses minor component
Seeded species may be present
Annual non-native species present
Bare ground areas large and connected
5.2
Utah juniper/singleleaf pinyon dominate
Wyoming big sagebrush trace or missing
Perennial bunchgrasses trace or missing
Annual non-native species present
Bare ground areas large and connected
Soil redistribution apparent
5.1a
T6A
R4A
R5A
Seeded State 6.0
6.1
Seeded species dominate
Wyoming big sagebrush may be present
Native bunchgrasses may be present
Annual non-native species present
6.2
Seeded species and Wyoming big sagebrush co-dominate
Native bunchgrasses may be present
Annual non-native species present
Utah juniper/single leaf pinyon may be present
6.3 (At Risk)
Wyoming big sagebrush dominant
Seeded species decrease
Annual non-native species increasing
Utah juniper/singleleaf pinyon may be present
6.1a
6.2a
6.2b
6.3a
T6B
R3A

MLRA 29
Group 13
Gravelly Loam 8-10" P.Z.
R029XY167NV

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community, dominated by grasses and forbs.
1.1b: Time and lack of disturbance such as fire or drought. Excessive herbivory may also decrease perennial understory.
1.2a: Time and lack of disturbance allows for shrub regeneration.
1.3a: Low severity fire or Aroga moth infestation resulting in a mosaic pattern.
1.3b: High severity fire significantly reduces sagebrush cover leading to early/mid-seral community.

Transition T1A: Introduction of non-native species such as cheatgrass and thistles.

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire and/or Aroga moth infestation creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community dominated by grasses and forbs; non-native annual species present.
2.1b: Time and lack of disturbance such as fire or drought. Inappropriate grazing management may also reduce perennial grass understory.
2.2a: Time and lack of disturbance allows for regeneration of sagebrush.
2.3a: Low severity fire and/or Aroga moth infestation creates sagebrush/grass mosaic. Brush management with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire significantly reduces sagebrush cover leading to early mid-seral community.

Transition T2A: Time and lack of disturbance and/or inappropriate grazing management (3.1).
Transition T2B: High severity fire and/or soil disturbance (4.1). Inappropriate grazing that favors shrubs in the presence of non-native annual species (4.2).
Transition T2C: Time and lack of disturbance allows for an increase in tree cover; inappropriate grazing management and/or chronic drought can reduce fine fuels and lead to increased tree establishment and dominance (5.1).

Shrub State 3.0 Community Phase Pathways
3.1a: Fire or brush treatments (i.e. mowing) with minimal soil disturbance.
3.2a: Time and lack of fire allows some shrubs to reestablish.

Transition T3A: Catastrophic fire and/or soil disturbance (4.1). Inappropriate grazing management in the presence of non-native annual species (4.2).
Transition T3B: Time and a lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management (5.1).

Restoration R3A: Brush management with minimal soil disturbance, coupled with seeding of desired species. Probability of success very low (6.1).

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of fire.
4.2a: Fire.

Restoration R4A: Seeding of desired species; may be coupled with herbicide; probability of success very low (6.1).

Tree State 5.0 Community Phase Pathways
5.1a: Time and lack of disturbance allows for tree maturation.

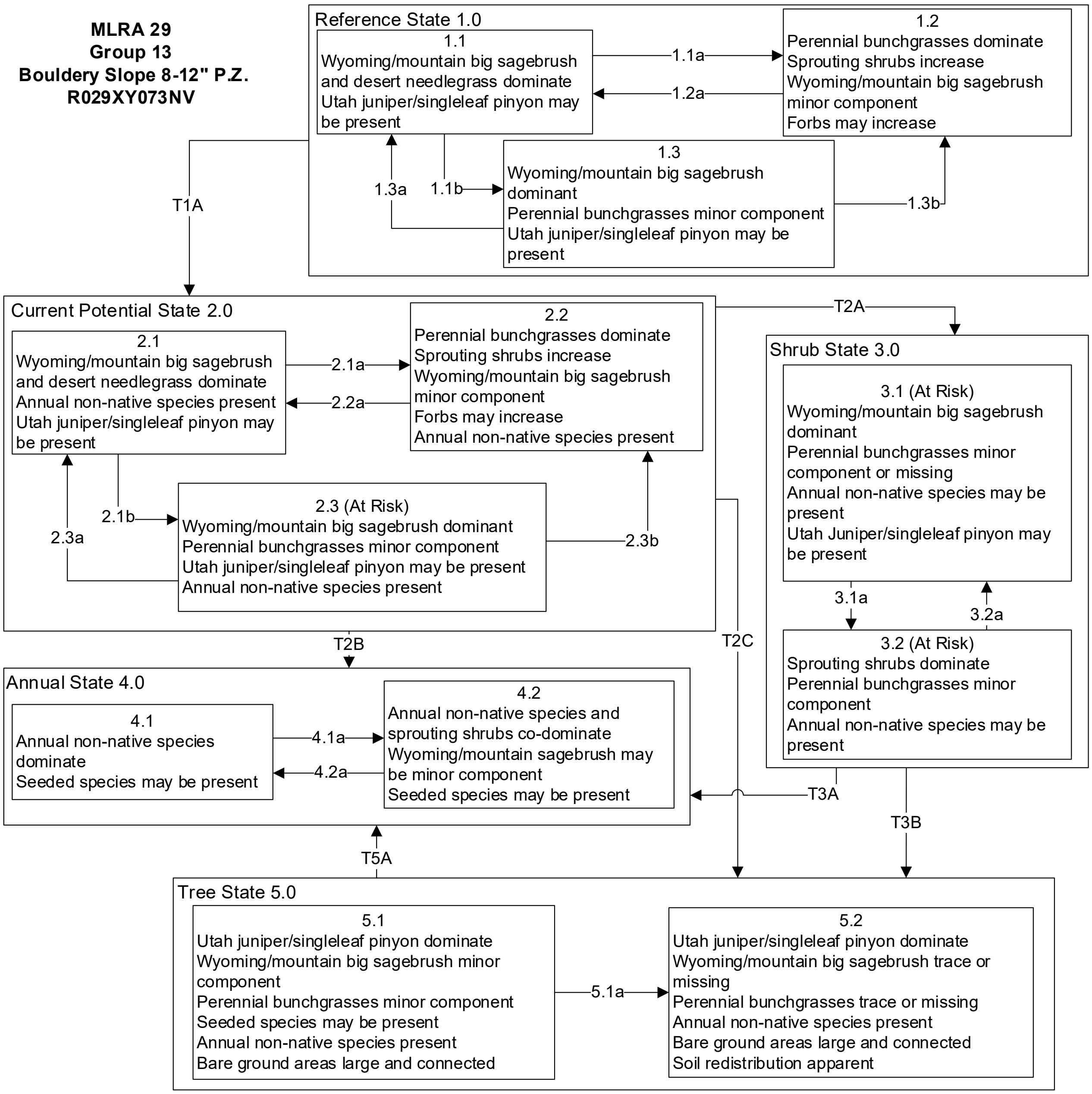
Restoration R5A: Tree removal and seeding of non-native desirable species such as crested wheatgrass.

Transition T5A: Catastrophic fire, inappropriate tree removal practices (5.1).

Seeded State 6.0 Community Phase Pathways
6.1a: Time and lack of disturbance may be coupled with inappropriate grazing management.
6.2a: Low severity fire.
6.2b: Inappropriate grazing management reduces bunchgrasses and increases density of sagebrush; usually a slow transition.
6.3a: Fire or brush treatment with minimal soil disturbance.

Transition T6A: Catastrophic fire and/or inappropriate grazing management.
Transition T6B: Time and a lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management (5.1).

MLRA 29
Group 13
Bouldery Slope 8-12" P.Z.
R029XY073NV



MLRA 29
Group 13
Bouldery Slope 8-12" P.Z.
R029XY073NV

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire and/or Aroga moth infestation creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community, dominated by grasses and forbs.
1.1b: Time and lack of disturbance such as fire allows big sagebrush to increase. Excessive herbivory and droughty may also decrease perennial understoy and allow big sagebrush to dominate.
1.2a: Time and lack of disturbance allows for big sagebrush to re-establish.
1.3a: Low severity fire, herbivory, Aroga moth infestation or combinations reduce big sagebrush overstory and create sagebrush/grass mosaic.
1.3b: High severity fire significantly reduces sagebrush cover leading to perennial bunchgrasses to dominate site.

Transition T1A: Introduction of non-native species such as cheatgrass and thistles.

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire and/or Aroga moth infestation creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community dominated by grasses and forbs; non-native annual species present.
2.1b: Time and lack of disturbance such as fire or drought. Inappropriate grazing management may also reduce perennial bunchgrass understory.
2.2a: Time and lack of disturbance allows for regeneration of sagebrush.
2.3a: Low severity fire and/or Aroga moth infestation creates sagebrush/grass mosaic. Late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire significantly reduces sagebrush cover leading to early mid-seral community.

Transition T2A: Time and lack of disturbance and/or inappropriate grazing management (3.1).
Transition T2B: High severity fire and/or soil disturbance (4.1). Inappropriate grazing that favors shrubs in the presence of non-native annual species (4.2).
Transition T2C: Time and lack of disturbance allows for an increase in tree cover; inappropriate grazing management and/or chronic drought can reduce fine fuels and lead to increased tree establishment and dominance (5.1).

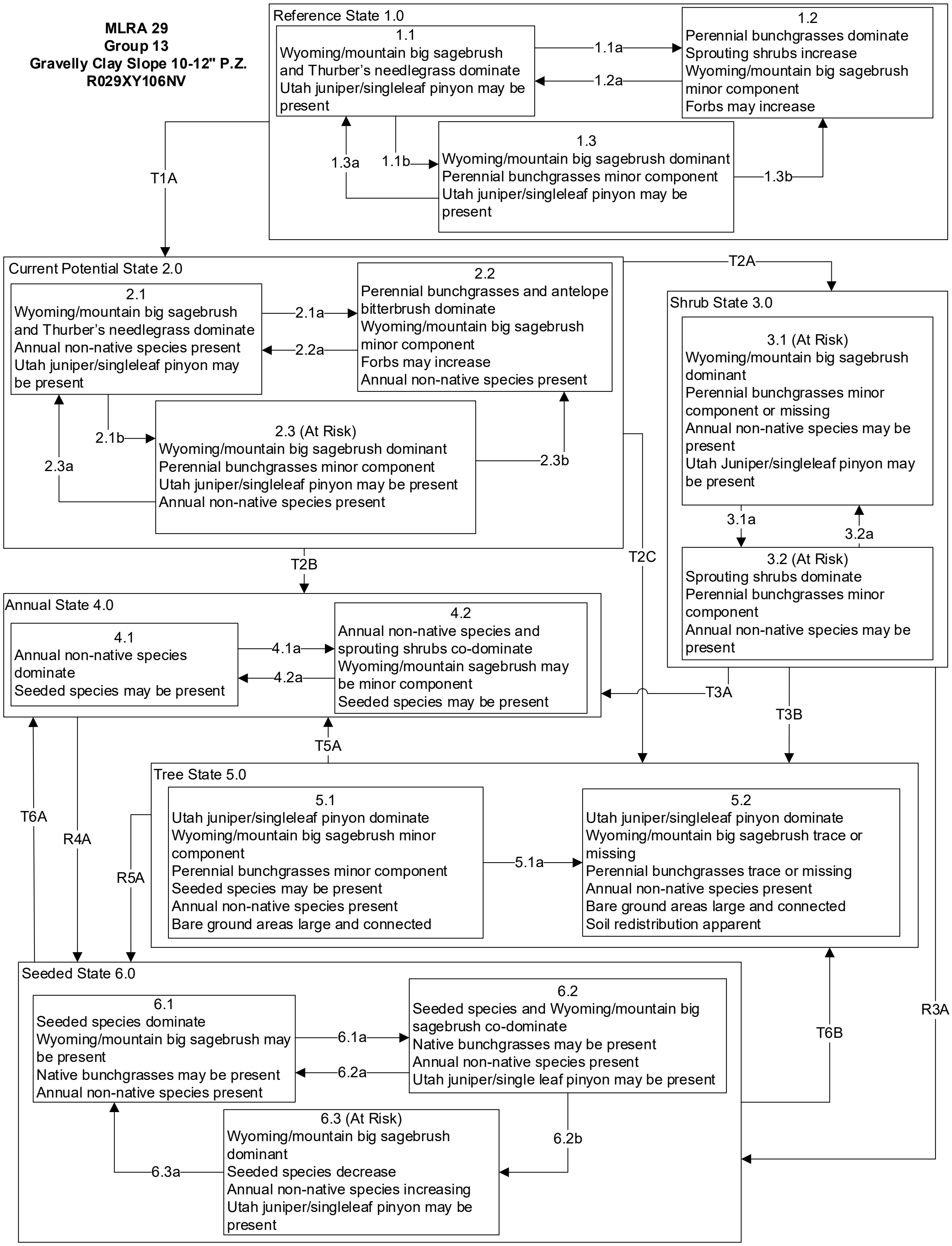
Shrub State 3.0 Community Phase Pathways
3.1a: Fire with minimal soil disturbance.
3.2a: Time and lack of fire allows some shrubs to reestablish.

Transition T3A: Catastrophic fire and/or soil disturbance (4.1). Inappropriate grazing management in the presence of non-native annual species (4.2).
Transition T3B: Time and a lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management (5.1).

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of fire.
4.2a: Fire.

Tree State 5.0 Community Phase Pathways
5.1a: Time and lack of disturbance allows for tree dominance.

Transition T5A: Catastrophic fire, inappropriate tree removal practices (5.1).


MLRA 29
Group 13
Gravelly Clay Slope 10-12" P.Z.
R029XY106NV
Reference State 1.0
1.1
Wyoming/mountain big sagebrush and Thurber's needlegrass dominate
Utah juniper/singleleaf pinyon may be present
1.2
Perennial bunchgrasses dominate
Sprouting shrubs increase
Wyoming/mountain big sagebrush minor component
Forbs may increase
1.3
Wyoming/mountain big sagebrush dominant
Perennial bunchgrasses minor component
Utah juniper/singleleaf pinyon may be present
1.1a
1.2a
1.1b
1.3a
1.3b
T1A
Current Potential State 2.0
2.1
Wyoming/mountain big sagebrush and Thurber's needlegrass dominate
Annual non-native species present
Utah juniper/singleleaf pinyon may be present
2.2
Perennial bunchgrasses and antelope bitterbrush dominate
Wyoming/mountain big sagebrush minor component
Forbs may increase
Annual non-native species present
2.3 (At Risk)
Wyoming/mountain big sagebrush dominant
Perennial bunchgrasses minor component
Utah juniper/singleleaf pinyon may be present
Annual non-native species present
2.1a
2.2a
2.1b
2.3a
2.3b
T2A
Shrub State 3.0
3.1 (At Risk)
Wyoming/mountain big sagebrush dominant
Perennial bunchgrasses minor component or missing
Annual non-native species may be present
Utah Juniper/singleleaf pinyon may be present
3.2 (At Risk)
Sprouting shrubs dominate
Perennial bunchgrasses minor component
Annual non-native species may be present
3.1a
3.2a
T2B
T2C
Annual State 4.0
4.1
Annual non-native species dominate
Seeded species may be present
4.2
Annual non-native species and sprouting shrubs co-dominate
Wyoming/mountain sagebrush may be minor component
Seeded species may be present
4.1a
4.2a
T3A
T3B
T5A
Tree State 5.0
5.1
Utah juniper/singleleaf pinyon dominate
Wyoming/mountain big sagebrush minor component
Perennial bunchgrasses minor component
Seeded species may be present
Annual non-native species present
Bare ground areas large and connected
5.2
Utah juniper/singleleaf pinyon dominate
Wyoming/mountain big sagebrush trace or missing
Perennial bunchgrasses trace or missing
Annual non-native species present
Bare ground areas large and connected
Soil redistribution apparent
5.1a
T6A
R4A
R5A
Seeded State 6.0
6.1
Seeded species dominate
Wyoming/mountain big sagebrush may be present
Native bunchgrasses may be present
Annual non-native species present
6.2
Seeded species and Wyoming/mountain big sagebrush co-dominate
Native bunchgrasses may be present
Annual non-native species present
Utah juniper/single leaf pinyon may be present
6.3 (At Risk)
Wyoming/mountain big sagebrush dominant
Seeded species decrease
Annual non-native species increasing
Utah juniper/singleleaf pinyon may be present
6.1a
6.2a
6.2b
6.3a
T6B
R3A

MLRA 29
Group 13
Gravelly Clay Slope 10-12" P.Z.
R029XY106NV

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire and/or Aroga moth infestation creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community, dominated by grasses and forbs.
1.1b: Time and lack of disturbance such as fire or drought. Excessive herbivory may also decrease perennial bunchgrasses.
1.2a: Time and lack of disturbance allows for shrub regeneration.
1.3a: Low severity fire and/or Aroga moth infestation resulting in a grass/sagebrush mosaic pattern.
1.3b: High severity fire significantly reduces sagebrush cover leading to early/mid-seral community.

Transition T1A: Introduction of non-native species such as cheatgrass and thistles.

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community dominated by grasses and forbs; non-native annual species present.
2.1b: Time and lack of disturbance such as fire or drought. Inappropriate grazing management may also reduce perennial bunchgrasses.
2.2a: Time and lack of disturbance allows for regeneration of sagebrush.
2.3a: Low severity fire and/or Aroga moth infestation creates sagebrush/grass mosaic. Brush management with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire significantly reduces sagebrush cover leading to early mid-seral community.

Transition T2A: Time and lack of disturbance and/or inappropriate grazing management (3.1).
Transition T2B: High severity fire and/or soil disturbance (4.1). Inappropriate grazing that favors shrubs in the presence of non-native annual species (4.2).
Transition T2C: Time and lack of disturbance allows for an increase in tree cover; inappropriate grazing management and/or chronic drought can reduce fine fuels and lead to increased tree establishment and dominance (5.1).

Shrub State 3.0 Community Phase Pathways
3.1a: Fire or brush treatments (i.e. mowing) with minimal soil disturbance.
3.2a: Time and lack of fire allows some shrubs to reestablish.

Transition T3A: Catastrophic fire and/or soil disturbance (4.1). Inappropriate grazing management in the presence of non-native annual species (4.2).
Transition T3B: Time and a lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management (5.1).

Restoration R3A: Brush management with minimal soil disturbance, coupled with seeding of desired species. Probability of success is moderate (6.1).

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of fire.
4.2a: Fire.

Restoration R4A: Seeding of desired species; may be coupled with herbicide; probability of success is moderate (6.1).

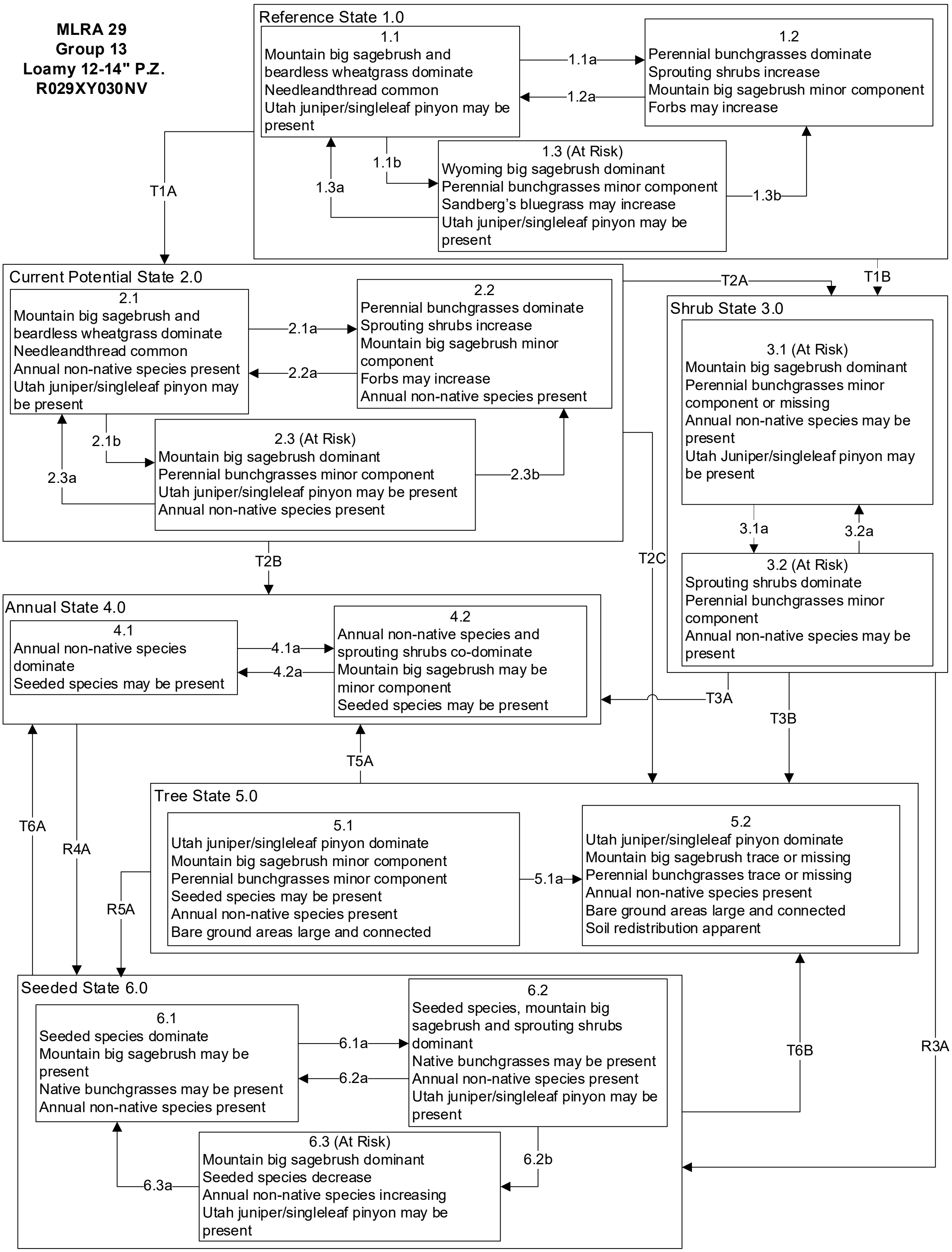
Tree State 5.0 Community Phase Pathways
5.1a: Time and lack of disturbance allows for tree maturation.

Restoration R5A: Tree removal and seeding of non-native desirable species such as crested wheatgrass.

Transition T5A: Catastrophic fire, inappropriate tree removal practices (5.1).

Seeded State 6.0 Community Phase Pathways
6.1a: Time and lack of disturbance may be coupled with inappropriate grazing management.
6.2a: Low severity fire.
6.2b: Inappropriate grazing management reduces bunchgrasses and increases density of sagebrush; usually a slow transition.
6.3a: Fire or brush treatment with minimal soil disturbance.

Transition T6A: Catastrophic fire and/or inappropriate grazing management.
Transition T6B: Time and a lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management (5.1).



MLRA 29
Group 13
Loamy 12-14" P.Z.
R029XY030NV
Reference State 1.0
1.1
Mountain big sagebrush and beardless wheatgrass dominate
Needleandthread common
Utah juniper/singleleaf pinyon may be present
1.1a
1.2a
1.2
Perennial bunchgrasses dominate
Sprouting shrubs increase
Mountain big sagebrush minor component
Forbs may increase
1.1b
1.3a
1.3 (At Risk)
Wyoming big sagebrush dominant
Perennial bunchgrasses minor component
Sandberg's bluegrass may increase
Utah juniper/singleleaf pinyon may be present
1.3b
T1A
T1B
Current Potential State 2.0
2.1
Mountain big sagebrush and beardless wheatgrass dominate
Needleandthread common
Annual non-native species present
Utah juniper/singleleaf pinyon may be present
2.1a
2.2a
2.2
Perennial bunchgrasses dominate
Sprouting shrubs increase
Mountain big sagebrush minor component
Forbs may increase
Annual non-native species present
2.1b
2.3a
2.3 (At Risk)
Mountain big sagebrush dominant
Perennial bunchgrasses minor component
Utah juniper/singleleaf pinyon may be present
Annual non-native species present
2.3b
T2A
Shrub State 3.0
3.1 (At Risk)
Mountain big sagebrush dominant
Perennial bunchgrasses minor component or missing
Annual non-native species may be present
Utah Juniper/singleleaf pinyon may be present
3.1a
3.2a
3.2 (At Risk)
Sprouting shrubs dominate
Perennial bunchgrasses minor component
Annual non-native species may be present
T2B
T2C
Annual State 4.0
4.1
Annual non-native species dominate
Seeded species may be present
4.1a
4.2a
4.2
Annual non-native species and sprouting shrubs co-dominate
Mountain big sagebrush may be minor component
Seeded species may be present
T3A
T3B
T5A
Tree State 5.0
5.1
Utah juniper/singleleaf pinyon dominate
Mountain big sagebrush minor component
Perennial bunchgrasses minor component
Seeded species may be present
Annual non-native species present
Bare ground areas large and connected
5.1a
5.2
Utah juniper/singleleaf pinyon dominate
Mountain big sagebrush trace or missing
Perennial bunchgrasses trace or missing
Annual non-native species present
Bare ground areas large and connected
Soil redistribution apparent
T6A
R4A
R5A
Seeded State 6.0
6.1
Seeded species dominate
Mountain big sagebrush may be present
Native bunchgrasses may be present
Annual non-native species present
6.1a
6.2a
6.2
Seeded species, mountain big sagebrush and sprouting shrubs dominant
Native bunchgrasses may be present
Annual non-native species present
Utah juniper/singleleaf pinyon may be present
6.2b
6.3a
6.3 (At Risk)
Mountain big sagebrush dominant
Seeded species decrease
Annual non-native species increasing
Utah juniper/singleleaf pinyon may be present
T6B
R3A

MLRA 29
Group 13
Loamy 12-14" P.Z.
R029XY030NV

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community, dominated by sprouting shrubs, grasses and forbs.
1.1b: Time and lack of disturbance such as fire or drought. Excessive herbivory may also decrease perennial grasses.
1.2a: Time and lack of disturbance allows for shrub regeneration.
1.3a: Low severity fire resulting in a mosaic pattern of sagebrush, sprouting shrubs, grasses and forbs
1.3b: High severity fire significantly reduces sagebrush cover leading to early/mid-seral community dominated by sprouting shrubs, grasses and forbs.

Transition T1A: Introduction of non-native species such as cheatgrass and mustards.
Transition T1B: Time and lack of disturbance and/or inappropriate grazing management or wild horse and burro management. Annual invasive species not present.

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community dominated by grasses and forbs; non-native annual species present.
2.1b: Time and lack of disturbance such as fire or drought. Inappropriate grazing management may also reduce perennial understory.
2.2a: Time and lack of disturbance allows for regeneration of sagebrush.
2.3a: Low severity fire creates sagebrush/grass mosaic. Brush management with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire significantly reduces sagebrush cover leading to early mid-seral community dominated by sprouting shrubs, grasses and forbs.

Transition T2A: Time and lack of disturbance and/or inappropriate grazing management (3.1).
Transition T2B: High severity fire and/or soil disturbance (4.1). Inappropriate grazing that favors shrubs in the presence of non-native annual species (4.2).
Transition T2C: Time and lack of disturbance allows for an increase in tree cover; inappropriate grazing management and/or chronic drought can reduce fine fuels and lead to increased tree establishment and dominance (5.1).

Shrub State 3.0 Community Phase Pathways
3.1a: Fire or brush treatments (i.e. mowing) with minimal soil disturbance.
3.2a: Time and lack of fire allows some shrubs to reestablish.

Transition T3A: Catastrophic fire and/or soil disturbance (4.1). Inappropriate grazing management in the presence of non-native annual species (4.2).
Transition T3B: Time and a lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management (5.1).

Restoration R3A: Brush management with minimal soil disturbance, coupled with seeding of desired species. Probability of success is moderate(6.1).

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of fire.
4.2a: Fire.

Restoration R4A: Seeding of desired species; may be coupled with herbicide; probability of success is moderate (6.1).

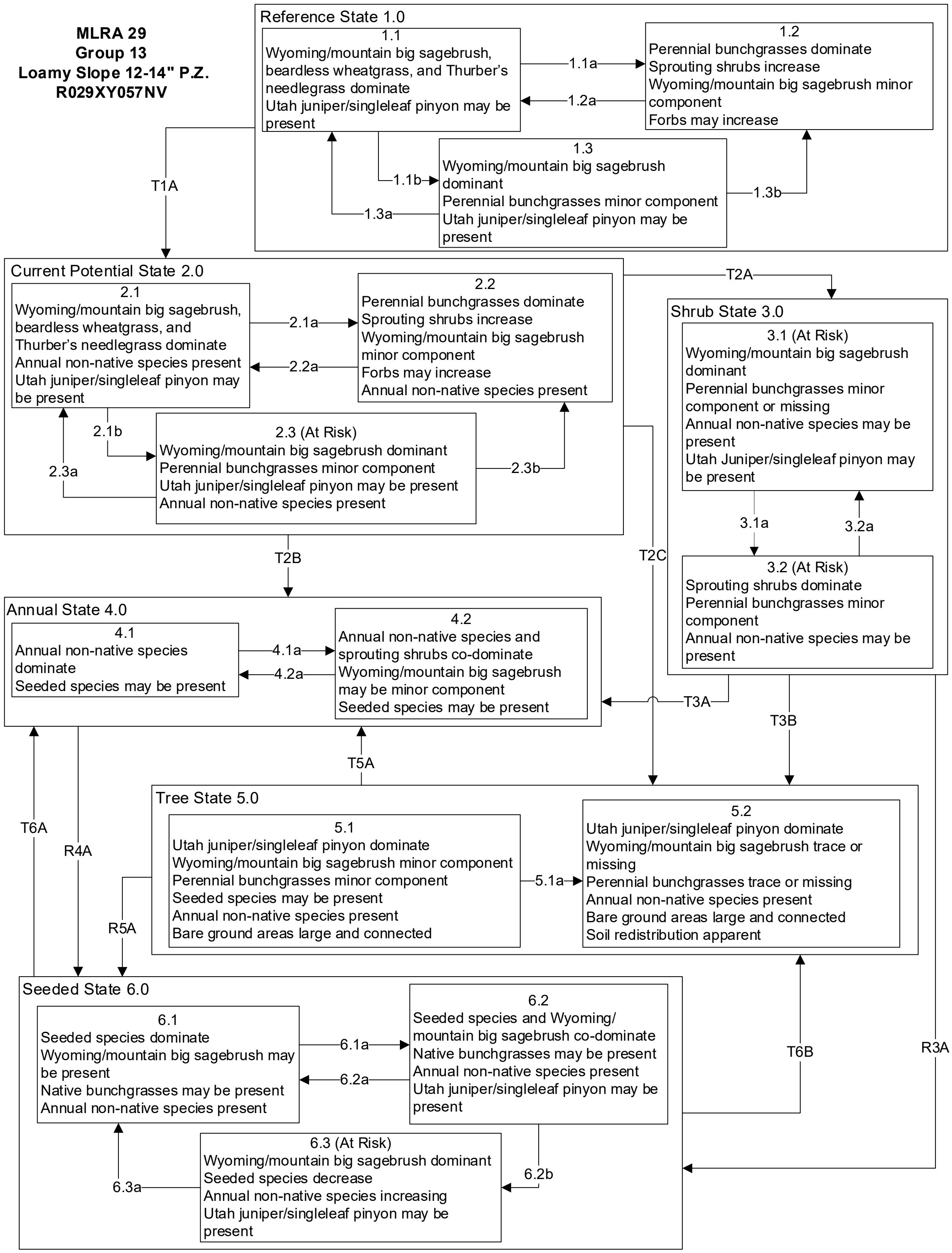
Tree State 5.0 Community Phase Pathways
5.1a: Time and lack of disturbance allows for tree maturation.

Restoration R5A: Tree removal and seeding of native and non-native species.

Transition T5A: Catastrophic fire, inappropriate tree removal practices (5.1).

Seeded State 6.0 Community Phase Pathways
6.1a: Time and lack of disturbance may be coupled with inappropriate grazing management.
6.2a: Low severity fire.
6.2b: Inappropriate grazing management reduces bunchgrasses and increases density of sagebrush; usually a slow transition.
6.3a: Fire or brush treatment with minimal soil disturbance.

Transition T6A: Catastrophic fire and/or inappropriate grazing management.
Transition T6B: Time and a lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management (5.1).



MLRA 29
Group 13
Loamy Slope 12-14" P.Z.
R029XY057NV
Reference State 1.0
1.1
Wyoming/mountain big sagebrush, beardless wheatgrass, and Thurber's needlegrass dominate
Utah juniper/singleleaf pinyon may be present
1.2
Perennial bunchgrasses dominate
Sprouting shrubs increase
Wyoming/mountain big sagebrush minor component
Forbs may increase
1.3
Wyoming/mountain big sagebrush dominant
Perennial bunchgrasses minor component
Utah juniper/singleleaf pinyon may be present
1.1a
1.2a
1.1b
1.3a
1.3b
T1A
Current Potential State 2.0
2.1
Wyoming/mountain big sagebrush, beardless wheatgrass, and Thurber's needlegrass dominate
Annual non-native species present
Utah juniper/singleleaf pinyon may be present
2.2
Perennial bunchgrasses dominate
Sprouting shrubs increase
Wyoming/mountain big sagebrush minor component
Forbs may increase
Annual non-native species present
2.3 (At Risk)
Wyoming/mountain big sagebrush dominant
Perennial bunchgrasses minor component
Utah juniper/singleleaf pinyon may be present
Annual non-native species present
2.1a
2.2a
2.1b
2.3a
2.3b
T2A
Shrub State 3.0
3.1 (At Risk)
Wyoming/mountain big sagebrush dominant
Perennial bunchgrasses minor component or missing
Annual non-native species may be present
Utah Juniper/singleleaf pinyon may be present
3.2 (At Risk)
Sprouting shrubs dominate
Perennial bunchgrasses minor component
Annual non-native species may be present
3.1a
3.2a
T2B
T2C
Annual State 4.0
4.1
Annual non-native species dominate
Seeded species may be present
4.2
Annual non-native species and sprouting shrubs co-dominate
Wyoming/mountain big sagebrush may be minor component
Seeded species may be present
4.1a
4.2a
T3A
T3B
T5A
Tree State 5.0
5.1
Utah juniper/singleleaf pinyon dominate
Wyoming/mountain big sagebrush minor component
Perennial bunchgrasses minor component
Seeded species may be present
Annual non-native species present
Bare ground areas large and connected
5.2
Utah juniper/singleleaf pinyon dominate
Wyoming/mountain big sagebrush trace or missing
Perennial bunchgrasses trace or missing
Annual non-native species present
Bare ground areas large and connected
Soil redistribution apparent
5.1a
T6A
R4A
R5A
Seeded State 6.0
6.1
Seeded species dominate
Wyoming/mountain big sagebrush may be present
Native bunchgrasses may be present
Annual non-native species present
6.2
Seeded species and Wyoming/mountain big sagebrush co-dominate
Native bunchgrasses may be present
Annual non-native species present
Utah juniper/singleleaf pinyon may be present
6.3 (At Risk)
Wyoming/mountain big sagebrush dominant
Seeded species decrease
Annual non-native species increasing
Utah juniper/singleleaf pinyon may be present
6.1a
6.2a
6.2b
6.3a
T6B
R3A

MLRA 29
Group 13
Loamy Slope 12-14" P.Z.
R029XY057NV

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire and/or Aroga moth creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community, dominated by sprouting shrubs, grasses and forbs.
1.1b: Time and lack of disturbance such as fire or drought. Excessive herbivory may also decrease perennial grasses.
1.2a: Time and lack of disturbance allows for shrub regeneration.
1.3a: Low severity fire and/or Aroga moth infestation resulting in a mosaic pattern.
1.3b: High severity fire significantly reduces sagebrush cover leading to early/mid-seral community dominated by sprouting shrubs, grasses and forbs.

Transition T1A: Introduction of non-native species such as cheatgrass and mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire and/or Aroga moth creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community dominated by sprouting shrubs, grasses and forbs; non-native annual species present.
2.1b: Time and lack of disturbance such as fire or drought. Inappropriate grazing management may also reduce perennial grasses.
2.2a: Time and lack of disturbance allows for regeneration of sagebrush.
2.3a: Low severity fire and/or Aroga moth infestation creates sagebrush/grass mosaic. Brush management with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire significantly reduces sagebrush cover leading to early mid-seral community.

Transition T2A: Time and lack of disturbance and/or inappropriate grazing management (3.1).
Transition T2B: High severity fire and/or soil disturbance (4.1). Inappropriate grazing that favors shrubs in the presence of non-native annual species (4.2).
Transition T2C: Time and lack of disturbance allows for an increase in tree cover; inappropriate grazing management and/or chronic drought can reduce fine fuels and lead to increased tree establishment and dominance (5.1).

Shrub State 3.0 Community Phase Pathways
3.1a: Fire or brush treatments (i.e. mowing) with minimal soil disturbance.
3.2a: Time and lack of fire allows some shrubs to reestablish.

Transition T3A: Catastrophic fire and/or soil disturbance (4.1). Inappropriate grazing management in the presence of non-native annual species (4.2).
Transition T3B: Time and a lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management (5.1).

Restoration R3A: Brush management with minimal soil disturbance, coupled with seeding of desired species. Probability of success is moderate (6.1).

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of fire.
4.2a: Fire.

Restoration R4A: Seeding of desired species; may be coupled with herbicide; probability of success is moderate (6.1).

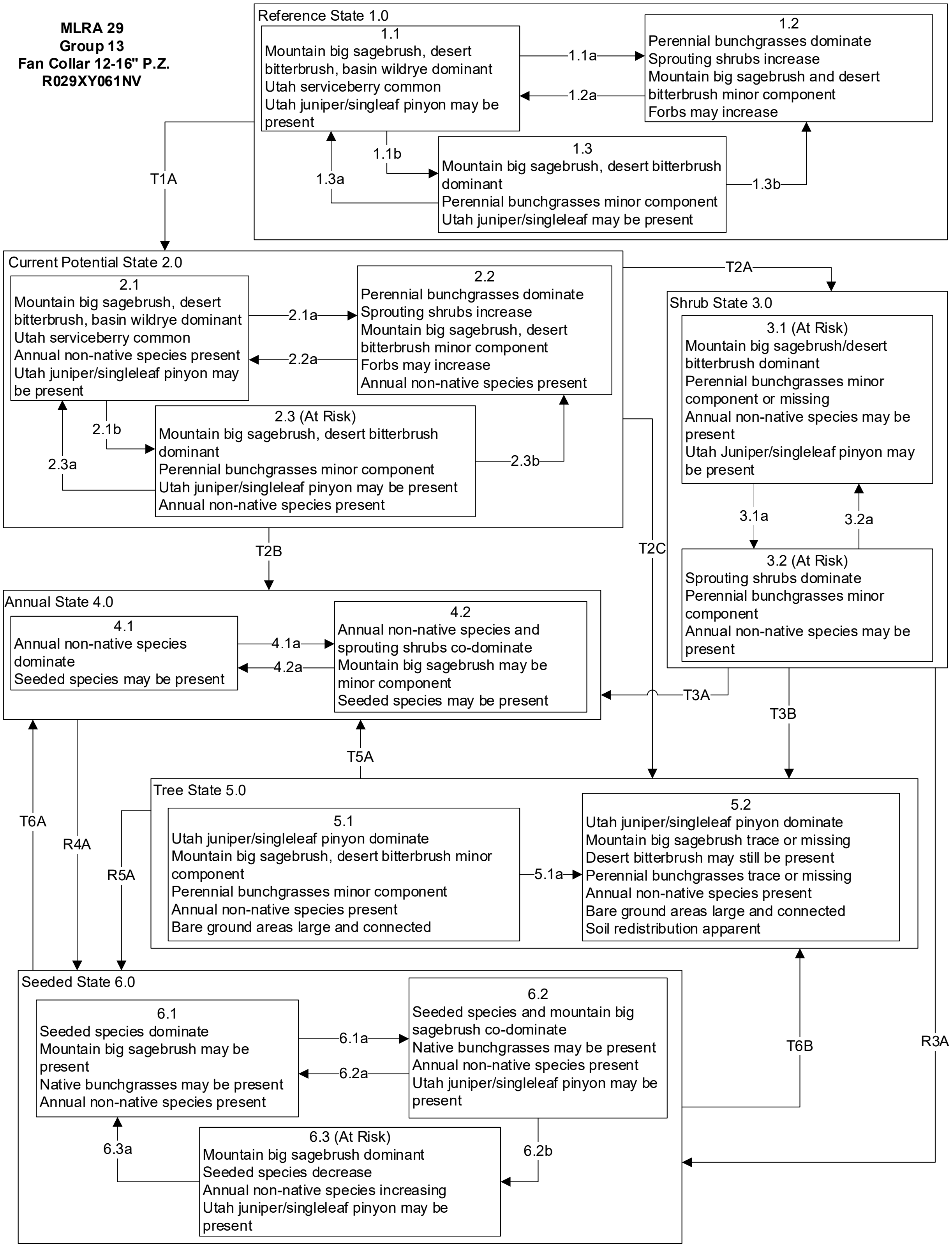
Tree State 5.0 Community Phase Pathways
5.1a: Time and lack of disturbance allows for tree maturation.

Restoration R5A: Tree removal and seeding of native and non-native species.

Transition T5A: Catastrophic fire, inappropriate tree removal practices (5.1).

Seeded State 6.0 Community Phase Pathways
6.1a: Time and lack of disturbance may be coupled with inappropriate grazing management.
6.2a: Low severity fire.
6.2b: Inappropriate grazing management reduces bunchgrasses and increases density of sagebrush; usually a slow transition.
6.3a: Fire or brush treatment with minimal soil disturbance.

Transition T6A: Catastrophic fire and/or inappropriate grazing management.
Transition T6B: Time and a lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management (5.1).


MLRA 29
Group 13
Fan Collar 12-16" P.Z.
R029XY061NV
Reference State 1.0
1.1
Mountain big sagebrush, desert bitterbrush, basin wildrye dominant
Utah serviceberry common
Utah juniper/singleaf pinyon may be present
1.2
Perennial bunchgrasses dominate
Sprouting shrubs increase
Mountain big sagebrush and desert bitterbrush minor component
Forbs may increase
1.3
Mountain big sagebrush, desert bitterbrush dominant
Perennial bunchgrasses minor component
Utah juniper/singleleaf may be present
1.1a
1.2a
1.1b
1.3a
1.3b
T1A
Current Potential State 2.0
2.1
Mountain big sagebrush, desert bitterbrush, basin wildrye dominant
Utah serviceberry common
Annual non-native species present
Utah juniper/singleleaf pinyon may be present
2.2
Perennial bunchgrasses dominate
Sprouting shrubs increase
Mountain big sagebrush, desert bitterbrush minor component
Forbs may increase
Annual non-native species present
2.3 (At Risk)
Mountain big sagebrush, desert bitterbrush dominant
Perennial bunchgrasses minor component
Utah juniper/singleleaf pinyon may be present
Annual non-native species present
2.1a
2.2a
2.1b
2.3a
2.3b
T2A
T2B
T2C
Shrub State 3.0
3.1 (At Risk)
Mountain big sagebrush/desert bitterbrush dominant
Perennial bunchgrasses minor component or missing
Annual non-native species may be present
Utah Juniper/singleleaf pinyon may be present
3.2 (At Risk)
Sprouting shrubs dominate
Perennial bunchgrasses minor component
Annual non-native species may be present
3.1a
3.2a
T3A
T3B
R3A
Annual State 4.0
4.1
Annual non-native species dominate
Seeded species may be present
4.2
Annual non-native species and sprouting shrubs co-dominate
Mountain big sagebrush may be minor component
Seeded species may be present
4.1a
4.2a
T5A
T6A
R4A
R5A
Tree State 5.0
5.1
Utah juniper/singleleaf pinyon dominate
Mountain big sagebrush, desert bitterbrush minor component
Perennial bunchgrasses minor component
Annual non-native species present
Bare ground areas large and connected
5.2
Utah juniper/singleleaf pinyon dominate
Mountain big sagebrush trace or missing
Desert bitterbrush may still be present
Perennial bunchgrasses trace or missing
Annual non-native species present
Bare ground areas large and connected
Soil redistribution apparent
5.1a
Seeded State 6.0
6.1
Seeded species dominate
Mountain big sagebrush may be present
Native bunchgrasses may be present
Annual non-native species present
6.2
Seeded species and mountain big sagebrush co-dominate
Native bunchgrasses may be present
Annual non-native species present
Utah juniper/singleleaf pinyon may be present
6.3 (At Risk)
Mountain big sagebrush dominant
Seeded species decrease
Annual non-native species increasing
Utah juniper/singleleaf pinyon may be present
6.1a
6.2a
6.2b
6.3a
T6B

MLRA 29
Group 13
Fan Collar 12-16" P.Z.
R029XY061NV

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire and/or Aroga moth infestation creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community, dominated by grasses and forbs.
1.1b: Time and lack of disturbance such as fire or drought. Excessive herbivory may also decrease perennial bunchgrasses.
1.2a: Time and lack of disturbance allows for shrub regeneration.
1.3a: Low severity fire or Aroga moth infestation resulting in a mosaic pattern.
1.3b: High severity fire significantly reduces sagebrush cover leading to early/mid-seral community.

Transition T1A: Introduction of non-native species such as cheatgrass and annual forbs.

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire and/or Aroga moth infestation creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community dominated by grasses and forbs; non-native annual species present.
2.1b: Time and lack of disturbance such as fire or drought. Inappropriate grazing management may also reduce perennial bunchgrasses.
2.2a: Time and lack of disturbance allows for regeneration of sagebrush.
2.3a: Low severity fire and/or Aroga moth infestation creates sagebrush/grass mosaic. Brush management with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire significantly reduces sagebrush cover leading to early mid-seral community.

Transition T2A: Time and lack of disturbance and/or inappropriate grazing management (3.1).
Transition T2B: High severity fire and/or soil disturbance (4.1). Inappropriate grazing that favors shrubs in the presence of non-native annual species (4.2).
Transition T2C: Time and lack of disturbance allows for an increase in tree cover; inappropriate grazing management and/or chronic drought can reduce fine fuels and lead to increased tree establishment and dominance (5.1).

Shrub State 3.0 Community Phase Pathways
3.1a: Fire or brush treatments (i.e. mowing) with minimal soil disturbance.
3.2a: Time and lack of fire allows some shrubs to reestablish.

Transition T3A: Catastrophic fire and/or soil disturbance (4.1). Inappropriate grazing management in the presence of non-native annual species (4.2).
Transition T3B: Time and a lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management (5.1).

Restoration R3A: Brush management with minimal soil disturbance, coupled with seeding of desired species. Probability of success high (6.1).

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of fire.
4.2a: Fire.

Restoration R4A: Seeding of desired species; may be coupled with herbicide; probability of success high (6.1).

Tree State 5.0 Community Phase Pathways
5.1a: Time and lack of disturbance allows for tree maturation.

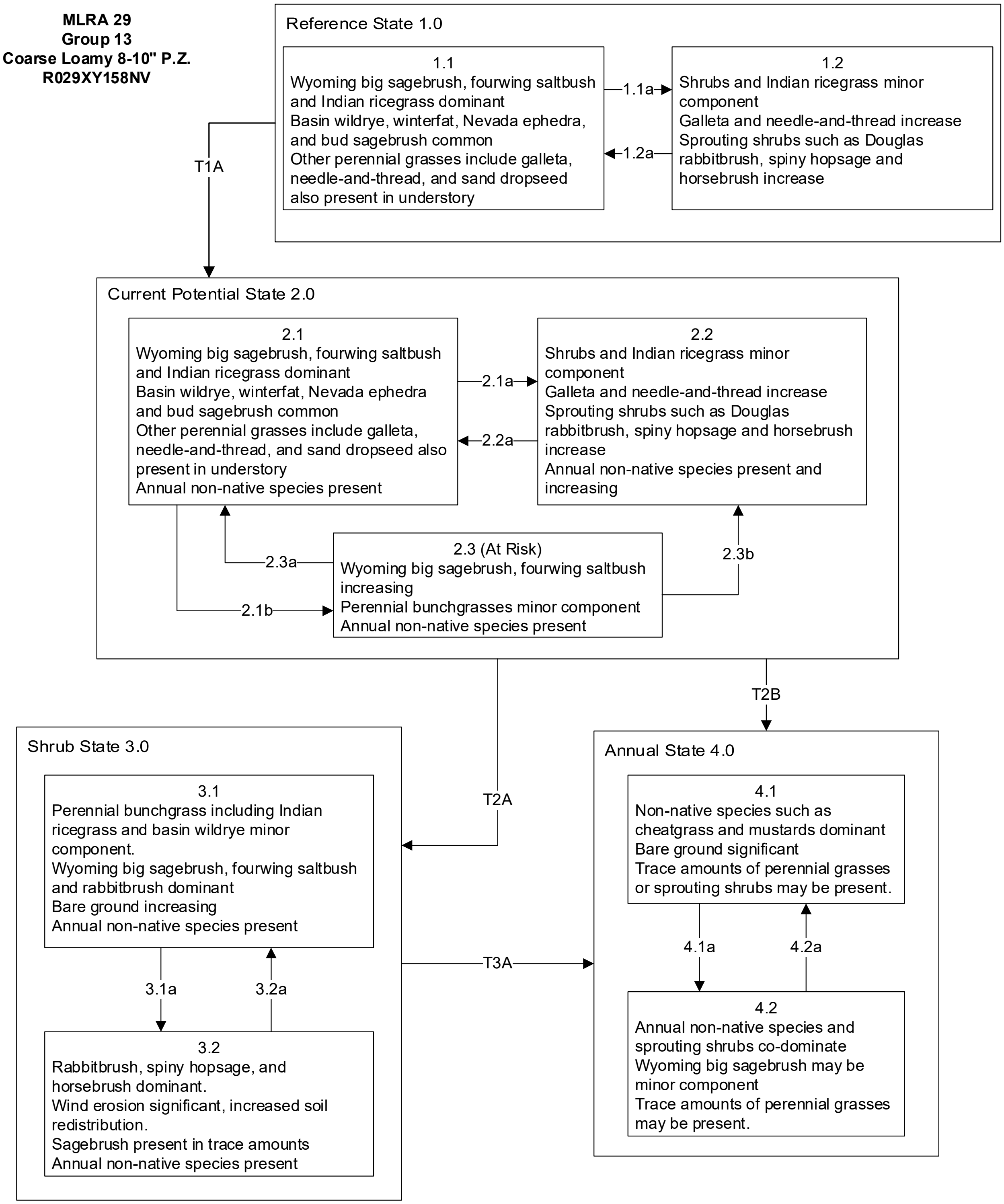
Transition T5A: Catastrophic fire, inappropriate tree removal practices (5.1).

Restoration R5A: Tree removal and seeding of native and non-native species.

Seeded State 6.0 Community Phase Pathways
6.1a: Time and lack of disturbance may be coupled with inappropriate grazing management.
6.2a: Low severity fire.
6.2b: Inappropriate grazing management reduces bunchgrasses and increases density of sagebrush; usually a slow transition.
6.3a: Fire or brush treatment with minimal soil disturbance.

Transition T6A: Catastrophic fire and/or inappropriate grazing management.
Transition T6B: Time and a lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management (5.1).

MLRA 29
Group 13
Coarse Loamy 8-10" P.Z.
R029XY158NV



MLRA 29
Group 13
Coarse Loamy 8-10" P.Z.
R029XY158NV

Reference State 1.0 Community Phase Pathways
1.1a: Long term drought, Aroga moth infestation of big sagebrush, time and/or herbivory favors increase of saltbush over deep-rooted perennial grasses. Herbivory impact may also increase galleta grass.
1.2a: Time, lack of disturbance allows Wyoming big sagebrush, winterfat, and Indian ricegrass to recover.

Transition T1A: Introduction of non-native annual weeds such as cheatgrass or mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Inappropriate early season grazing management reduces Indian ricegrass and basin wildrye. Above average precipitation or prolonged drought reduces the shrub coverage, allowing perennial grasses and episodic forbs increase.
2.1b: Inappropriate early season grazing management reduces deep-rooted perennial bunchgrasses in interspaces, allows dominance of shrubs to increase in density.
2.2a: Time, lack of disturbance allows Wyoming big sagebrush, fourwing saltbush, winterfat and Indian ricegrass to recover. Over time deeper-rooted shrubs and grasses will outcompete their shallower-rooted counterparts.
2.3a: Low severity fire, and improper grazing management that reduces saltbush and winterfat. Perennial bunchgrasses or galleta grass increase.
2.3b: Severe fire fueled by dead shrub fuels from severe drought decreases or eliminates saltbush . Perennial bunchgrasses dominate the site.

Transition T2A: Long-term inappropriate grazing management and/or long term drought (to 3.1). Fire would cause transition to Community Phase 3.2.

Transition T2B: Catastrophic fire. Long-term inappropriate grazing management (to 4.1).

Shrub State 3.0 Community Phase Pathways
3.1a: Fire, Aroga moth infestation, and/or inappropriate grazing management decreases or eliminates the overstory of Wyoming big sagebrush, fourwing saltbush and winterfat.
3.2a: Time, lack of disturbance allows for regeneration of Wyoming big sagebrush.

Transition T3A: Severe fire and/or inappropriate grazing management with higher than normal spring precipitation (to 4.1).

Transition T4A: Long-term, inappropriate grazing management, severe drought, and/or soil disturbing treatments, combined with significant soil loss and redistribution

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of fire
4.2a: Fire

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MLRA 29 Group 14: Loamy soils with mountain big sagebrush and needlegrasses

Description of MLRA 29 Disturbance Response Group 14

Disturbance Response Group (DRG) 14 consists of three ecological sites within Major Land Resource Area 29. These sites range in precipitation from 12 to over 20 in. The elevation range of this group is 6,000 to 11,000 ft. Slopes range from 2 to 75%, but slope gradients of 15 to 50% are typical. Annual production for a normal year ranges from 600 to 1,500 lb/ac. The reference plant communities are dominated by mountain big sagebrush *(Artemisia tridentata* ssp. *vaseyana)*, snowberry (*Symphoricarpos oreophilus*), Utah serviceberry (*Amelanchier utahensis*), Letterman's needlegrass, (*Achnatherum lettermanii*), mountain brome (*Bromus marginatus*), and muttongrass *(Poa fendleriana)*. The soils of these sites range from deep to very deep, have a mollic epipedon, and are formed from residuum and colluvium derived from mixed rock sources. Subsoils are moderately coarse- to moderately fine-textured and may be slightly acidic. These soils have high amounts of rock fragments on the surface and throughout the profile. The soil temperature regime is cryic to frigid, seldom mesic. The soil moisture regime is xeric.

Disturbance Response Group 14 Ecological Sites:

Loamy Slope 16+" P.Z. – Modal	R029XY051NV
Loamy 16+" P.Z.	R029XY050NV
Mountain Slope 12-14" P.Z.	R029XY138NV

Modal Site:

The Loamy Slope 16+" P.Z. (R029XY051NV) ecological site is the modal site that represents this DRG, as it has the most acres mapped. This site occurs on straight to convex mountain sideslopes on all exposures. It is restricted to northerly aspects at the lower elevations of its occurrence. Slopes range from 8 to 75%, but slope gradients of 15 to 50% are typical. Elevation ranges from 8,000 to about 9,500 ft. The soils are moderately deep to deep and well drained. These soils are loamy to loamy-skeletal. The available water holding capacity is moderate. This site provides a cool, moist environment for plant growth because of the elevations and precipitation zone at which it occurs. The soil moisture regime is xeric and the soil temperature regime is cryic to frigid, rarely mesic. Runoff is medium to rapid and the potential for sheet and rill erosion is moderate. The reference plant community is dominated by mountain big sagebrush, Letterman's needlegrass and muttongrass. Average production for a normal year is about 1,100 lb/ac with a vegetative composition of approximately 50% grasses, 35% shrubs, and 15% forbs.

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasives. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans a unique area in Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area. Flashy, summer storm events contribute significantly to annual precipitation as well. Air and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

Periodic drought regularly influences sagebrush ecosystems, with drought duration and severity increasing throughout the 20th century in much of the Intermountain West (Miller et al. 2008b). Major shifts from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006).

Thus, the sagebrush communities that dominate this DRG have high spatial and temporal variability in precipitation, both over years and within growing seasons. Nutrient availability is typically low but increases with elevation and closely follows moisture availability. The resource supporting the greatest amount of plant growth is usually water stored in the soil profile during the winter.

Native insect outbreaks are also important drivers of ecosystem dynamics in sagebrush communities. Climate is generally believed to influence the timing of insect outbreaks, especially the Aroga moth (*Aroga websteri*), a sagebrush defoliator. Aroga moth infestations occurred in the Great Basin in the 1960s and early 1970s, and have been ongoing in Nevada since 2004 (Bentz et al. 2008). Thousands of acres of big sagebrush have been impacted, with partial to complete die-off observed. Aroga moths can partially or entirely kill individual plants or entire stands of big sagebrush (Furniss and Barr 1975), however, stand level impacts occur primarily in Wyoming sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) dominated areas.

The ecological sites in this DRG are dominated by deep-rooted, cool-season perennial bunchgrasses and long-lived shrubs (50+ years) with high root-to-shoot ratios. The perennial bunchgrasses generally have somewhat shallower root systems than the shrubs, but root densities are higher than those of shrubs in the upper 0.5 m (20 in.) of soil (Comstock and Ehleringer 1992). General differences in root depth distributions between grasses and shrubs result in resource partitioning in these shrub/grass systems.

Mountain big sagebrush, the dominant shrub of this group, is generally long-lived; therefore, it is not necessary for new individuals to recruit every year for perpetuation of the stand. Infrequent large recruitment events and simultaneous low, continuous recruitment is the foundation of population maintenance (Noy-Meir 1973). Survival of the seedlings is dependent on adequate moisture conditions. Sagebrush has a flexible generalized root system with development of both deep taproots and laterals near the surface (Dobrowolski et al. 1990). In general, these shrubs root to the full depth of the winter-spring soil moisture recharge, which ranges from 1 to over 3 m (3 to 9 ft). (Comstock and Ehleringer 1992). Root length of mature sagebrush plants was measured to a depth of 2 m (6.5 ft) in alluvial soils in Utah (Richards and Caldwell 1987).

Mountain snowberry is an erect, deciduous shrub growing to heights of 20 to 60 in. (Tisdale and Hironaka 1981). Snowberry reproduces by rhizomes, layering, and by seed. Mountain snowberry is a weak sprouter following fire (Wright et al. 1979). This plant provides habitat for wildlife, including deer, small mammals and birds (Dittberner and Olson 1983).

Utah serviceberry is a large, fire-tolerant shrub that is a subdominant vegetative component of this DRG. This plant has is accustomed to rocky slopes, canyons, and stream banks at elevations up to 9,000 ft or more. It has a deep spreading root system and is found in areas with 12 to 20 in. of annual precipitation. Utah serviceberry provides good habitat for wildlife and the berries are consumed by birds and small mammals (Noller 2008).

Letterman's needlegrass, the most common needlegrass in this DRG, is a fine-stemmed, cool-season bunchgrass that reaches 12 to 24 in. tall. It forms large clumps and is found on dry soils in a variety of vegetation communities, including high elevation meadows, subalpine grasslands, open areas underneath aspen, and in sagebrush communities (Tisdale and Hironaka 1981). This densely tufted species is more drought tolerant than Columbia needlegrass (*Achnatherum nelsonii*) and western needlegrass (*Achnatherum occidentale*), and it is able to grow in a variety of soil qualities and textures (Banner et al. 2011).

Muttongrass is a tufted, multi-flowered, cool-season perennial bunchgrass that can grow between 8 and 30 in. tall and has narrow leaves, which range from 1 to 3 mm wide (Stubbendieck et al. 2017). Muttongrass is one of the most drought-tolerant bluegrasses and is useful for restoring communities disturbed by fire, grazing, or mining, but is limited in its use due to low seed viability (Forsling and Dayton 1931). Muttongrass are most frequently pistillate, but staminate plants do occasionally occur, which are able to hybridize and crossbreed with other bluegrasses. Muttongrass is found throughout the western United States as a primary component of the understory of pinyon-juniper communities and aspen/pine forests, indicating a high tolerance for shade (Tilley et al. 2007).

Mountain brome is a short-lived, pioneer, cool-season perennial bunchgrass, found in relatively moist habitats in mountain big sagebrush communities, where annual precipitation is equal to or greater than 16 in. The grass is typically 20 to 40 in. tall, sometimes up to 60 in. Leaves are flat and broad, mostly soft hairy, but can be glabrous of scabrous (Tilley et al. 2006b)

Spike fescue (*Leucopoa kingii*) is a native, deep-rooted, cool-season perennial bunchgrass that grows between 30 and 90 cm (12 to 35 in.) tall in dense, erect tufts up to 2 m (6.5 ft) wide (Vallentine 1961, Cronquist et al. 1977). This grass is most often found in high elevations on rocky slopes and on moderately deep, well drained, loamy soils (Houston et al. 2001). Spike fescue is dioecious and male plants are more commonly found on more mesic soils, while female plants prefer more xeric soils (Fox and Harrison 1981). It primarily spreads its seeds through the wind, but can also regenerate through rhizomes, allowing it to quickly recover after fire (Bradley et al. 1992, Houston et al. 2001).

Infilling and expansion by singleleaf pinyon and Utah juniper has been occurring since the late 1800s due to changes in climate, grazing and fire (Miller et al. 2019). Without disturbance, singleleaf pinyon and Utah juniper will dominate the site and out-compete other species for resources severely reducing both the shrub and herbaceous understory (Lett and Knapp 2005, Miller et al. 2019). However, bluegrasses may remain underneath trees on north-facing slopes. The potential for soil erosion increases as tree cover increases and the understory plant community cover declines (Pierson et al. 2010).

The ecological sites in this DRG have moderate to high resilience to disturbance and resistance to invasion. Resilience increases with elevation, aspect, precipitation, and nutrient availability. Long-term disturbance response may be influenced by small differences in landscape topography. Concave areas receive run-in from adjacent landscapes and consequently retain more moisture to support the growth of deep-rooted perennial grasses (i.e. Letterman’s needlegrass) whereas convex areas where runoff occurs are slightly less resilient and may support more shallow-rooted perennial grasses (i.e. muttongrass). North slopes are also more resilient than south slopes because lower soil surface temperatures operate to keep moisture content higher on northern exposures. Three possible stable states have been identified for this DRG.

Annual Invasive Species:

The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and depressed competition or can increase resource pools by the decomposition of dead plant material following disturbance. The invasion of sagebrush communities by cheatgrass (*Bromus tectorum*) has been linked to disturbances (fire, abusive grazing) that have resulted in fluctuations in resources (Chambers et al. 2007). The introduction of annual weedy species, like cheatgrass, may cause an increase in fire frequency. Conversely, as fire frequency decreases, sagebrush will increase, trees may invade and perennial bunchgrasses and forbs may be reduced. However, the ecological sites in this DRG are highly resilient and resistant to invasive annual grasses primarily due to receiving greater than 16 in. of annual precipitation.

Fire Ecology:

Fire is believed to be the dominant, natural disturbance in big sagebrush communities. Several authors suggest pre-settlement fire return intervals in mountain big sagebrush communities varied from 15 to 25 years (Burkhardt and Tisdale 1969, Houston 1973, Miller et al. 2000, Miller and Tausch 2001). Kitchen and McArthur (2007) suggest a mean fire return interval of 40 to 80 years for mountain big sagebrush communities. The range from 15 to 80 years likely reflects the differences in elevation and precipitation where mountain big sagebrush communities occur. On a landscape scale, multiple seral stages were represented in a mosaic reflecting periodic reoccurrence of fire and other disturbances. Post-fire hydrologic recovery and resilience is primarily influenced by pre-fire site conditions, fire severity, and post-fire weather and land use that relate to vegetation recovery. Fire adaptation by herbaceous species is generally superior to sagebrush, which is typically killed by fire (Akinsoji 1988). Sites with low abundances of native perennial grasses and forbs typically have reduced resiliency following disturbance and are less resistant to invasion or increases in cheatgrass and mustards (Miller et al. 2013).

Mountain big sagebrush is killed by fire (Neuenschwander 1980, Blaisdell et al. 1982) and does not resprout (Blaisdell 1953). Post-fire regeneration occurs from seed and will vary depending on site characteristics, seed source, and fire characteristics. Mountain big sagebrush seedlings can grow rapidly and may reach reproductive maturity within 3 to 5 years. Mountain big sagebrush may return to pre-burn density and cover within 15 to 20 years following fire, but establishment after severe fires may proceed more slowly (Bunting et al. 1987).

Depending on fire severity, snowberry and rabbitbrush may increase after fire. Douglas' rabbitbrush (*Chrysothamnus viscidiflorus*), a minor component in this DRG, is top-killed by fire, but sprouts vigorously after fire (Kuntz 1982, Akinsoji 1988). Snowberry is also top-killed by fire, but sprouts after fire from rhizomes (Leege and Hickey 1971, Noste and Bushey 1987). Snowberry has been noted to regenerate well and exceed pre-burn biomass in the third season after a fire (Merrill et al. 1982).

Utah serviceberry is top-killed by fire, but sprouts from the underground root crown after disturbance (Bradley 1984). This plant is drought tolerant, exhibiting greater tolerance to dehydration than western serviceberry (*A. alnifoli*a), a trait that should enhance the potential for crown sprouting following summer fire (Bradley 1984). Utah serviceberry can also re-colonize an area after fire via seeds, but this can require up to 8 to 10 years for plants to be fully matured and productive (Noller 2008).

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The initial condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species' response. For most forbs and grasses, the growing points are located at or below the soil surface providing relative protection from disturbances that decrease above-ground biomass, such as grazing or fire. Thus, fire mortality is more correlated to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant, and abundance of old growth (Wright 1971, Young 1983).

Most bunchgrasses are harmed by fire, and fire typically causes a decrease in reproduction, density, and cover in bunchgrasses (Ellsworth and Kauffman 2010). Needlegrasses are slightly to moderately damaged by fire depending on season of burn (Wright and Klemmedson 1965). Letterman’s needlegrass is most susceptible to fire when burned during mid-summer (Banner et al. 2011), but recovers well after fire (Monsen et al. 2004b).

Muttongrass is top killed by fire but will regrow after low to moderate severity fires (Monsen et al. 2004a). Research by Vose and White (1991) found minimal difference in density and number of plants following fall fire in muttongrass communities. However, high severity fire has been shown to kill muttongrass with little to no recovery (Erdman 1970).

Mountain brome has fair tolerance to fire, and is often seeded after wildfire for erosion control. The species germinates and establishes quickly when seeded making it a good choice for recovery of fire impacted, high elevation ranges (Tilley et al. 2006a).

Spike fescue is a broad-leaf grass and is relatively tolerant of fire and is generally known to increase after fire (Cook et al. 1994). It will reestablish by windblown seed from off-site seed sources (Bradley et al. 1992).

Utah juniper and singleleaf pinyon occur in minor amounts on these ecological sites. Mortality in burned stands is a function of fire weather, fuel structure, and crown continuity (Miller et al. 2019). Both species are most vulnerable to fire when under 4 ft tall, however, mortality of trees over 6 ft tall is unlikely except under extreme fire weather conditions or when sufficient ladder fuels are present (Dwyer and Pieper 1967, Wright et al. 1979, Bradley et al. 1992, Miller et al. 2013). Larger trees, because they have foliage farther from the ground and thicker bark, can survive low severity fires, however, mortality typically occurs when 60% or more of the crown is scorched (Bradley et al. 1992). Singleleaf pinyon mature trees do not self-prune their dead branches allowing for accumulated fuel in the crowns. This characteristic and the relative flammability of the foliage make individual mature trees more susceptible to fire than juniper (Bradley et al. 1992). However, high severity fires were not likely in this community in its reference condition due to low production of understory vegetation and low density of trees per acre.

Livestock/Wildlife Grazing Interpretations:

Despite low palatability, mountain big sagebrush is eaten by sheep, cattle, goats, and horses (Welch 2005). Chemical analysis indicates that the leaves of big sagebrush equal alfalfa meal *(Medicago sativa)* in protein, have a higher carbohydrate content, and yield twelvefold more fat (USFS 1937). Many wildlife species are dependent on the sagebrush ecosystem including the greater sage grouse *(Centrocercus urophasianus)*, sage sparrow (*Artemisiospiza nevadensis*), pygmy rabbit *(Brachylagus idahoensis)*, and the sagebrush vole *(Lemmiscus curtatus)*. Dobkin and Sauder (2004) identified 61 species, including 24 mammals and 37 birds, associated with the shrub-steppe habitats of the Intermountain West. There is evidence that wild ungulates utlize mountain big sagebrush as winter browse. Fecal samples from ungulates in Montana showed that bighorn sheep, mule deer, and elk all consumed mountain big sagebrush in small amounts in winter, while cattle had no sign of sagebrush use. In studies by Personius et al. (1987) and Sheehy and Winward (1981), mountain big sagebrush was one of the most preferred taxon by mule deer.

Mountain big sagebrush sites provide nesting, brood-rearing, and fall and winter habitat for sage grouse. Sage grouse require sagebrush for food and cover during each stage of their life cycle. The abundance and diversity of perennial forbs and grasses provides important food for hens during the pre-laying period and comprise more than half of the juvenile diet until the broods are approximately 3 months old (McAdoo and Back 2001). Sage grouse require a dynamic sagebrush habitat, and make use of multiple seral stages following different disturbances throughout the year. For example, they use recently burned or grazed areas for brood-rearing and foraging, while mature sagebrush stands in late seral stages provided cover and nesting habitat. (Crawford et al. 2004). The increase of singleleaf pinyon and Utah juniper trees in sagebrush ecosystems is threatening sage grouse. Pinyon-juniper expansion brings a higher number of predators into an area and reduces the amount of suitable sagebrush habitat, and there is a direct link between pinyon-juniper cover and its negative effect on sage grouse distribution (Coates et al. 2016).

Mountain snowberry, a sub-dominant shrub on these sites, provides fair forage for deer, elk and sheep, however it rates as poor forage for cattle (Sampson and Jespersen 1963) and is considered worthless for horses (Dayton 1931). Although not highly nutritious or palatable, mountain snowberry is frequently one of the first species to leaf out, making it a highly sought after food in the early spring. Plants withstand browsing well and produce numerous basal sprouts following use (Costello 1944).

Utah serviceberry, also a sub-dominant in this group, is highly palatable to wildlife and is readily consumed by sheep and cattle (Blauer et al. 1976). Light grazing stimulates growth, and full vigor can be maintained under a use of 60% or less in fall or winter.

Letterman's needlegrass provides valuable forage for both livestock and wildlife (Parker 1975). It begins growth early in the year and is available to be utilized when other grasses are not yet palatable (Ellison 1954), and is especially important fall forage for big game (Monsen et al. 2004a). Letterman's needlegrass has been shown to increase under long-term grazing by sheep and there is some evidence that it decreases under light grazing by cattle and horses (Ellison 1954, Bowns and Bagley 1986). It also declines when grazing is excluded for a long time (Turner 1969). While Letterman's needlegrass provides forage for both livestock and wildlife, it is only rated as fair for cattle and poor for sheep (USFS 1937).

Muttongrass is very palatable for wildlife and livestock and is rated as excellent forage for cattle and horses, and good for sheep. Muttongrass starts growth in late winter or early spring and provides excellent early feed. Muttongrass foliage cures well and is good fall forage, but not as good as spring or summer (Humphrey et al. 1952).

Mountain brome is highly palatable in the spring, providing good forage for cattle, sheep, and horses. Big game, including deer, elk, and big horn sheep also graze the plant. The seeds are readily consumed by small mammals and birds. Grazing utilization of less than 50% is recommended (Tilley et al. 2006a).

Spike fescue is fairly palatable and nutritious for both livestock and wildlife in the spring, but becomes less palatable in summer as it matures (Hess and Alexander 1986, Houston et al. 2001). It is an important forage species for mule deer (Kufeld et al. 1973).

Overgrazing by cattle leads to a decline in understory plants like Letterman's needlegrass and an increase in mountain big sagebrush. Muttongrass may become dominant, typically located under shrub canopies. Annual weedy forbs and cheatgrass could occur however, an annual state is unlikely. A combination of overgrazing and prolonged drought may lead to soil redistribution, increased bare ground, and a loss in plant production.

State and Transition Model Narrative for Group 14:

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for MLRA 29 Disturbance Response Group 14.

Three possible states have been identified for this DRG including a Reference State, Current Potential State, and a Tree State.

Reference State 1.0:

The Reference State is representative of the natural range of variability under pristine conditions. The reference state has three general community phases: a grass-shrub dominant phase, a perennial grass dominant phase and a shrub-grass dominant phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire, periodic long-term drought and/or insect or disease attack.

Community Phase 1.1:
The reference plant community is dominated by mountain big sagebrush, Letterman's needlegrass and muttongrass. Other common species include mountain brome, spike fescue, mountain snowberry and Utah serviceberry. Utah juniper or singleleaf pinyon may be present in minor amounts. Potential vegetative composition by air-dry weight is approximately 50% grasses, 15% forbs and 35% shrubs. Approximate ground cover (basal and crown) is 25 to 35%. Total annual air-dry production ranges from 700 to 1,300 lb/ac.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
A low severity fire would decrease the sagebrush overstory and allow for understory perennial grasses to increase. Fires are typically low severity resulting in a mosaic pattern due to low fuel loads. A fire following an unusually wet spring, facilitating an increase in fine fuels, may be more severe and reduce sagebrush cover to trace amounts creating an early-seral community, dominated by perennial grasses and forbs.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.3:
Time and lack of disturbance such as fire allows sagebrush to increase and become decadent. Long-term drought, herbivory, or combinations of these will cause a decline in perennial bunchgrasses and fine fuels leading to a reduced fire frequency and allowing sagebrush to dominate the site.

Community Phase 1.2:
This community phase is characteristic of a post-disturbance, early seral community phase. Letterman's needlegrass, muttongrass, and other perennial grasses dominate. Snowberry, rabbitbrush, and Utah serviceberry may be sprouting. Sagebrush may be present in unburned patches. Forbs may increase post-fire but will likely return to pre-burn levels within a few years.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
Absence of disturbance over time allows mountain big sagebrush to increase.

Community Phase 1.3:

Mountain big sagebrush dominates the plant community in the absence of disturbance and deep-rooted perennial bunchgrasses in the understory are reduced. Utah juniper and/or singleleaf pinyon may be present.

Loamy Slope 16"+ P.Z. (R029XY051NV), Reference State 1.3, T. Stringham, June 2023

Community Phase Pathway 1.3a, from Phase 1.3 to 1.1:
A low severity fire, Aroga moth infestation or combinations of these will reduce the sagebrush overstory and create a sagebrush/grass mosaic.

Community Phase Pathway 1.3b, from Phase 1.3 to 1.2:
High severity fire will decrease or eliminate the overstory of sagebrush and allow for the perennial bunchgrasses to dominate the site. Fires will typically be high intensity due to the dominance of sagebrush resulting in removal of the overstory shrub community.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0

Trigger: Introduction of annual non-native species

Slow variable: Over time the annual non-native plants will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

T1B: Transition from Reference State 1.0 to Tree State 3.0

Trigger: Prolonged fire suppression, combined with periods of favorable recruitment conditions for pinyon and juniper, such as wet years followed by mild winters.

Feedbacks and ecological processes: As trees establish and mature, they increasingly intercept precipitation and outcompete herbaceous and shrub species for soil water and nutrients. Over time, this shift leads to decreased herbaceous production, reduced organic matter inputs, and disrupted nutrient cycling. Loss of fine fuels further reduces fire frequency, reinforcing tree dominance.

Slow variables: Gradual increase in tree cover and biomass over time; concurrent reduction in herbaceous cover, especially deep-rooted perennial grasses.

Threshold: Transition is considered crossed when tree canopy closure and resource competition are sufficient to suppress the regeneration of shrubs and perennial grasses. Evidence includes widespread sagebrush mortality, visible skeletons, and a significant decline in understory composition and function.

Current Potential State 2.0:

This state is similar to the Reference State 1.0 with similar community phases. Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of invasive weeds. This state has the same three general community phases. These non-natives can be highly flammable, and can promote fire where historically fire had been infrequent. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate and adaptations for seed dispersal.

Community Phase 2.1:
This community phase is compositionally similar to the Reference State Community Phase 1.1 with the presence of non-native species in trace amounts. Mountain big sagebrush is the major overstory shrub in this plant community, however, snowberry is also common. Letterman's needlegrass and muttongrass are the dominant understory species. Annual non-native species are present and Utah juniper and/or singleleaf pinyon may be present in minor amounts.

Loamy Slope 16+" P.Z. (R029XY051NV), Current Potential State 2.1, T. Stringham, June 2021

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
A low severity fire would decrease the sagebrush overstory and allow for understory perennial grasses to increase. Fires are typically low severity resulting in a mosaic pattern due to low fuel loads. A fire following an unusually wet spring, facilitating an increase in fine fuels, may be more severe and reduce sagebrush cover to trace amounts creating an early-seral community, dominated by perennial grasses and forbs

Community Phase Pathway 2.1b, from Phase 2.1 to 2.3:
Time and lack of disturbance such as fire allows sagebrush to increase and become decadent. Long-term drought, inappropriate grazing management, or combinations of these will cause a decline in perennial bunchgrasses and fine fuels leading to a reduced fire frequency and allowing sagebrush to dominate the site. Utah juniper and singleleaf pinyon may also increase in cover.

Community Phase 2.2:
This community phase is characteristic of a post-disturbance, early seral community phase. Letterman's needlegrass, muttongrass, and other perennial grasses dominate. Snowberry, rabbitbrush and bitterbrush (*Purshia tridentata*) may be sprouting. Sagebrush maybe present in unburned patches. Perennial forbs may increase post-fire but will likely return to pre-burn levels within a few years. Annual non-native species are stable to increasing.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Absence of disturbance over time allows mountain big sagebrush to increase.

Community Phase 2.3:
Mountain big sagebrush dominates the plant community in the absence of disturbance and deep-rooted perennial bunchgrasses in the understory are reduced. Snowberry,

rabbitbrush and other sprouting shrubs increase. Utah juniper and/or singleleaf pinyon may be present and annual non-natives are present.

Loamy 16+" P.Z. (R029XY051NV), Current Potential State 2.3, T. Stringham, June 2021

Community Phase Pathway 2.3a, from Phase 2.3 to 2.1:
A low severity fire, brush management with minimal soil disturbance, Aroga moth infestation or combinations will reduce the sagebrush overstory and create a sagebrush/grass mosaic. Late fall/winter grazing causing mechanical damage to sagebrush will also reduce sagebrush cover.

Community Phase Pathway 2.3b, from Phase 2.3 to 2.2:
Fire will decrease or eliminate the overstory of sagebrush and allow for the perennial bunchgrasses to dominate the site. Fires will typically be high intensity due to the dominance of sagebrush resulting in removal of the overstory shrub community. Annual non-native species respond well to fire and may increase post-burn.

T2A: Transition from Current Potential 2.0 to Tree State 3.0:

Trigger: Time and lack of disturbance or management action allows pinyon and juniper to dominate. This may be coupled with grazing management that favors tree establishment by reducing perennial grass production, reducing fine fuels, and lengthening the fire return interval.

Feedbacks and ecological processes: Trees increasingly dominate use of soil water, contributing to reductions in soil water availability to grasses and shrubs. Overtime, grasses and shrubs are outcompeted. Reduced herbaceous and shrub production slows soil organic matter inputs and increases soil erodibility through loss of cover and root structure. Fire return intervals are lengthened.

Slow variables: Over time the abundance and size of trees will increase.

Threshold: Trees dominate ecological processes and the number of shrub skeletons exceed the number of live shrubs.

Tree State 3.0:

This state is characterized by a dominance of singleleaf pinyon and/or Utah juniper in the overstory. This state occurs where sagebrush sites exist adjacent to forest ecological sites. Mountain big sagebrush and perennial bunchgrasses may still be present, but they are no longer controlling site resources. Skeletons of dead sagebrush plants are apparent. Soil moisture, soil nutrients, soil organic matter distribution and nutrient cycling have been spatially and temporally altered.

Community Phase 3.1:
Utah juniper and/or singleleaf pinyon dominate overstory. Mountain big sagebrush is decadent and dying and deep-rooted perennial bunchgrasses are decreasing. Recruitment of sagebrush is minimal. Annual non-natives may or may not be present while bare ground interspaces are large and connected.

Loamy Slope 16+" P.Z. (R029XY051NV), Tree State 3.1, T. Stringham, June 2021

Community Phase Pathway 3.1a, from phase 3.1 to 3.2:
Absence of disturbance over time allows for tree cover and density to further increase and out-compete the herbaceous understory species for sunlight, nutrients and soil moisture.

Community Phase 3.2:
Utah juniper and/or singleleaf pinyon trees dominate overstory. Mountain big sagebrush is decadent and dying with numerous skeletons present or sagebrush may be

missing from the system. Needlegrass's present in trace amounts or missing entirely. Muttongrass is dominant in the understory and primarily occurs under tree canopies. Bare ground interspaces are large and connected. Soil redistribution is evident.

Potential Resilience Differences with Other Ecological Sites in this Group:

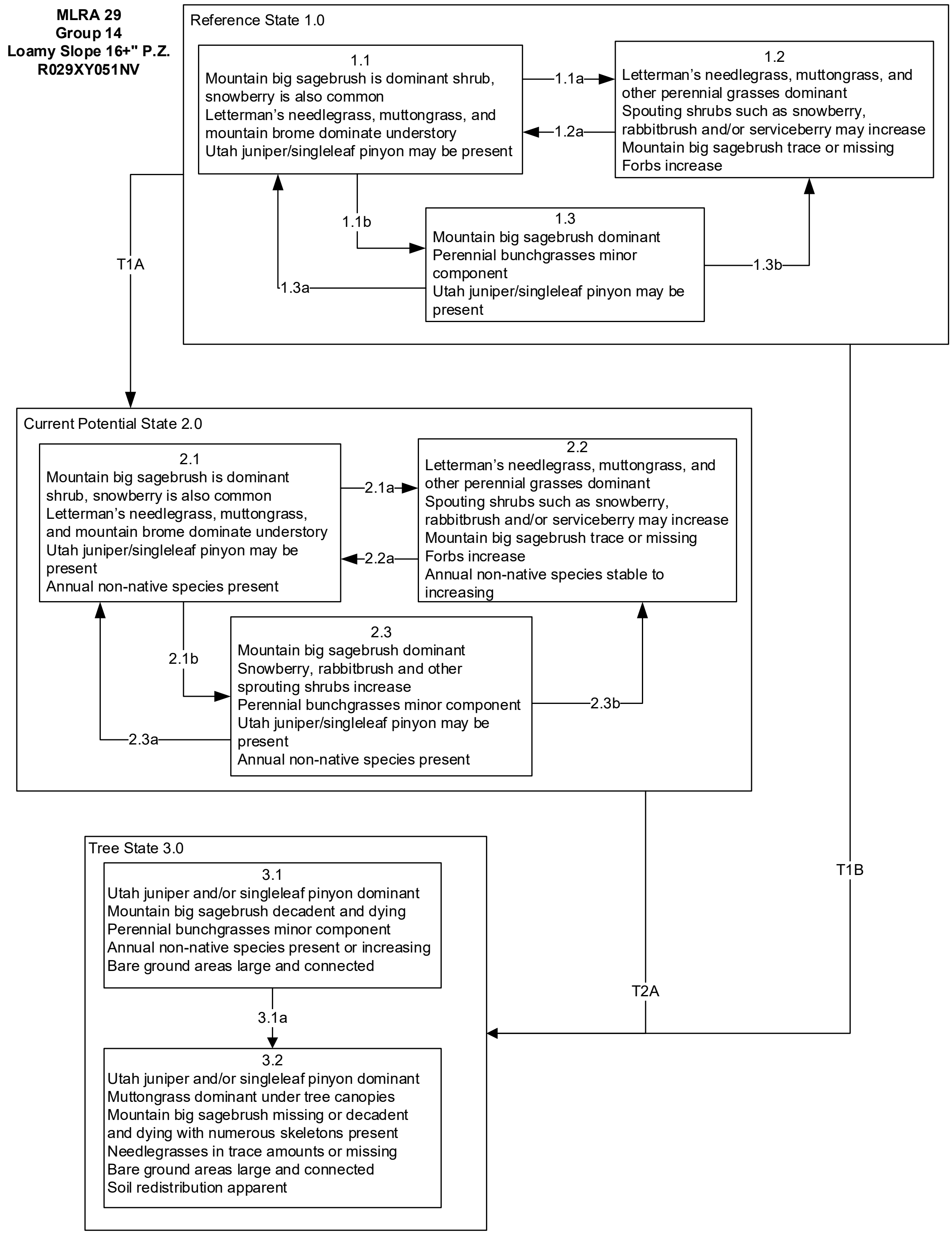
Loamy 16"+ P.Z. (R029XY050NV):

This site has deeper soils than the modal ecological site and is therefore more productive. It also contains larger components of Columbia and western needlegrasses. In the reference state, this site does not contain any Utah Juniper or singleleaf pinyon, but can be readily invaded by these species.

Mountain Slope 12-14" P.Z. (R029XY138NV):

This site occurs on mountain sideslopes on all exposures at elevation ranges from 7,000 to 8,500 ft. Mountain big sagebrush and curl-leaf mountain mahogany (*Cercocarpus ledifolius*) dominate the overstory while muttongrass dominates the understory as described in the ecological site description. This site is less productive and less resilient than the modal ecological site.

Modal State and Transition Model for Group 14 in MLRA 29:



MLRA 29
Group 14
Loamy Slope 16+" P.Z.
R029XY051NV

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire creates sagebrush/grass mosaic; high severity fire significantly reduces sagebrush cover and leads to early-seral community dominated by grasses and forbs.
1.1b: Time and lack of disturbance such as fire allows increase of sagebrush. Drought and/or herbivory decreases perennial understory.
1.2a: Time and lack of disturbance allows for regeneration of sagebrush.
1.3a: Low severity fire and/or Aroga moth creates sagebrush/grass mosaic.
1.3b: High severity fire significantly reduces sagebrush cover, allows perennial bunchgrasses to dominate.

Transition T1A: Introduction of annual non-native species.

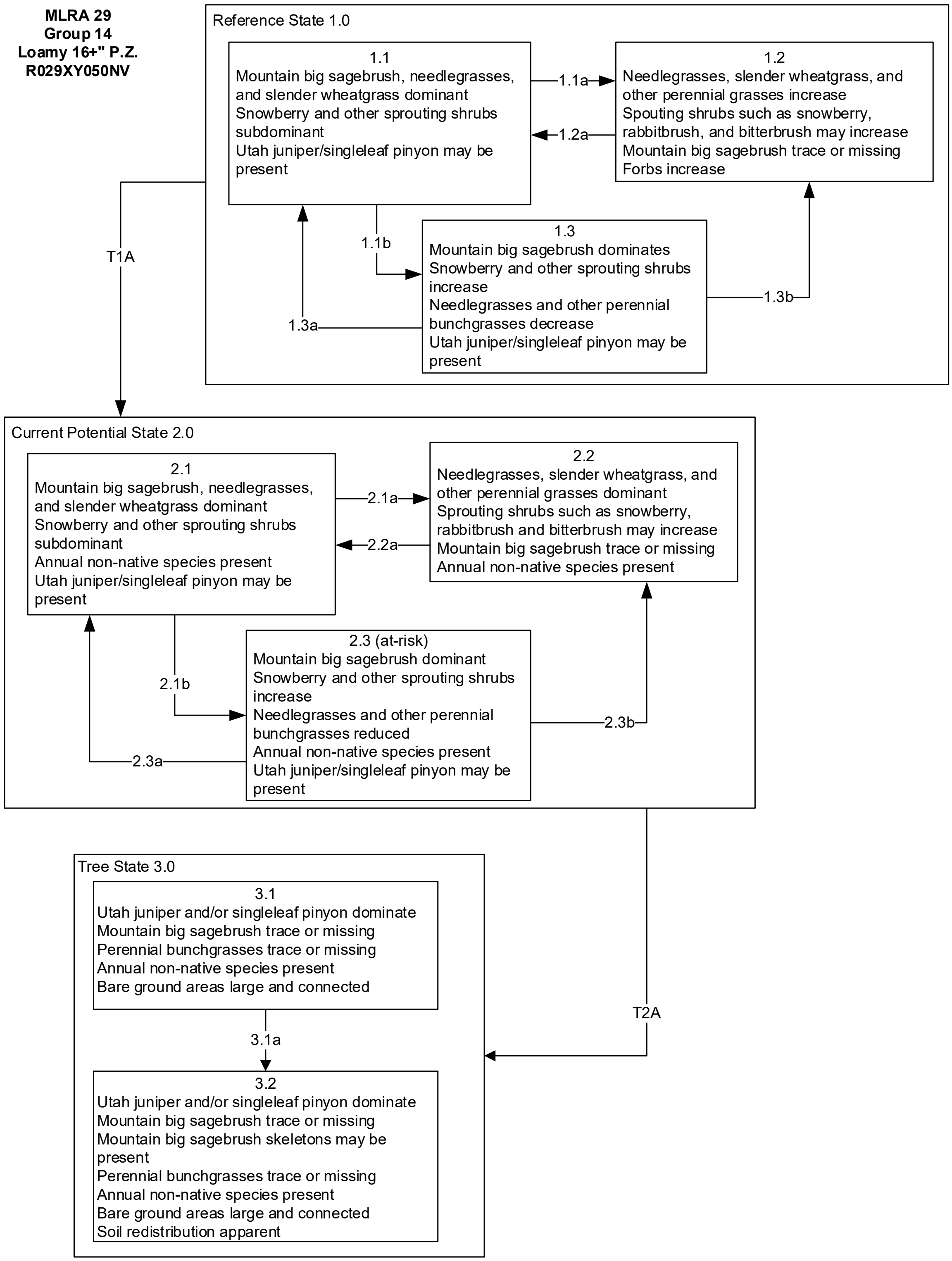
Transition T1B: Tree canopy closure and resource competition are sufficient to suppress the regeneration of shrubs and perennial grasses.

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire creates sagebrush/grass mosaic; high severity fire significantly reduces sagebrush cover and leads to early-seral community dominated by grass.
2.1b: Time and lack of disturbance such as fire allows sagebrush to increase and become decadent; long-term drought and/or inappropriate grazing management may also decrease perennial understory and allow sagebrush to be dominant.
2.2a: Time and lack of disturbance allows for regeneration of sagebrush.
2.3a: Low severity fire, brush management with minimal soil disturbance and/or Aroga moth creates sagebrush/grass mosaic; late-fall/winter grazing causes mechanical damage to sagebrush, reduces sagebrush cover.
2.3b: High severity fire significantly reduces sagebrush cover, allows perennial bunchgrasses to become dominant.

Transition T2A: Time and lack of disturbance or management actions allows for trees to dominate site resources; may be facilitated by inappropriate grazing management reducing fine fuels and lengthening the fire return interval (to 3.1).

Tree State 3.0 Community Phase Pathways
3.1a: Time and lack of disturbance allows for maturation of the tree community.

Additional State and Transition Models for Group 14 in MLRA 29:



MLRA 29
Group 14
Loamy 16+" P.Z.
R029XY050NV

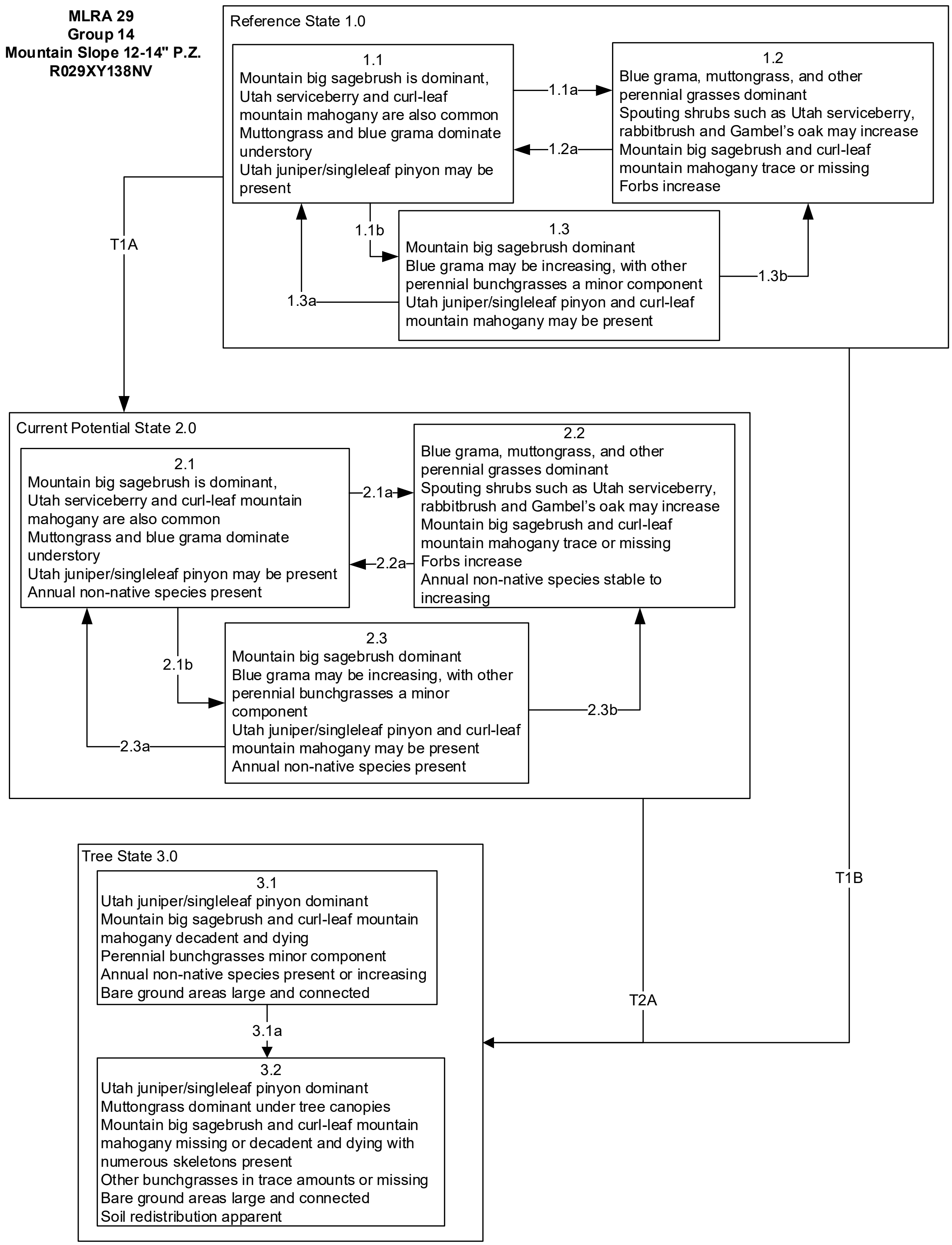
Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire creates sagebrush/grass mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community dominated by grasses and forbs.
1.1b: Time and lack of disturbance such as fire. Drought and/or herbivory may also decrease perennial understory.
1.2a: Time and lack of disturbance allows for regeneration of sagebrush.
1.3a: Low severity fire and/or Aroga moth creates sagebrush/grass mosaic.
1.3b: High severity fire significantly reduces sagebrush cover leading to early/mid-seral community.

Transition T1A: Introduction of annual non-native species.

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire creates sagebrush/grass mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community dominated by grasses and forbs.
2.1b: Time and lack of disturbance such as fire allows sagebrush to increase and become decadent; long-term drought and/or inappropriate grazing management may also decrease perennial understory and facilitate an increase is sagebrush density / cover.
2.2a: Time and lack of disturbance allows for regeneration of sagebrush.
2.3a: Low severity fire and/or Aroga moth creates sagebrush/grass mosaic. Brush management with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire significantly reduces sagebrush cover leading to early/mid-seral community.

Transition T2A: Time and lack of disturbance allows for trees to dominate site resources; may be facilitated by inappropriate grazing management reducing fine fuels and lengthening the fire return interval (3.1).

Tree State 3.0 Community Phase Pathways
3.1a: Time and lack of disturbance allows for maturation of the tree community.


MLRA 29
Group 14
Mountain Slope 12-14" P.Z.
R029XY138NV
Reference State 1.0
1.1
Mountain big sagebrush is dominant,
Utah serviceberry and curl-leaf
mountain mahogany are also common
Muttongrass and blue grama dominate
understory
Utah juniper/singleleaf pinyon may be
present
1.1a
1.2a
1.2
Blue grama, muttongrass, and other
perennial grasses dominant
Spouting shrubs such as Utah serviceberry,
rabbitbrush and Gambel's oak may increase
Mountain big sagebrush and curl-leaf
mountain mahogany trace or missing
Forbs increase
1.1b
1.3
Mountain big sagebrush dominant
Blue grama may be increasing, with other
perennial bunchgrasses a minor component
Utah juniper/singleleaf pinyon and curl-leaf
mountain mahogany may be present
1.3a
1.3b
T1A
Current Potential State 2.0
2.1
Mountain big sagebrush is dominant,
Utah serviceberry and curl-leaf mountain
mahogany are also common
Muttongrass and blue grama dominate
understory
Utah juniper/singleleaf pinyon may be present
Annual non-native species present
2.1a
2.2a
2.2
Blue grama, muttongrass, and other
perennial grasses dominant
Spouting shrubs such as Utah serviceberry,
rabbitbrush and Gambel's oak may increase
Mountain big sagebrush and curl-leaf
mountain mahogany trace or missing
Forbs increase
Annual non-native species stable to
increasing
2.1b
2.3
Mountain big sagebrush dominant
Blue grama may be increasing, with other
perennial bunchgrasses a minor
component
Utah juniper/singleleaf pinyon and curl-leaf
mountain mahogany may be present
Annual non-native species present
2.3a
2.3b
Tree State 3.0
3.1
Utah juniper/singleleaf pinyon dominant
Mountain big sagebrush and curl-leaf mountain
mahogany decadent and dying
Perennial bunchgrasses minor component
Annual non-native species present or increasing
Bare ground areas large and connected
3.1a
3.2
Utah juniper/singleleaf pinyon dominant
Muttongrass dominant under tree canopies
Mountain big sagebrush and curl-leaf mountain
mahogany missing or decadent and dying with
numerous skeletons present
Other bunchgrasses in trace amounts or missing
Bare ground areas large and connected
Soil redistribution apparent
T2A
T1B

MLRA 29
Group 14
Mountain Slope 12-14" P.Z.
R029XY138NV

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire creates sagebrush/grass mosaic; high severity fire significantly reduces sagebrush cover and leads to early-seral community dominated by grasses and forbs.
1.1b: Time and lack of disturbance such as fire allows increase of sagebrush. Drought and/or herbivory decreases perennial understory.
1.2a: Time and lack of disturbance allows for regeneration of sagebrush.
1.3a: Low severity fire and/or Aroga moth creates sagebrush/grass mosaic.
1.3b: High severity fire significantly reduces sagebrush cover, allows perennial bunchgrasses to dominate.

Transition T1A: Introduction of annual non-native species.

Transition T1B: Tree canopy closure and resource competition are sufficient to suppress the regeneration of shrubs and perennial grasses.

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire creates sagebrush/grass mosaic; high severity fire significantly reduces sagebrush cover and leads to early-seral community dominated by grass.
2.1b: Time and lack of disturbance such as fire allows sagebrush to increase and become decadent; long-term drought and/or inappropriate grazing management may also decrease perennial understory and allow sagebrush to be dominant.
2.2a: Time and lack of disturbance allows for regeneration of sagebrush.
2.3a: Low severity fire, brush management with minimal soil disturbance and/or Aroga moth creates sagebrush/grass mosaic; late-fall/winter grazing causes mechanical damage to sagebrush, reduces sagebrush cover.
2.3b: High severity fire significantly reduces sagebrush cover, allows perennial bunchgrasses to become dominant.

Transition T2A: Time and lack of disturbance or management actions allows for trees to dominate site resources; may be facilitated by inappropriate grazing management reducing fine fuels and lengthening the fire return interval (to 3.1).

Tree State 3.0 Community Phase Pathways
3.1a: Time and lack of disturbance allows for maturation of the tree community.

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MLRA 29 Group 15: Steep slopes with serviceberry and muttongrass

Description of MLRA 29 Disturbance Response Group 15

Disturbance Response Group (DRG) 15 consists of three ecological sites. These sites occur on mountain sideslopes, backslopes, and fan remnants from 4,800 to about 7,000 ft. The precipitation ranges from 12 to 16 in. with slopes ranging from 15 to 75%. The soils on these sites are typically shallow to moderately deep and well drained with low water holding capacity and permeability. These soils are normally medium to highly acidic with mesic soil temperature and typic aridic soil moisture regimes. The soil's profile is characterized by its high quantity of stones, cobbles and gravels and thin top soil, typically less than 6 to 10 in. thick to underlying material, which are commonly lacustrine or tuffaceous deposits. Due to the site's steep slopes and sparse vegetation, runoff is high and surface soils are subject to sheet and rill erosion. The reference plant community for these sites varies depending on precipitation, elevation and aspect. The shrub component is dominated by Utah serviceberry (*Amelanchier utahensis*), Stansbury cliffrose (*Purshia stansburiana*), antelope bitterbrush (*Purshia tridentata*), desert ceanothus (*Ceanothus greggii*), and Wyoming big sagebrush (*Artemisia tridentata ssp. wyomingensis*). The dominant understory species is muttongrass (*Poa fendleriana*). Production ranges from 600 to 1,000 lb/ac.

Disturbance Response Group 15 Ecological Sites:

Eroded North Slope 12-14" P.Z. – Modal	R029XY165NV
Stony Loam 12-16" P.Z.	R029XY098NV
Eroded South Slope 12-14" P.Z.	R029XY166NV

Modal Site:

The Eroded North Slope 12-14" P.Z. ecological site is the modal site that represents this DRG, as it has the most acres mapped. This site occurs on mountain backslopes and eroded fan remnants on northerly exposures from 4,800 to 6,100 ft. Precipitation ranges from 12 to 14 in. and slopes range from 15 to 30%. The soils on this site are typically shallow to moderately deep and well drained with low water holding capacity and permeability. These soils are normally medium to highly acidic with mesic soil temperature and typic aridic soil moisture regimes. The soil profile is characterized by its thin top soil, typically less than 6 to 10 in. thick to underlying material, which are commonly lacustrine or tuffaceous deposits. Due to the site's steep slopes and sparse vegetation, runoff is high and surface soils are subject to sheet and rill erosion. The reference plant community is dominated by Utah serviceberry, antelope bitterbrush, Stansbury cliffrose, and muttongrass. Several other shrubs and trees occur on this site including singleleaf ash (*Fraxinus anomala*), Gambel oak (*Quercus gambelii*), Sonoran scrub oak (*Quercus* *turbinella*), desert ceanothus, singleleaf pinyon (*Pinus monophylla*) and Utah juniper (*Juniperus osteosperma*). Average annual production in a normal year is 600 lb/ac.

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasive species. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans a unique area in Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area. Flashy, summer storm events contribute significantly to annual precipitation as well. Air and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

Periodic drought regularly influences desert ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West (Miller et al. 2008a). Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006). The ecological sites in this DRG are dominated by muttongrass, a deep-rooted cool-season, perennial bunchgrass and long-lived shrubs (50+ years) with high root to shoot ratios. The dominant shrubs, Utah serviceberry, bitterbrush and big sagebrush usually root to the full depth of the winter-spring soil moisture recharge, which ranges from 1 to over 3 m (3 to 10 ft) (Comstock and Ehleringer 1992). Root length of mature sagebrush plants was measured to a depth of 2 m (6.6 ft) in alluvial soils in Utah (Richards and Caldwell 1987). Tap roots of antelope bitterbrush have been documented from 4.5 to 5.4 m (15 to 18 ft) in length (McConnell 1961).

Utah serviceberry utilizes a deep, spreading root system, resulting in drought tolerance once established (Larese-Casanova 2012b). These shrubs have a flexible generalized root system with development of both deep taproots and laterals near the surface (Comstock and Ehleringer 1992).

Utah serviceberry is a large shrub that grows from 2 to 4 m (6.5 to 13 ft) tall and typically grows in big sagebrush, pinyon-juniper, and aspen communities (Hammond 2012). Despite typically being found surrounded by other species, serviceberry seedlings can be out-competed by dense stands of grasses and forbs. Utah serviceberry is top-killed by fire but sprouts from an underground crown, and its branches, leaves, and berries all provide forage for wildlife and livestock (Noller 2008). Utah serviceberry is more drought tolerant than other serviceberry species, and its root system is very deep and spreading, well adapted for coarse-textured soils (Hammond 2012). However, Utah serviceberry has been found to be intolerant of high water tables and poorly drained soils. The only pest known to be a serious threat to Utah serviceberry is cedar-apple rust (*Gymnosporangium juniperi-virginianae*), which Utah serviceberry can host in its leaves and berries when growing in proximity to junipers (*Juniperus* spp.) (Wasser 1982).

Antelope bitterbrush is a widely distributed shrub of deep and well drained soils (Nord 1965, Stubbendieck et al. 1992), occurring from southern British Columbia southward along the east side of the Cascade Mountain range and the Sierra Nevada to central California and east to Montana, Wyoming and Colorado (Hitchcock et al. 1961). Antelope bitterbrush roots are associated with nodules containing the nitrogen-fixing actinomycete *Frankia* (Krannitz 1997). Antelope bitterbrush is a critical browse species for wintering mule deer herds and highly preferred by domestic livestock during late summer, fall and winter months when herbaceous vegetation dries up and is low in digestible protein (Clements and Young 2002). However, excessive utilization of the current annual growth is reported to reduce flowering and seed production the next season (Hormay 1943).

Big sagebrush and antelope bitterbrush are generally long-lived; therefore, it is not necessary for new individuals to recruit every year for perpetuation of the stand. Infrequent large recruitment events and simultaneous low, continuous recruitment is the foundation of population maintenance (Noy-Meir 1973). Survival of the seedlings is dependent on adequate moisture conditions.

Stansbury cliffrose is distributed from north-central Nevada east to north-central Utah and south to southern California, central New Mexico and northern Mexico (Benson and Darrow 1981b, Price and Brotherson 1987). Stansbury cliffrose is a drought-resistant native shrub that typically grows from 1 to 6 ft tall but may reach heights of 25 ft. It has a taproot and much-branched, spreading lateral roots when not restricted by bedrock. This species is considered a moderately long-lived shrub. Brotherson et al. (1987) and Price and Brotherson (1987) reported that 40 to 45 years was the modal age class of a population in the Wasatch Range of Utah. The oldest living individual was 69 years. Stansbury cliffrose provides cover and browse for mule deer, pronghorn, desert bighorn sheep, livestock, game birds, songbirds and rodents (Price and Brotherson 1987).

Muttongrass, the dominant perennial grass species in this DRG, is a tufted, multi-flowered, perennial bunchgrass that can grows between 8 and 30 in. tall and has narrow leaves, which range from 1 to 3 mm wide. Muttongrass is found throughout the western United States as a primary component of the understory of pinyon-juniper communities and aspen and pine forests (Tilley et al. 2007). It is found in lower elevations in the northern extent of its native range, and higher elevations in the south. Muttongrass has a fibrous root system that reaches a depth of approximately 10 in., which provides good surface erosion control (Tilley et al. 2007). Muttongrass is one of the most drought-tolerant bluegrasses and is useful for restoring communities disturbed by fire, grazing, or mining, but is limited in its use due to low seed viability. Muttongrass plants are most frequently pistillate, but staminate plants do occasionally occur, which are able to hybridize and crossbreed with other bluegrasses (Tilley et al. 2007).

The ecological sites in this DRG have moderate to high resilience to disturbance and resistance to invasion. Plant community alteration is driven primarily by natural disturbances such as drought, insects, fire, and soil erosion resulting from unstable soils on steep slopes. Resilience increases with elevation, aspect, precipitation, and nutrient availability. Long-term disturbance response may be influenced by small differences in landscape topography. North slopes are more resilient than south slopes because lower soil surface temperatures operate to keep moisture content higher on northern exposures.

Invasive Annual Species:

The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and depressed competition or can increase resource pools by the decomposition of dead plant material following disturbance. The presence of exotic annual plants within these ecosystems decreases ecosystem resilience and resistance to disturbance through competition for limited resources. Peters and Bunting (1994) cites multiple authors on the extent of the soil profile exploited by the competitive non-native annual cheatgrass (*Bromus tectorum*). Specifically, the depth of rooting is dependent on the size the plant achieves, and in competitive environments, cheatgrass roots were found to penetrate only 15 cm (6 in.) whereas isolated plants and pure stands were found to root at least 1 m in depth (3.2 ft) with some plants rooting as deep as 1.5 to 1.7 m (5 to 5.5 ft).

The species most likely to invade these sites is cheatgrass. Cheatgrass is a cool-season annual grass that maintains an advantage over native plants in part because it is a prolific seed producer, can germinate in the autumn or spring, tolerates grazing, and increases with frequent fire (Klemmedson and Smith 1964, Miller 1999). Cheatgrass originated from Eurasia and was first reported in North America in the late 1800s. Pellant and Hall (1994) found 3.3 million acres of public lands dominated by cheatgrass and suggested that another 76 million acres were susceptible to invasion by winter annuals including cheatgrass and medusahead (*Taeniatherum caput-medusae*).

Recent modeling and empirical work by Bradford and Lauenroth (2006) suggest that seasonal patterns of precipitation input and temperature are also key factors determining regional variation in the growth, seed production, and spread of invasive annual grasses. The phenomenon of cheatgrass “die-off” provides opportunities for restoration of perennial and native species (Baughman et al. 2016, Baughman et al. 2017). The causes of these events are not fully understood, but there is ongoing work to try to predict where they occur, in the hopes of aiding conservation planning (Weisberg et al. 2017, Brehm 2019).

Methods to control cheatgrass include herbicide application, prescribed fire, targeted grazing, and rangeland seeding. Mapping potential or current invasion vectors is a management method designed to increase the cost-effectiveness of control methods. Spraying with herbicide (imazapic or imazapic + glyphosate) and seeding with crested wheatgrass and Sandberg bluegrass has been found to be more successful at combating cheatgrass than spraying alone (Sheley et al. 2012). To date, most seeding success has occurred with non-native wheatgrass species. Perennial grasses, especially crested wheatgrass, are able to suppress cheatgrass growth when mature (Blank et al. 2020). Where native bunchgrasses are missing from the site, revegetation of annual grass-invaded rangelands has been shown to have a higher likelihood of success when using introduced perennial bunchgrasses such as crested wheatgrass Butler et al. (2011), (Davies et al. 2015b, Clements et al. 2017) tested four herbicides (imazapic, imazapic + glyphosate, rimsulfuron, and sulfometuron + chlorsulfuron) for suppression of cheatgrass, medusahead (*Taeniatherum caput-medusae*), and North Africa grass (*Ventenata dubia*) within residual stands of native bunchgrass. Additionally, they tested the same four herbicides followed by seeding of six bunchgrasses (native and non-native) with varying success (Butler et al. 2011). Herbicide-only treatments appeared to remove competition for established bluebunch wheatgrass by providing 100% control of North Africa grass and medusahead and greater than 95% control of cheatgrass (Butler et al. 2011). Caution in using these results is advised, as only 1 year of data was reported.

In considering the combination of pre-emergent herbicide and prescribed fire for invasive annual grass control, it is important to assess the tolerance of desirable brush species to the herbicide being applied. Vollmer and Vollmer (2008) tested the tolerance of alderleaf mountain mahogany (*Cercocarpus montanus*), antelope bitterbrush, and multiple sagebrush species to three rates of imazapic with and without methylated seed oil as a surfactant. They found that a cheatgrass control program in an antelope bitterbrush community should not exceed imazapic at 8 oz/ac with or without surfactant. Sagebrush, regardless of species or rate of application, was not affected. However, many environmental variables were not reported in this study and managers should install test plots before broad-scale herbicide application is initiated.

Fire Ecology:

These ecological sites occur in the Clover Mountains of eastern Lincoln County. The vegetation in this area is considered 'Interior Chaparral' by (Brooks et al. 2007) and 'Mountain Brush' by (Ramsey and West 2009). Historical fire return intervals were likely 50 to 100 years but may have varied widely across the area (Cable 1975). This ecosystem is fire-dependent and exclusion of fire can lead to encroachment by woodland and forest species (Brooks et al. 2007). Non-native grasses can increase the fire frequency to the point where even the fire-adapted species cannot recover. Where non-native grasses dominate, the fire return intervals are less than 20 years. With the shortened fire return interval, seed banks of the interior chaparral shrub species will be depleted (Brooks et al. 2007).

Utah serviceberry is a large, fire-tolerant shrub that is a major component of this DRG. It is top-killed by fire, but sprouts from the underground root crown after disturbance (Carmichael et al. 1978). However, sprouting is reliant on the amount of moisture in the soil (Whitworth et al. 1984), therefore climatic variation influences post-fire sprouting success. Utah serviceberry can also re-colonize an area after fire via seeds, but this can require up to 8 to 10 years for plants to reach maturity (Noller 2008).

Antelope bitterbrush is moderately fire tolerant (McConnell and Smith 1977). It regenerates by seed and sprouting (Blaisdell and Mueggler 1956, McArthur et al. 1983), however it has been reported that bitterbrush is generally eradicated by fire in the western Great Basin, in part because seed distribution is limited (Billings 1952). Sprouting ability is highly variable and has been attributed to genetics, plant age, phenology, soil moisture and texture and fire severity (Blaisdell and Mueggler 1956, Blaisdell et al. 1982, Clark et al. 1982, Cook et al. 1994). Bitterbrush sprouts from a region on the stem approximately 1.5 in. above and below the soil surface; the plant rarely sprouts if the root crown is killed by fire (Blaisdell and Mueggler 1956). Low intensity fires may allow for bitterbrush to sprout; however, community response also depends on soil moisture levels at time of fire (Murray 1983). Lower soil moisture allows more charring of the stem below ground level (Blaisdell and Mueggler 1956), thus sprouting will usually be more successful after a spring fire than after a fire in summer or fall (Murray 1983, Busse et al. 2000, Kerns et al. 2006). If cheatgrass is present, bitterbrush seedling success is much lower. The factor that most limits establishment of bitterbrush seedlings is competition for water resources with the invasive species cheatgrass (Clements and Young 2002).

Mountain and Wyoming big sagebrush are killed by fire (Neuenschwander 1980, Blaisdell et al. 1982) and do not sprout (Blaisdell 1953). Post-fire regeneration occurs from seed and will vary depending on site characteristics, seed source, and fire characteristics. Mountain big sagebrush may return to pre-burn density and cover within 15 to 20 years following fire, but establishment after severe fires may proceed more slowly (Bunting et al. 1987). Conversely, recovery time for Wyoming big sagebrush is estimated at 50 to 120 or more years (Baker 2006).

Other common shrub species on this site possess varying responses to fire. Stansbury cliffrose has mixed results after fire and survivability depends on timing of fire and age of plants. It is generally considered a weak sprouter and is generally killed by severe fire (Ralphs 1976).

Gambel oak is a fire-adapted species with adventitious buds and a sprouting root crown (Harper et al. 1985). Sonoran scrub oak is top-killed by fire and depending on fire intensity and severity and climatic factors, this oak typically sprouts from the root crown and rhizomes (Pase 1969). Singleleaf ash is top-killed by fire and will resprout from the root crown (Schlesinger 1990). Desert ceanothus is usually killed by fire but may resprout depending on timing of fire, soil moisture, plant size and physiological condition. Desert ceanothus has long-lived seeds that require heat stimulation or scarification but mortality of seeds varies with fire severity and seed depth (Keeley and Zedler 1978).

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The initial condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species response. For most forbs and grasses the growing points are located at or below the soil surface providing relative protection from disturbances which decrease above ground biomass, such as grazing or fire. Thus, fire mortality is more correlated to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant and abundance of old growth (Wright 1971, Young 1983). Muttongrass, the grass component on this site, is top-killed by fire but will sprout after low to moderate severity fires. A study by (Vose and White 1991) in an open sawtimber site found minimal difference in overall effect of burning on muttongrass.

The introduction of annual weedy species, like cheatgrass, may cause an increase in fire frequency and eventually lead to an annual invasive state, however this condition was not observed during field verification. Conversely, as fire frequency decreases, shrubs will increase and with inappropriate grazing management the perennial bunchgrasses and forbs may be reduced.

Livestock/Wildlife Grazing Interpretations:

Utah serviceberry is highly palatable to wildlife and livestock (McCulloch 1955). The leaves, branches, and berries are consumed by many wildlife species, including big game, birds, and small mammals (Noller 2008).

Antelope bitterbrush is also an important shrub species to a variety of animals, such as domestic livestock, antelope, deer, and elk. Bitterbrush is critical browse for mule deer (*Odocoileus hemionus*), as well as domestic livestock, antelope, and elk (Wood et al. 1995, Clements and Young 2002). Grazing tolerance of antelope bitterbrush is dependent on site conditions (Garrison 1953).

Despite low palatability, mountain big sagebrush is eaten by domestic sheep, cattle, and horses. Chemical analysis indicates that the leaves of big sagebrush equal alfalfa meal in protein, have a higher carbohydrate content, and yield twelvefold more fat (USFS 1937). Many wildlife species are dependent on the sagebrush ecosystem including the greater sage grouse, sage sparrow, pygmy rabbit and the sagebrush vole. (Dobkin and Sauder 2004) identified 61 species, including

24 mammals and 37 birds, associated with the shrub-steppe habitats of the Intermountain West.

Generally, Wyoming big sagebrush is the least palatable of the big sagebrush taxa (Sheehy and Winward 1981, Bray et al. 1991) however, it may receive light or moderate use depending upon the amount of understory herbaceous cover (Tweit and Houston 1980). Personius et al 1987 found Wyoming big sagebrush and basin big sagebrush to be intermediately palatable to mule deer when compared to mountain big sagebrush (most palatable) and black sagebrush (least palatable) (Personius et al. 1987).

Muttongrass is very palatable for wildlife and livestock and is rated as excellent forage for cattle and horses, and good for sheep. Muttongrass starts growth in late winter or early spring and provides excellent early feed. Muttongrass foliage cures well and is good fall forage, but not as good as spring or summer (Humphrey et al. 1952).

State and Transition Model Narrative for Group 15:

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 29 Disturbance Response Group 15. Three states have been identified for this DRG, including Reference, Current Potential and Shrub State.

Reference State 1.0:

The Reference State 1.0 is a representative of the natural range of variability under pristine conditions. The reference state has three general community phases; a shrub-grass dominant phase, a perennial grass dominant phase and a shrub dominant phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire and/or periodic drought.

Community Phase 1.1:
Utah serviceberry dominates the overstory with sub-dominants of antelope bitterbrush and Stansbury cliffrose. Muttongrass is the dominant understory species. Wyoming and/or mountain big sagebrush may be present along with birchleaf mountain mahogany, Gambel oak, singleleaf ash and desert ceanothus. Utah juniper and/or singleleaf pinyon may also be present in minor amounts. Potential vegetative composition by air-dry weight is approximately 30% grasses, 10% forbs, 60% shrubs and up to 1% trees. Approximate ground cover (basal and crown) is 35 to 45%. Total annual air-dry production ranges from 400 to 800 lb/ac.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
Fire would reduce or eliminate Stansbury cliffrose, bitterbrush and big sagebrush and allow for sprouting shrubs and perennial bunchgrasses to dominate the site. A fire following an unusually wet spring may be more severe and reduce serviceberry, bitterbrush, cliffrose, mountain mahogany, and sagebrush to trace amounts.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.3:
Chronic drought may reduce fire frequency and/or increased time between disturbances (fire) facilitates an increase in shrub cover over deep-rooted perennial bunchgrasses. Long fire return intervals allow for reestablishment of seed banks and the development of the fuel loads and spatial continuity necessary for fire to occur (Brooks et al. 2007).

Community Phase 1.2:
This community phase is characteristic of a post-disturbance, early to mid-seral community phase. Muttongrass dominates, while Indian ricegrass (*Achnatherum hymenoides*) and bottlebrush squirreltail (*Elymus elymoides*) may increase. Utah serviceberry, bitterbrush, Stansbury cliffrose, and big sagebrush cover and production is greatly reduced. Sprouting shrubs such as Sonoran scrub and Gambel oak, singleleaf ash, birchleaf mountain mahogany (*Cercocarpus montanus* var. *glaber*), and desert ceanothus will increase.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
Time and lack of fire allows for shrubs to reestablish.

Community Phase 1.3:
Utah serviceberry and other sprouting shrubs increase in the absence of disturbance. Utah serviceberry, cliffrose and bitterbrush dominate the overstory. Big sagebrush may be increasing. Deep-rooted perennial bunchgrasses are reduced. Utah juniper and/or singleleaf pinyon may be present.

Community Phase Pathway 1.3a, from Phase 1.3 to 1.1:
A low severity fire or other localized disturbances will reduce the non-sprouting shrub overstory and create a shrub/grass mosaic. Winter drought, reducing deep soil moisture recharge, may also reduce the shrub component, allowing recovery of the perennial bunchgrass understory.

Community Phase Pathway 1.3b, from Phase 1.3 to 1.2:
Fire, following a wet spring, will significantly decrease or eliminate the non-sprouting shrub overstory and allow for the perennial bunchgrasses to dominate the site. Sprouting shrubs will increase.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0:

Trigger: Introduction of non-native annual species, such as cheatgrass.

Slow variables: Over time the annual non-native plants will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

This state is similar to the Reference State 1.0 with the same community phases. Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of invasive weeds. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate and adaptations for seed dispersal. Additionally, the presence of highly flammable, non-native species reduces state resilience by promoting fire in historically un-affected areas.

Community Phase 2.1:
Utah serviceberry dominates the overstory with sub-dominants of bitterbrush and cliffrose. Muttongrass is the dominant understory species. Wyoming and/or mountain big sagebrush may be present along with birchleaf mountain mahogany, Gambel oak, singleleaf ash and desert ceanothus. Utah juniper and/or singleleaf pinyon may also be present. Utah juniper and/or singleleaf pinyon may be present. Annual invasive species are present.

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
Fire would reduce or eliminate Stansbury cliffrose, bitterbrush and big sagebrush and allow for perennial bunchgrasses and sprouting shrubs to dominate the site. A fire following an unusually wet spring may be more severe and reduce serviceberry, bitterbrush, Stansbury cliffrose, and sagebrush to trace amounts. Annual non-native species increasing.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.3:
Chronic drought and/or inappropriate grazing management may reduce fire frequency and/or increased time between disturbances (fire) facilitates an increase in shrub cover over deep-rooted perennial bunchgrasses.

Community Phase 2.2:

This community phase is characteristic of a post-disturbance, early to mid-seral community phase. Muttongrass dominates, while needleandthread, Indian ricegrass and bottlebrush squirreltail may increase. Utah serviceberry, bitterbrush, Stansbury cliffrose, and big sagebrush cover and production is greatly reduced. Sprouting shrubs such as Sonoran scrub and Gambel oak, singleleaf ash, birchleaf mountain mahogany, and desert ceanothus will increase.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Time and lack of disturbance and/or grazing management that favors the establishment and growth of shrubs, allowing the shrub component to recover.

Community Phase 2.3 (At Risk):
Shrubs like Utah serviceberry, bitterbrush, Stansbury cliffrose, big sagebrush, birchleaf mountain mahogany dominate the overstory while perennial bunchgrasses in the understory are reduced. Annual non-natives species may be stable or increasing.

Eroded North Slope 12-14" P.Z. (R029XY165NV), Current Potential 2.3, T.Stringham, June 2022

Community Phase Pathway 2.3a, from Phase 2.3 to 2.1:
A low severity fire and/or grazing management that reduces the non-sprouting shrub component and create a shrub/grass mosaic. Winter drought, reducing deep soil moisture recharge, may also reduce the shrub component, allowing recovery of the perennial bunchgrass understory. Annual non-native species are present and may increase in this community.

Community Phase Pathway 2.3b, from Phase 2.3 to 2.2:
Wildfire, prescribed burn or other brush removal treatments, will initially decrease or eliminate non-sprouting shrubs and allow for the perennial bunchgrasses and sprouting shrubs to dominate the site. Annual non-native species respond well to fire and may increase post-burn.

T2A: Transition from Current Potential State 2.0 to Shrub State 3.0:

Trigger: Inappropriate, long-term grazing of perennial bunchgrasses and/or chronic spring / summer drought allows shrubs to increase.

Slow variables: Long term decrease in deep-rooted perennial grass density.

Threshold: Loss of deep-rooted perennial bunchgrasses changes spatial and temporal nutrient cycling and nutrient redistribution, and reduces soil organic matter and soil moisture.

Shrub State 3.0:

This state has one community phase that is characterized by a dominance of Utah serviceberry, Stansbury cliffrose, and antelope bitterbrush. Birchleaf mountain mahogany, Gambel oak, desert ceanothus, big sagebrush, Utah juniper and singleleaf pinyon are also present. Muttongrass, Indian ricegrass, and bottlebrush squirreltail are sparse. Shrub cover exceeds site concept and may be decadent, reflecting stand maturity and lack of seedling establishment due to competition with mature plants. The shrub overstory dominates site resources such that soil water, nutrient capture, nutrient cycling and soil organic matter are temporally and spatially redistributed. Bare ground has increased and soil redistribution may be increasing. This community phase is also considered At-Risk of a Tree State; however, field observations suggest it is highly unlikely that trees would dominate site resources. Surface soil instability may also limit tree establishment.

Community Phase 3.1 (At Risk):
Utah serviceberry, Stansbury cliffrose and antelope bitterbrush dominates overstory while deep-rooted perennial bunchgrasses may be present in trace amounts. Other common shrubs include birchleaf mountain mahogany, Gambel oak, singleleaf ash and desert ceanothus. Utah juniper and/or singleleaf pinyon may also be present. Singleleaf pinyon and Utah juniper present and increasing. Annual non-natives and bare ground are increasing.

Stony Loam 12-16" P.Z. (R029XY098NV), Shrub State 3.1, T. Stringham, June 2022

States Not Observed in Group 15:

Tree State: A Tree State was not seen for this group, though such a state may be possible at higher ends of the precipitation gradient within this group, particularly on the Stony Loam 12-16" ecological site (R029XY098NV). A Tree State was found observed for a similar disturbance response group (DRG 8) within MLRA 26 (Stringham et al. 2021).

Annual State: Chaparral stands that have burned repeatedly and lost most of the shrub cover have lost their shrub seed bank. Non-native annuals and early seral perennials typically dominate these stands. Burns are patchy, fire intensity is low and fire return intervals are less than 20 years (Brooks et al. 2007). This non-native, annual species dominated condition was not observed.

Potential Resilience Differences with Other Ecological Sites in this Group:

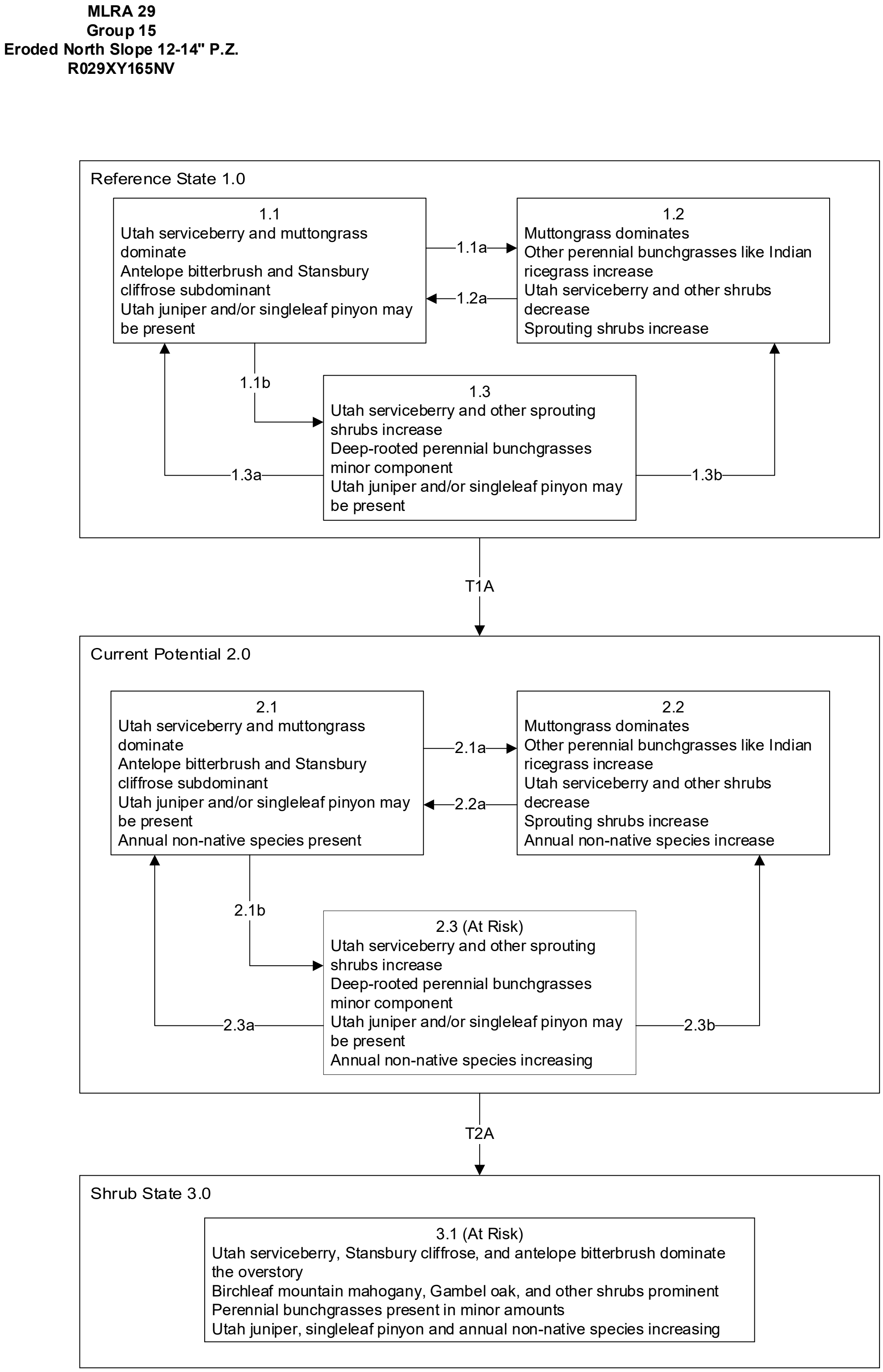
Stony Loam 12-16" P.Z. (R029XY098NV)

This site generally occurs at higher elevations (6,000 to 7,000 ft) and with higher slope gradients (30–75%). Increased precipitation potential may elevate risk of sheet and rill erosion, however plant production per acre is higher suggesting increased resilience. A Tree State would be more likely for this ecological site possibly increasing the risk of sheet and rill erosion prominent in the modal site. High amounts of stones, cobbles and gravels reduce available water holding capacity.

Eroded South Slope 12-14" P.Z. (R029XY166NV)

This site occurs on mountain backslopes and eroded fan remnants on southerly exposures in eastern Lincoln County. Moisture from summer convention storms provides an important source of precipitation from July through September. Stansbury cliffrose, desert ceanothus, and Wyoming big sagebrush dominate the site. Because this site occurs in the eastern portion of MLRA 29, chaparral species such as yucca (*Yucca* spp.), Sonoran scrub oak and Utah serviceberry are common. Annual production is lower than the modal site due to the southerly aspect and this site is less resilient than the modal.

Modal State and Transition Model for Group 15 in MLRA 29:



MLRA 29
Group 15
Eroded North Slope 12-14" P.Z.
R029XY165NV

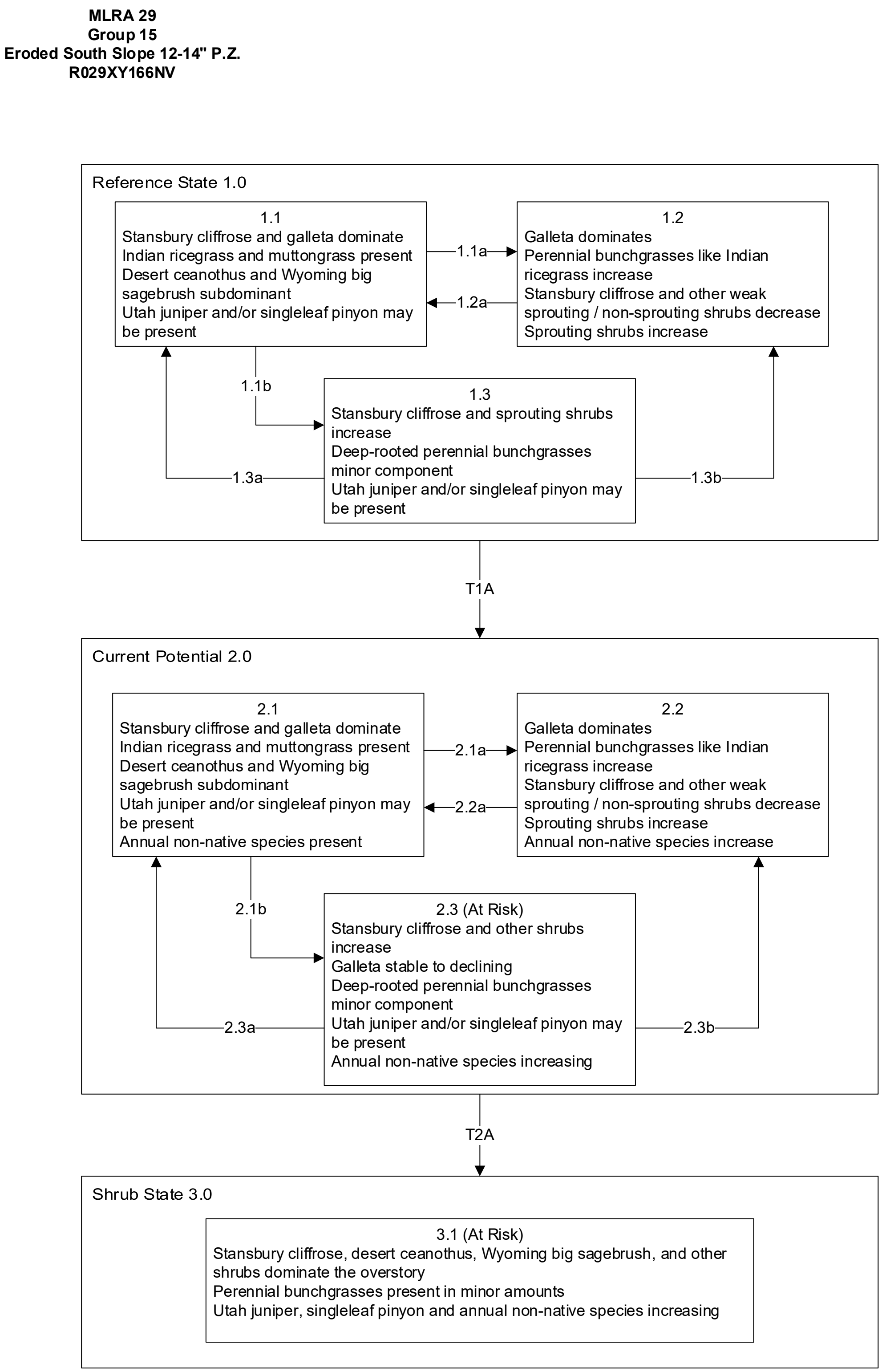
Reference State 1.0 Community Pathways
1.1a: Fire reduces or eliminates Utah serviceberry, antelope bitterbrush, Stansbury cliffrose and other shrubs, allowing perennial grasses and sprouting shrubs to increase.
1.1b: Time, lack of disturbance or chronic drought decreases perennial bunchgrasses and allows increase in shrub cover.
1.2a: Time, lack of disturbance allows shrubs to reestablish.
1.3a: Low severity fire or other localized disturbances reduces Utah serviceberry and other non-sprouting shrubs and creates a shrub/ grass mosaic. Winter drought may also reduce shrub cover, allowing recovery of perennial bunchgrasses.
1.3b: Fire reduces Utah serviceberry and other non-sprouting shrubs and allows for perennial bunchgrasses to dominate site.

Transition T1A: Introduction of non-native annual species.

Current Potential 2.0 Community Pathways
2.1a: Fire reduces or eliminates Utah serviceberry, antelope bitterbrush, Stansbury cliffrose and other shrubs, allowing perennial grasses and sprouting shrubs to increase. Annual non-native species are likely to increase.
2.1b: Time, lack of disturbance or chronic drought decreases perennial bunchgrasses and allows increase in shrub cover.
2.2a: Time, lack of disturbance allows shrubs to reestablish.
2.3a: Low severity fire and/or grazing management and/or winter drought reduces the shrub component, allowing recovery of the perennial bunchgrass understory.
2.3b: Wildfire, prescribed burning or other brush removal treatments reduces shrub cover overstory, allowing perennial grasses to increase. Annual non-native species respond well to fire and may increase.

Transition T2A: Inappropriate, long-term grazing of perennial bunchgrasses and/or chronic spring/summer drought allows shrubs to increase.

Additional State and Transition Models for Group 15 in MLRA 29:



MLRA 29
Group 15
Eroded South Slope 12-14" P.Z.
R029XY166NV

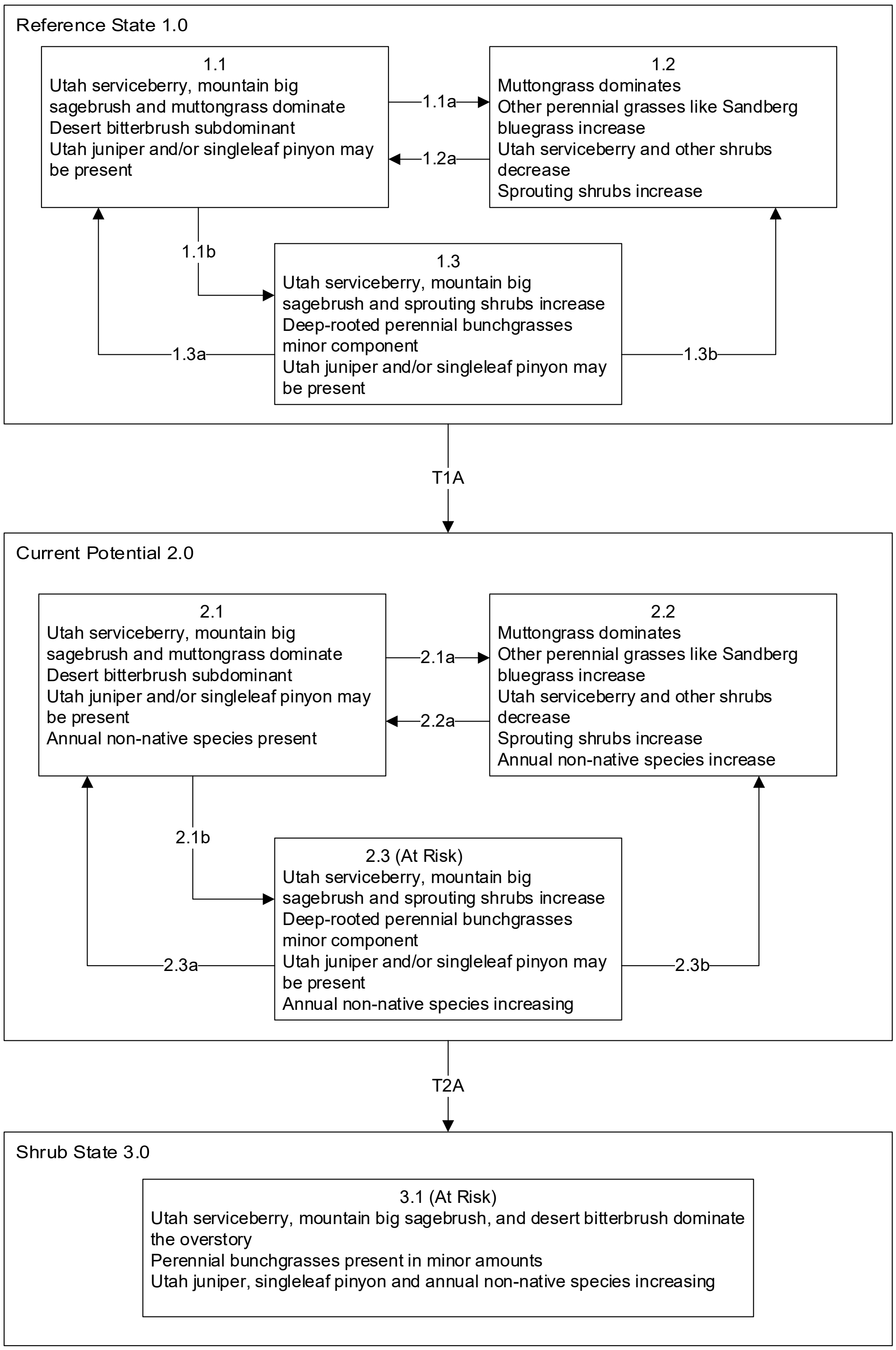
Reference State 1.0 Community Pathways
1.1a: Fire reduces or eliminates Stansbury cliffrose and Wyoming big sagebrush, allowing perennial grasses and sprouting shrubs to increase.
1.1b: Time, lack of disturbance or chronic drought decreases perennial bunchgrasses and allows increase in shrub cover.
1.2a: Time, lack of disturbance allows shrubs to reestablish.
1.3a: Low severity fire or other localized disturbances reduces big sagebrush and other non-sprouting shrub overstory and creates shrub/ grass mosaic. Chronic winter drought may also reduce shrub cover, allowing recovery of perennial bunchgrasses.
1.3b: Fire significantly reduces Stansbury cliffrose, sagebrush and other weak or non-sprouting shrubs and allows for perennial bunchgrasses to dominate site.

Transition T1A: Introduction of non-native annual species.

Current Potential 2.0 Community Pathways
2.1a: Fire reduces or eliminates Stansbury cliffrose and Wyoming big sagebrush, allowing perennial grasses and sprouting shrubs to increase. Annual non-native species are likely to increase.
2.1b: Time, lack of disturbance or chronic drought decreases perennial bunchgrasses and allows increase in shrub cover.
2.2a: Time, lack of disturbance allows shrubs to reestablish.
2.3a: Low severity fire and/or grazing management and/or winter drought reduces the shrub component, allowing recovery of the perennial bunchgrass understory.
2.3b: Wildfire, prescribed burning or other brush removal treatments reduces shrub cover overstory, allowing perennial grasses to increase. Annual non-native species respond well to fire and may increase.

Transition T2A: Inappropriate, long-term grazing of perennial bunchgrasses and/or chronic spring/summer drought allows shrubs to increase.

MLRA 29
Group 15
Stony Loam 12-16" P.Z.
R029XY098NV



MLRA 29
Group 15
Stony Loam 12-16" P.Z.
R029XY098NV

Reference State 1.0 Community Pathways
1.1a: Fire reduces or eliminates desert bitterbrush, Utah serviceberry, and mountain big sagebrush, allowing perennial grasses and sprouting shrubs to increase.
1.1b: Time, lack of disturbance or chronic drought decreases perennial bunchgrasses and allows increase in shrub cover.
1.2a: Time, lack of disturbance allows shrubs to reestablish.
1.3a: Low severity fire or other localized disturbances reduces mountain big sagebrush and other non-sprouting shrubs and creates shrub/grass mosaic. Chronic winter drought may reduce shrub cover, allowing recovery of perennial bunchgrasses.
1.3b: Fire reduces sagebrush and other weak or non-sprouting shrubs and allows for perennial bunchgrasses to dominate site.

Transition T1A: Introduction of non-native annual species.

Current Potential 2.0 Community Pathways
2.1a: Fire reduces or eliminates desert bitterbrush, Utah serviceberry, and mountain big sagebrush, allowing perennial grasses and sprouting shrubs to increase. Annual non-native species are likely to increase.
2.1b: Time, lack of disturbance or chronic drought decreases perennial bunchgrasses and allows increase in shrub cover.
2.2a: Time, lack of disturbance allows shrubs to reestablish.
2.3a: Low severity fire and/or grazing management and/or chronic winter drought reduces the shrub component, allowing recovery of the perennial bunchgrass understory.
2.3b: Wildfire, prescribed burning or other brush removal treatments reduces shrub cover, allowing perennial grasses to increase. Annual non-native species respond well to fire and may increase.

Transition T2A: Lack of fire, inappropriate, long-term grazing of perennial bunchgrasses and/or chronic spring/summer drought allows shrubs to increase.

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MLRA 29 Group 16: Clayey soils with low sagebrush and cool-season grasses

Description of MLRA 29 Disturbance Response Group 16

Disturbance Response Group (DRG) 16 consists of two ecological sites. The precipitation zone for these sites ranges from 8 to 14 in. (8–36 cm). The elevation range of this group is 5,500 to about 7,500 ft (1,676–2,286 m). Slopes range from 2 to 50%. Soils on these sites range from shallow to moderately deep with available water capacity ranging from moderately low to low. Soils exhibit root restrictive layers such as bedrock or dense clays within the subsoil which limit plant growth. The argillic horizon within the profile limits deep soil water percolation often leading to saturated near surface soil conditions in the spring and droughty soils in the summer. Due to slow percolation these soils can experience surface water loss through runoff. Annual production in a normal year ranges from 300 to 400 lb/ac for the group. The reference plant community for these sites varies depending on precipitation, elevation and landform. The shrub component is dominated by low sagebrush (*Artemisia arbuscula*), and muttongrass (*Poa fendleriana*), purple threeawn (*Aristida purpurea*), desert needlegrass (*Achnatherum speciosum*), and Indian ricegrass (*Achnatherum hymenoides*) are important understory grasses in this DRG.

Disturbance Response Group 16 Ecological Sites:

Cobbly Claypan 12-14" P.Z. – Modal	R029XY163NV
Claypan 8-12" P.Z.	R029XY062NV

Modal Site:

The Cobbly Claypan 12-14" P.Z. (R029XY163NV) ecological site is the modal for this group as it has the most acres mapped. This site occurs on sideslopes of hills and mountains on all exposures. Slope generally ranges from 2 to 50%, but slope gradients of 15 to 30% are most typical. Elevations are 5,500 to about 6,500 ft (1,676–1,981 m). Average annual precipitation is 12 to 14 in. (30–36 cm). The soils of this site are typically shallow, well drained and exhibit very slow permeability. The available water capacity is moderately low to low. Infiltration is restricted once soils are wetted and water is lost by runoff or evaporation. Soils have an argillic horizon with an abrupt textural boundary at a depth of 3 to 8 in. (8–20 cm). Surface soils have a high percentage of exposed rock fragments which limit area suitable for plant germination and survival.

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasive species. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans a unique area in Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. Most of the annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area. Flashy, summer storm events contribute significantly to annual precipitation as well. Air and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980)

However, periodic drought regularly influences sagebrush ecosystems, and drought duration and severity has increased throughout the 20th century in much of the Intermountain West (Schlaepfer et al. 2017, Wuebbles et al. 2017, Snyder et al. 2019). Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006).

The ecological sites in this DRG are dominated by deep-rooted cool-season, perennial bunchgrasses, a diversity of perennial forbs, and long-lived shrubs (50+ years) with high root to shoot ratios. The dominant shrubs usually root to the full depth of the winter-spring soil moisture recharge, but are limited on this site due to depth to a restrictive layer (duripan, bedrock) (Dobrowolski et al. 1990) to less than 1.0 m (3.3 ft) (Jensen 1990). These shrubs have a flexible generalized root system with development of both taproots and laterals near the surface (Comstock and Ehleringer 1992).

Low sagebrush is fairly drought tolerant, but also tolerates periodic wetness during some portions of the growing season (Fosberg and Hironaka 1964, Blackburn et al. 1968b, a, 1969, Hironaka 1994). It grows on soils that have a strongly-structured argillic horizon close to the soil surface, limiting available rooting depth (Fosberg and Hironaka 1964, Zamora and Tueller 1973, Winward 1980). Low sagebrush is also susceptible to the sagebrush defoliator, Aroga moth (*Aroga websteri*). Aroga moth can partially or entirely kill individual plants or entire stands of big sagebrush (Furniss and Barr 1975), but the research is inconclusive of the damage sustained by low sagebrush populations.

Utah serviceberry is a large shrub that grows from 2 to 4 m (6.5 to 13 ft) tall, and typically grows in big sagebrush, pinyon-juniper, and aspen communities (Hammond 2012). Despite typically being found surrounded by other species, serviceberry seedlings can be out-competed by dense stands of grasses and forbs. Utah serviceberry is top-killed by fire, but sprouts from an underground crown, and its branches, leaves, and berries all provide forage for wildlife and livestock (Noller 2008). *A. utahensis* is more drought tolerant than other serviceberry species, and its root system is very deep and spreading and well adapted to coarse-textured soils (Hammond 2012). However, Utah serviceberry has been found to be intolerant of high water tables and poorly drained soils. The only pest known to be a serious threat to Utah serviceberry is cedar-apple rust (*Gymnosporangium juniperi-virginianae*), which *A. utahensis* can host in its leaves and berries when growing in proximity to junipers (*Juniperus* spp.) (Wasser 1982).

The perennial bunchgrasses that are dominant include muttongrass, Indian ricegrass, and desert needlegrass. These species generally have somewhat shallower root systems than the shrubs, but root densities are typically higher than those of shrubs in the upper 0.5 m (1.6 ft) of the soil profile. General differences in root depth distributions between grasses and shrubs results in resource partitioning in these shrub/grass systems.

Muttongrass is a tufted, multi-flowered, cool-season perennial bunchgrass that can grow between 8 and 30 in. (20–76 cm) tall and has narrow leaves, which range from 1.5 to 4 m (<1 in.) wide. It is found in lower elevations in the northern extent of its native range, and higher elevations in the south. Muttongrass is one of the most drought-tolerant bluegrasses and is useful for restoring communities disturbed by fire, grazing, or mining, but is limited in its use due to low seed viability. Muttongrass plants are most frequently pistillate, but staminate plants do occasionally occur, which are able to hybridize and crossbreed with other bluegrasses. Muttongrass is found throughout the western United States as a primary component of the understory of pinyon-juniper communities and aspen and pine forests (Tilley et al. 2007).

Indian ricegrass is a long-lived, cool-season perennial bunchgrass that grows from 4 to 24 in. (10–61 cm) in height (Blaisdell and Holmgren 1984). Primarily adapted to coarse-textured soils, its deep, fibrous root system makes Indian ricegrass one of the most drought-tolerant native species (Booth et al. 1980). Unlike other cool-season species, Indian ricegrass does not require vernalization (exposure to cold) in order to produce flowers and flowering can continue into late fall with favorable environmental conditions. This allows the seeds in each panicle to ripen over a longer period of time than most other species thus providing a greater opportunity for successful seed production (Jones 1990).

Desert needlegrass is a cool-season, deep-rooted, perennial bunchgrass that grows from 1 to 2 ft (30–61 cm) tall. Primarily found on coarse soils with little or no profile development, the plant tolerates low precipitation environments and often occurs in areas that receive 3 to 14 in. (8–36 cm) of annual moisture (Perryman and Skinner 2007). Desert needlegrass, once mature, is not a preferred forage source with some use by cattle and little to none by sheep (Sampson et al. 1951).

The Great Basin sagebrush communities have high spatial and temporal variability in precipitation both among years and within growing seasons (MacMahon 1980). Nutrient availability is typically low but increases with elevation and closely follows moisture availability. The invasibility of plant communities is often linked to resource availability. The invasion of sagebrush communities by cheatgrass (*Bromus tectorum*) has been linked to disturbances (fire, abusive grazing, extended drought) that have resulted in fluctuations in resources (Beckstead and Augspurger 2004, Chambers et al. 2007, Johnson et al. 2011). Disturbance can increase resources for invasive species through native species mortality or damage. Soil water and nutrient availability can increase with native species mortality and decomposition further aiding invasive species establishment (Whisenant 1999, Miller et al. 2013).

The introduction of annual non-native species, like cheatgrass, may cause an increase in fire frequency and eventually lead to an annual dominated state. Long-term, chronic, growing season grazing, may reduce the perennial grass community and facilitate an increase in low sagebrush density and cover. Infilling by singleleaf pinyon (*Pinus monophylla*) and Utah juniper (*Juniperus osteosperma*) may also occur with an extended fire return interval. This will occur on sites that are proximate to existing stands of pinyon or juniper. In the absence of disturbance, singleleaf pinyon and Utah juniper may dominate the site and low sagebrush will be severely reduced along with the herbaceous understory. Bluegrasses may remain underneath trees on north-facing slopes. The potential for soil erosion increases as the Utah juniper woodland matures and the understory plant community cover declines.

The ecological sites in this DRG have low to moderate resilience to disturbance and resistance to invasion. Resilience increases with elevation, aspect, increased precipitation and increased nutrient availability. Long-term disturbance response may be influenced by small differences in landscape topography. Concave areas receive run-in from adjacent landscapes and consequently retain more moisture to support the growth of deep-rooted perennial grasses (i.e. Indian ricegrass or desert needlegrass) whereas convex areas are slightly less resilient and may have more shallow-rooted perennial grasses (i.e. bluegrass or squirreltail). North slopes are also more resilient than south slopes because lower soil surface temperatures operate to keep moisture content higher on northern exposures. Five possible stable states have been identified for this DRG.

Annual Invasive Species:

The species most likely to invade these sites are cheatgrass and red brome (*Bromus rubens*). Both species are cool-season, winter annual grasses that maintain an advantage over native plants in part because they are prolific seed producers, able to germinate in the autumn or spring and to increase with frequent fire (Klemmedson and Smith 1964, Miller et al. 1994). Although, inappropriate livestock grazing has been linked to cheatgrass expansion, a growing body of literature indicates cheatgrass is expanding into areas protected from or never exposed to livestock grazing (Reid et al. 2006). Red brome and cheatgrass originated from Eurasia and the Mediterranean regions and both were first reported in North America in the late 1800s (Furbush 1953, Mack and Pyke 1983, West 1994). Pellant and Hall (1994) found 3.3 million acres of public lands dominated by cheatgrass and suggested that another 76 million acres were susceptible to invasion. Unlike cheatgrass, red brome was intentionally seeded near the University of Arizona from 1906 to 1908 for evaluation as a forage plant where it soon escaped. By the 1960s, red brome dominated even relatively undisturbed areas of Nevada, Utah, and Arizona (Reid et al. 2006).

Methods to control annual invasive grasses include herbicide, fire, grazing, and seeding of primarily non-native wheatgrasses. Spraying with herbicide (imazapic or imazapic + glyphosate, or indaziflam) and seeding with introduced wheatgrass or a native grass / introduced wheatgrass mix has been found to be more successful than at combating cheatgrass than spraying alone (Sheley et al. 2012, Clements et al. 2022). Clements et al. (2022), found the application of imazapic was highly successful at decreasing cheatgrass densities and enhancing seed mix performance. The introduced seed mix performed significantly better than the native and native/introduced mix through year two of the study. Courkamp et al. (2022) compared the efficacy of indaziflam and imazapic for controlling cheatgrass through multiple years. Results suggest imazapic suppresses cheatgrass cover and density significantly for two years whereas indaziflam was effective for 4+ years.

Fire Ecology:

Low sagebrush is killed by fire and does not sprout (Tisdale and Hironaka 1981). Fire risk is greatest following a wet, productive year when there is greater production of fine fuels (Beardall and Sylvester 1976). Fire return intervals are not well understood because these ecosystems rarely coincide with fire-scarred conifers, however, a wide range of 20 to well over 100 years has been estimated (Miller and Rose 1995, 1999, Knick et al. 2005, Baker 2006). Historically, fires were probably patchy due to the low productivity of these sites (Beardall and Sylvester 1976, Ralphs and Busby 1979, Wright et al. 1979, Smith and Busby 1981). Fine fuel loads generally average 100 to 400 lb/ac but are occasionally as high as 600 lb/ac in low sagebrush habitat types (Bradley et al. 1992). Reestablishment occurs from off-site wind-dispersed seed (Young 1983). Recovery time of low sagebrush following fire is variable (Young 1983). Without sufficient seed source nearby, it may take decades for sagebrush to reestablish on a site. Little research has focused on low sagebrush recovery post-fire, but we have observed 25+ year old fire scars in this DRG with little to no recruitment. Slow regeneration may subsequently worsen erosion (Blaisdell and Holmgren 1984). We were unable to find any substantial research on success of seeding low sagebrush after fire.

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. Muttongrass, a dominant component on this site, is top killed by fire but will resprout after low to moderate severity fires. A study by Vose and White (1991) in an open sawtimber site found minimal difference in overall effect of burning on muttongrass.

Desert needlegrass may increase after burning. In a summation of 13 studies, Abella (2009) found that desert needlegrass increased in abundance (derived from cover, density, or frequency depending on the source of publication) on burned to unburned sites. Thatcher and Hart (1974) observed an increase in desert needlegrass in areas which appeared to have burned on a relict site, however they attributed this to soil type rather than species response. Webb and Wilshire (1980) found desert needlegrass exhibited 2 to 4 times more cover on streets of a Nevada ghost town which had been abandoned 51 years prior.

Indian ricegrass, is fairly fire tolerant which is likely due to its low culm density and below ground plant crowns (Wright 1985). Vallentine (1989) cites several studies in the sagebrush zone that classified Indian ricegrass as being slightly damaged from late summer burning. Indian ricegrass has also been found to reestablish on burned sites through seed dispersed from adjacent unburned areas (Young et al. 1983, West 1994). Thus, the presence of surviving, seed producing plants facilitates the reestablishment of Indian ricegrass. Grazing management following fire to promote seed production and establishment of seedlings is important. When properly planted and managed, Indian ricegrass can be a key factor in a community recovering from disturbance because it can grow in rough, rocky, coarse, and otherwise unattractive soils (Booth et al. 1980).

Thus, the initial condition of the bunchgrasses within the site, along with seasonality and intensity of the fire, all factor into the individual species response. Purple threeawn has been found to increase, post-fire, on rangelands in poor condition prior to fire. Additionally, spring grazing after fire likely will favor purple threeawn over the cool-season bunchgrasses (Evans and Tisdale 1972).

Utah serviceberry is a large, fire-tolerant shrub that is a sub-dominant component of this DRG. It is top-killed by fire, but sprouts from the underground root crown after disturbance (Bradley 1984). The plant is drought tolerant, exhibiting greater tolerance to dehydration than western serviceberry (*A. alnifolia*), a trait that should enhance the potential for crown sprouting following summer fire (Bradley 1984). *A. utahensis* can also re-colonize an area after fire via seeds, but this can require up to 8 to 10 years for plants to be fully matured and productive (Noller 2008).

The grasses likely to invade this site are cheatgrass and red brome. These invasive grasses displace desirable perennial grasses, reduce livestock forage, and accumulate large fuel loads that foster frequent fires (Davies and Svejcar 2008). Invasion by annual grasses can alter the fire cycle by increasing fire size, fire season length, rate of spread, numbers of individual fires, and likelihood of fires spreading into native or managed ecosystems (D'Antonio and Vitousek 1992, Brooks et al. 2004). While historical fire return intervals are estimated at 15 to 100 years, areas dominated with cheatgrass are estimated to have a fire return interval of 3 to 5 years (Whisenant and Uresk 1990). The mechanisms by which invasive annual grasses alter fire regimes likely interact with climate. For example, cheatgrass cover and biomass vary with climate (Chambers et al. 2007) and are promoted by wet and warm conditions during the fall and spring. Invasive annual species have been shown able to take advantage of high N availability following fire through higher growth rates and increased seedling established relative to native perennial grasses (Monaco et al. 2003).

Livestock/Wildlife Grazing Interpretations:

Domestic sheep and, to a much lesser degree, cattle consume low sagebrush, particularly during the spring, fall, and winter (Sheehy and Winward 1981). Heavy dormant season grazing by sheep will reduce sagebrush cover and increase grass production (Laycock 1967). Severe trampling damage to supersaturated soils could occur if sites are used in early spring when there is abundant snowmelt. Trampling damage, particularly from cattle or horses, in low sagebrush habitat types is greatest when high clay content soils are wet. In drier areas with more gravelly soils, no serious trampling damage occurs, even when the soils are wet (Hironaka et al. 1983). Bunchgrasses, in general, best tolerate light grazing after seed formation. Britton et al. (1990) observed the effects of clipping date on basal area of five bunchgrasses in eastern Oregon and found grazing from August to October (after seed set) has the least impact. Heavy grazing (> 60% utilization) during the growing season, for multiple years in a row, will reduce perennial bunchgrasses and increase sagebrush (Laycock 1967). Abusive grazing by cattle, sheep, or horses will likely increase low sagebrush, rabbitbrush, and some forbs such as arrowleaf balsamroot (*Balsamorhiza sagittata*). Annual non-native weedy species such as cheatgrass and mustards, and potentially medusahead, may invade.

Low sagebrush sites are often used for strutting grounds for the greater sage-grouse (*Centrocercus urophasianus*) because the low cover allows for high visibility of strutting males (McAdoo and Back 2001). Sage-grouse also use these sites during the winter where sagebrush provides food and cover (Braun et al. 2005).

Utah serviceberry is a very important plant because of the amount of food, cover, and habitat it provides to both livestock and wildlife. Its leaves, branches, and berries are used by many wildlife species, including big game, birds, and small animals (Noller 2008). *A. utahensis* is highly palatable to wildlife and livestock, and is a preferred forage for elk (McCulloch 1955).

Muttongrass is very palatable for wildlife and livestock and is rated as excellent forage for cattle and horses, and good for sheep. Muttongrass starts growth in late winter or early spring and provides excellent early feed. Muttongrass foliage cures well and is good fall forage, but not as good as spring or summer (Humphrey et al. 1952).

Desert needlegrass is palatable to all classes of livestock when young, however, after maturity it is avoided by sheep and moderately used by horses and cattle. The seed of desert needlegrass has a prominent, sharp callus that can injure the eyes and mouths of grazing animals, therefore grazing prior to seed set is typical. The plant tolerates light grazing in the growing season, however excessive use may reduce or eliminate desert needlegrass from the area (Perkins 2008).

State and Transition Model Narrative for Group 16:

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 29 Disturbance Response Group 16 modal ecological site.

Reference State 1.0:

The Reference State 1.0 is a representative of the natural range of variability under pristine conditions. The reference state has three general community phases: a shrub/grass co-dominant phase, a perennial grass dominant phase and a shrub-grass dominant phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire, periodic drought and/or insect or disease attack.

Community Phase 1.1:
The reference plant community is dominated by low sagebrush and muttongrass. Forbs and other grasses make up smaller components. Singleleaf pinyon and/or Utah juniper may be present. Potential vegetative composition is approximately 40% grasses, 10% forbs, 50% shrubs and up to 1% trees. Approximate ground cover (basal and crown) is 35 to 40%. Total annual air-dry production ranges from 300 to 600 lb/ac.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
Fire will decrease or eliminate the overstory of sagebrush and allow for the perennial bunchgrasses to dominate the site. Fires will typically be low severity resulting in a mosaic pattern due to low fuel loads. A fire following an unusually wet spring may be more severe and reduce sagebrush cover to trace amounts.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.3:
Time and lack of disturbance such as fire allows for sagebrush to increase and become decadent. Long-term drought, herbivory, or combinations of these will cause a decline in perennial bunchgrasses and fine fuels leading to a reduced fire frequency and allowing sagebrush to dominate the site.

Community Phase 1.2:
This community phase is characteristic of a post-disturbance, early/mid-seral community. Muttongrass and other perennial bunchgrasses dominate. Depending on fire severity patches of intact sagebrush may remain. Utah serviceberry, Gambel oak and other sprouting shrubs may increase. Perennial forbs may be a significant component for a number of years following fire.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
Time and lack of disturbance will allow sagebrush to increase.

Community Phase 1.3:
Sagebrush increases in the absence of disturbance. Decadent sagebrush dominates the overstory and the deep-rooted perennial bunchgrasses in the understory are reduced either from competition with shrubs and/or from herbivory.

Community Phase Pathway 1.3a, from Phase 1.3 to 1.1:
A low severity fire, herbivory or combinations will reduce the sagebrush overstory and create a sagebrush/grass mosaic.

Community Phase Pathway 1.3b, from Phase 1.3 to 1.2:
Fire will decrease or eliminate the overstory of sagebrush and allow for the perennial bunchgrasses to dominate the site. Fires may be high severity in this community phase due to the dominance of sagebrush resulting in removal of overstory shrub community.

T1A: Transition from the Reference State 1.0 to Current Potential State 2.0

Trigger: This transition is caused by the introduction of non-native annual plants, such as cheatgrass, red brome, and annual mustards.

Slow variables: Over time the annual non-native species will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

This state is similar to the Reference State 1.0 with the same three community phases. Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of invasive weeds. This state has three general community phases. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These feedbacks include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal.

Community Phase 2.1:
This community phase is similar to the Reference State Community Phase 1.1, with the presence of non-native species in trace amounts. Sagebrush and muttongrass dominate. Forbs and other shrubs and grasses make up smaller components of the community.

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
Fire reduces the shrub overstory and allows for perennial bunchgrasses to dominate. Fires are typically low severity resulting in a mosaic pattern due to low fuel loads. A fire following an unusually wet spring or a change in management favoring an increase in fine fuels may be more severe and reduce sagebrush cover to trace amounts. Annual non-native species are likely to increase after fire.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.3:
Time and lack of disturbance allows for sagebrush to increase and become decadent. Long-term drought may reduce bunchgrass density allowing sagebrush to dominate the site. Inappropriate grazing management reduces the perennial bunchgrass understory; conversely purple threeawn and/or squirreltail (*Elymus elymoides*) may increase in the understory depending on grazing management.

Community Phase 2.2:
This community phase is characteristic of a post-disturbance, early to mid-seral community where annual non-native species are present. Sagebrush is present in trace amounts; perennial bunchgrasses and perennial forbs dominate the site. Depending on fire severity patches of intact sagebrush may remain. Utah serviceberry, Gambel oak and other sprouting shrubs may increase. Annual non-native species are stable or increasing within the community.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Time and lack of disturbance and/or grazing management that favors the establishment and growth of sagebrush allows the shrub component to recover. The establishment of low sagebrush can take many years.

Community Phase 2.3 (At-Risk):
This community is at risk of crossing a threshold to another state. Sagebrush dominates the overstory and perennial bunchgrasses in the understory are reduced, either from competition with shrubs or from inappropriate grazing, or from both. Purple threeawn and/or squirreltail may increase and become dominant. Annual non-native species may be stable or increasing due to lack of competition with perennial bunchgrasses. This site is susceptible to further degradation from grazing, drought, and fire.

Community Phase Pathway 2.3a, from Phase 2.3 to 2.1:
A change in grazing management that reduces shrubs will allow for the perennial bunchgrasses in the understory to increase. Heavy late-fall or winter grazing may cause mechanical damage and subsequent death to sagebrush, facilitating an increase in the herbaceous understory. Brush treatments with minimal soil disturbance will also decrease sagebrush and release the perennial understory. A low severity fire would decrease the overstory of sagebrush and allow for the understory perennial grasses to increase. Due to low fuel loads in this state, fires will likely be small creating a mosaic pattern. Annual non-native species are present and may increase in the community.

Community Phase Pathway 2.3b, from Phase 2.3 to 2.2:
Fire eliminates/reduces the overstory of sagebrush and allows for the understory perennial grasses to increase. Fires may be high severity in this community phase due to the dominance of sagebrush resulting in removal of overstory shrub community. Utah serviceberry, Gambel oak or other sprouting shrubs may increase. Annual non-native species respond well to fire and may increase post burn.

T2A: Transition from Current Potential State 2.0 to Shrub State 3.0:

Trigger: To Community Phase 3.1: Inappropriate grazing will decrease or eliminate deep-rooted perennial bunchgrasses and increase bare ground and grazing-tolerant grasses. Shrub growth and establishment is favored under these conditions. To Community Phase 3.2: Severe fire in Community Phase 2.3 will remove sagebrush overstory, decrease perennial bunchgrasses and enhance mat-forming forb production. Purple threeawn and/or squirreltail may increase. Annual non-native species are present.

Slow variables: Long-term decrease in deep-rooted perennial grass density.

Threshold: Loss of deep-rooted perennial bunchgrasses changes nutrient cycling, nutrient redistribution, and reduces soil organic matter.

T2B: Transition from Current Potential State 2.0 to Tree State 5.0

Trigger: Time and lack of disturbance facilitates establishment and maturation of singleleaf pinyon and Utah juniper trees.

Feedbacks and ecological processes: Trees increasingly dominate use of soil water, contributing to reductions in soil water availability to grasses and shrubs. Overtime, grasses and shrubs are outcompeted. Reduced herbaceous and shrub production slows soil organic matter inputs and increases soil erodibility through loss of cover and root structure.

Slow variables: Long-term increase in singleleaf pinyon and/or singleleaf pinyon density.

Threshold: Trees dominate ecological processes. Number of shrub skeletons exceed number of live shrubs.

T2C: Transition from Current Potential State 2.0 to Annual State 4.0:

Trigger: Catastrophic fire or soil disturbing vegetation treatment would transition to Community Phase 4.1.

Slow variables: Increased production and cover of non-native annual species.

Threshold: Loss of deep-rooted perennial bunchgrasses and shrubs changes temporal and spatial nutrient capture and cycling within the community. Increased, continuous fine fuels modify the fire regime by increasing frequency, size and spatial variability of fires.

Shrub State 3.0:

This state is a product of many years of heavy grazing during time periods harmful to perennial bunchgrasses. Purple threeawn and/or squirreltail increase and become dominant as the more palatable muttongrass decreases. Bare ground increases significantly. Annual forbs may be a significant or dominant component of the understory, resulting in bare ground after they senesce in the summer. Perennial mat-forming forbs may increase. Sagebrush dominates the overstory and sprouting shrubs may be a significant component. Sagebrush cover exceeds site concept and may be decadent, reflecting stand maturity and lack of seedling establishment due to competition with mature plants. The shrub overstory and purple threeawn / squirreltail / annual forbs understory dominate site resources such that soil water, nutrient capture, nutrient cycling and soil organic matter are temporally and spatially redistributed.

Community Phase 3.1 (At Risk):
Decadent sagebrush dominates the overstory. Sprouting shrubs may be a significant component. Deep-rooted perennial bunchgrasses are present in trace amounts or may be absent from the community. Purple threeawn and/or squirreltail, and/or annual forbs dominate the understory. Perennial mat-forming forbs may increase. Bare ground may be significant. Singleleaf pinyon and/or Utah juniper may be encroaching but are not yet affecting understory vegetation.

Cobbly Claypan 12-14" P.Z. (R029XY163NV), Shrub State 3.1, T. Stringham, June 2022

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:
Fire, and/or heavy fall grazing causing mechanical damage to shrubs will greatly reduce the sagebrush to trace amounts and allow for purple threeawn and/or squirreltail and/or annual forbs to dominate the understory. Sprouting shrubs increase.

Community Phase 3.2:
Purple threeawn and/or squirreltail and/or annual forbs are dominant. Deep-rooted perennial bunchgrasses are a minor component or missing. Annual non-native species may be present but are not dominant. Sprouting shrubs dominate overstory. Trace amounts of sagebrush may be present. Singleleaf pinyon and/or Utah juniper may be present but are not yet affecting understory vegetation.

Community Phase Pathway 3.2a, from Phase 3.2 to 3.1:
Time and lack of disturbance and/or grazing management that favors the establishment and growth of sagebrush allows the shrub component to recover. The establishment of low sagebrush can take many years.

T3A: Transition from Shrub State 3.0 to Annual State 4.0:

Trigger: Fire and/or treatments that disturb the soil and existing plant community.

Slow variables: Increased seed production (following a wet spring) and cover of annual non-native species.

Threshold: Increased, continuous fine fuels modify the fire regime by changing frequency, intensity, size and spatial variability of fires. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and sagebrush truncate energy capture and impact the temporal and spatial aspects of nutrient cycling and distribution.

T3B: Transition from Shrub State 3.0 to Tree State 5.0:

Trigger: Absence of disturbance over time allows Utah juniper and/or singleleaf pinyon dominance.

Feedbacks and ecological processes: Trees increasingly dominate use of soil water, contributing to reductions in soil water availability to grasses and shrubs. Overtime, grasses and shrubs are outcompeted. Reduced herbaceous and shrub production slows soil organic matter inputs and increases soil erodibility through loss of cover and root structure.

Slow variables: Long-term increase in singleleaf pinyon pine and/or Utah juniper density.

Threshold: Trees overtop sagebrush and out-compete shrubs for water and sunlight. Shrub skeletons exceed live shrubs in number. There is minimal recruitment of new shrub cohorts.

Annual State 4.0:

An abiotic threshold has been crossed and state dynamics are driven by fire and time. The herbaceous understory is dominated by annual non-native species such as cheatgrass and mustards. Resiliency has declined and further degradation from fire facilitates a cheatgrass and sprouting shrub plant community. Fire return interval has shortened due to the dominance of cheatgrass in the understory and is a driver in site dynamics.

Community Phase 4.1:
Annuals non-native species dominate. Sagebrush and perennial bunchgrasses may still be present in trace amounts. Surface erosion may increase with summer convection storms and would be verified through increased pedestalling of plants, rill formation or extensive water flow paths.

Community Phase Pathway 4.1a, from Phase 4.1 to 4.2:
Time and lack of disturbance allows Gambel oak and/or other sprouting shrubs to recover after fire. Probability of sagebrush establishment is extremely low.

Community Phase 4.2:
Utah serviceberry and Gambel oak are typically the dominant overstory shrubs. Sagebrush is a minor component or missing. Annual non-native species dominate the understory.


Cobbly Claypan 12-14" P.Z. (R029XY163NV), Annual State 4.2, T. Stringham, June 2022

Community Phase Pathway 4.2a, from Phase 4.2 to 4.1:
Fire reduces/eliminates overstory brush component and allows for annual non-native species to dominate the site.

Tree State 5.0:

This state is characterized by a dominance of Utah juniper and/or singleleaf pinyon in the overstory. Low sagebrush and perennial bunchgrasses may still be present, but they are no longer controlling site resources. Soil moisture, soil nutrients and soil organic matter distribution and cycling have been spatially and temporally altered.

Community Phase 5.1:
Utah juniper and/or singleleaf pinyon dominates the overstory and site resources. Trees are actively growing with noticeable leader growth. Trace amounts of muttongrass may be found under tree canopies along with purple threeawn and squirreltail. Mat-forming forbs may dominate interspace. Sagebrush is stressed and dying. Annual non-native species are present under tree canopies. Bare ground interspaces are large and connected.

Community Phase Pathway 5.1a, from Phase 5.1 to 5.2:
Time and lack of disturbance or management action allows Utah juniper and/or singleleaf pinyon to further mature and dominate site resources.

Community Phase 5.2:
Utah juniper and/or singleleaf pinyon dominates the site and tree leader growth is minimal; annual non-native species may be the dominant understory species and will typically be found under the tree canopies. Trace amounts of sagebrush may be present;

however, dead skeletons will be more numerous than living sagebrush. Bunchgrass may or may not be present. Mat-forming forbs may be present in trace amounts. Bare ground interspaces are large and connected. Soil redistribution is evident.

Community Phase Pathway 5.2a, from Phase 5.2 to 5.1:
Tree thinning treatment, typically done for fuels management.

T5A: Transition from Tree State 5.0 to Annual State 4.0:

Trigger: Catastrophic fire causing a stand replacement event will cause a transition to Annual State 4.1. Inappropriate tree removal practices with soil disturbance will cause a transition to the Annual State 4.0.

Slow variables: Increased production and cover of non-native annual species under tree canopies.

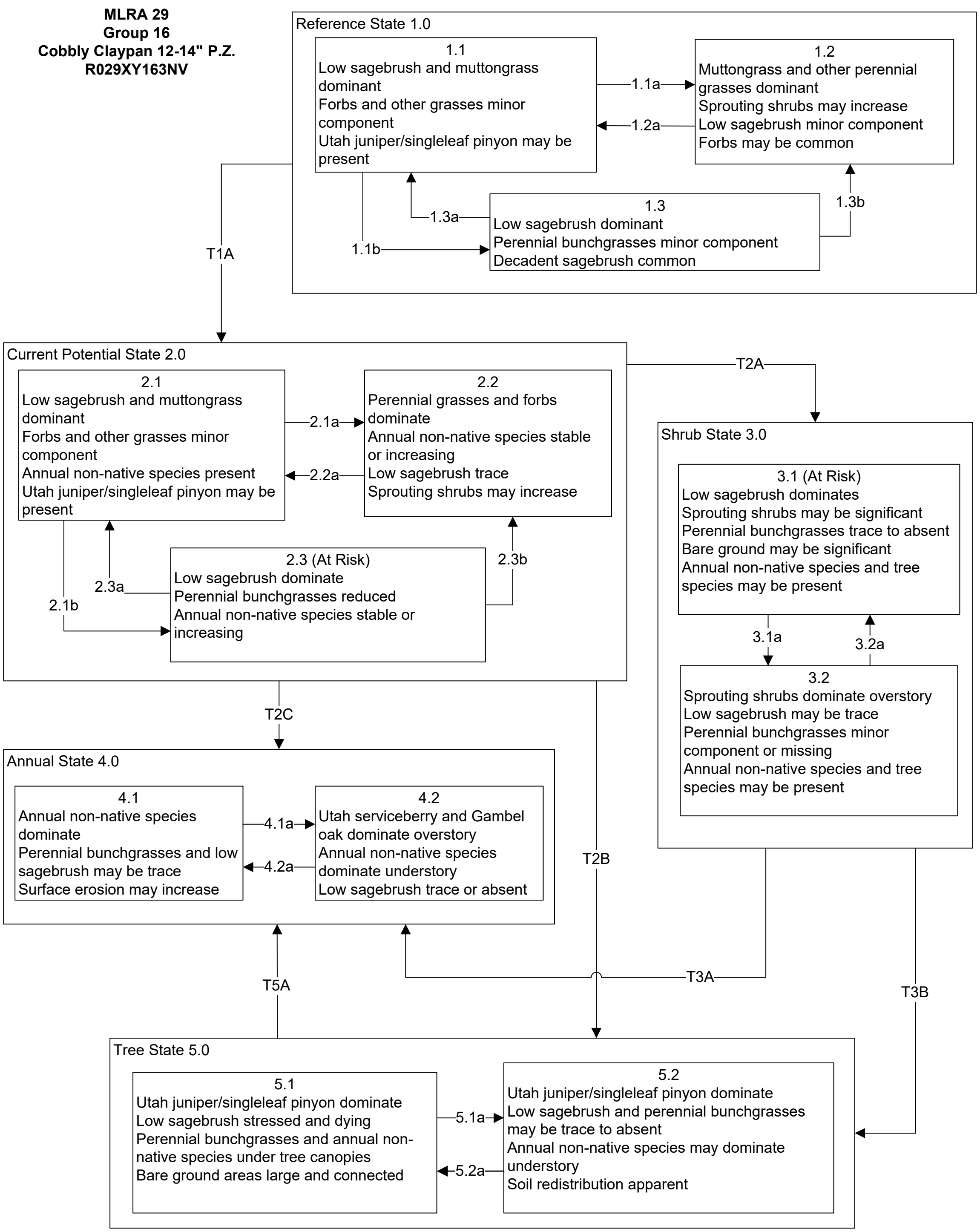
Threshold: Closed tree canopy with non-native annual species dominant in the understory changes the intensity, size and spatial variability of fires. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and sagebrush truncate energy capture and impact nutrient cycling and distribution.

Potential Resilience Differences with Other Ecological Sites in this Group:

Claypan 8-12" P.Z. (R029XY062NV):

This site is similar to the modal site, however desert needlegrass and Indian ricegrass are the dominant understory grasses. The presence of these two grasses indicates a drier and less resilient plant community. Production is slightly lower than the modal site for this DRG, reflecting the hotter and drier conditions. The likelihood of a tree state is minimal, however where this site is located adjacent to singleleaf pinyon and/or Utah juniper woodlands the potential for encroachment exists. This site is similar to the modal site with five stable states.

Modal State and Transition Model for Group 16 in MLRA 29:



MLRA 29
Group 16
Cobbly Claypan 12-14" P.Z.
R029XY163NV

Reference State 1.0 Community Pathways
1.1a: Low severity fire, herbivory, insect attack, or combinations creates grass/sagebrush mosaic. High severity fire is possible and may significantly reduce sagebrush and lead to early/mid-seral community, dominated by perennial grasses and sprouting shrubs.
1.1b: Time and lack of disturbance such as fire, chronic drought, inappropriate grazing management, or combinations of these would allow the sagebrush overstory to increase and dominate the site.
1.2a: Time and lack of disturbance allows for shrub re-establishment.
1.3a: Low severity fire, herbivory, insect attacks, or combinations will reduce sagebrush and create a sagebrush/grass mosaic.
1.3b: High severity fire significantly reduces sagebrush cover allowing for perennial bunchgrasses and sprouting shrubs to dominate, leading to early/mid-seral community.

Transition T1A: Introduction of annual non-native species.

Current Potential State 2.0 Community Pathways:
2.1a: Low severity fire, herbivory, insect attack, or combinations creates grass/sagebrush mosaic. High severity fire is possible and may significantly reduce sagebrush and lead to early/mid-seral community, dominated by perennial grasses and sprouting shrubs; non-native annual species likely to increase after fire.
2.1b: Time and lack of disturbance such as fire, chronic drought, inappropriate grazing management, or combinations of these would allow the sagebrush overstory to increase and dominate the site.
2.2a: Time and lack of disturbance and/or grazing management that favors shrub establishment.
2.3a: Low severity fire, late fall/winter grazing, or brush treatment with minimal soil disturbance creates sagebrush/grass mosaic.
2.3b: High severity fire significantly reduces sagebrush cover and leads to early/mid-seral community. Annual non-native species and sprouting shrubs may increase post-burn.

Transition T2A: Inappropriate grazing management favoring shrub dominance, increasing bare ground, and reducing perennial bunchgrasses will lead to Shrub State 3.1. Severe fire in Community Phase 2.3 will decrease sagebrush overstory and perennial bunchgrasses.
Transition T2B: Time and lack of disturbance allows for maturation of tree community.
Transition T2C: Catastrophic fire or soil disturbing treatment leads to Annual State 4.1.

Shrub State 3.0 Community Pathways
3.1a: Fire and/or heavy fall grazing reduces shrub cover, allowing perennial grasses and annual forbs to dominate with sprouting shrubs increasing.
3.2a: Time and lack of disturbance, and/or grazing management that favors shrub re-establishment.

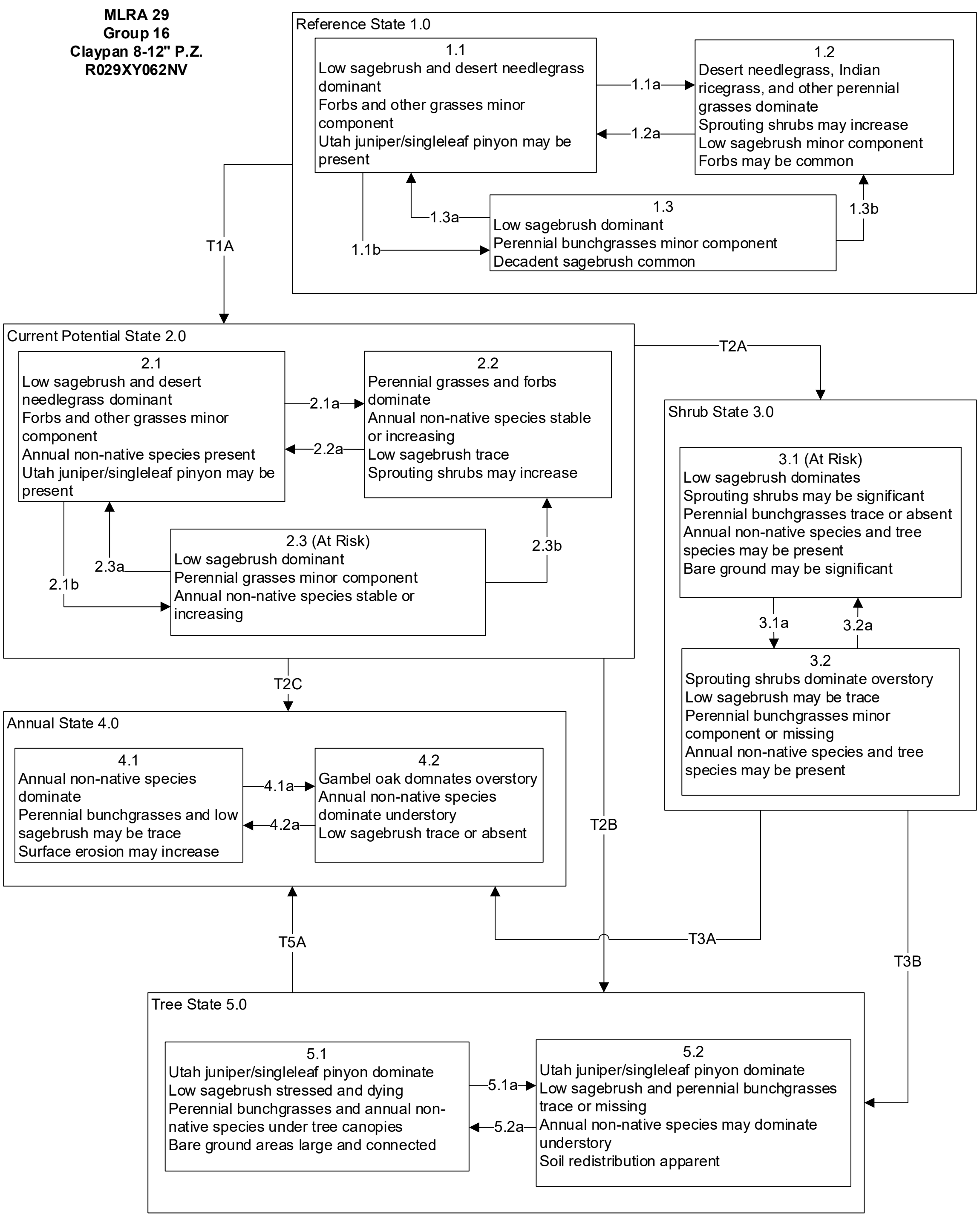
Transition T3A: Fire and/or soil disturbing treatments alter the plant community.
Transition T3B: Time and lack of disturbance allows for maturation of the tree community.

Annual State 4.0
4.1a: Time and lack of disturbance allows Utah serviceberry, Gambel oak, and/or other sprouting shrubs to recover after fire.
4.2a: Fire reduces or eliminates shrub overstory, allowing annual non-native species to dominate.

Tree State 5.0 Community Pathways
5.1a: Time and lack of disturbance, or management action allows for maturation of the tree community.
5.2a: Tree thinning treatment.

Transition T5A: Catastrophic fire that significantly reduces or eliminates tree and any remaining shrub overstory will cause transition to Annual State 4.1. Inappropriate tree removal practices with soil disturbances will cause transition to Annual State 4.0.

Additional State and Transition Models for Group 16 in MLRA 29:



MLRA 29
Group 16
Claypan 8-12" P.Z.
R029XY062NV

Reference State 1.0 Community Pathways
1.1a: Low severity fire, herbivory, insect attack, or combinations creates grass/sagebrush mosaic. High severity fire is possible and may significantly reduce sagebrush and lead to early/mid-seral community, dominated by perennial grasses and sprouting shrubs.
1.1b: Time and lack of disturbance such as fire, chronic drought, inappropriate grazing management, or combinations of these would allow the sagebrush overstory to increase and dominate the site.
1.2a: Time and lack of disturbance allows for shrub re-establishment.
1.3a: Low severity fire, herbivory, insect attacks, or combinations will reduce sagebrush and create a sagebrush/grass mosaic.
1.3b: High severity fire significantly reduces sagebrush cover allowing for perennial bunchgrasses and sprouting shrubs to dominate, leading to early/mid-seral community.

Transition T1A: Introduction of annual non-native species.

Current Potential State 2.0 Community Pathways:
2.1a: Low severity fire, herbivory, insect attack, or combinations creates grass/sagebrush mosaic. High severity fire is possible and may significantly reduce sagebrush and lead to early/mid-seral community, dominated by perennial grasses and sprouting shrubs; non-native annual species likely to increase after fire.
2.1b: Time and lack of disturbance such as fire, chronic drought, inappropriate grazing management, or combinations of these would allow the sagebrush overstory to increase and dominate the site.
2.2a: Time and lack of disturbance and/or grazing management that favors shrub establishment.
2.3a: Low severity fire, late fall/winter grazing, or brush treatment with minimal soil disturbance creates sagebrush/grass mosaic.
2.3b: High severity fire significantly reduces sagebrush cover and leads to early/mid-seral community. Annual non-native species and sprouting shrubs may increase post-burn.

Transition T2A: Inappropriate grazing management favoring shrub dominance, increasing bare ground, and reducing perennial bunchgrasses will lead to Shrub State 3.1. Severe fire in Community Phase 2.3 will decrease sagebrush overstory and perennial bunchgrasses.
Transition T2B: Time and lack of disturbance allows for maturation of tree community.
Transition T2C: Catastrophic fire or soil disturbing treatment leads to Annual State 4.1.

Shrub State 3.0 Community Pathways
3.1a: Fire and/or heavy fall grazing reduces shrub cover, allowing perennial grasses and annual forbs to dominate with sprouting shrubs increasing.
3.2a: Time and lack of disturbance, and/or grazing management that favors shrub re-establishment.

Transition T3A: Fire and/or soil disturbing treatments.
Transition T3B: Time and lack of disturbance allows for maturation of the tree community.

Annual State 4.0
4.1a: Time and lack of disturbance allows Gambel oak and/or other sprouting shrubs to recover after fire
4.2a: Fire reduces or eliminates shrub overstory, allowing annual non-native species to dominate.

Tree State 5.0 Community Pathways
5.1a: Time and lack of disturbance, or management action allows for maturation of the tree community.
5.2a: Tree thinning treatment.

Transition T5A: Catastrophic fire that significantly reduces or eliminates tree and any remaining shrub overstory will cause transition to Annual State 4.1. Inappropriate tree removal practices with soil disturbances will cause transition to Annual State 4.0.

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MLRA 29 Group 17: High precipitation zone low sagebrush with needlegrasses

Description of MLRA 29 Disturbance Response Group 17

Disturbance Response Group (DRG) 17 consists of four ecological sites. The annual precipitation for these sites ranges from 12 to over 20 in. (30–51 cm). Elevations range from 6,000 to over 9,500 ft (1,829–2,896 m). Slopes range from 2 to over 50%, however, slopes of 4 to 30% are typical. Soils for these sites range from very shallow to moderately deep, and they typically exhibit a clay layer that can restrict root growth. The reference plant communities of these sites are dominated by low sagebrush (*Artemisia arbuscula*), black sagebrush *(Artemisia nova)*, Thurber's needlegrass (*Achnatherum thurberianum*), Letterman's needlegrass (*Achnatherum lettermanii),* and muttongrass (*Poa fendleriana)*. Production for a normal year ranges from 250 to 450 lb/ac.

Disturbance Response Group 17 Ecological Sites:

Claypan 16" + P. Z. – Modal	R029XY052NV
Claypan 12-16" P.Z.	R029XY055NV
Mountain Ridge 16" + P.Z.	R029XY053NV
Mountain Ridge 12-16" P.Z.	R029XY056NV

Modal Site:

The Claypan 16"+ P.Z. (R029XY052NV) ecological site is the modal site for this group, as it has the most acres mapped. This site occurs on straight to convex mountain summits and sideslopes on all exposures. This site is restricted to northerly aspects at the lower elevations of its occurrence. Slopes range from 2 to over 50%, but slope gradients of 4 to 30% are most typical. Elevations are 8,000 to about 9,500 ft (2,438–2,896 m). Average annual precipitation is about 16 to over 20 in. (41–51 cm). Production in a normal year is 450 lb/ac. The soils in this site are typically shallow to moderately deep and formed in residuum and colluvium, and the potential for sheet and rill erosion is moderate. Many soils have only a thin, clayey horizon just above bedrock. Water holding capacity is moderate, permeability is moderate, and runoff is medium to rapid.

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasive species. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans a unique area in Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area. Flashy, summer storm events contribute significantly to annual precipitation as well. Air and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

The ecological sites in this DRG are dominated by shallow and deep-rooted cool season, perennial bunchgrasses, and long-lived shrubs (50+ years) with high root-to-shoot ratios. The dominant shrubs usually root to the full depth of the winter-spring soil moisture recharge, which ranges from 1 to over 3 m (3.3 to 9.8 ft) (Dobrowolski et al. 1990). However, community types with low sagebrush as the dominant shrub were found to have soil depths and thus available rooting depths of 71 to 81 cm (28 to 33 in.) in a study in northeast Nevada (Jensen 1990). These shrubs have a flexible generalized root system with development of both deep taproots and laterals near the surface (Comstock and Ehleringer 1992). The ecological sites in this group have very shallow soil depths, resulting in low available water holding capacity and therefore low productivity. Additionally, these sites occur on harsh windswept ridgeline positions that favor low-stature vegetation.

Periodic drought regularly influences sagebrush ecosystems, and drought duration and severity has increased throughout the 20th century in much of the Intermountain West. Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability with the soil profile (Bates et al. 2006).

Low sagebrush is fairly drought tolerant but also tolerates periodic wetness during the early growing season. Low sagebrush is also susceptible to the sagebrush defoliator, Aroga moth

(*Aroga websteri*). Aroga moth can partially or entirely kill individual plants or entire stands of big sagebrush (Furniss and Barr 1975), but the research is inconclusive on the damage sustained by low sagebrush populations. Low sagebrush is very similar to black sagebrush, but black sagebrush has entire leaves on the flowering stems and stalked flower heads (Tilley and St. John 2012a).

Black sagebrush is co-dominate on the Mountain Ridge 12-16" P.Z. (R029XY056NV) ecological site. Black sagebrush is generally long-lived; therefore, it is not necessary for new individuals to recruit every year for perpetuation of the stand. Black sagebrush usually inhabits sites intolerable for other sagebrush species (Tilley and St. John 2012a).

The Great Basin sagebrush communities have high spatial and temporal variability in precipitation both among years and within growing seasons. Nutrient availability is typically low but increases with elevation and closely follows moisture availability. The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and depressed competition or can increase resource pools by the decomposition of dead plant material following disturbance. The invasion of sagebrush communities by cheatgrass (*Bromus tectorum*) has been linked to disturbances (fire, abusive grazing) that have resulted in fluctuations in resources (Chambers et al. 2007).

The perennial bunchgrasses that are dominant include Thurber’s needlegrass, Letterman’s needlegrass, and muttongrass. These species generally have somewhat shallower root systems than associated shrubs, but root densities are often as high as or higher than those of shrubs in the upper 0.5 m (1.6 ft) of the soil profile. General differences in root depth distributions between grasses and shrubs result in resource partitioning in these shrub/grass systems.

Thurber’s needlegrass is a densely caespitose native perennial bunchgrass with culms 30 to 60 cm (12 to 24 in.) tall which regenerates through seeds and tillers (Stubbendieck et al. 1992). Analysis of NRCS soils data shows that Thurber’s needlegrass has a statistically significant preference for more clay-rich soil in the top 50 cm (20 in.) of the soil profile when compared to perennial grasses, in general, within Nevada (Soil Survey Staff 2024). Analysis of BLM terrestrial vegetation monitoring data within MLRA 29 suggests that this species most commonly co-occurs in shrub communities with yellow rabbitbrush (*Chrysothamnus viscidiflorus*), jointfir (*Ephedra spp.*), black sagebrush, and spiny hopsage (*Grayia spinosa*), along with squirreltail (*Elymus elymoides*), Indian ricegrass (*Achnatherum hymenoides*), and galleta (*Pleuraphis jamesii*) as the most common co-occurring perennial grasses (BLM 2024a, b). Within this group, Thurber's needlegrass is found in the ecological sites in the 12–16 in. (30–41 cm) precipitation zone.

Letterman's needlegrass is a native perennial bunchgrass that typically grows in large clumps. It reproduces by seed and is characterized as an aggressive seed producer, which allows it to repopulate areas affected by disturbance (Ellison and Aldous 1952). Analysis of terrestrial monitoring data shows that Letterman's needlegrass shares a similar shrub and grass co-occupancy profile to Thurber's needlegrass, with the exception that it also co-occurs commonly with low sagebrush in areas with more singleleaf pinyon (*Pinus monophylla*) and Utah juniper (*Juniperus osteosperma*) while having a higher co-occurrence with muttongrass instead of James' galleta (BLM 2024a). This grass is found at the higher elevation ecological sites within this group (16+ in.).

Muttongrass, one of the dominant understory species of this group, is a tufted, multi-flowered, perennial bunchgrass that can grow between 8 and 30 in. (20–76 cm) tall and has narrow leaves, which range from 1 to 3 mm (<1 in.) wide. It is found in lower elevations in the northern extent of its native range, and higher elevations in the south. Muttongrass is one of the most drought-tolerant bluegrasses and is useful for restoring communities disturbed by fire, grazing, or mining, but is limited in its use due to low seed viability. Muttongrass plants are most frequently pistillate, but staminate plants do occasionally occur, which are able to hybridize and crossbreed with other bluegrasses. Muttongrass is found throughout the western United States as a primary component of the understory of pinyon-juniper communities and aspen and pine forests (Tilley et al. 2007). Analysis of NRCS soils data shows that, like Thurber's needlegrass, muttongrass has a preference for more clay rich soils when compared to perennial grasses as a whole in Nevada (Soil Survey Staff 2024). Analysis for terrestrial monitoring data in MLRA 29 shows primary woody co-occurrence with singleleaf pinyon and Utah juniper, with primary associated shrubs being Mormon tea (*Ephedra viridis*), yellow rabbitbrush, Utah serviceberry (*Amelanchier utahensis*), and Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*). Perennial grasses commonly co-occurring with muttongrass are squirreltail, Sandberg bluegrass (*Poa secunda*), and Indian ricegrass (BLM 2024a, b).

The ecological sites in this DRG have moderate to high resilience to disturbance and resistance to invasion. Resilience increases with elevation, aspect, increased precipitation, and increased nutrient availability. Three possible alternative stable states have been identified for this DRG.

Annual Invasive Species:

The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and decomposition of dead plant material following disturbance further increases resource pools. The presence of exotic annual plants within these ecosystems decreases ecosystem resilience and resistance to disturbance through competition for limited resources. Dobrowolski et al. (1990) cite multiple authors on the extent of the soil profile exploited by the competitive exotic annual cheatgrass.

Specifically, the depth of rooting is dependent on the size the plant achieves, and in competitive environments, cheatgrass roots were found to penetrate only 15 cm (6 in.) whereas isolated plants and pure stands were found to root at least 1 m (3.2 ft) in depth with some plants rooting as deep as 1.5 to 1.7 m (4.9 to 5.6 ft).

The species most likely to invade these sites is cheatgrass. Cheatgrass is a cool-season annual grass that maintains an advantage over native plants in part because it is a prolific seed producer, can germinate in the autumn or spring, tolerates grazing, and increases with frequent fire (Klemmedson and Smith 1964, Miller and Rose 1999). Cheatgrass originated from Eurasia and was first reported in North America in the late 1800s (Furbush 1953, Mack and Pyke 1983). Pellant and Hall (1994) found 3.3 million acres of public lands dominated by cheatgrass and suggested that another 76 million acres were susceptible to invasion by winter annuals including cheatgrass.

Recent modeling and empirical work by Bradford and Lauenroth (2006) suggest that seasonal patterns of precipitation input and temperature are also key factors determining regional variation in the growth, seed production, and spread of invasive annual grasses. The phenomenon of cheatgrass "die-off" provides opportunities for restoration of perennial and native species (Baughman et al. 2016, Baughman et al. 2017). The causes of these events are not fully understood, but there is ongoing work to try to predict where they occur, in the hopes of aiding conservation planning (Weisberg et al. 2017, Brehm 2019).

Methods to control cheatgrass include herbicide application, prescribed fire, targeted grazing, and rangeland seeding. Mapping potential or current invasion vectors is a management method designed to increase the cost-effectiveness of control methods. Spraying with herbicide (imazapic or imazapic + glyphosate) and seeding with crested wheatgrass (*Agropyron cristatum*) and Sandberg bluegrass has been found to be more successful at combating cheatgrass than spraying alone (Sheley et al. 2012). To date, most seeding success has occurred with non-native wheatgrass species. Perennial grasses, especially crested wheatgrass, are able to suppress cheatgrass growth when mature (Blank et al. 2020). Where native bunchgrasses are missing from the site, revegetation of annual grass-invaded rangelands has been shown to have a higher likelihood of success when using introduced perennial bunchgrasses such as crested wheatgrass (Davies et al. 2015b, Clements et al. 2017). Butler et al. (2011) tested four herbicides (imazapic, imazapic + glyphosate, rimsulfuron, and sulfometuron + chlorsulfuron) for suppression of cheatgrass, medusahead (*Taeniatherum caput-medusae*), and North Africa grass (*Ventenata dubia*) within residual stands of native bunchgrass. Additionally, they tested the same four herbicides followed by seeding of six bunchgrasses (native and non-native) with varying success (Butler et al. 2011). Herbicide-only treatments appeared to remove competition for established bluebunch wheatgrass by providing 100% control of North Africa grass and medusahead and greater than 95% control of cheatgrass (Butler et al. 2011). Caution in using these results is advised, as only 1 year of data was reported.

In considering the combination of pre-emergent herbicide and prescribed fire for invasive annual grass control, it is important to assess the tolerance of desirable brush species to the herbicide being applied. Vollmer and Vollmer (2008) tested the tolerance of mountain mahogany (*Cercocarpus montanus*), antelope bitterbrush, and multiple sagebrush species to three rates of imazapic with and without methylated seed oil as a surfactant. They found that a cheatgrass control program, utilizing imazapic, in an antelope bitterbrush community should not exceed 8 oz/ac with or without surfactant. Sagebrush, regardless of species or rate of application, was not affected. However, many environmental variables were not reported in this study and managers should install test plots before broad-scale herbicide application is initiated.

Fire Ecology:

Fire is not a major ecological component of these community types (Winward 2001), and would be patchy and infrequent when they occur due to the low productivity of the sites. Fire return intervals have been estimated at 100 to 200 years (Kitchen and McArthur 2007). Low sagebrush is killed by fire and does not sprout (Tisdale and Hironaka 1981). Establishment after fire is from seed, generally blown in and not from the seed bank (Bradley et al. 1992). Fire risk is greatest following a wet, productive year when there is greater production of fine fuels (Beardall and Sylvester 1976). Fine fuel loads generally average 100 to 400 lb/ac but are occasionally as high as 600 lb/ac in low sagebrush habitat types (Bradley et al. 1992). Recovery time of low sagebrush following fire is variable (Young 1983). After fire, if regeneration conditions are favorable, low sagebrush recovers in 2 to 5 years, however, on harsh sites where cover is low to begin with and/or erosion occurs after fire, recovery may require more than 10 years (Young 1983). Slow regeneration may subsequently worsen erosion (Blaisdell et al. 1982).

Black sagebrush plants have no morphological adaptations for surviving fire and must reestablish from seed following fire (Wright et al. 1979). The ability of black sagebrush to establish after fire is mostly dependent on the amount of seed deposited in the seed bank the year before the fire. Seeds typically do not persist in the soil for more than one growing season (Beetle 1960). A few seeds may remain viable in soil for two years (Meyer 2008a); however, even in dry storage, black sagebrush seed viability has been found to drop rapidly over time, from 81% to 1% viability after two and 10 years of storage, respectively (Stevens et al. 1981). Thus, repeated frequent fires can eliminate black sagebrush from a site, however black sagebrush in zones receiving 12 to 16 in. (30–41 cm) of annual precipitation has been found to have greater fire survival (Boltz 1994). In lower precipitation zones rabbitbrush may become the dominant shrub species following fire, often with an understory of Sandberg bluegrass and/or cheatgrass and other annual non-native species.

Thurber's needlegrass is very susceptible to fire caused mortality. Burning has been found to decrease the vegetative and reproductive vigor of Thurber's needlegrass (Uresk et al. 1976). Fire can cause high mortality, in addition to reducing basal area and yield of Thurber's needlegrass (Britton et al. 1990). The fine leaves and densely tufted growth form make this grass susceptible to subsurface charring of the crowns (Wright and Klemmedson 1965). Although timing of fire highly influences the response and mortality of Thurber's needlegrass, smaller bunch sizes are less likely to be damaged by fire (Wright and Klemmedson 1965). However, Thurber's needlegrass often survives fire and will continue growth when conditions are favorable (Koniak 1985). Thus, the initial condition of the bunchgrasses within the site, along with seasonality and intensity of the fire, all factor into the individual species response.

At the time of this document's publication, very little research has been done on the effects of fire on Letterman's needlegrass. However, most bunchgrasses are harmed by fire, and fire typically causes a decrease in reproduction, density, and cover in bunchgrasses (Ellsworth and Kauffman 2010). Bates et al. (2011) found bunchgrass (*Achnatherum nelsonii* and *Achnatherum lettermanii*) density decreased 50% following autumn prescribed fire in phase III western juniper woodlands in southwest Idaho, with density not recovering in a three-year period following fire. Seedling density was much higher at year three in these grasses however, implying recovery in the short-to-medium term was possible. Needlegrasses, in general, are slightly to moderately damaged by fire depending on the season of burn. They tend to be more susceptible when burned during mid-summer (Wright and Klemmedson 1965).

Muttongrass, a dominant component in this group, is top-killed by fire but will sprout after low to moderate severity fires. A study by Vose and White (1991) in an open saw timber site found minimal difference in the overall effect of burning on muttongrass.

Livestock/Wildlife Grazing Interpretations:

Domestic sheep and, to a much lesser degree, cattle consume low sagebrush, particularly during the spring, fall, and winter (Sheehy and Winward 1981). Heavy dormant season grazing by sheep will reduce sagebrush cover and increase grass production (Laycock 1967). Severe trampling damage to supersaturated soils could occur if sites are used in early spring when there is abundant snowmelt. Trampling damage, particularly from cattle or horses, in low sagebrush habitat types is greatest when high clay content soils are wet. In drier areas with more gravelly soils, no serious trampling damage occurs, even when the soils are wet (Hironaka et al. 1983).

Low sagebrush sites are often used for strutting grounds for Greater sage-grouse (*Centrocercus urophasianus*) because the low cover allows for high visibility of strutting males (McAdoo and Back 2001). Sage-grouse also use these sites during the winter where sagebrush provides food and cover (Braun et al. 2005).

Black sagebrush palatability has been rated as moderate to high depending on the ungulate and the season of use (Horton 1989, Wambolt 1996). The palatability of black sagebrush increases the potential negative impacts on remaining black sagebrush plants from grazing or browsing pressure following fire (Wambolt 1996). Pronghorn utilize black sagebrush heavily (Beale and Smith 1970). On the Desert Experiment Range, black sagebrush was found to comprise 68% of pronghorn diet even though it was only the third most common plant. Fawns were found to prefer black sagebrush utilizing it more than all other forage species combined (Beale and Smith 1970). Domestic livestock will also utilize black sagebrush. The domestic sheep industry that emerged in the Great Basin in the early 1900s was largely based on wintering domestic sheep in black sagebrush communities (Mozingo 1987c). Domestic sheep will browse black sagebrush during all seasons of the year depending on the availability of other forage species, with greater amounts being consumed in fall and winter. Black sagebrush is generally less palatable to cattle than to domestic sheep and wild ungulates (McArthur et al. 1979); however, cattle use of black sagebrush has also been shown to be greatest in fall and winter (Schultz and McAdoo 2002), with only trace amounts being consumed in summer (Van Vuren 1984). Dormant season use of black sagebrush can reduce sagebrush density and increase the density of bunchgrasses such as Indian ricegrass.

Needlegrasses have a high forage value specifically in the western ranges. When mature the foliage can become coarse and reduce the palatability of these grasses, however, they remain green longer than other grasses and mature well, making them valuable forage for late fall and winter. The seeds of these grasses are mechanically injurious to grazing animals and can sometimes work into the tissues of the mouth, tongue, ears, and nose of livestock and game animals (USFS 1937).

Thurber’s needlegrass is an important forage source for livestock and wildlife in the arid regions of the West (Ganskopp 1988). Although the seeds are apparently not injurious, grazing animals avoid them when they begin to mature. Sheep, however, have been observed to graze the leaves closely, leaving stems untouched (Eckert and Spencer 1987). Heavy grazing during the growing season has been shown to reduce the basal area of Thurber’s needlegrass (Eckert and Spencer 1987), suggesting that both seasonality and utilization are important factors in management of this plant. A single defoliation, particularly during the boot stage, was found to reduce herbage production and root mass thus potentially lowering the competitive ability of this needlegrass (Ganskopp 1988).

At the time of this document’s publication, the effects of grazing on Letterman’s needlegrass are not well documented. However, it is known to be palatable to many species of livestock and wildlife, including cattle, sheep, horses, pronghorn (*Antilocapra americana*), elk (*Cervus canadensis*), mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), small mammals, and birds. It typically is only palatable early in the season because as Letterman’s needlegrass ages, it dries and becomes coarse and wiry, which can injure an animal’s mouth and leads to it being avoided by most animals later in the season (Dittberner and Olson 1983).

Muttongrass is very palatable for wildlife and livestock and is rated as excellent forage for cattle and horses, and good for sheep. Muttongrass starts growth in late winter or early spring and provides excellent early feed. Muttongrass foliage cures well and is good fall forage, but not as good as spring or summer (Humphrey et al. 1952), and can withstand moderately heavy grazing (Marquiss and Lang 1959).

State and Transition Model Narrative for Group 17:

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 29 Disturbance Response Group 17.

Reference State 1.0:

The Reference State 1.0 is representative of the natural range of variability under pristine conditions. The Reference State has three general community phases: a shrub-grass dominant phase, a perennial grass dominant phase and a shrub dominant phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire, periodic drought and/or insect or disease attack.

Community Phase 1.1:
The reference plant community is dominated by low sagebrush, Letterman's needlegrass, and muttongrass. A diversity of forbs and other grasses such as pine needlegrass and Sandberg bluegrass are a minor component. Potential vegetative composition by air-dry weight is approximately 50% grasses, 10% forbs and 40% shrubs. Approximate ground cover (basal and crown) is 35 to 45%. Total annual air-dry production ranges from 300 to 700 lb/ac.

Claypan 16" + P.Z. (R029XY052NV), Reference State 1.1, T. Stringham, June 2021

Claypan 16" + P.Z. (R029XY052NV), Reference State 1.1, T. Stringham, June 2023

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
Fire reduces the shrub overstory and allows perennial bunchgrasses to dominate the site. Fires are typically low severity resulting in a mosaic pattern due to low fuel loads. A fire following an unusually wet spring or a change in management favoring an increase in fine fuels may be more severe and reduce sagebrush cover to trace amounts.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.3:
Long-term drought, herbivory, or combinations of these will cause a decline in perennial bunchgrasses and fine fuels leading to a reduced fire frequency and allowing sagebrush to dominate the site.

Community Phase 1.2:
This community phase is characteristic of a post-disturbance, early to mid-seral community. Low sagebrush is present in trace amounts; perennial bunchgrasses and forbs dominate the site. Depending on fire severity, patches of intact sagebrush may remain. Rabbitbrush may be sprouting or dominant in the community. Perennial forbs may be a significant component for several years following fire.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
Release from drought allows the perennial bunchgrasses to increase.

Community Phase 1.3:
Sagebrush dominates the overstory and perennial bunchgrasses in the understory are reduced, either from competition with shrubs or from inappropriate grazing, or from both. Rabbitbrush may be a significant component. Bluegrasses may increase and become dominant. This site is susceptible to further degradation from grazing, drought, and fire.

Mountain Ridge 12-16" P.Z. (R029XY056NV), Reference 1.3, T. Stringham, June 2021

Mountain Ridge 12-16" P.Z. (R029XY056NV), Reference 1.3, T. Stringham, June 2021

Community Phase Pathway 1.3a, from Phase 1.3 to 1.1:
A low severity fire, or late fall/winter herbivory causing mechanical damage to sagebrush or combinations will reduce the sagebrush overstory and create a sagebrush/grass mosaic.

Community Phase Pathway 1.3b, from Phase 1.3 to 1.2:
Fire eliminates/reduces the overstory of sagebrush and allows for the understory perennial grasses to increase. Fires may be high severity in this community phase due to the dominance of sagebrush resulting in removal of overstory shrub community.

T1A: Transition from the Reference State 1.0 to Current Potential State 2.0

Trigger: This transition is caused by the introduction of non-native annual plants.

Slow variables: Over time the annual non-native species will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

This state is similar to the Reference State 1.0. Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of invasive weeds. This state has the same three general community phases. These non-native species can be highly flammable and promote fire where historically fire had been infrequent. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These feedbacks include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal.

Community Phase 2.1
This community phase is similar to the Reference State Community Phase 1.1, with the presence of non-native species. This community is dominated by low sagebrush, Letterman's needlegrass or Thurber's needlegrass, and muttongrass. A diversity of forbs and other grasses like pine needlegrass and Sandberg bluegrass make up smaller components.

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
Fire reduces the shrub overstory and allows for perennial bunchgrasses and perennial forbs to dominate the site. Fires are typically low severity resulting in a mosaic pattern due to low fuel loads. A fire following an unusually wet spring or a change in management favoring an increase in fine fuels may be more severe and reduce sagebrush cover to trace amounts. Annual non-native species are likely to increase after fire.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.3:
Time and lack of disturbance allow for sagebrush to increase and become decadent. Long-term drought reduces fine fuels and leads to a reduced fire frequency, allowing sagebrush to dominate the site. Inappropriate grazing management reduces the

perennial bunchgrass understory; conversely bluegrasses may increase in the understory depending on grazing management.

Community Phase 2.2:
This community phase is characteristic of a post-disturbance, early to mid-seral community where annual non-native species are present. Low sagebrush is present in trace amounts; perennial bunchgrasses and forbs dominate the site. Depending on fire severity, patches of intact sagebrush may remain. Rabbitbrush may be sprouting or dominant in the community. Perennial forbs may be a significant component for several years following fire. Annual non-native species are stable or increasing within the community.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Time and lack of disturbance and/or grazing management that favor the establishment and growth of sagebrush allows the shrub component to recover. The establishment of low sagebrush can take many years.

Community Phase 2.3 (At Risk):
This community is at risk of crossing a threshold to another state. Sagebrush dominates the overstory and perennial bunchgrasses in the understory are reduced, either from competition with shrubs or from inappropriate grazing, or from both. Rabbitbrush may be a significant component. Bluegrasses may increase and become dominant. Annual non-native species may be stable or increasing due to lack of competition with perennial bunchgrasses. This site is susceptible to further degradation from grazing, drought, and fire.

Community Phase Pathway 2.3a, from Phase 2.3 to 2.1:
A change in grazing management that reduces shrubs will allow for the perennial bunchgrasses in the understory to increase. Heavy late-fall or winter grazing may cause mechanical damage and subsequent death to sagebrush, facilitating an increase in the herbaceous understory. Low sagebrush are palatable shrub species and can decrease with increased grazing pressure. Brush treatments with minimal soil disturbance will also decrease sagebrush and release the perennial understory. A low severity fire would decrease the overstory of sagebrush and allow for the understory perennial grasses to increase. Due to low fuel loads in this state, fires will likely be small, creating a mosaic pattern. Annual non-native species are present and may increase in the community.

Community Phase Pathway 2.3b, from Phase 2.3 to 2.2:
Fire eliminates/reduces the overstory of sagebrush and allows for the understory perennial grasses to increase. Fires may be high severity in this community phase due to the dominance of sagebrush resulting in removal of overstory shrub community. Annual non-native species respond well to fire and may increase post burn.

T2A: Transition from Current Potential State 2.0 to Shrub State 3.0

Trigger: To Community Phase 3.1: Inappropriate, chronic, grazing will decrease or eliminate deep-rooted perennial bunchgrasses, increase bluegrasses and favor shrub growth and establishment. To Community Phase 3.2: Severe fire in Community Phase 2.3 will remove sagebrush overstory and decrease deep-rooted perennial bunchgrasses and enhance bluegrasses. Annual non-native species will increase.

Slow variables: Long term decrease in deep-rooted perennial grass density.

Threshold: Loss of deep-rooted perennial bunchgrasses changes nutrient cycling, nutrient redistribution, and reduces soil organic matter.

Shrub State 3.0:

This state has two community phases, a shrub dominated phase, and a bluegrass/annual grass dominated phase. This state is a product of many years of excessive grazing during time periods harmful to perennial bunchgrasses. Sandberg bluegrass and/or muttongrass and perennial forbs will increase with a reduction in deep-rooted perennial bunchgrass competition and become the dominant grass. Sagebrush dominates the overstory and rabbitbrush may be a significant component. Sagebrush cover exceeds site concept and may be decadent, reflecting stand maturity and lack of seedling establishment due to competition with mature plants. The shrub overstory and bluegrass understory dominate site resources such that soil water, nutrient capture, nutrient cycling and soil organic matter are temporally and spatially redistributed.

Community Phase 3.1 (At Risk):
Decadent sagebrush dominates the overstory with perennial forbs dominant in the understory. Rabbitbrush may be a significant component. Deep-rooted perennial bunchgrasses may be present in minor amounts or absent from the community. Sandberg bluegrass, squirreltail and annual non-native species increase. Singleleaf pinyon and Utah juniper may be present.

Mountain Ridge 12-16" P.Z. (R029XY056NV), Shrub State 3.1, T. Stringham, May 2021

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:
Fire, heavy fall grazing causing mechanical damage to shrubs, and/or brush treatments with minimal soil disturbance, will greatly reduce the overstory shrubs to trace amounts and allow for bluegrasses to dominate the site.

Community Phase 3.2 (Not observed in MLRA 29):
Sandberg bluegrass dominates the site. Annual non-native species may be present but are not dominant. Trace amounts of sagebrush or rabbitbrush may be present. In similar groups within other MLRAs, perennial forbs can become a significant component of the plant community (Stringham et al. 2015a).

Community Phase Pathway 3.2a, from Phase 3.2 to 3.1:
Time and lack of disturbance and/or grazing management that favor the establishment and growth of sagebrush allows the shrub component to recover. The establishment of low sagebrush can take many years.

States Not Observed in Group 17:

Tree State: While a Tree State was not seen for this group, there was evidence of phase I pinyon and/or juniper encroachment within this group while in a Shrub State. Nearby densities of pinyon and juniper in at least one of these sites implies that a Tree State may be possible. Tree States have been observed in similar disturbance response groups in MLRA 23 Group 2 (Stringham et al. 2019), MLRA 26 Group 2 (Stringham et al. 2021), and MLRA 28 Groups 4A and 4B (Stringham et al. 2015a).

Annual State: An Annual State was not seen for this group, though such a state may be possible at lower ends of the precipitation gradient within this group. An Annual State was found within other similar MLRA groupings: MLRA 24 Group 5A (Stringham et al. 2017), and in MLRA 25 Group 2 (Stringham et al. 2015b).

Forb State: A similar ecological grouping, MLRA 25 Group 2 (Stringham et al. 2015b) contains a Forb State, where native, deep-rooted perennial, cool-season forbs dominate. This state is a result of heavy use by sheep bedding and grazing.

Eroded State: A similar ecological grouping MLRA 28 Groups 4A and 4B (Stringham et al. 2015a) contain an Eroded State, which in that case is a result of soil redistribution and erosion from the occurrence fire in a Tree State.

Potential Resilience Differences with Other Ecological Sites in this Group:

Mountain Ridge 16+" P.Z. (R029XY053NV):

The plant community is dominated by low sagebrush, needlegrasses (Letterman's needlegrass and/or pine needlegrass), and a bluegrass (muttongrass and/or Sandberg bluegrass), with the addition of a small amount of fringed sagebrush in the shrub community. This site is less productive (30 to 60%) when compared to the modal site primarily due to shallower soils. This site also has more of its production in shrubs and forbs, with less production in grasses. Due to these differences, it is expected that this site has less resilience than the modal site and may transition to an alternative state more easily.

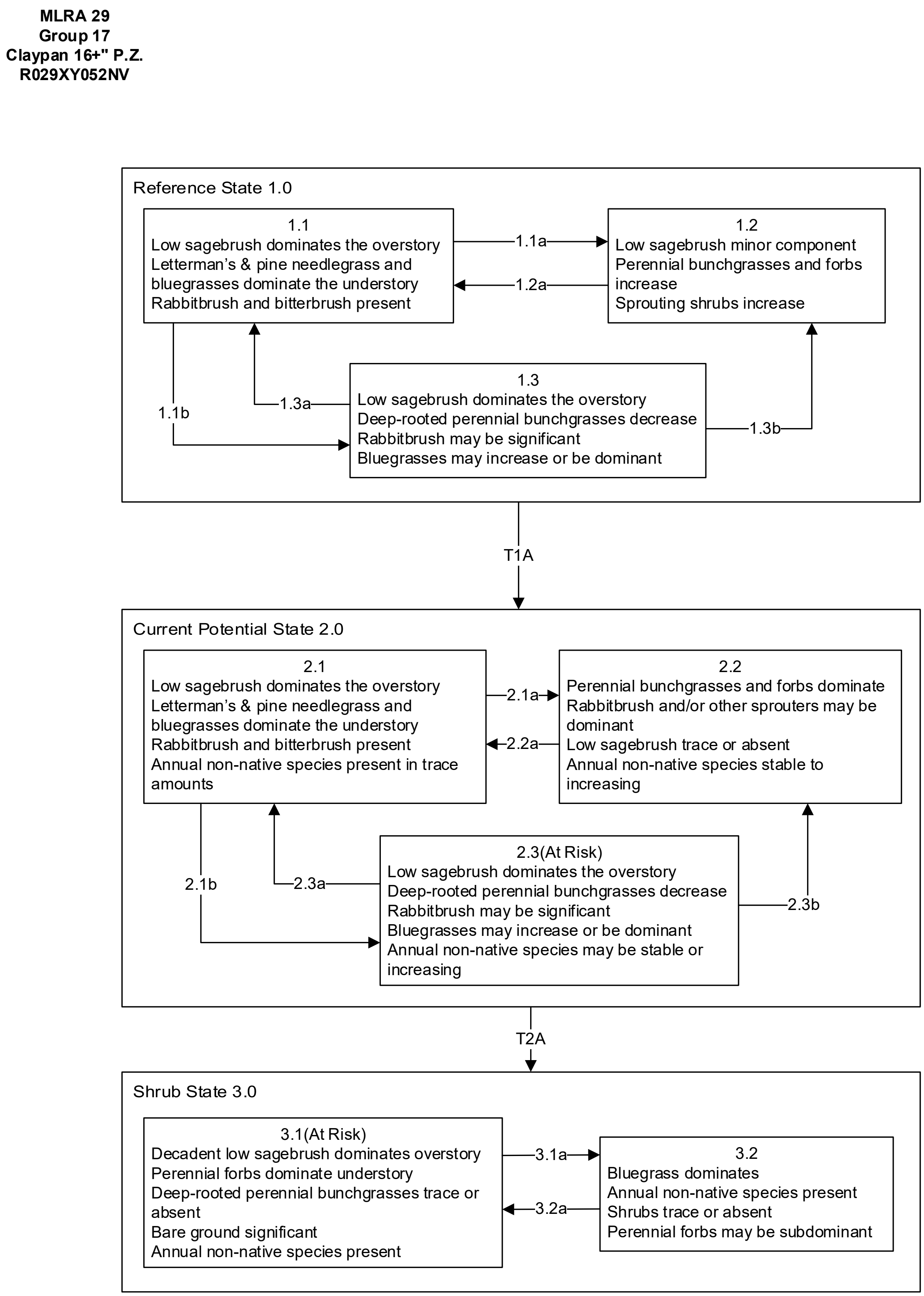
Claypan 12-16" P.Z. (R029XY055NV):

The plant community is dominated by low sagebrush, Thurber's needlegrass, and muttongrass, with more Indian ricegrass and needle-and-thread grass than the modal site. Major plant community composition by growth habit is similar to the modal site, with a similar or slightly lower production than the modal site. This site occurs on generally lower elevations (6,000 to 8,000 ft (1,829–2,438 m) on less aggressive slopes (2 to 15%). This site should have similar resilience to the modal site at the upper range of its precipitation (16 in.) but lower resilience towards the lower end of its range 12 in. (30 cm). While an Annual State was not seen in this group, the common landforms on which this site is found make it more vulnerable to fire and invasion, especially at lower elevations.

Mountain Ridge 12-16" P.Z. (R029XY056NV):

The plant community is dominated by a mix of low sagebrush and black sagebrush, Thurber's needlegrass, and muttongrass. Notable minor changes from the modal site include the loss of higher elevation shrubs such as Utah serviceberry and antelope bitterbrush, with the addition of lower elevation shrubs such as winterfat and spiny hopsage. This site occurs on generally lower elevations (6,000 to 8,000 ft [1,829–2,438 m]) than the modal site with, in general, shallower soils. Total production is significantly less than the modal site, driven by shallow soils and lower water holding capacity. This site is less resilient than the modal site and is more easily transitioned to an alternative state.

Modal State and Transition Model for Group 17 in MLRA 29:



MLRA 29
Group 17
Claypan 16+" P.Z.
R029XY052NV

Reference State 1.0 Community Pathways
1.1a: Low severity fire reduces shrub overstory, allows for perennial bunchgrasses to dominate the site.
1.1b: Long-term drought and/or herbivory reduces perennial bunchgrasses. Allows sagebrush to dominate the site.
1.2a: Release from drought allows for the perennial bunchgrasses to increase.
1.3a: Low severity fire or late fall/winter herbivory causing mechanical damage to low sagebrush allows for a perennial bunchgrass and shrub mosaic.
1.3b: Fire eliminates/reduces sagebrush overstory, allows for perennial bunchgrass understory to increase.

Transition T1A: Introduction of non-native annual plants.

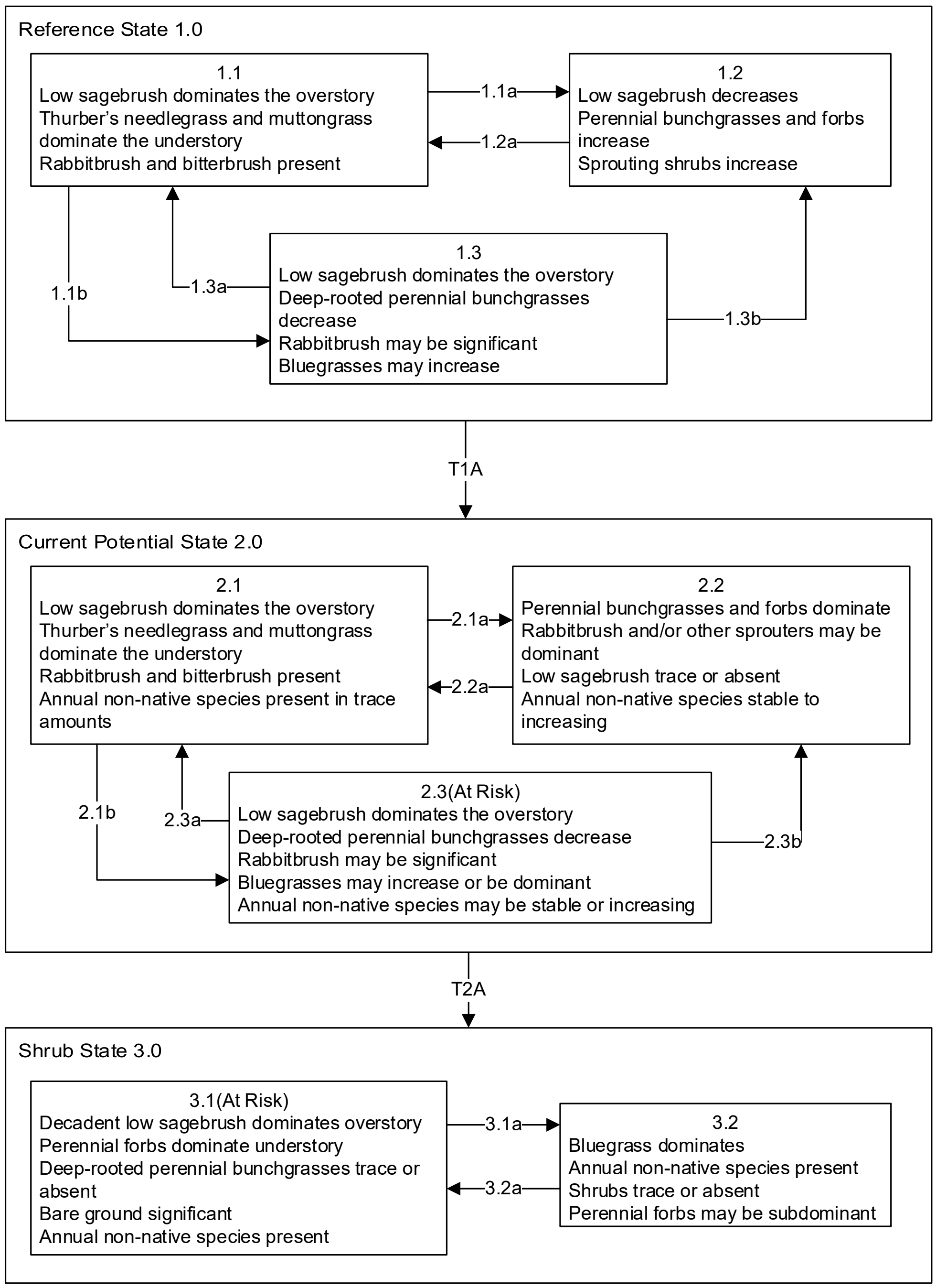
Current Potential State 2.0 Community Pathways
2.1a: Low severity fire reduces shrub overstory, allows perennial bunchgrasses and perennial forbs to dominate site.
2.1b: Time, lack of disturbance allows for sagebrush to increase. Inappropriate grazing management reduces perennial bunchgrass understory.
2.2a: Time, lack of disturbance allows shrub component to recover.
2.3a: Low severity fire or change in grazing management decreases low sagebrush and allows perennial bunchgrasses to dominate the site.
2.3b: Fire eliminates/reduces sagebrush overstory, allows for perennial bunchgrass understory to increase.

Transition T2A: Inappropriate grazing will decrease or eliminate perennial bunchgrasses and favor shrub growth, leading to Community Phase 3.1. Severe fire will remove sagebrush overstory and allow annual non-native species to thrive, leading to Community Phase 3.2.

Shrub State 3.0 Community Pathways
3.1a: Fire, heavy fall grazing causing mechanical damage to shrubs, and/or brush treatments with minimal soil disturbance allows bluegrasses to dominate the site.
3.2: Time, lack of disturbance and/or grazing management allows sagebrush to recover.

Additional State and Transition Models for Group 17 in MLRA 29:

MLRA 29
Group 17
Claypan 12-16" P.Z.
R029XY055NV



MLRA 29
Group 17
Claypan 12-16" P.Z.
R029XY055NV

Reference State 1.0 Community Pathways
1.1a: Low severity fire reduces shrub overstory, allows for perennial bunchgrasses to dominate the site.
1.1b: Long-term drought and/or herbivory reduces perennial bunchgrasses. Allows sagebrush to dominate the site.
1.2a: Release from drought allows for the perennial bunchgrasses to increase.
1.3a: Low severity fire or late fall/winter herbivory causing mechanical damage to low sagebrush allows for a perennial bunchgrass and shrub mosaic.
1.3b: Fire eliminates/reduces sagebrush overstory, allows for perennial bunchgrass understory to increase.

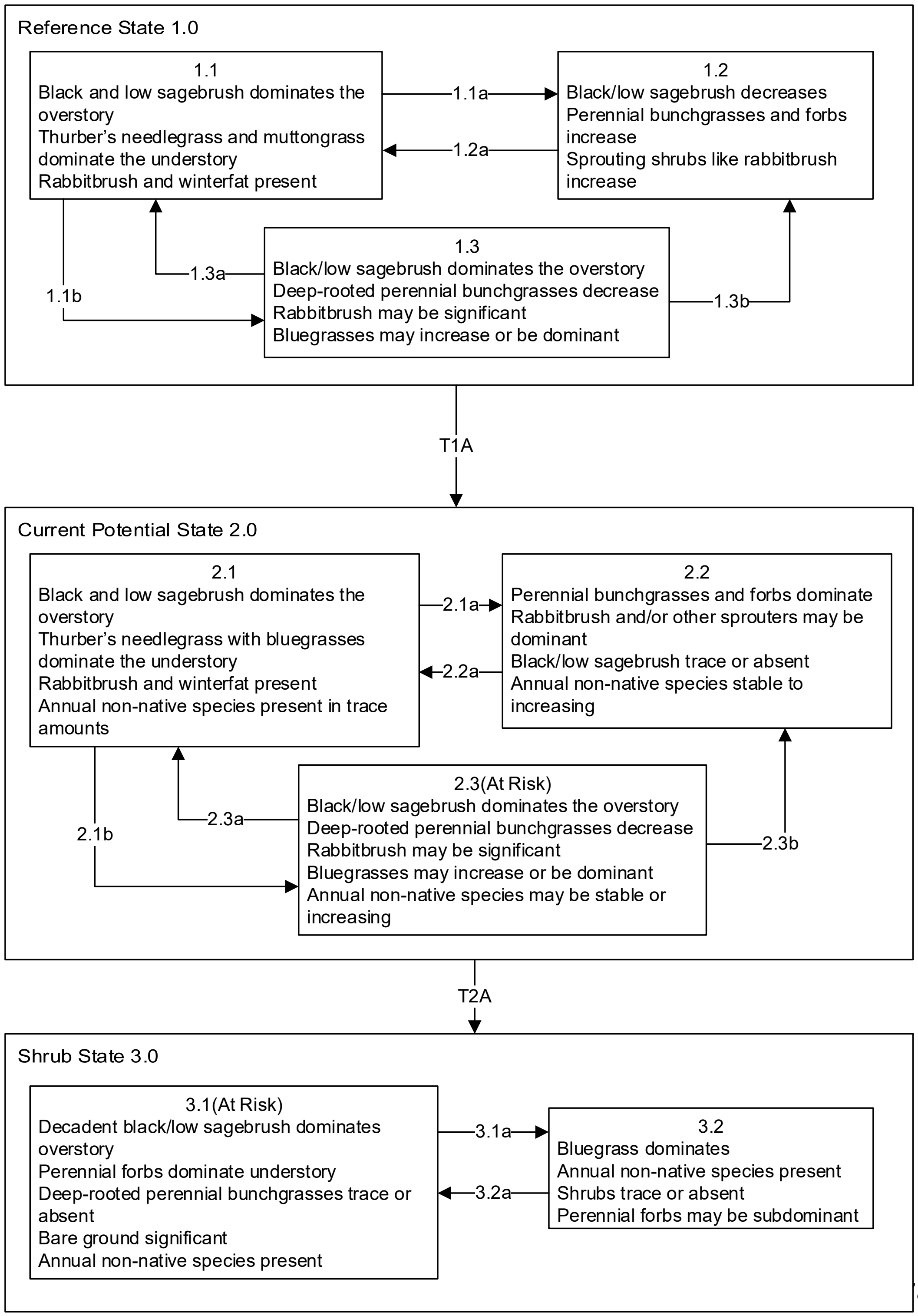
Transition T1A: Introduction of non-native annual plants.

Current Potential State 2.0 Community Pathways
2.1a: Low severity fire reduces shrub overstory, allows perennial bunchgrasses and perennial forbs to dominate site.
2.1b: Time, lack of disturbance allows for sagebrush to increase. Inappropriate grazing management reduces perennial bunchgrass understory.
2.2a: Time, lack of disturbance allows shrub component to recover.
2.3a: Low severity fire or change in grazing management decreases low sagebrush and allows perennial bunchgrasses to dominate the site.
2.3b: Fire eliminates/reduces sagebrush overstory, allows for perennial bunchgrass understory to increase.

Transition T2A: Inappropriate grazing will decrease or eliminate perennial bunchgrasses and favor shrub growth, leading to Community Phase 3.1. Severe fire will remove sagebrush overstory and allow annual non-native species to thrive, leading to Community Phase 3.2.

Shrub State 3.0 Community Pathways
3.1a: Fire, heavy fall grazing causing mechanical damage to shrubs, and/or brush treatments with minimal soil disturbance allows bluegrasses to dominate the site.
3.2: Time, lack of disturbance and/or grazing management allows sagebrush to recover.

MLRA 29
Group 17
Mountain Ridge 12-16" P.Z.
R029XY056NV



MLRA 29
Group 17
Mountain Ridge 12-16" P.Z.
R029XY056NV

Reference State 1.0 Community Pathways
1.1a: Low severity fire reduces shrub overstory, allows for perennial bunchgrasses to dominate the site.
1.1b: Long-term drought and/or herbivory reduces perennial bunchgrasses. Allows sagebrush to dominate the site.
1.2a: Release from drought allows for the perennial bunchgrasses to increase.
1.3a: Low severity fire or late fall/winter herbivory causing mechanical damage to sagebrush allows for a perennial bunchgrass and shrub mosaic.
1.3b: Fire eliminates/reduces sagebrush overstory, allows for perennial bunchgrass understory to increase.

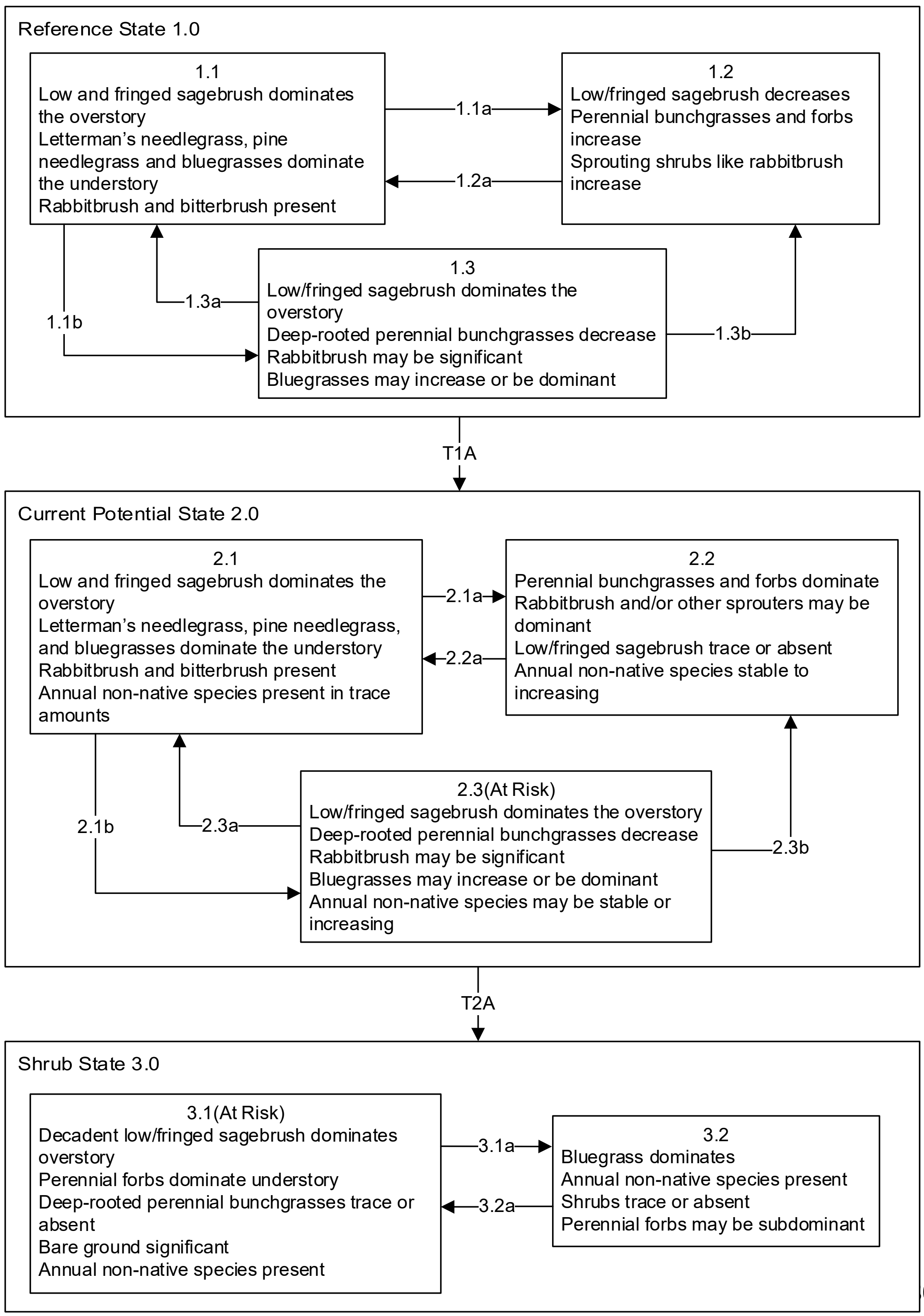
Transition T1A: Introduction of non-native annual plants.

Current Potential State 2.0 Community Pathways
2.1a: Low severity fire reduces shrub overstory, allows perennial bunchgrasses and perennial forbs to dominate site.
2.1b: Time, lack of disturbance allows for sagebrush to increase. Inappropriate grazing management reduces perennial bunchgrass understory.
2.2a: Time, lack of disturbance allows shrub component to recover.
2.3a: Low severity fire or change in grazing management decreases sagebrush and allows perennial bunchgrasses to dominate the site.
2.3b: Fire eliminates/reduces sagebrush overstory, allows for perennial bunchgrass understory to increase.

Transition T2A: Inappropriate grazing will decrease or eliminate perennial bunchgrasses and favor shrub growth, leading to Community Phase 3.1. Severe fire will remove sagebrush overstory and allow annual non-native species to thrive, leading to Community Phase 3.2.

Shrub State 3.0 Community Pathways
3.1a: Fire, heavy fall grazing causing mechanical damage to shrubs, and/or brush treatments with minimal soil disturbance allows bluegrasses to dominate the site.
3.2: Time, lack of disturbance and/or grazing management allows sagebrush to recover.

MLRA 29
Group 17
Mountain Ridge 16+" P.Z.
R029XY053NV



MLRA 29
Group 17
Mountain Ridge 16+" P.Z.
R029XY053NV

Reference State 1.0 Community Pathways
1.1a: Low severity fire reduces shrub overstory, allows for perennial bunchgrasses to dominate the site.
1.1b: Long-term drought and/or herbivory reduces perennial bunchgrasses. Allows sagebrush to dominate the site.
1.2a: Release from drought allows for the perennial bunchgrasses to increase.
1.3a: Low severity fire or late fall/winter herbivory causing mechanical damage to sagebrush allows for a perennial bunchgrass and shrub mosaic.
1.3b: Fire eliminates/reduces sagebrush overstory, allows for perennial bunchgrass understory to increase.

Transition T1A: Introduction of non-native annual plants.

Current Potential State 2.0 Community Pathways
2.1a: Low severity fire reduces shrub overstory, allows perennial bunchgrasses and perennial forbs to dominate site.
2.1b: Time, lack of disturbance allows for sagebrush to increase. Inappropriate grazing management reduces perennial bunchgrass understory.
2.2a: Time, lack of disturbance allows shrub component to recover.
2.3a: Low severity fire or change in grazing management decreases sagebrush and allows perennial bunchgrasses to dominate the site.
2.3b: Fire eliminates/reduces sagebrush overstory, allows for perennial bunchgrass understory to increase.

Transition T2A: Inappropriate grazing will decrease or eliminate perennial bunchgrasses and favor shrub growth, leading to Community Phase 3.1. Severe fire will remove sagebrush overstory and allow annual non-native species to thrive, leading to Community Phase 3.2.

Shrub State 3.0 Community Pathways
3.1a: Fire, heavy fall grazing causing mechanical damage to shrubs, and/or brush treatments with minimal soil disturbance allows bluegrasses to dominate the site.
3.2: Time, lack of disturbance and/or grazing management allows sagebrush to recover.

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MLRA 29 Group 18: Fans with pygmy sagebrush and needlegrasses

Description of MLRA 29 Disturbance Response Group 18

Disturbance Response Group (DRG) 18 consists of only one ecological site. This site occurs on erosional fan remnants, fan skirts, and beach terraces. Precipitation ranges from 8 to 10 in. Slopes range from 2 to about 30%, but slope gradients of 2 to 8% are most typical, and elevation ranges from 5,000 to 5,700 ft. The soils temperature regime is mesic and the soil moisture regime is typic aridic. Soils are derived from mixed alluvium, lake bed sediments or eroded sedimentary materials. Surfaces are usually gravelly and the textures are gravelly sandy loams to loams. Soils are shallow to moderately deep and well-drained, but effective rooting depths range from very shallow to shallow. Available water holding capacity is very low, and runoff rates are medium. Annual production for a normal year is 175 lb/ac. The plant community is dominated by pygmy sagebrush (*Artemisia pygmaea*). Indian ricegrass (*Achnatherum hymenoides*), and needle-and-thread (*Hesperostipa comata*), galleta (*Hilaria jamesii*), shadscale saltbush (*Atriplex confertifolia*), and yellow rabbitbrush (*Chrysothamnus viscidiflorus*) are also commonly found on this site.

Disturbance Response Group 18 Ecological Sites:

Barren Fan 8-10" P.Z. – Modal R029XY092NV

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasive species. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans a unique area in Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area. Flashy, summer storm events contribute significantly to annual precipitation as well. Air and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992).

Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

Periodic drought regularly influences Great Basin ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West. Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006). Nutrient availability is typically low but increases with elevation and closely follows moisture availability. The moisture resource supporting the greatest amount of C3 plant growth is usually the water stored in the soil profile during the winter, however summer rain supports the growth of C4 plants. The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and depressed competition or can increase resource pools by the decomposition of dead plant material following disturbance. The invasion of Great Basin plant communities by cheatgrass and other non-native annual grasses has been linked to disturbances (fire, abusive grazing) that have resulted in fluctuations in resources (Chambers et al. 2007).

In the Great Basin, the majority of annual precipitation is received during the winter and early spring. This continental semiarid climate regime favors growth and development of deep-rooted shrubs and herbaceous cool season plants using the C3 photosynthetic pathway (Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow results in deeper percolation of moisture into the soil profile. Herbaceous plants, more shallow-rooted than shrubs, grow earlier in the growing season and thrive on spring rains, while the deeper-rooted shrubs lag in phenological development because they draw from deeply infiltrating moisture from snowmelt the previous winter. However, MLRA 29 is located between the northern, winter precipitation dominated regions of the Great Basin and the southern summer precipitation dominated Mohave region. Consequently, summer precipitation influences the plant species found within MLRA 29 and a mix of C3 and C4 plants is common.

The ecological site in this DRG is dominated by deep-rooted cool season, perennial bunchgrasses and long-lived shrubs (50+ years) with high root to shoot ratios. The dominant shrubs usually root to the full depth of the winter-spring soil moisture recharge, which ranges from 1 to 3 m (3.2 to 9.5 ft) (Comstock and Ehleringer 1992). The perennial bunchgrasses generally have somewhat shallower root systems than the shrubs, but root densities are often as high as or higher than those of shrubs in the upper 0.5 m (1.6 ft) but taper off more rapidly than shrubs. General differences in root depth distributions between grasses and shrubs results in resource partitioning in these shrub/grass systems.

The introduction of annual weedy species, like cheatgrass (*Bromus tectorum*), may cause an increase in fire frequency and eventually lead to an annual state. Conversely, as fire frequency decreases, shrub species will increase and with inappropriate grazing management the perennial bunchgrasses and forbs may be reduced.

Variability in plant community composition and production depends on soil surface texture and depth. Needle-and-thread grass is adapted to coarser textured soils whereas Indian ricegrass will increase with sandy soil surfaces, and squirreltail (*Elymus elymoides*), Sandberg's bluegrass (*Poa secunda*), and galleta grass prefer finer textured soils. Prolonged drought and/or abusive grazing will cause a decrease in Indian ricegrass and needle-and-thread grass while pygmy sagebrush, galleta, and bare ground increases. Cheatgrass, halogeton (*Halogeton glomeratus)*, Russian thistle (*Salsola tragus*) and other non-native annual weeds are likely to invade this site.

Indian ricegrass, is a hardy, cool-season, densely tufted, long-lived perennial bunchgrass that grows from 4 to 24 inches in height (Blaisdell and Holmgren 1984). Primarily adapted to coarse textured soils, its deep, fibrous root system makes Indian ricegrass one of the most drought-tolerant native species (Booth et al. 1980). Unlike other cool-season species, Indian ricegrass does not require vernalization (exposure to cold) in order to produce flowers and flowering can continue into late fall with favorable environmental conditions. This allows the seeds in each panicle to ripen over a longer period of time than most other species thus providing a greater opportunity for successful seed production (Jones 1990). When properly planted and managed, Indian ricegrass can help recover disturbed areas by competing with invasive species and providing cover and forage (Booth et al. 1980).

Needle-and-thread grass is a native, perennial, tufted, cool-season plant common to the western United States. Needle-and-thread begins growth early in the spring, flowers in June and matures seed in July. The source of its name is the 4- to 5-inch long awn, which detaches from the inflorescence with the seed and gives the appearance of a short needle and long thread. The plant is very drought tolerant and prefers coarse soils. It is most commonly found in the 7 to 16 in. precipitation zone (NRCS 2013).

The ecological site within this DRG may experience high wind erosion, especially with a decrease in vegetative cover. This can be caused by inappropriate grazing practices, long term drought, off-road vehicle use and/or fire.

The ecological site in this DRG has low resilience to disturbance and resistance to invasion. Increased resilience increases with elevation, aspect, increased precipitation and increased nutrient availability. Three alternative states have been identified for this DRG.

Annual Invasive Species:

The species most likely to invade these sites is cheatgrass. Cheatgrass is a cool season annual grass that maintains an advantage over native plants in part because it is a prolific seed producer, can germinate in the autumn or spring, tolerates grazing, and increases with frequent fire (Klemmedson and Smith 1964, Miller et al. 1999). Cheatgrass originated from Eurasia and was first reported in North America in the late 1800s (Furbush 1953, Mack and Pyke 1983). Pellant and Hall (1994) found 3.3 million acres of public lands dominated by cheatgrass and suggested that another 76 million acres were susceptible to invasion by winter annuals including cheatgrass and medusahead.

Recent modeling and empirical work by Bradford and Lauenroth (2006) suggests that seasonal patterns of precipitation input and temperature are also key factors determining regional variation in the growth, seed production, and spread of invasive annual grasses. The phenomenon of cheatgrass "die-off" provides opportunities for restoration of perennial and native species (Baughman et al. 2016, Baughman et al. 2017). The causes of these events are not fully understood, but there is ongoing work to try to predict where they occur, in the hopes of aiding conservation planning (Weisberg et al. 2017, Brehm 2019).

Methods to control cheatgrass include herbicide application, prescribed fire, targeted grazing, and rangeland seeding. Mapping potential or current invasion vectors is a management method designed to increase the cost effectiveness of control methods. Spraying with herbicide (imazapic or imazapic + glyphosate) and seeding with crested wheatgrass and Sandberg bluegrass has been found to be more successful at combating cheatgrass than spraying alone (Sheley et al. 2012). Butler et al. (2011) tested four herbicides (imazapic, imazapic + glyphosate, rimsulfuron, and sulfometuron + chlorsulfuron) for suppression of cheatgrass, medusahead (*Taeniatherum caput-medusae*) and North Africa grass (*Ventenata dubia*) within residual stands of native bunchgrass. Additionally, they tested the same four herbicides followed by seeding of six bunchgrasses (native and non-native) with varying success (Butler et al. 2011). Herbicide-only treatments appeared to remove competition for established bluebunch wheatgrass by providing 100% control of North Africa grass and medusahead and greater than 95% control of cheatgrass (Butler et al. 2011). Caution in using these results is advised, as only 1 year of data was reported.

After a wildfire, there is opportunity to intervene with seeding to establish perennial plants that will compete with cheatgrass. To date, most seeding success has occurred with non-native wheatgrass species. Perennial grasses, especially crested wheatgrass, are able to suppress cheatgrass growth when mature (Blank et al. 2020). Where native bunchgrasses are missing from the site, revegetation of annual grass invaded rangelands has been shown to have a higher likelihood of success when using introduced perennial bunchgrasses such as crested wheatgrass (Davies et al. 2015b, Clements et al. 2017).

Fire Ecology:

Fire is a very rare disturbance in this plant community, likely occurring in years with above average rainfall and production. Historically, pygmy sagebrush communities had sparse understories and bare soil in shrub interspaces, making these communities very resistant to fire.

Pygmy sagebrush does not sprout following fire or other disturbance and only regenerates from seed (Walton et al. 1986, Arizona Game and Fish Department 2004). Recovery time may require 50 to 120 or more years (Baker 2006).

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The initial condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species response. For most forbs and grasses the growing points are located at or below the soil surface providing relative protection from disturbances which decrease above ground biomass, such as grazing or fire. Thus, fire mortality is more correlated to duration and intensity of heat, which is related to culm density, culm-leaf morphology, root morphology, size of plant and abundance of old growth (Wright 1971, Young et al. 1983). However, season and severity of the fire will influence plant response. Plant response will vary depending on post-fire soil moisture availability.

Indian ricegrass, a dominant grass on this site, is fairly fire tolerant (Wright 1985), which is likely due to its low culm density and below ground plant crowns. Vallentine (1989) cites several studies in the sagebrush zone that classified Indian ricegrass as being slightly damaged from late summer burning. Indian ricegrass has also been found to reestablish on burned sites through seed dispersed from adjacent unburned areas (Young et al. 1983, West 1994). Thus, the presence of surviving, seed producing plants facilitates the reestablishment of Indian ricegrass. Grazing management following fire to promote seed production and establishment of seedlings is important.

Needle-and-thread is a fine leaf grass and is considered sensitive to fire (Akinsoji 1988, Bradley et al. 1992, Miller et al. 2013). In a study by Wright and Klemmedson (1965), season of burn rather than fire intensity seemed to be the crucial factor in mortality for needle-and-thread grass. Early spring season burning was seen to kill the plants while August burning had no effect. Thus, under wildfire scenarios needle-and-thread is often present in the post-burn community.

Galleta grass has been found to increase following fire likely due to its rhizomatous root structure and ability to re-sprout (Jameson 1962). This sod-forming grass species may retard reestablishment of deeper-rooted bunchgrasses. Fire in this community, although rare, will significantly reduce pygmy sagebrush and shadscale while promoting establishment of an annual weed community with varying amounts of galleta and rabbitbrush.

Livestock/Wildlife Grazing Interpretations:

Pygmy sagebrush is found in eastern Nevada, central and western Utah, and northern Arizona and northwestern New Mexico on desert calcareous soils (Arizona Game and Fish Department 2004). Pygmy sagebrush is a small cushion-like evergreen shrub and has little to no value as browse for wildlife or livestock (Johnson 1987, McArthur and Stevens 2004). It does, however, provide important groundcover in the dry, alkaline areas where little else will grow (McArthur and Stevens 2004).

Indian ricegrass is a preferred forage species for livestock and wildlife (Cook 1962, Booth et al. 1980). This species is often heavily utilized in winter because it cures well (Booth et al. 1980). It is also readily utilized in early spring, being a source of green feed before most other perennial grasses have produced new growth (Quinones 1981). Booth et al. (1980) note that the plant does well when utilized in winter and spring. Cook and Child (1971) however, found that repeated heavy grazing reduced crown cover, which may reduce seed production, density, and basal area of these plants. Additionally, heavy early spring grazing reduces plant vigor and stand density (Stubbendieck et al. 1985). In eastern Idaho, productivity of Indian ricegrass was at least 10 times greater in undisturbed plots than in heavily grazed ones (Pearson 1965). However, a study by Cook and Child (1971) found significant reduction in plant cover after 7 years of rest from heavy (90%) and moderate (60%) spring use, suggesting moderate spring grazing may be necessary to maintain Indian ricegrass vigor. The seed crop may be reduced where grazing is heavy (Bich et al. 1995). Tolerance to grazing increases after May, thus early spring deferment may be necessary for stand enhancement (Pearson 1965, Cook and Child 1971)however, utilization of less than 60% is recommended.

Needle-and-thread grass is not grazing tolerant and will be one of the first grasses to decrease under heavy grazing pressure (Smoliak et al. 1972, Tueller and Blackburn 1974). Heavy grazing is likely to reduce basal area of these plants (Smoliak et al. 1972). With the reduction in competition from deep rooted perennial bunchgrass, shallower-rooted grasses such as galleta may increase (Smoliak et al. 1972).

Galleta is a highly palatable forage species for cattle, sheep, deer (*Odocoileus spp.*), pronghorn (*Antilocapra americana*), and horses during late spring and summer while it is green (Stubbendieck et al. 2017). Due to its rhizomatous characteristics, galleta grass is particularly tolerant of heavy grazing and trampling (Pratt et al. 2002). This species will also initiate more than one phenological cycle if summer precipitation is present (Everett et al. 1980), allowing galleta to grow and propagate after defoliation.

Thus, heavy spring grazing (>60% defoliation), year after year, causes a decrease in Indian ricegrass and needle-and-thread grass, facilitating an increase in galleta, pygmy sagebrush and rabbitbrush. Continued abusive grazing leads to increased bare ground and invasion by annual weeds (e.g., cheatgrass and halogeton). Pygmy sagebrush and/or rabbitbrush may become dominant with an annual understory. With further deterioration, bare ground increases, soil redistribution accelerates and site productivity decreases. On some soils, erosion can result in increased surface salts and development of desert pavement. Reestablishment of perennials is limited in areas of extensive desert pavement.

State and Transition Model Narrative for Group 18:

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 29 disturbance response group 18. Three states have been identified: Reference, Current Potential, and Shrub. NOTE: this ecological site was not observed in MLRA 29, however, a similar site in MLRA 28B was observed and documented.

Reference State 1.0:

The Reference State 1.0 is a representative of the natural range of variability under pristine conditions. The reference state has two general community phases: a shrub-grass dominant phase and a shrub dominant phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by precipitation, periodic long term and/or insect or disease attack. This site is very stable, with little variation in plant community composition. Wet years will increase grass production, while drought years will reduce production. Shrub production will also increase during wet years.

Community Phase 1.1:
This community is dominated by pygmy sagebrush. Indian ricegrass and needle-and-thread grass are co-dominants in the understory. Forbs and other grasses such as galleta, squirreltail and Sandberg bluegrass make up smaller components. Utah juniper is described in the site concept and may or may not be present. Potential vegetative composition by air-dry weight is approximately 20% grasses, 5% forbs and 75% shrubs and trees. Approximate ground cover (basal and crown) is 8 to 15%. Total annual air-dry production ranges from 100 to 250 lb/ac. Community phase changes are primarily a function of chronic drought. Drought will favor shrubs over perennial bunchgrasses. However, long-term drought will result in an overall decline in plant community production, regardless of functional group.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
Long-term drought and/or herbivory. Drought will favor shrubs over perennial bunchgrasses. Fire is very infrequent to non-existent.

Community Phase 1.2:

This community is dominated by pygmy sagebrush. Perennial bunchgrasses such as Indian ricegrass and needle-and-thread are decreased. Galleta, rabbitbrush and matted perennial forbs (*Phlox* spp.) may increase.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
Release from long term drought and/or herbivory would allow the vegetation to increase and bare ground would eventually decrease.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0:

Trigger: This transition is caused by the introduction of non-native annual plants, such as cheatgrass, mustards, and/or Russian thistle.

Slow variables: Over time the annual non-native species will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

This state is similar to Reference State 1.0 with two similar community phases. Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of invasive weeds. Non-natives may increase in abundance but will not become dominant within this State. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These feedbacks include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal.

Community Phase 2.1:
This community is compositionally similar to Reference State Community Phase 1.1 with the presence of non-native species in trace amounts. This community is dominated by pygmy sagebrush. Indian ricegrass and needle-and-thread grass makeup the understory. Forbs and other grasses make up smaller components. Utah juniper is described in the site concept and may or may not be present. Community phase changes are primarily a function of chronic drought. Fire is very infrequent due to low fuel loads.

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
Inappropriate growing season grazing favors galleta grass and unpalatable shrubs over bunchgrasses. Prolonged drought will also decrease the perennial bunchgrasses in the understory.

Community Phase 2.2:
Pygmy sagebrush and other shrubs increase while Indian ricegrass and needle-and-thread grass decline. Bare ground increases along with annual weeds. Galleta grass and rabbitbrush may increase. Prolonged drought may lead to an overall decline in the plant community.

Barren Fan 8-12" P.Z. (R028BY040NV), Phase 2.2, T. Stringham, May 2012

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Release from long term drought and/or appropriate grazing management that facilitates an increase in perennial grasses.

T2A: Transition from Current Potential State 2.0 to Shrub State 3.0:

Trigger: Long-term inappropriate grazing and/or long-term chronic drought will decrease or eliminate deep-rooted perennial bunchgrasses and favor shrub and galleta grass dominance.

Slow variables: Long term decrease in deep-rooted perennial grass density.

Threshold: Loss of deep-rooted perennial bunchgrasses changes nutrient cycling, nutrient redistribution, and reduces soil organic matter.

Shrub State 3.0:

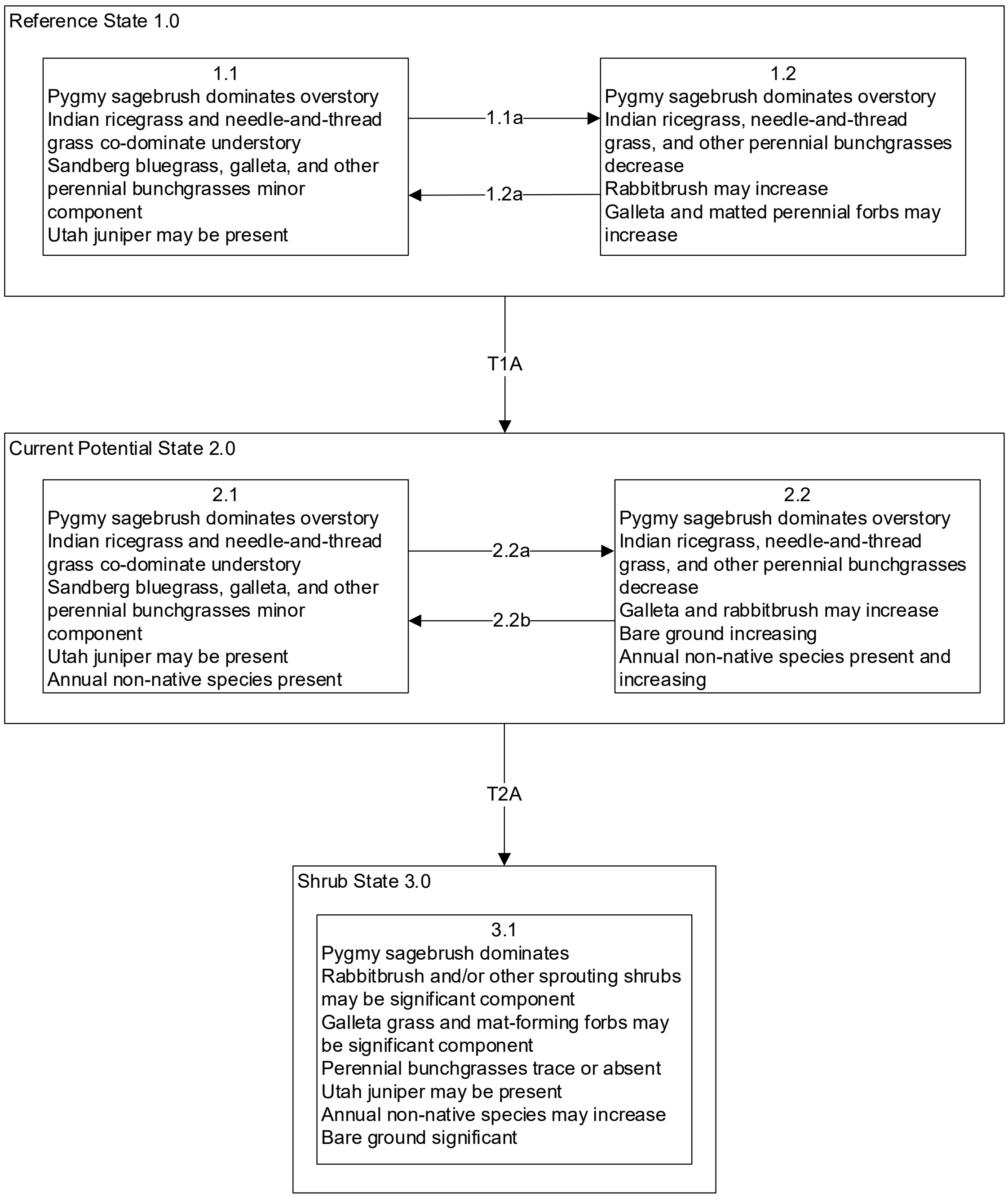
This state has one community phase that is characterized by a pygmy sagebrush and rabbitbrush overstory with a galleta grass and mat forming forb understory. The site has crossed a biotic threshold and site processes are being controlled by shrubs and shallowed rooted herbaceous species. Shrub cover exceeds the site concept and may be decadent, reflecting stand maturity and lack of seedling establishment due to competition with mature plants. The shrub overstory dominates site resources such that soil water, nutrient capture, nutrient cycling and soil organic matter are temporally and spatially redistributed. Bare ground has increased.

Community Phase 3.1:
Decadent pygmy sagebrush dominates the overstory. Rabbitbrush and/or other sprouting shrubs may be a significant component. Galleta grass and mat-forming forbs may be significant component. Deep-rooted perennial bunchgrasses may be present in trace amounts or absent from the community. Annual non-native species may increase. Bare ground is significant. Utah juniper may be present.

Eroded Barren Fan (R028AY123NV), Phase 3.1, T. Stringham, August 2013

Modal State and Transition Model for Group 18 in MLRA 29:

MLRA 29
Group 18
Barren Fan 8-10" P.Z.
R029XY092NV



MLRA 29
Group 18
Barren Fan 8-10" P.Z.
R029XY092NV

Reference State 1.0 Community Phase Pathways
1.1a: Long-term drought and/or herbivory, favoring shrub establishment.
1.2a: Release from drought and/or herbivory allows herbaceous vegetation to increase and bare ground to decrease.

Transition T1A: Introduction of non-native annual species.

Current Potential 2.0 Community Phase Pathways
2.1a: Prolonged drought and/or inappropriate grazing season grazing favors galleta grass and unpalatable shrubs over bunchgrasses.
2.2a: Release from drought and/or appropriate grazing management that allows for an increase in perennial grasses.

Transition T2A: Long-term inappropriate grazing management and/or long-term chronic drought decreases or eliminates perennial bunchgrasses, and favors shrub and galleta grass establishment.

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<u>MLRA 29 Group 19: Pinyon and juniper woodland with black sagebrush understory</u>

Description of MLRA 29 Disturbance Response Group 19

Disturbance Response Group (DRG) 19 consists of four ecological sites. Precipitation is 10 to 16 in. Elevations range from 5,500 to 8,200 ft and slopes are greatly variable, ranging from 4 to over 75%. The soils in this group are typically very shallow to shallow and available water holding capacity is low. These soils usually have high amounts of rock fragments at the soil surface which occupy plant growing space, yet help to reduce evaporation and conserve soil moisture. Runoff is rapid and potential for sheet and rill erosion is moderate to severe depending on slope. This group is dominated by singleleaf pinyon (*Pinus monophylla*) and/or Utah juniper (*Juniperus osteosperma*) with black sagebrush (*Artemisia nova*) or low sagebrush (*Artemisia arbuscula*) as the primary understory shrub. Other shrubs in the group include desert bitterbrush (*Purshia glandulosa*), Stansbury's cliffrose (*Purshia stansburiana)*, Gambel oak (*Quercus gambelii*), Sonoran scrub oak (*Quercus turbinella*), greenleaf manzanita (*Arctostaphylos patula*), desert ceanothus (*Ceanothus greggii*), yellow silktassel (*Garrya flavescens*), and Utah serviceberry (*Amelanchier utahensis*). The understory grasses include Indian ricegrass (*Achnatherum hymenoides*), muttongrass (*Poa fendleriana*), bottlebrush squirreltail (*Elymus elymoides*), and blue grama (*Bouteloua gracilis*). Under medium canopy cover (21 to 35%, dependent on ecological site), understory production ranges from 150 to 700 lb/ac.

Disturbance Response Group 19 Ecological Sites:

PIMO-JUOS/ARNO4 – Modal	F029XY069NV
JUOS/ARNO4/ACHY (Shallow Rocky Loam 10-12" P.Z.)	F029XY071NV
PIMO-JUOS/ARAR8-AMUT	F029XY068NV
PIMO-JUOS/ARNO4-QUGA	F029XY083NV

Modal Site:

The PIMO-JUOS/ARNO4/POFE (F029XY069NV) ecological site is the modal site that represents this group as it has the most acres mapped. This woodland community occurs on mountain and hill sideslopes and summits on all aspects. The site is found from 5,800 to about 8,200 ft in elevation on slopes that typically range from 15 to 50%. Average annual precipitation is 12 to 16 in. The soils are typically very shallow to shallow and well drained. The soils are skeletal, with 35 to over 50% gravels, cobbles, or stones, by volume, distributed throughout their profile. Available water capacity is low, but trees and shrubs can extend their roots into fissures within the underlying material allowing them to utilize deep moisture. There are high amounts of rock fragments at the soil surface which occupy plant growing space, yet help to reduce evaporation and conserve soil moisture. Runoff is medium to rapid and potential for sheet and rill erosion is moderate to severe depending on the slope.

An overstory canopy cover of about 20 to 25% is assumed to be representative of tree dominance on this site in the pristine environment. Wildfire is recognized as a natural disturbance that strongly influenced the structure and composition of the climax vegetation of this woodland site. This site is dominated by singleleaf pinyon and Utah juniper. Black sagebrush and Stansbury's cliffrose are the typical understory shrubs. Yellow rabbitbrush (*Chrysothamnus viscidiflorus*) and green ephedra (*Ephedra viridis*) are shrubs that are also commonly found on this site. Muttongrass is the most prevalent understory grass. In the mature woodland phase, overstory tree canopy composition is about 50 to 70% singleleaf pinyon and 30 to 50% Utah juniper. Understory vegetative is strongly influenced by tree competition, overstory shading, and duff accumulation. Average understory production ranges from 150 to 400 lb/ac with a medium canopy cover of 21 to 35%.

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development, and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasives. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans across Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area, especially in eastern Nevada, when strong convection storms contribute significantly to annual precipitation. Moisture and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

Periodic drought regularly influences Great Basin ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West (Miller et al. 2008a). Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006).

Pinyon and juniper-dominated plant communities in the cold desert of the Great Basin and Colorado Plateau occupy over 18 million hectare (44,800,000 ac) (Miller and Tausch 2001, Miller et al. 2019). Soils occupied by persistent woodlands are most commonly shallow to restrictive layers including claypans, calcareous horizons, and fractured bedrock (Miller et al. 2019). In addition, soil surfaces are typically very coarse-textured with gravelly to extremely cobbly material, often resulting in very low to low soil moisture storage (Miller et al. 2019). In the mid to late 1900s the number of pinyon and juniper trees established per decade began to increase compared to the previous several hundred years. The substantial increase in conifer establishment is attributed to a number of factors the most important being (1) cessation of the aboriginal burning (Tausch 1999), (2) change in climate with rising temperatures (Heyerdahl et al. 2006), (3) the reduced frequency of fire likely driven by the introduction of domestic livestock, (4) a decrease in wildfire frequency along with improved wildfire suppression efforts and (5) potentially increased CO_2 levels favoring woody plant establishment (Bunting 1994, Tausch 1999). Miller et al. (2008b) found pre-settlement tree densities averaged 2 to 11 per acre in six woodlands studied across the Intermountain West. Current stand densities range from 80 to 358 trees/ac. In Utah, Nevada, and Oregon, trees established prior to 1860 accounted for only 2% or less of the total population of pinyon and juniper (Miller et al. 2008b). The research strongly suggests that for over 200 years prior to settlement, woodlands in the Great Basin were relatively low density with limited rates of establishment (Miller and Tausch 2001, Miller et al. 2008b). This evidence strongly suggests that tree canopy cover of 10 to 20% may be more representative of these sites in pristine condition. Increases in pinyon and juniper densities post-settlement were the result of both infill in mixed-age tree communities and expansion into shrub-steppe communities. Pre-settlement trees accounted for less than 2% of the stands sampled in Nevada, Oregon, and Utah (Miller et al. 1999, Miller and Tausch 2001, Miller et al. 2008b). However, the proportion of old-growth can vary depending on disturbance regimes, soils, and climate. Some ecological sites are capable of supporting persistent woodlands, likely due to specific soils and climate resulting in infrequent stand replacement disturbance regimes. In the Great Basin, old-growth trees have been found to typically grow on rocky shallow or sandy soils that support little understory vegetation to carry a fire (Holmes et al. 1986, Miller and Rose 1995, West et al. 1998).

Infilling by younger trees increases canopy cover causing a decrease in understory perennial vegetation and an increase in bare ground. As pinyon and juniper trees increase in density so has their litter. Phenolic compounds of juniper scales can have an inhibitory effect on grass growth (Jameson 1970). Furthermore, infilling shifts stand-level biomass from ground fuels to canopy fuels which has the potential to significantly impact fire behavior. The more tree-dominated pinyon and juniper woodlands become, the less likely they are to burn under moderate conditions, resulting in infrequent high-intensity fires (Gruell 1999, Miller et al. 2008b). Additionally, as the understory vegetation declines in vigor and density with increased canopy, the seed and propagules of the understory plant community also decrease significantly. The increase in bare ground allows for the invasion of non-native annual species such as cheatgrass and with intensive wildfire, the potential for conversion to annual exotics is a serious threat (Tausch 1999, Miller et al. 2008b).

Singleleaf pinyon and Utah juniper are long-lived tree species with wide ecological amplitudes (Tausch et al. 1981, West et al. 1998, Weisberg and Ko 2012). The maximum ages of pinyon and juniper exceed 1,000 years and stands with maximum age classes are only found on steep rocky slopes with no evidence of fire (West et al. 1975). Pinyon is slow-growing and very intolerant to shade with the exception of young plants, usually first-year seedlings (Tueller and Clark 1975). Singleleaf pinyon seedling establishment is episodic. Population age structure is affected by drought, which reduces seedling and sapling recruitment more than other age classes. The ecotones between singleleaf pinyon woodlands and adjacent shrublands and grasslands provide favorable microhabitats for singleleaf pinyon seedling establishment since they are active zones for seed dispersal, nurse plants are available, and singleleaf pinyon seedlings are only affected by competition from grass and other herbaceous vegetation for a couple of years.

Specific successional pathways after disturbance in pinyon-juniper stands are dependent on a number of variables, such as plant species present at the time of disturbance and their individual responses to disturbance, past management, type and size of disturbance, available seed sources in the soil or adjacent areas, and site and climatic conditions throughout the successional process.

Utah juniper can be killed by a fungus called Juniper Pocket Rot (*Pyrofomes demidoffi*), also known as white trunk rot (Eddleman et al. 1994, Durham 2014). Pocket rot enters the tree through any wound or opening that exposes the heartwood. In an advanced stage, this fungus can cause high mortality (Durham 2014). Dwarf mistletoe (*Phorandendron* spp.) a parasitic plant, may also affect Utah juniper and without treatment or pruning, may kill the tree 10 to 15 years after infection. Seedlings and saplings are most susceptible to the parasite (Christopherson 2014). Other diseases affecting juniper are: witches'-broom (*Gymnosporangium* spp.) that may girdle and kill branches; leaf rust (*Gymnosporangium* spp.) on leaves and young branches; and juniper blight (*Phomopsis* spp.). Flat-head borers (*Chrysobothris spp.*) attack the wood; long-horned beetles (*Methia juniper*, *Styloxus bicolor*) girdle limbs and twigs; and round-head borers (*Callidium* spp.) attack twigs and limbs (Tueller and Clark 1975).

Phillips (1909) recognized that the pinyons are more resistant to disease than most of the conifers with which it associates. Hepting (1971) lists several diseases affecting pinyon including: foliage diseases, tarspot needle cast (*Davisomycella ampla)*, stem diseases such as blister rust (*Cronartium ribicola*) and dwarf mistletoe (*Arceuthobium spp.*), root diseases and trunk rots, red heart rot, and butt rot (caused by *Polyporus schweinitzii*). The pinyon ips beetle

(*Ips confuses*) and pinyon needle scale (*Matsucoccus acalyptus*) are both native insects to Nevada that attack pinyon pines throughout their range. The pinyon needle scale weakens trees by killing needles older than 1 year. Sometimes small trees are killed by repeated feeding and large trees are weakened to the point that they are attacked by the pinyon ips beetle. The beetle typically kills weak and damaged trees (Phillips and Reboletti 2014). During periods of long-term drought, the impact of these two insects on singleleaf pinyon can be substantial.

The pinyon jay (*Gymnorhinus cyanocephalus*) and other members of the seed caching corvids play an important role in pinyon pine regeneration. These birds cache the seeds in the soil for future use. Those seeds that escape harvesting by the birds and rodents have the opportunity to germinate under favorable soil and climatic conditions (Lanner 1981). A mutualistic relationship exists between the trees that produce food and the animals that disperse the seeds, thereby ensuring the perpetuation of the trees. Large crops of seeds may stimulate reproduction in birds, especially the pinyon jay (Ligon 1974).

Pinyon and juniper growth is dependent mostly upon soil moisture stored from winter precipitation, mainly snow. Much of the summer precipitation is ineffective, being lost in runoff after summer convection storms or by evaporation and interception (Tueller and Clark 1975). Pinyon and juniper are highly resistant to drought which is common in the Great Basin. Tap roots of pinyon and juniper have a relatively rapid rate of root elongation and are thus able to persist until precipitation conditions are more favorable (Emerson 1932).

In the Great Basin, the majority of annual precipitation is received during the winter and early spring. This continental semiarid climate regime favors the growth and development of deep-rooted shrubs and herbaceous cool season plants using the C3 photosynthetic pathway (Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow results in deeper percolation of moisture into the soil profile. Herbaceous plants, more shallow-rooted than shrubs, grow earlier in the growing season and thrive on spring rains, while the deeper-rooted shrubs lag in phenological development because they draw from deeply infiltrating moisture from snowmelt the previous winter. Periodic drought regularly influences sagebrush ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West. Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006).

The ecological sites in this DRG are co-dominated by sagebrush and cool season, perennial bunchgrasses. Black sagebrush, the dominant shrub of this group, is a low growing, evergreen shrub with a flat-topped crown. It reaches heights of 4 to 20 in. tall and its leaves can be grayish to dark green. Black sagebrush is found primarily on shallow soils that are well drained, gravelly and often calcareous (Thatcher 1959, Hironaka 1963, Zamora and Tueller 1973). Community types with black sagebrush as the dominant shrub were found to have soil depths and available rooting depths of 77 to 81 cm (30 to 32 in.) in a study in northeast Nevada (Jensen 1990). As a generally long-lived species, it is not necessary for new individuals to recruit every year for perpetuation of the stand. Infrequent large recruitment events and simultaneous low, continuous recruitment is the foundation of population maintenance (Noy-Meir 1973). Survival of the seedlings is dependent on adequate moisture conditions. Black sagebrush usually inhabits sites intolerable for other sagebrush species, forming unique communities (Tilley and St. John 2012a). The species is also a tetraploid meaning that it contains four homologous sets of chromosomes. This causes the smaller stature and slow growth rate of black sagebrush and increases its resistance to drought (Mahalovich and McArthur 2004).

Low sagebrush is fairly drought tolerant, but also tolerates periodic wetness during some portions of the growing season (Fosberg and Hironaka 1964, Blackburn et al. 1968a, b, 1969). It grows on soils that have a strongly-structured argillic (clay) horizon close to the soil surface, limiting available rooting depth (Fosberg and Hironaka 1964, Zamora and Tueller 1973, Winward 1980). Low sagebrush is also susceptible to the sagebrush defoliator, Aroga moth (*Aroga websteri*). Aroga moth can partially or entirely kill individual plants or entire stands of big sagebrush (Furniss and Barr 1975), but the research is inconclusive of the damage sustained by low sagebrush populations.

Utah serviceberry is a large shrub that grows from 2 to 4 m (6.6 to 13.1 ft) tall and typically grows in big sagebrush, pinyon-juniper, and aspen communities (Hammond 2012). Despite typically being found surrounded by other species, serviceberry seedlings can be out-competed by dense stands of grasses and forbs. Utah serviceberry is top-killed by fire but resprouts from an underground crown, and its branches, leaves, and berries all provide forage for wildlife and livestock (Noller 2008). Utah serviceberry is more drought tolerant than other serviceberry species, and its root system is very deep and spreading and well adapted to coarse-textured soils (Hammond 2012). However, Utah serviceberry has been found to be intolerant of high water tables and poorly drained soils. The only pest known to be a serious threat to Utah serviceberry is cedar-apple rust (*Gymnosporangium juniperi-virginianae*), which Utah serviceberry can host in its leaves and berries when growing in proximity to Junipers (*Juniperus* spp.) (Wasser et al. 1982).

Gambel oak is a deciduous small tree or shrub that is found in the foothills and lower mountains of western North America. It typically grows to less than 30 ft in height, but can occasionally reach 50 ft. Gambel oak provides cover, habitat, and food for many different wildlife species, including mule deer, elk, bears, songbirds and small mammals (Jester et al. 2008). Gambel oak’s primary form of reproduction is vegetative, and new plants sprout from an extensive root system (Jester et al. 2008). The ability to sprout after disturbance facilitates reestablishment following fire (Premoli and Steinke 2008).

Sonoran scrub oak intermixes with Gambel oak in some locations in MLRA 29, however, it is typically sub-dominant to Gambel oak. Sonoran scrub oak has been found to root over 30 ft deep and also exhibits extensive lateral rooting (Saunier 1964). Sonoran scrub oak, is an aggressive sprouter and quickly reestablishes after fire or other disturbances. Like its cousin

Gambel oak, it provides quality wildlife habitat and acorns are readily consumed by small mammals, bears, birds and other animals.

Desert bitterbrush, antelope bitterbrush, and cliffrose, all in the *Purshia* genus, occur frequently but not abundantly on the ecological sites within this DRG. Hybridization is common among these species, making field identification challenging (Booth et al. 2008). The shrubs are drought tolerant and all provide high quality browse for domestic and wild ungulates (Bishop et al. 2001). In general, bitterbrush and cliffrose are moderately fire tolerant (McConnell and Smith 1977). These shrubs regenerate primarily by seed and may resprout (Blaisdell and Mueggler 1956, Blaisdell et al. 1982), however sprouting ability is highly variable and has been attributed to genetics, plant age, phenology, soil moisture and texture and fire severity (Blaisdell and Mueggler 1956, Blaisdell et al. 1982, Clark et al. 1982, Cook et al. 1994). Rodent caching of seed has been identified as an important mechanism for establishment of new plants (Alexander et al. 1974).

The perennial bunchgrasses that are sub-dominant to the shrubs include Indian ricegrass, muttongrass, and bottlebrush squirreltail. These species generally have somewhat shallower root systems than the shrubs, but root densities are often as high as or higher than those of shrubs in the upper 0.5 m (1.6 ft) of the soil profile. General differences in root depth distributions between grasses and shrubs result in resource partitioning in these shrub/grass systems.

Muttongrass, one of the dominant understory species of this group, is a tufted, multi-flowered, perennial bunchgrass that can grow between 8 and 30 in. tall and has narrow leaves, which range from 1 to 3 mm wide. It is found in lower elevations in the northern extent of its native range, and higher elevations in the south. Muttongrass is one of the most drought-tolerant bluegrasses and is useful for restoring communities disturbed by fire, grazing, or mining, but is limited in its use due to low seed viability. Muttongrass plants are most frequently pistillate, but staminate plants do occasionally occur, which are able to hybridize and crossbreed with other bluegrasses. Muttongrass is found throughout the western United States as a primary component of the understory of pinyon-juniper communities and aspen and pine forests (Tilley et al. 2007).

Indian ricegrass is a long-lived, cool-season perennial bunchgrass that grows from 4 to 24 inches in height (Blaisdell and Holmgren 1984). Primarily adapted to coarse textured soils, its deep, fibrous root system makes Indian ricegrass one of the most drought-tolerant native species (Booth et al. 1980). Unlike other cool-season species, Indian ricegrass does not require vernalization (exposure to cold) in order to produce flowers and flowering can continue into late fall with favorable environmental conditions. This allows the seeds in each panicle to ripen over a longer period of time than most other species thus providing a greater opportunity for successful seed production (Jones 1990).

Squirreltail is a short, cool-season bunchgrass that grows between 10 to 45 cm (3.9 to 17.7 in.) tall. It is an allotetraploid that can self-pollinate and is able to hybridize with other grasses, including other species of *Elymus* and some species of *Hordeum* (barley). Squirreltail is a very adaptable grass that is found in all western states in the U.S., western Canada, and portions of Mexico. Squirreltail can be found above 2,000 ft in elevation, and in areas that receive at least 5 in. of precipitation per year.

The ecological sites in this DRG have low to moderate resilience to disturbance and resistance to invasion. Resilience increases with elevation, aspect, increased precipitation, and increased nutrient availability. Four possible stable states have been identified for this DRG.

Annual Invasive Species:

The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and decomposition of dead plant material following disturbance further increases resource pools. The presence of exotic annual plants within these ecosystems decreases ecosystem resilience and resistance to disturbance through competition for limited resources. Dobrowolski et al. (1990) cite multiple authors on the extent of the soil profile exploited by the competitive non-native annual cheatgrass (*Bromus tectorum*). Specifically, the depth of rooting is dependent on the size the plant achieves, and in competitive environments, cheatgrass roots were found to penetrate only 15 cm (6 in.) whereas isolated plants and pure stands were found to root at least 1 m (3.2 ft) in depth with some plants rooting as deep as 1.5 to 1.7 m (0.5 to 0.6 ft).

The species most likely to invade these sites is cheatgrass. Cheatgrass is a cool-season annual grass that maintains an advantage over native plants in part because it is a prolific seed producer, can germinate in the autumn or spring, tolerates grazing, and increases with frequent fire (Klemmedson and Smith 1964, Miller and Rose 1999). Cheatgrass originated from Eurasia and was first reported in North America in the late 1800s (Furbush 1953, Mack and Pyke 1983). Pellant and Hall (1994) found 3.3 million acres of public lands dominated by cheatgrass and suggested that another 76 million acres were susceptible to invasion by winter annuals including cheatgrass and medusahead (*Taeniatherum caput-medusae*).

Recent modeling and empirical work by Bradford and Lauenroth (2006) suggest that seasonal patterns of precipitation input and temperature are also key factors determining regional variation in the growth, seed production, and spread of invasive annual grasses. The phenomenon of cheatgrass “die-off” provides opportunities for restoration of perennial and native species (Baughman et al. 2016, Baughman et al. 2017). The causes of these events are not fully understood, but there is ongoing work to try to predict where they occur, in the hopes of aiding conservation planning (Weisberg et al. 2017, Brehm 2019).

Methods to control cheatgrass include herbicide application, prescribed fire, targeted grazing, and rangeland seeding. Mapping potential or current invasion vectors is a management method designed to increase the cost-effectiveness of control methods. Spraying with herbicide (imazapic or imazapic + glyphosate) and seeding with crested wheatgrass and Sandberg bluegrass has been found to be more successful at combating cheatgrass than spraying alone (Sheley et al. 2012). To date, most seeding success has occurred with non-native wheatgrass species. Perennial grasses, especially crested wheatgrass, are able to suppress cheatgrass growth when mature (Blank et al. 2020). Where native bunchgrasses are missing from the site, revegetation of annual grass-invaded rangelands has been shown to have a higher likelihood of success when using introduced perennial bunchgrasses such as crested wheatgrass (Davies et al. 2015b, Clements et al. 2017). Butler et al. (2011) tested four herbicides (imazapic, imazapic + glyphosate, rimsulfuron, and sulfometuron + chlorsulfuron) for suppression of cheatgrass, medusahead, and North Africa grass (*Ventenata dubia*) within residual stands of native bunchgrass. Additionally, they tested the same four herbicides followed by seeding of six bunchgrasses (native and non-native) with varying success (Butler et al. 2011). Herbicide-only treatments appeared to remove competition for established bluebunch wheatgrass by providing 100% control of North Africa grass and medusahead and greater than 95% control of cheatgrass (Butler et al. 2011). Caution in using these results is advised, as only 1 year of data was reported.

In considering the combination of pre-emergent herbicide and prescribed fire for invasive annual grass control, it is important to assess the tolerance of desirable brush species to the herbicide being applied. Vollmer and Vollmer (2008) tested the tolerance of mountain mahogany (*Cercocarpus montanus*), antelope bitterbrush, and multiple sagebrush species to three rates of imazapic with and without methylated seed oil as a surfactant. They found that a cheatgrass control program, utilizing imazapic, in an antelope bitterbrush community should not exceed 8 oz/ac with or without surfactant. Sagebrush, regardless of species or rate of application, was not affected. However, many environmental variables were not reported in this study and managers should install test plots before broad-scale herbicide application is initiated.

Fire Ecology:

Limited data exists that describes fire histories across woodlands in the Great Basin. Pre-settlement fire return intervals in the Great Basin National Park, Nevada were found to have a mean range between 50 to 100 years with north-facing slopes burning every 15 to 20 years and rocky landscapes with sparse understory very infrequently (Gruell 1999). Results were less conclusive in a similar study in the Bodie Hills; however, it was apparent that old (300+ years old) pinyon primarily survived in protected, low-fuel areas. Woodland dynamics are largely attributed to long-term climatic shifts (temperature and amount and distribution of precipitation) and the extent and return intervals of fire (Miller and Tausch 2001, Miller et al. 2019). Historically, lightning-ignited fires were likely common but typically did not affect more than a few individual trees. Replacement fires were uncommon to rare (100 to 600 years) and occurred primarily during extreme fire behavior conditions.

Utah juniper is usually killed by fire and is most vulnerable to fire when it is under 4 ft tall (Bradley et al. 1992). Larger trees, because they have foliage farther from the ground and thicker bark, can survive low severity fires but mortality does occur when 60% or more of the crown is scorched (Bradley et al. 1992). Singleleaf pinyons are also most vulnerable to fire when less than 4 ft tall, however mature trees do not self-prune their dead branches allowing for accumulated fuel in the crowns. This characteristic and the relative flammability of the foliage make individual mature trees susceptible to fire (Bradley et al. 1992). With the low production of the understory vegetation and low density of trees per acre, high severity fires within this plant community were not likely and rarely became crown fires (Bradley et al. 1992, Miller and Tausch 2001). However, both the infilling of younger trees into old-growth stands and the expansion of trees into surrounding sagebrush communities have increased the risk of loss of pre-settlement trees through the increased landscape level continuity of fuels (Miller et al. 2008b).

Singleleaf pinyon and Utah juniper reestablish by seed from nearby seed sources or surviving seeds. Junipers have a long-lived seed bank due to delayed germination by impermeable seed coats, immature or dormant embryos, and germination inhibitors (Schupp et al. 1999). Singleleaf pinyon trees have relatively short-lived seeds with little innate dormancy that form only temporary seed banks with most seeds germinating in the spring following dispersal (Meeuwig and Basset 1983). The density of pinyon seeds in the seed bank is dependent upon the current year's cone crop. Singleleaf pinyon is known to have favorable cone production every 2 to 3 years thus the potential for a large temporary seed bank is high during mast years and likely low during non-mast years (Schupp et al. 1999). The role of nurse plant requirements is important to post-fire establishment. Schupp et al. (1999) found that singleleaf pinyon seedlings rarely establish in interspaces or open environments. In contrast, Utah juniper seedlings were found capable of establishing in interspace microhabitats as frequently as under sagebrush. Therefore, fire that removes both trees and understory shrubs in pinyon-juniper woodlands may have a relatively greater effect on the establishment of pinyon than juniper.

The initial response of native understory species following fire correlates closely with percent crown cover. In general, research indicates that understory response to disturbance is most productive when crown cover is at or below 20% while beyond 30% there is a rapid decline in understory species and soil seed reserves (Huber et al. 1999). The reference community understory vegetation of black sagebrush, muttongrass, and Indian ricegrass, further supports the evidence of a pre-settlement community with an open overstory and infrequent ground fire.

Black sagebrush plants have no morphological adaptations for surviving fire and must reestablish from seed following fire (Wright et al. 1979). The ability of black sagebrush to establish after fire is mostly dependent on the amount of seed deposited in the seed bank the year before the fire. Seeds typically do not persist in the soil for more than one growing season (Beetle 1960). A few seeds may remain viable in soil for 2 years (Meyer 2008a); however, even in dry storage, black sagebrush seed viability has been found to drop rapidly over time, from

81% to 1% viability after 2 and 10 years of storage, respectively (Stevens et al. 1981). Thus, repeated frequent fires can eliminate black sagebrush from a site, however black sagebrush in zones receiving 12 to 16 in. of annual precipitation have been found to have greater fire survival (Boltz 1994). In lower precipitation zones rabbitbrush may become the dominant shrub species following fire, often with an understory of Sandberg bluegrass and/or cheatgrass and other weedy species.

Low sagebrush is killed by fire and does not sprout (Tisdale and Hironaka 1981). Fire risk is greatest following a wet, productive year when there is greater production of fine fuels (Beardall and Sylvester 1976). Fire return intervals are not well understood because these ecosystems rarely coincide with fire-scarred conifers, however a ride range of 20 to well over 100 years has been estimated (Miller and Rose 1999, Knick et al. 2005, Baker 2006). Historically, fires were probably patchy due to the low productivity of these sites (Beardall and Sylvester 1976, Ralphs and Busby 1979, Wright et al. 1979, Smith and Busby 1981). Fine fuel loads generally average 100 to 400 lb/ac (110 to 450 kg/ha) but are occasionally as high as 600 lb/ac (680 kg/ha) in low sagebrush habitat types (Bradley et al. 1992). Reestablishment occurs from off-site wind-dispersed seed (Young 1983). Recovery time of low sagebrush following fire is variable (Young 1983). After fire, if regeneration conditions are favorable, low sagebrush recovers in 2 to 5 years, however on harsh sites where cover is low to begin with and/or erosion occurs after fire, recovery may require more than 10 years (Young 1983). Slow regeneration may subsequently exacerbate erosion (Blaisdell et al. 1982).

Bitterbrush and cliffrose are moderately fire tolerant (McConnell and Smith 1977). These shrubs regenerate primarily by seed and may resprout (Blaisdell and Mueggler 1956, McArthur and Welch 1982), however, sprouting ability is highly variable and has been attributed to genetics, plant age, phenology, soil moisture and texture, and fire severity (Blaisdell and Mueggler 1956, Blaisdell et al. 1982, Clark et al. 1982, Cook et al. 1994). Bitterbrush sprouts from a region on the stem approximately 1.5 in. above and below the soil surface; the plant rarely sprouts if the root crown is killed by fire (Blaisdell and Mueggler 1956). Bitterbrush and cliffrose may resprout following a low-intensity fire however, sprouting response also depends on soil moisture levels at the time of fire (Murray 1983). Lower soil moisture allows more charring of the stem below ground level (Blaisdell and Mueggler 1956), thus sprouting will usually be more successful after a spring fire than after a fire in summer or fall (Murray 1983, Busse et al. 2000, Kerns et al. 2006). If cheatgrass is present, bitterbrush and cliffrose seedling success is much lower. The factor that most limits the establishment of these seedlings is competition for water resources with the invasive species cheatgrass (Clements and Young 2002).

Gambel and Sonoran scrub oak are both highly fire tolerant due to their root sprouting ability (Kaufmann et al. 2016). Communities with one or both of these species in the understory may convert to an oak dominated condition following fire. This condition may persist for many decades.

Utah serviceberry is a large, fire-tolerant shrub that may occur on one or more the ecological sites contained within this DRG. It is top-killed by fire, but sprouts from the underground root crown after disturbance (Carmichael et al. 1978). However, this resprouting is reliant on the amount of moisture in the soil and Utah serviceberry is more adapted for drier soils, which will limit the potential for a sprout to successfully grow (Hammond 2012). *A. utahensis* can also re-colonize an area after fire via seeds, but this can require up to 8 to 10 years for plants to be fully matured and productive (Noller 2008).

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The initial condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species' response. For most forbs and grasses the growing points are located at or below the soil surface providing relative protection from disturbances that decrease above-ground biomass, such as grazing or fire. Thus, fire mortality is more correlated to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant, and abundance of old growth (Wright 1971, Young 1983). However, the season and severity of the fire will influence plant response. Plant response will vary depending on post-fire soil moisture availability.

Muttongrass, a dominant component in this group, is top killed by fire but will sprout after low to moderate severity fires. A study by Vose and White (1991) in an open saw timber site found minimal difference in the overall effect of burning on muttongrass (Vose and White 1991).

Indian ricegrass is fairly fire tolerant (Wright 1985), which is likely due to its low culm density and below-ground plant crowns. Vallentine (1989) cites several studies in the sagebrush zone that classified Indian ricegrass as being slightly damaged from late summer burning. Indian ricegrass has also been found to reestablish on burned sites through seeds dispersed from adjacent unburned areas (Young 1983, West 1994). Thus, the presence of surviving, seed-producing plants facilitates the reestablishment of Indian ricegrass. Grazing management following fire to promote seed production and establishment of seedlings is important (Booth et al. 1980).

Bottlebrush squirreltail is considered one of the most fire-resistant bunchgrasses due to its small size, coarse stems, and sparse leafy material (Wright and Klemmedson 1965, Wright 1971, Britton et al. 1990). Post-fire regeneration occurs from surviving root crowns and from on- and off-site seed sources (Bradley et al. 1992). Bottlebrush squirreltail has the ability to produce large numbers of highly germinable seeds, with relatively rapid germination (Young and Evans 1977) when exposed to the correct environmental cues. Squirreltail is capable of facultative fall or spring germination, develops extensive roots at low temperatures, and produces seeds early in the season (Reynolds and Fraley 1989, Hironaka 1994, Monsen et al. 2004b). Recent research indicates that squirreltail is capable of relatively rapid natural selection to improve survival in low-water, competitive environments (Kulpa and Leger 2013). These traits and others make squirreltail competitive with cheatgrass and medusahead (Hironaka and Sindelar 1975, Hironaka 1994). Squirreltail reproduces primarily through seed. The long awns of the fruit allow for wind dispersal up to 130 ft away from the parent plant facilitating colonization of burned rangelands (Hironaka and Tisdale 1963, Marlette and Anderson 1986).

Livestock/Wildlife Grazing Interpretations:

Pinyon-juniper woodlands provide a diversity of habitats for wildlife. Although the foliage of pinyon and juniper varies in palatability among fauna, pinyon nuts and juniper berries are preferred by many species. The understory species provide fruits and browse for large ungulates, small mammals, birds, and beavers (Wildlife Action Plan Team 2012).

Ungulates will use pinyon and juniper trees for cover and graze the foliage. The understory species also provide critical browse for deer (Odocoileus spp.). The trees provide important cover for mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis*), wild horses (*Equus ferus*), mountain lion (*Puma concolor*), bobcat (*Lynx rufus*), and pronghorn (*Antilocapra americana*) (Logan and Irwin 1985, Evans 1988, Coates and Schemnitz 1994, Gottfried and Severson 1994).

Mule deer is considered the dominant big game species in the pinyon-juniper woodland and depend heavily on these woodlands for cover, shelter, and emergency forage during severe winters (Frischknecht 1975). Mule deer will eat singleleaf pinyon and juniper foliage, using the foliage moderately in winter, spring, and summer (Kufeld et al. 1973). Deep snows in higher elevation forest zones force mule deer and elk down into pinyon-juniper habitats during winter. This change in habitat allows mule deer and elk to browse the dwarf trees and shrubs (Gottfried and Severson 1994).

The diet of pronghorn antelope varies considerably; however, singleleaf pinyon was shown to comprise 1 to 2% of winter diet of pronghorn that occur in pinyon-juniper habitat. Desert bighorn sheep (*Ovis nelson*) may utilize pinyon-juniper habitat, but only where the terrain is rocky and steep (Gottfried et al. 2000). Gray foxes (*Urocyon cinereoargenteus*), bobcats, coyotes (*Canis latran*s), weasels (*Mustela frenata*), skunks (*Mephitis* spp.), badgers (*Taxidea taxus*), and ringtail cats (*Bassariscus astutus*) search for prey in pinyon-juniper habitat woodlands (Short and McCulloch 1977).

Juniper "berries" or berry-cones are eaten by black-tailed jackrabbits, *Lepus californicus*, and coyotes (Gese et al. 1988, Kitchen et al. 2000). A study by Kitchen et al. (2000) conducted in juniper-pinion habitat found vegetation in coyote scats was mainly grass seeds or juniper berries. Jackrabbits are a major dispenser of juniper seeds (Schupp et al. 1999). The pinyon mouse (*Peromyscus truei*) is a pinyon-juniper obligate and uses the woodlands for cover and food (Hoffmeister 1981). Other small mammals include the porcupine (*Hystricomorph hystricidae*), desert cottontail (*Sylvilagus audubonii*), Nuttall's cottontail (*S. nuttallii*), deer mouse (*Peromyscus maniculatus*), Great Basin pocket mouse (*Perognathus parvus*), chisel-toothed kangaroo rat (*Dipodomys microps*) and desert woodrat (*Neotoma lepida*) (Turkowski and Watkins 1976).

Many bird species are associated with the pinyon-juniper habitat; some are permanent residents, some summer residents, and some winter residents, depending upon location. For birds and bats, the woodland provides structure for nesting and roosting, and locations for foraging. Singleleaf pinyon provides a number of cavities and the stringy, fibrous bark provides quality nesting material as well as the food provided by the tree's seeds and berries (Short and McCulloch 1977). Many bird species depend on juniper berry-cones and pine nuts for fall and winter food (Balda and Masters 1980). Several bird species are obligates including gray flycatcher (*Epidonax wrightii),* scrub jay (*Aphelocoma californica)*, plain titmouse (*Parus inornatus ridgwayi*), and gray vireo (*Vireo vicinior*); several species are semi-obligates including black-chinned hummingbird (*Archilochus alexandri*), ash-throated flycatcher (*Myiarchus cinerascens*), pinion jay, American bushtit (*Psaltriparus minimus*), Bewick's wren (*Thryomanes bewickii*), Northern mockingbird (*Mimus polyglottos*), blue-gray gnatcatcher (*Polioptila caerulea*), black-throated gray warbler (*Dendroica nigrescens*), house finch (*Haemorhous mexicanus*), spotted towhee (*Pipilo maculatus*), lark sparrow (*Chondestes grammacus*) and black-chinned sparrow (*Zonotrichia atricapilla*) (Balda and Masters 1980). Ferruginous hawk (*Buteo regalis*), a conservation priority species due to recent population declines in Nevada, nests in older trees of sufficient size and structure to support their large nest platforms (Holechek 1981).

Diurnal reptiles include the sagebrush swift (*Sceloporus graciosus*), the blue-bellied lizard (*Sceloporus elongates*)*,* the western collard lizard (*Crotaphytus collaris*), the Great Basin rattlesnake (*Oreganus lutosus*), the Great Basin gopher snake (*Pituophis catenifer*), and horned lizard (*Phrynosoma spp.*) also occur in Utah juniper habitat (Frischknecht 1975). However, the distribution of most of the herpetofauna present in pinyon-juniper woodlands is poorly understood and more research and management are needed.

The history of livestock grazing in the pinyon-juniper ecosystem goes back more than 200 years, depending on the particular locality within the ecosystem (Hurst 1975). Historically, pinyon-juniper woodlands were much more open, and they supported a diverse understory that provided forage for both livestock and wildlife. Historic livestock overuse and increased stand densities have reduced the carrying capacity of these pinyon-juniper stands and many current stands only provide shade and shelter for livestock.

Black sagebrush palatability has been rated as moderate to high depending on the ungulate and the season of use (Horton 1989, Wambolt 1996). The palatability of black sagebrush increases the potential negative impacts on remaining black sagebrush plants from grazing or browsing pressure following fire (Wambolt 1996). Pronghorn utilize black sagebrush heavily (Beale and Smith 1970). On the Desert Experiment Range, black sagebrush was found to comprise 68% of pronghorn diet even though it was only the third most common plant. Fawns were found to prefer black sagebrush utilizing it more than all other forage species combined (Beale and Smith 1970). Domestic livestock will also utilize black sagebrush. The domestic sheep industry that emerged in the Great Basin in the early 1900s was largely based on wintering domestic sheep in black sagebrush communities (Mozingo 1987c). Domestic sheep will browse black sagebrush during all seasons of the year depending on the availability of other forage species with greater amounts being consumed in fall and winter. Black sagebrush is generally less palatable to cattle than to domestic sheep and wild ungulates, however, cattle use of black sagebrush has also been shown to be greatest in fall and winter (Schultz and McAdoo 2002), with only trace amounts being consumed in summer (Van Vuren 1984).

Domestic sheep and, to a much lesser degree, cattle consume low sagebrush, particularly during the spring, fall, and winter (Sheehy and Winward 1981). Heavy dormant season grazing by sheep will reduce sagebrush cover and increase grass production (Laycock 1967). Trampling damage, particularly from cattle or horses, in low sagebrush habitat types is greatest in areas with high clay content soils during spring snowmelt when surface soils are saturated. In drier areas with more gravelly soils, trampling is less of a problem (Hironaka et al. 1983).

Bunchgrasses, in general, best tolerate light grazing after seed formation. Britton et al. (1990) observed the effects of clipping date on basal area of five bunchgrasses in eastern Oregon, and found grazing from August to October (after seed set) has the least impact. Heavy grazing during the growing season will reduce perennial bunchgrasses and increase sagebrush (Laycock 1967). Abusive grazing by cattle or horses allows unpalatable plants like low sagebrush, rabbitbrush and some forbs such as arrowleaf balsamroot to become dominant on the site. Sandberg bluegrass is also grazing tolerant due to its short stature. Annual non-native weedy species such as cheatgrass, mustards, and medusahead may invade.

Antelope bitterbrush is critical browse for mule deer, as well as domestic livestock, pronghorn, and elk (Wood et al. 1995). Grazing tolerance of antelope bitterbrush is dependent on-site conditions (Garrison 1953). Cattle tend to graze bitterbrush in higher areas than sheep or deer and take off newer twig growth, keeping them shorter. Palatability varies between plants and stages of growth, degree of use, and location. Columbian black-tailed deer and antelope usually graze it in the spring and summer, mule deer in the winter, and livestock in the summer. It is rather shade intolerant (Hormay 1943). Antelope bitterbrush initiates growth in the spring and finishes by late summer. It grows large ephemeral leaves in the spring and then small overwintering leaves in the late summer. Antelope bitterbrush recovers vigorously with new growth after defoliation from grazing, and potential growth remains the same or is enhanced by browsing. Antelope bitterbrush will allocate additional resources to new growth to recover from browsing (Bilbrough and Richards 1993).

Gambel and Sonoran scrub oak are considered important species for wildlife forage, even though it is not highly palatable. This is due to how widespread and abundant it is, especially on winter ranges. Gambel oak leaves provide important forage for deer and elk year-round., and acorns are an extremely valuable mast crop, especially for black bears in the fall (Jester et al. 2008). Due to being a sprouter, Gambel oak can provide valuable forage and cover in post-fire communities (Premoli and Steinke 2008).

Utah serviceberry is a very important plant because of the amount of food, cover, and habitat it provides to both livestock and wildlife. Its leaves, branches, and berries are used by many wildlife species, including big game, birds, and small animals (Noller 2008). Utah serviceberry is highly palatable to wildlife and livestock and is a preferred forage for elk (McCulloch 1955).

Indian ricegrass is a preferred forage species for livestock and wildlife (Cook 1962, Booth et al. 2006). This species is often heavily utilized in winter because it cures well (Booth et al. 2006). It is also readily utilized in early spring, being a source of green feed before most other perennial grasses have produced new growth (Quinones 1981). Booth et al. (2006) note that the plant does well when utilized in winter and spring. Cook and Child (1971), however, found that repeated heavy grazing reduced crown cover, which may reduce seed production, density, and basal area of these plants. Additionally, heavy early spring grazing reduces plant vigor and stand density (Stubbendieck et al. 1985). In eastern Idaho, productivity of Indian ricegrass was at least 10 times greater in undisturbed plots than in heavily grazed ones (Pearson 1965). Cook and Child (1971) found a significant reduction in plant cover after 7 years of rest from heavy (90%) and moderate (60%) spring use. The seed crop may be reduced where grazing is heavy (Bich et al. 1995). Tolerance to grazing increases after May, thus spring deferment may be necessary for stand enhancement (Pearson 1964, Cook and Child 1971); however, utilization of less than 60% is recommended. In summary, adaptive management is required to manage this bunchgrass well.

Muttongrass is very palatable for wildlife and livestock and is rated as excellent forage for cattle and horses, and good for sheep. Muttongrass starts growth in late winter or early spring and provides excellent early feed. Muttongrass foliage cures well and is good fall forage, but not as good as spring or summer (Humphrey et al. 1952).

Bottlebrush squirreltail has the ability to produce large numbers of highly germinable seeds, with relatively rapid germination (Young and Evans 1977) when exposed to the correct environmental cues. Early spring growth and the ability to grow at low temperatures contribute to the persistence of bottlebrush squirreltail among cheatgrass-dominated ranges (Hironaka and Tisdale 1973). Squirreltail generally increases in abundance when moderately grazed or protected (Hutchings and Stewart 1953). In addition, moderate trampling by livestock in big sagebrush rangelands of central Nevada enhanced bottlebrush squirreltail seedling emergence compared to untrampled conditions. Heavy trampling however was found to significantly reduce germination sites (Eckert and Spencer 1987). Squirreltail is more tolerant of grazing than Indian ricegrass but all bunchgrasses are sensitive to overutilization within the growing season.

Bunchgrasses, in general, tolerate moderate grazing anytime of the year. Growing season grazing should not occur more than once every other year and once every third year is recommended. Britton et al. (1990) observed the effects of clipping date on the basal area of five bunchgrasses in eastern Oregon and found grazing from August to October (after seed set) has the least impact. Heavy grazing, year after year during the growing season, will reduce perennial bunchgrasses and increase sagebrush. Abusive grazing by cattle or horses will likely increase sagebrush, rabbitbrush, and deep-rooted perennial forbs such as arrowleaf balsamroot (*Balsamorhiza* spp.) Annual non-native weedy species such as cheatgrass and mustards, and potentially medusahead may invade.

State and Transition Model Narrative for Group 19:

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 29 disturbance response group 19.

Reference State 1.0:

The Reference State 1.0 is representative of the natural range of variability under pristine conditions. This reference state has four general community phases: a mature woodland phase (1.1), a shrub-herbaceous phase (1.2), an immature woodland phase (1.3), and an over-mature woodland phase (1.4). State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire, periodic drought, and/or insect or disease attack. Fires within this community are infrequent and likely small and patchy due to low fuel loads. This fire type will create a plant community mosaic that will include all/most of the following community phases within this state.

Community Phase 1.1:

This phase is characterized by widely dispersed mature pinyon and juniper trees with a black sagebrush and perennial bunchgrass understory. The visual aspect is dominated by singleleaf pinyon and Utah juniper with canopy cover of 20 to 35%. Trees have reached maximal or near maximal heights for the site and many tree crowns may be flat- or round-topped. At fire-safe sites, dominant trees average greater than 15 inches in diameter at one-foot stump height. Muttongrass is the most prevalent grass in the understory. Black sagebrush is the primary understory shrub. Forbs are minor components. Overall, the understory is sparse with production ranging between 150 to 400 lb/ac.

PIMO-JUOS/ARNO4-POFE (F029XY069NV), Reference 1.1, T. Stringham, June 2022

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
A high-severity crown fire will eliminate or reduce the singleleaf pinyon and Utah juniper overstory and the shrub component. This allows for the perennial bunchgrasses to dominate the site. Sprouting shrubs may increase.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.4:
Time without disturbances such as fire, drought, or disease will allow for the gradual infilling of singleleaf pinyon and Utah juniper.

Community Phase 1.2:
This community phase is characterized by a post-fire shrub and herbaceous community. Muttongrass and other perennial bunchgrasses dominate. Forbs may increase after a fire but will likely return to pre-burn levels within a few years. Pinyon and juniper seedlings up to 4 ft in height may be present. Black sagebrush may be present in unburned patches. Burned tree skeletons may be present; however, these have little or no effect on the understory vegetation.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.3:
Time without disturbances such as fire, drought, or disease will allow for the gradual maturation of the singleleaf pinyon and Utah Juniper component. Black sagebrush reestablishes.

Community Phase 1.3:
This community phase is characterized by an immature woodland, with pinyon and juniper trees averaging over 4.5 ft in height. Tree canopy cover is between 10 to 20%. Tree crowns are typically cone- or pyramidal-shaped. Understory vegetation is dominated by black sagebrush and perennial bunchgrasses as well as smaller tree seedlings and saplings.

Community Phase Pathway 1.3a, from 1.3 to 1.1:
Time without disturbances such as fire, drought, or disease will allow for the gradual maturation of singleleaf pinyon and Utah juniper. Infilling by younger trees continues. Excessive herbivory may also reduce the perennial grass understory.

Community Phase Pathway 1.3b, from Phase 1.3 to 1.2:
Fire reduces or eliminates tree canopy, allowing perennial grasses to dominate the site.

Community Phase 1.4 (At-Risk):
This phase is dominated by singleleaf pinyon and Utah juniper. The stand exhibits mixed age classes and canopy cover may be greater than 30%. The density and vigor of the black sagebrush and perennial bunchgrass understory is decreased. Bare ground areas are likely to increase. Mat-forming forbs such as phlox may increase. This community is at risk of crossing a threshold; without proper management this phase will transition to the Infilled Tree State 3.0.

Community Phase Pathway 1.4a, from Phase 1.4 to 1.1:
Low intensity fire, insect infestation, or disease kills individual trees within the stand reducing canopy cover to less than 20%. Over time, young trees mature to replace and maintain the mature woodland. The black sagebrush and perennial bunchgrass community increases in density and vigor.

Community Phase Pathway 1.4b, from Phase 1.4 to 1.2:
A high-severity crown fire will eliminate or reduce the singleleaf pinyon and Utah juniper overstory and the shrub component which will allow for the perennial bunchgrasses to dominate the site.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0:

Trigger: Introduction of non-native annual species.

Slow variables: Over time the annual non-native plants will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

T1B: Transition from Reference State 1.0 to Infilled Tree State 3.0

Trigger: Time and a lack of disturbance allow trees to dominate site resources; may be coupled with inappropriate herbivory and/or fire suppression that favors shrub and tree dominance.

Slow variables: Over time the abundance and size of trees will increase.

Threshold: Pinyon and juniper canopy cover is greater than 50%. Little understory vegetation remains due to competition with trees for site resources. Black sagebrush skeletons common.

Current Potential State 2.0:

This state is similar to the Reference State 1.0, with four general community phases: a mature woodland tree phase (1.1), a shrub-herbaceous phase (1.2), an immature woodland phase (1.3), and an over-mature woodland phase (1.4) Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of non-native species. These non-natives, particularly cheatgrass, can be highly flammable and promote fire where historically fire had been infrequent. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal. Fires within this community with the small amount of non-native annual species present are likely still small and patchy due to low fuel loads. This fire type will create a plant community mosaic that will include all/most of the following community phases within this state.

Community Phase 2.1:

This phase is characterized by widely dispersed mature pinyon and juniper trees with a black sagebrush and perennial bunchgrass understory. The visual aspect is dominated by singleleaf pinyon and Utah juniper with canopy cover from 20 to 35% or more. Trees have reached maximal or near maximal heights for the site and many tree crowns may be flat- or round-topped. At fire-safe sites, dominant trees average greater than 15 inches in diameter at one-foot stump height. Muttongrass is the most prevalent grass in the understory. Black sagebrush is the primary understory shrub. Forbs are minor components. Overall, the understory is sparse with production ranging between 150 to 400 lb/ac. Non-native, annual species are a minor component.

PIMO-JUOS/ARNO4-POFE (F029XY069NV), Current Potential 2.1, T. Stringham, June 2022

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
A high-severity crown fire will eliminate or reduce the singleleaf pinyon and Utah juniper overstory and the shrub component. This allows for the perennial bunchgrasses to dominate. Sprouting shrubs may increase.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.4:
Time without disturbances such as fire, drought, or disease will allow for the gradual infilling of singleleaf pinyon and Utah juniper.

Community Phase 2.2:
This community phase is characterized by a post-fire shrub and herbaceous community. Muttongrass and other perennial grasses dominate. Forbs may increase post-fire but will likely return to pre-burn levels within a few years. Pinyon and juniper seedlings up to 4 ft in height may be present. Black sagebrush may be present in unburned patches. Burned tree skeletons may be present; however, these have little or no effect on the understory vegetation. Sprouting shrubs may increase. Annual non-native species generally respond well after fire and may be stable or increasing within the community.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.3:

Time without disturbances such as fire, drought, or disease will allow for the gradual maturation of the singleleaf pinyon and Utah Juniper component. Black sagebrush reestablishes. Excessive herbivory may also reduce perennial grass understory further facilitating sagebrush or tree establishment.

Community Phase 2.3:

This community phase is characterized by an immature woodland, with pinyon and juniper trees averaging over 4.5 ft in height. Tree canopy cover is between 10 to 20%.

Tree crowns are typically cone- or pyramidal-shaped. Understory vegetation is dominated by black sagebrush and perennial bunchgrasses as well as smaller tree seedling and saplings. Annual non-native species are present.

Community Phase Pathway 2.3a, from Phase 2.3 to 2.1:

Time without disturbances such as fire, drought, or disease will allow for the gradual maturation of singleleaf pinyon and Utah juniper. Infilling by younger trees continues. Excessive herbivory may reduce perennial grass density and facilitate tree and shrub establishment.

Community Phase Pathway 2.3b, from Phase 2.3 to 2.2:

Fire reduces or eliminates tree canopy, allowing perennial grasses to dominate the site.

Community Phase 2.4 (At-Risk):

This phase is dominated by singleleaf pinyon and Utah juniper. The stand exhibits mixed age classes and canopy cover exceeds 30%. The density and vigor of the black sagebrush and perennial bunchgrass understory is decreased. Bare ground areas are likely to increase. Mat-forming forbs may increase. Annual non-native species are present primarily under tree canopies. This community is at risk of crossing a threshold, without proper management this phase will transition to the Infilled Tree State 3.0.

PIMO-JUOS/ARAR8-AMUT (F029XY068NV), Current Potential 2.4, T. Stringham, June 2022

PIMO-JUOS/ARNO4-ACHY (F029XY071NV), Current Potential 2.4, T. Stringham, June 2022

Community Phase Pathway 2.4a, from Phase 2.4 to 2.1:

Low intensity fire, insect infestation, or disease kills individual trees within the stand reducing canopy cover to 20% or less. Over time young trees mature to replace and maintain the old-growth woodland. The black big sagebrush and perennial bunchgrass community increases in density and vigor. Annual non-natives present in trace amounts.

Community Phase Pathway 2.4b, from Phase 2.4 to 2.2:
A high-severity crown fire will eliminate or reduce the singleleaf pinyon and Utah juniper overstory and the shrub component which will allow for the perennial bunchgrasses to dominate the site. Annual non-native grasses typically respond positively to fire and may increase in the post-fire community.

T2A: Transition from Current Potential State 2.0 to Infilled Tree State 3.0:

Trigger: Time and a lack of disturbance allow trees to dominate site resources; may be coupled with inappropriate grazing management that favors shrub and tree dominance.

Slow variables: Over time the abundance and size of trees will increase.

Threshold: Singleleaf pinyon and Utah juniper canopy cover is greater than 50%. Little understory vegetation remains due to competition with trees for site resources.

T2B: Transition from Current Potential State 2.0 to Annual State 4.0:

Trigger: Catastrophic crown fire facilitates the establishment of non-native, annual species.

Slow variables: Increase in tree crown cover, loss of perennial understory and an increase in annual non-native species.

Threshold: Cheatgrass or other non-native annuals dominate understory. Loss of deep-rooted perennial bunchgrasses changes spatial and temporal nutrient cycling and nutrient redistribution, and reduces soil organic matter. Increased canopy cover of trees allows severe stand-replacing fire. The increased seed bank of non-native, annual species responds positively to post-fire conditions facilitating the transition to an Annual State.

Infilled Tree State 3.0:

This state has two community phases that are characterized by the dominance of Utah juniper and singleleaf pinyon in the overstory. This state is identifiable by over 50% cover of Utah juniper and singleleaf pinyon, exhibiting a mixed age class. Older trees are at maximal height and upper crowns may be flat-topped or rounded. Younger trees are typically cone- or pyramidal-shaped. Understory vegetation is sparse due to increasing shade and competition from trees.

Community Phase 3.1:
Singleleaf pinyon and Utah juniper dominate the aspect. Understory vegetation is thinning. Perennial bunchgrasses are sparse and black sagebrush skeletons are as common as live shrubs due to tree competition for soil water, overstory shading, and duff accumulation. Tree canopy cover is greater than 50%. Annual non-native species are present or co-dominate in the understory. Bare ground areas are prevalent.

PIMO-JUOS/ARAR8-AMUT (F029XY068NV), Infilled State 3.1, T. Stringham, May 2022

PIMO-JUOS/ARAR8-AMUT (F029XY068NV), Infilled State 3.1, T. Stringham, May 2022

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:
Time without disturbances such as fire, drought, or disease will allow for the gradual maturation of singleleaf pinyon and Utah juniper. Infilling by younger trees continues.

Community Phase 3.2:
Singleleaf pinyon and Utah juniper dominate the aspect. Tree canopy cover exceeds 35%. Understory vegetation is sparse to absent. Perennial bunchgrasses, if present exist in the drip line or under the canopy of trees. Black sagebrush skeletons are common or the sagebrush has been extinct long enough that only scattered limbs remain. Mat-forming forbs or Sandberg bluegrass (*Poa secunda*) may dominate interspaces. Annual non-native species are present and are typically found under the trees. Bare ground areas are large and interconnected. Soil redistribution may be extensive.

T3A: Transition from Infilled Tree State 3.0 to Annual State 4.0:

Trigger: Canopy fire reduces the pinyon and juniper overstory and facilitates the annual non-native species in the understory to dominate the site.

Slow variables: Over time, cover, production and seed bank of annual non-native species increases.

Threshold: Loss of deep-rooted perennial bunchgrasses and shrubs changes temporal and spatial nutrient capture and cycling within the community. Increase in canopy cover of trees increases rainfall interception and reduces soil moisture for understory species. Increased canopy cover of trees increases the risk for severe stand-replacing crown fire. The increased seed bank of non-native, annual species responds positively to post-fire conditions facilitating the transition to an Annual State.

R3A: Restoration from Infilled Tree state 3.0 to Current Potential State 2.0:

Manual or mechanical thinning of trees or prescribed fire, coupled with seeding. Probability of success is highest from community phase 3.1.

Annual State 4.0:

This state has two community phases that are characterized by the dominance of annual non-native species such as cheatgrass and mustards in the understory. Time since fire may facilitate the maturation of sprouting shrubs such as yellow rabbitbrush and ephedra. Ecological dynamics are significantly altered in this state. Annual non-native species create a highly combustible fuel bed that shortens the fire return interval. Nutrient cycling is spatially and temporally truncated as annual plants contribute significantly less to deep soil carbon.

Community Phase 4.1:
Cheatgrass, mustards and other non-native annual species dominate the site. Trace amounts of perennial bunchgrasses may be present. Sprouting shrubs may be present and increasing. Tree skeletons present.

Community Phase Pathway 4.1a, from Phase 4.1 to 4.2:
Time and lack of disturbance allows sprouting shrubs to recover after fire. Probability of sagebrush establishment is very low.

Community Phase 4.2:
Sprouting shrubs dominate the site. Cheatgrass, mustards and other non-native species present. Trace amounts of perennial bunchgrasses. Bare ground increasing. Tree skeletons present.

PIMO-JUOS/ARNO4-POFE (F029XY069NV), Annual State 4.1, T. Stringham, June 2022

Potential Resilience Differences with Other Ecological Sites in this Group:

JUOS/ARNO4-PUST/ACHY (F029XY071NV):

This site typically occurs at lower elevations and receives less annual precipitation than the modal site. It is dominated by Utah juniper in the overstory and black sagebrush and Indian ricegrass in the understory. Tree site index is lower than the modal. Singleleaf pinyon can be found in small amounts at higher elevations. Probability of conversion to the Annual State is higher.

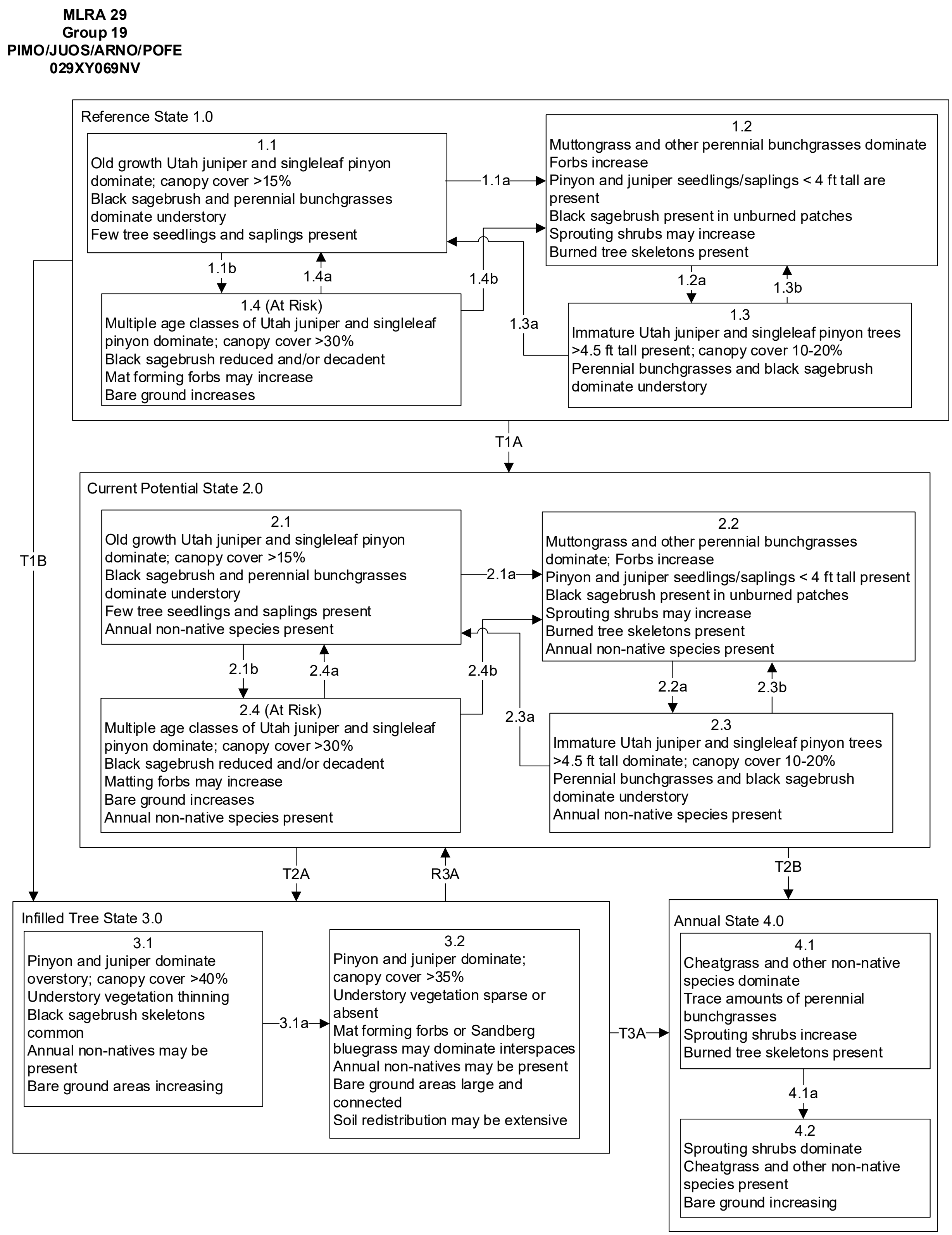
PIMO-JUOS/ARAR8-AMUT (F029XY068NV):

This site is very similar to the modal site; however, the dominant sagebrush is low sagebrush. The site also carries a wide variety of sprouting shrubs: Utah serviceberry, manzanita, ephedra, and Gambel and Sonoran scrub oak. The strong component of sprouting shrubs suggests a conversion to a sprouting shrub dominated state after fire. A description of the Sprouting Shrub State is provided in DRG 21. This site was not observed.

PIMO-JUOS/ARNO4-QUGA (F029XY083NV):

This ecological site is very similar to the modal site, with exception of Gambel oak occurring as a co-dominant with black sagebrush. Muttongrass and blue grama are the most prevalent understory grasses. Gambel oak is an aggressive sprouter, therefore large-scale disturbances, such as fire, may cause a conversion to a sprouting shrub dominated state. A description of the Sprouting Shrub State is provided in DRG 21. This was not observed.

Modal State and Transition Model for Group 19 in MLRA 29:



MLRA 29
Group 19
PIMO/JUOS/ARNO/POFE
029XY069NV

Reference State 1.0 Community Pathways
1.1a: High severity crown fire reduces or eliminates tree cover, allowing perennial bunchgrasses to dominate.
1.1b: Time and lack of disturbance such as fire, disease, or drought allows younger trees to infill.
1.2a: Time and lack of disturbance such as fire or drought facilitates establishment of pinyon, juniper and black sagebrush.
1.3a: Time and lack of disturbance such as fire, insects, or drought allows maturation of the woodland.
1.3b: Fire.
1.4a: Low severity fire, insect infestation, or disease removes individual trees and reduces total tree cover.
1.4b: High severity crown fire reduces or eliminates tree cover.

Transition T1A: Introduction of non-native annual species.
Transition T1B: Time and a lack of disturbance allows for trees to dominate site resources; may be coupled with inappropriate grazing management and/or fire suppression that favors shrub and tree dominance.

Current Potential State 2.0 Community Pathways
2.1a: High severity crown fire reduces or eliminates tree cover, allowing perennial bunchgrasses to dominate.
2.1b: Time and lack of disturbance such as fire, disease, or drought allows younger trees to infill.
2.2a: Time and lack of disturbance such as fire or drought facilitates establishment of trees and black sagebrush. Excessive herbivory may also reduce perennial grass understory.
2.3a: Time and lack of disturbance such as fire, insects, disease or drought allows maturation of the woodland. Excessive herbivory may also reduce perennial grass understory.
2.3b: Fire.
2.4a: Low severity fire, insect infestation, or disease removes individual trees and reduces total tree cover.
2.4b: High severity crown fire reduces or eliminates tree cover.

Transition T2A: Time and a lack of disturbance allows for trees to dominate site resources; may be coupled with inappropriate grazing management and/or fire suppression that favors shrub and tree dominance.
Transition T2B: High-severity crown fire facilitates the establishment of non-native, annual weeds.

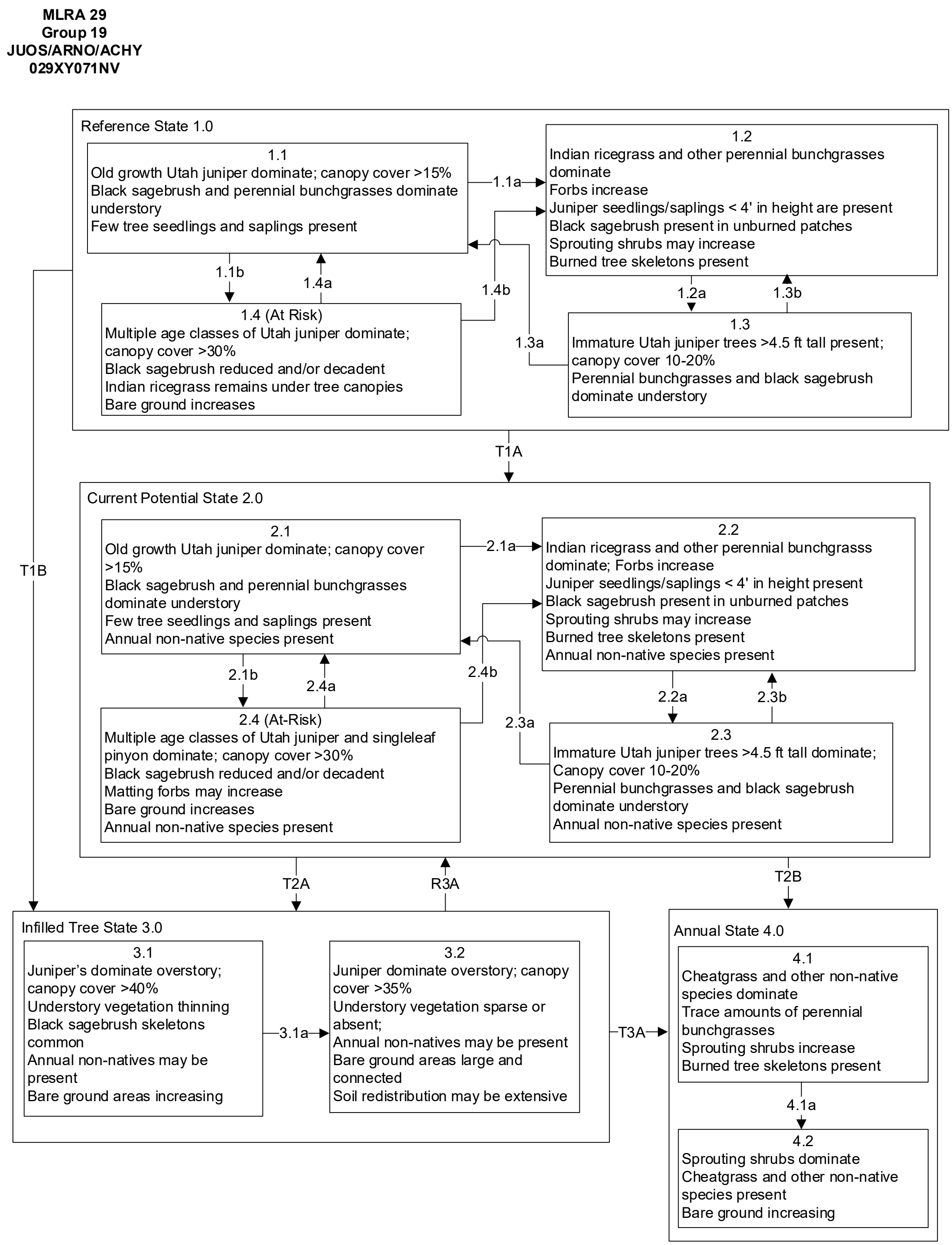
Infilled Tree State 3.0 Community Pathways
3.1a: Time and lack of disturbance such as fire, disease, or drought allows younger trees to infill.

Transition T3A: High-severity crown fire facilitates the establishment of non-native, annual weeds.

Restoration R3A: Mechanical or hand thinning of trees coupled with seeding. Prescribed fire during fall or winter coupled with seeding. Success unlikely from phase 3.2.

Annual State 4.0 Community Pathways
4.1a: Time and lack of disturbance such as fire allows sprouting shrubs to recover.

Additional State and Transition Models for Group 19 in MLRA 29:



MLRA 29
Group 19
JUOS/ARNO/ACHY
029XY071NV

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1.3a: Time and lack of disturbance such as fire, insects, or drought allows maturation of the woodland.
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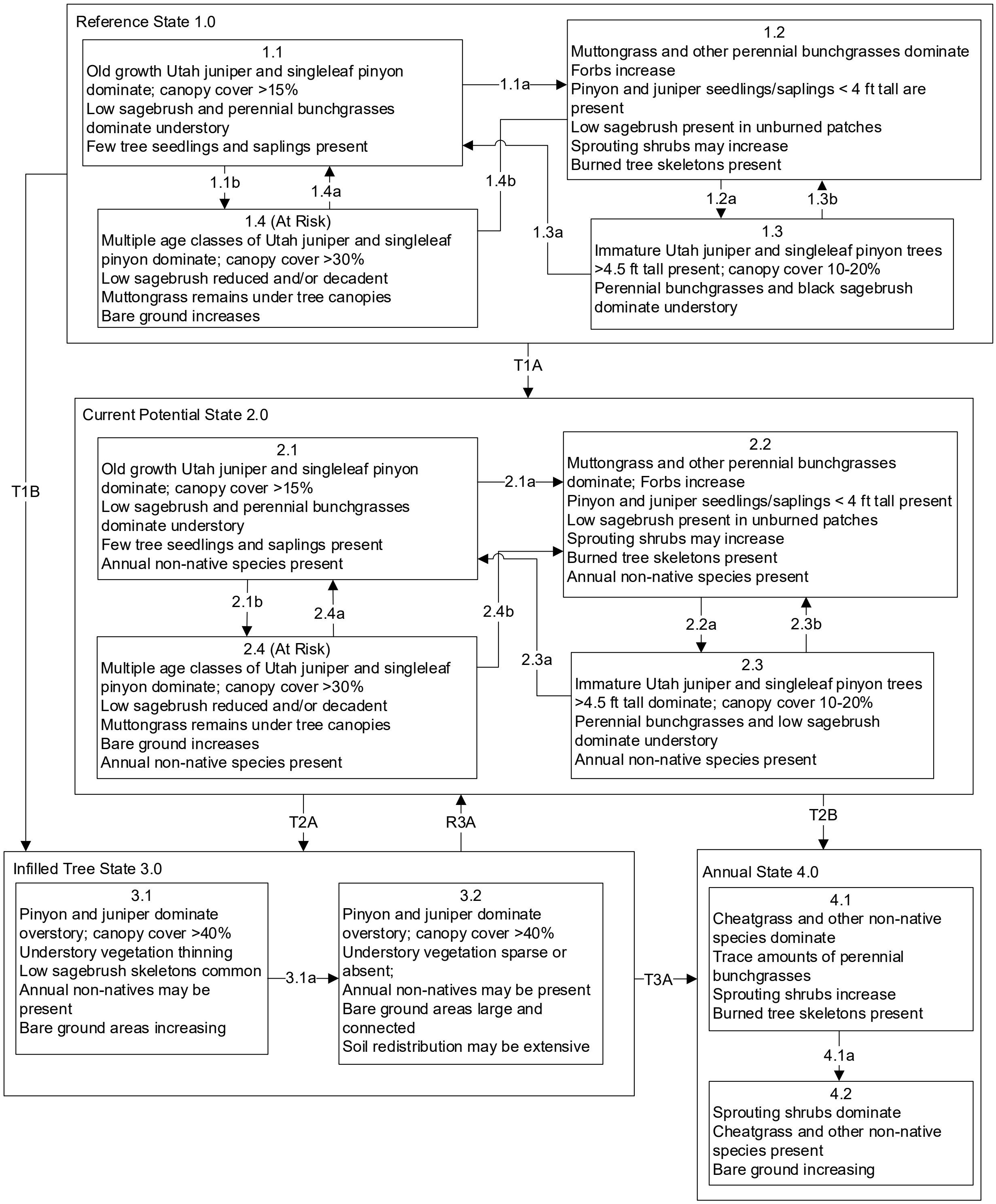
MLRA 29
Group 19
PIMO/JUOS/ARAR8-AMUT
029XY068NV



MLRA 29
Group 19
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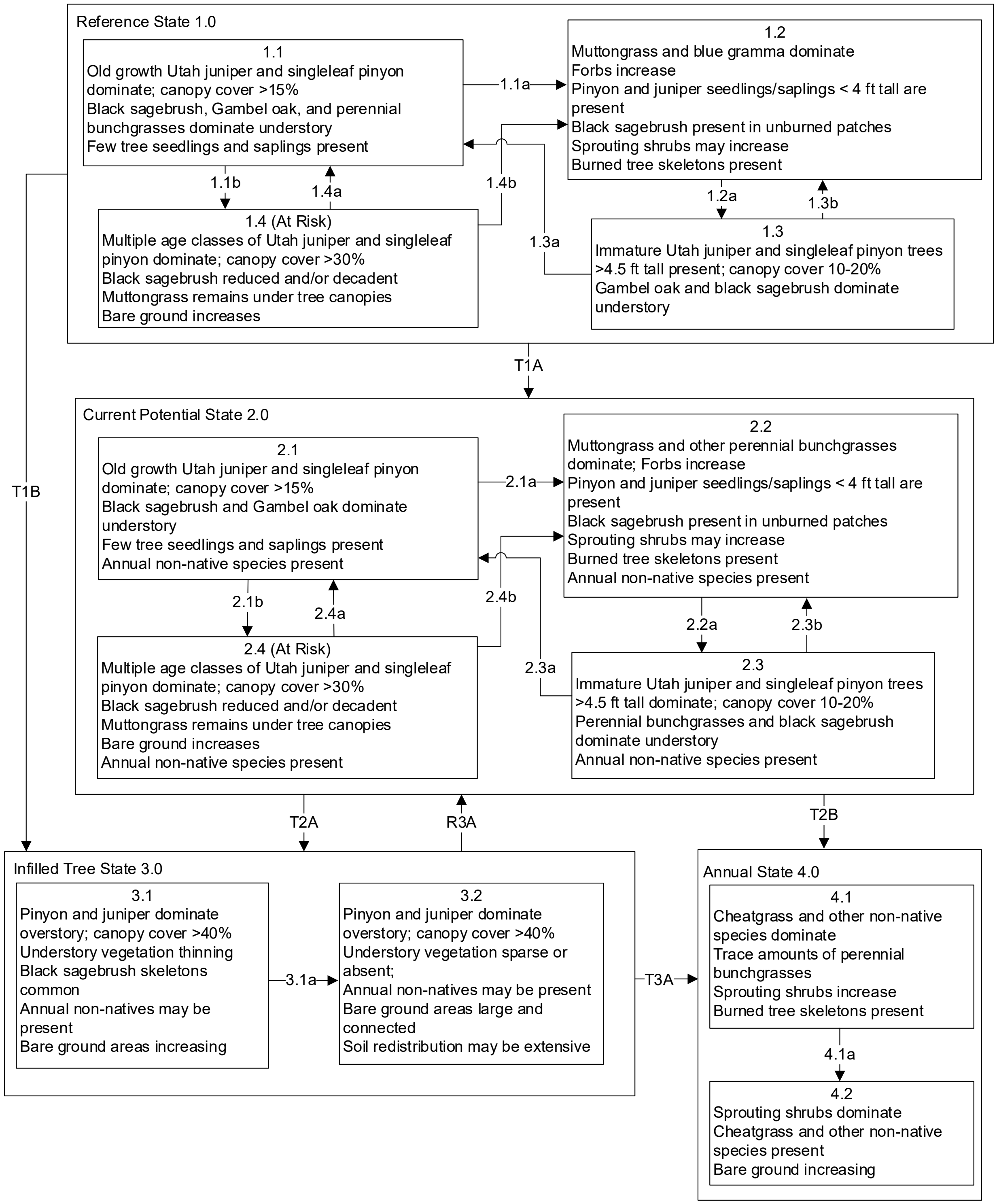
MLRA 29
Group 19
PIMO/JUOS/ARNO/QUGA
029XY083NV



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MLRA 29 Group 20: Pinyon and juniper woodland with mountain big sagebrush understory

Description of MLRA 29 Disturbance Response Group 20

Disturbance Response Group (DRG) 20 consists of five ecological sites. The precipitation ranges from 10 to 18+ in. The slope ranges from 4 to over 100%, however typical slopes range from 30 to 75%. Elevations range from 6,000 to over 9,000 ft. The soils are range from very shallow to deep and are well drained. They are typically skeletal and have 30 to 75% gravels, cobbles, or stones distributed throughout the profile as well as coarse fragments at the soil surface. Potential for rill and sheet erosion is moderate to high depending on slope. The soil temperature regime is mesic or frigid and the soil moisture regime is ustic or xeric. The dominant vegetation common to all sites within this group is an overstory of singleleaf pinyon (*Pinus monophylla).* Utah juniper (*Juniperus osteosperma)* is co-dominant with pinyon on three ecological sites. Mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*) is the dominant understory shrub species, and other shrub species include antelope bitterbrush (*Purshia tridentata*), Stansbury cliffrose (*Purshia stansburiana*), desert snowberry (*Symphoricarpos longiflorus*), and Utah serviceberry (*Amelanchier utahensis*). At lower elevations of this site, Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) is the dominant understory shrub. The perennial grass component is dominated by muttongrass (*Poa fendleriana*). Other species important to these sites include a suite of needlegrasses including, Letterman needlegrass (*Achnatherum lettermanii)*, Thurber's needlegrass (*Achnatherum thurberianum*), and Columbia needlegrass (*Achnatherum nelsonii ssp. nelsonii*) and Indian ricegrass (*Achnatherum hymenoides).* Understory production ranges from 125 to 600 lb/ac with a canopy cover of 10 to 35%.

Disturbance Response Group 20 Ecological Sites:

PIMO-JUOS/ARTRV – Modal	F029XY066NV
PIMO-JUOS/ARTRV	F029XY095NV
PIMO-JUOS/PUST	F029XY058NV
PIMO/ARTRV/POFE	F029XY103NV
PIMO/ARTRV/POFE	F029XY102NV

Modal Site:

The singleleaf pinyon-Utah juniper/mountain big sagebrush/muttongrass (F029XY066NV) site is the modal for this DRG as it has the most acres mapped. This woodland site occurs on mountain sideslopes at mostly northerly aspects at lower elevations, and on all aspects at higher elevations. Slopes range from 15 to over 100%, but are typically 30 to 50%. Elevations are 7,000 to about 8,500 ft. Average annual precipitation is 12 to about 16 in. Soils are shallow to moderately deep. These soils are typically skeletal with as much as 75% gravels, cobbles or stones, by volume, distributed throughout the profile. Available water holding capacity is low, but trees and shrubs extend their roots into fractures in the bedrock allowing them to utilize deep moisture. High amounts of rock fragments are present at the soil surface, occupying plant growing space, yet helping to reduce evaporation and conserve soil moisture. Coarse fragments on the surface help reduce evaporation thus conserving soil moisture. Runoff is medium to rapid and potential for erosion is moderate to severe depending on slope. This site is dominated by singleleaf pinyon, while Utah juniper is generally sub-dominant to present in trace amounts. An overstory canopy of average of 25% is assumed to be representative of tree dominance on this site in the pristine environment. However, current research indicates a canopy cover of 10 to 20% is likely more appropriate to represent this site condition in pre-European contact condition (Miller et al. 2008b). Mountain big sagebrush is the principal understory shrub and muttongrass, Letterman and Columbia needlegrass are the prominent understory grasses. Utah serviceberry, Stansbury cliffrose, and antelope bitterbrush are also important shrubs in this community. Overstory tree canopy composition is about 50 to 60% singleleaf pinyon and about 40 to 50% Utah juniper. Understory vegetative composition is about 60% grasses, 10% forbs and 30% shrubs and young trees in a mature woodland averaging 20 to 30% canopy cover. Average understory production ranges from 250 to 600 lb/ac with 400 lb/ac typical for a normal precipitation year. Understory production includes the total annual production of all species within 4.5 ft of the ground surface.

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasive species. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans across Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area, especially in eastern Nevada, when strong convection storms contribute significantly to annual precipitation. Moisture and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

Periodic drought regularly influences Great Basin ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West (Miller et al. 2008a). Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006).

Pinyon and juniper-dominated plant communities in the cold desert of the Great Basin and Colorado Plateau occupy over 18 million hectare (44,800,000 ac) (Miller and Tausch 2001, Miller et al. 2019). Soils occupied by persistent woodlands are most commonly shallow to restrictive layers including argillic horizons, calcareous horizons, and fractured bedrock (Miller et al. 2019). In addition, soil surfaces are typically very coarse-textured with gravelly to extremely cobbly material, often resulting in very low to low soil moisture storage (Miller et al. 2019). In the mid to late 1900s, the number of pinyon and juniper trees established per decade began to increase compared to the previous several hundred years. The substantial increase in conifer establishment is attributed to a number of factors the most important being (1) cessation of the aboriginal burning (Tausch 1999), (2) change in climate with rising temperatures (Heyerdahl et al. 2006), (3) the reduced frequency of fire likely driven by the introduction of domestic livestock, (4) a decrease in wildfire frequency along with improved wildfire suppression efforts and (5) potentially increased CO2 levels favoring woody plant establishment (Bunting 1994, Tausch 1999). Miller et al. (2008b) found pre-settlement tree densities averaged 2 to 11 per ac in six woodlands studied across the Intermountain West. Current stand densities range from 80 to 358 trees per ac. In Utah, Nevada, and Oregon, trees established prior to 1860 accounted for only 2% or less of the total population of pinyon and juniper (Miller et al. 2008b). The research strongly suggests that for over 200 years prior to settlement, woodlands in the Great Basin were relatively low density with limited rates of establishment (Miller and Tausch 2001, Miller et al. 2008b). This evidence strongly suggests that tree canopy cover of 10 to 20% may be more representative of these sites in pristine condition. Increases in pinyon and juniper densities post-settlement were the result of both infill in mixed-age tree communities and expansion into shrub-steppe communities. Pre-settlement trees accounted for less than 2% of the stands sampled in Nevada, Oregon, and Utah (Miller et al. 1999, Miller and Tausch 2001, Miller et al. 2008b). However, the proportion of old-growth can vary depending on disturbance regimes, soils, and climate. Some ecological sites are capable of supporting persistent woodlands, likely due to specific soils and climate resulting in infrequent stand replacement disturbance regimes. In the Great Basin, old-growth trees have been found to typically grow on rocky shallow or sandy soils that support little understory vegetation to carry a fire (Holmes et al. 1986, Miller and Rose 1995, West et al. 1998).

Infilling by younger trees increases canopy cover causing a decrease in understory perennial vegetation and an increase in bare ground. As pinyon and juniper trees increase in density so has their litter. Phenolic compounds of juniper scales can have an inhibitory effect on grass growth (Jameson 1970). Furthermore, infilling shifts stand-level biomass from ground fuels to canopy fuels which has the potential to significantly impact fire behavior. The more tree-dominated pinyon and juniper woodlands become, the less likely they are to burn under moderate conditions, resulting in infrequent high-intensity fires (Gruell 1999, Miller et al. 2008b). Additionally, as the understory vegetation declines in vigor and density with increased canopy, the seed and propagules of the understory plant community also decrease significantly. The increase in bare ground allows for the invasion of non-native annual species such as cheatgrass (*Bromus tectorum*) and with intensive wildfire, the potential for conversion to annual exotics is a serious threat (Tausch 1999, Miller et al. 2008b).

Singleleaf pinyon and Utah juniper are long-lived tree species with wide ecological amplitudes (Tausch et al. 1981, West et al. 1998, Weisberg and Ko 2012). The maximum ages of pinyon and juniper exceed 1,000 years and stands with maximum age classes are only found on steep rocky slopes with no evidence of fire (West et al. 1975). Pinyon is slow-growing and very intolerant to shade with the exception of young plants, usually first-year seedlings (Tueller and Clark 1975). Singleleaf pinyon seedling establishment is episodic. Population age structure is affected by drought, which reduces seedling and sapling recruitment more than other age classes. The ecotones between singleleaf pinyon woodlands and adjacent shrublands and grasslands provide favorable microhabitats for singleleaf pinyon seedling establishment since they are active zones for seed dispersal, nurse plants are available, and singleleaf pinyon seedlings are only affected by competition from grass and other herbaceous vegetation for a couple of years.

Specific successional pathways after disturbance in pinyon-juniper stands are dependent on a number of variables, such as plant species present at the time of disturbance and their individual responses to disturbance, past management, type and size of disturbance, available seed sources in the soil or adjacent areas, and site and climatic conditions throughout the successional process.

Insects and diseases of western juniper are not well understood or studied (Eddleman et al. 1994). Utah juniper can be killed by a fungus called Juniper Pocket Rot (*Pyrofomes demidoffi*), also known as white trunk rot (Eddleman et al. 1994, Durham 2014). Pocket rot enters the tree through any wound or opening that exposes the heartwood. In an advanced stage, this fungus can cause high mortality (Durham 2014). Dwarf mistletoe (*Arceuthobium spp.)* a parasitic plant, may also affect Utah juniper and without treatment or pruning, may kill the tree 10 to 15 years after infection. Seedlings and saplings are most susceptible to the parasite (Christopherson 2014). Other diseases affecting juniper are: witches' broom (*Gymnosporangium* spp.) that may girdle and kill branches; leaf rust (*Gymnosporangium* spp.) on leaves and young branches; and juniper blight (*Phomopsis* spp.). Flat-head borers (*Chrysobothris spp.*) attack the wood; long-horned beetles (*Methia juniper*, *Styloxus bicolor*) girdle limbs and twigs; and round-head borers (*Callidium* spp.) attack twigs and limbs (Tueller and Clark 1975).

Phillips (1909) recognized that the pinyons are more resistant to disease than most of the conifers with which it associates. Hepting (1971) lists several diseases affecting pinyon including: foliage diseases, tarspot needle cast (*Davisomycella ampla)*, stem diseases such as blister rust (*Cronartium ribicola)* and dwarf mistletoe, root diseases and trunk rots, red heart rot, and butt rot (caused by *Polyporus schweinitzii)*. The pinyon ips beetle (*Ips confuses*) and pinyon needle scale (*Matsucoccus acalyptus*) are both native insects to Nevada that attack pinyon pines throughout their range. The pinyon needle scale weakens trees by killing needles older than 1 year. Sometimes small trees are killed by repeated feeding and large trees are weakened to the point that they are attacked by the pinyon ips beetle. The beetle typically kills weak and damaged trees (Phillips and Reboletti 2014). During periods of long-term drought, the impact of these two insects on singleleaf pinyon can be substantial.

The pinyon jay (*Gymnorhinus cyanocephalus)* and other members of the seed caching corvids play an important role in pinyon pine regeneration. These birds cache the seeds in the soil for future use. Those seeds that escape harvesting by the birds and rodents have the opportunity to germinate under favorable soil and climatic conditions (Lanner 1981). A mutualistic relationship exists between the trees that produce food and the animals that disperse the seeds, thereby ensuring the perpetuation of the trees. Large crops of seeds may stimulate reproduction in birds, especially the pinyon jay (Ligon 1974).

Pinyon and juniper growth is dependent mostly upon soil moisture stored from winter precipitation, mainly snow. Much of the summer precipitation is ineffective, being lost in runoff after summer convection storms or by evaporation and interception (Tueller and Clark 1975). Pinyon and juniper are highly resistant to drought which is common in the Great Basin. Tap roots of pinyon and juniper have a relatively rapid rate of root elongation and are thus able to persist until precipitation conditions are more favorable (Emerson 1932).

In the Great Basin, the majority of annual precipitation is received during the winter and early spring. This continental semiarid climate regime favors the growth and development of deep-rooted shrubs and herbaceous cool-season plants using the C3 photosynthetic pathway (Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow results in deeper percolation of moisture into the soil profile. Herbaceous plants, more shallow-rooted than shrubs, grow earlier in the growing season and thrive on spring rains, while the deeper-rooted shrubs lag in phenological development because they draw from deeply infiltrating moisture from snowmelt the previous winter.

Mountain big sagebrush*,* the dominant shrub of this group, is generally long-lived; therefore, it is not necessary for new individuals to recruit every year for perpetuation of the stand. Infrequent large recruitment events and simultaneous low, continuous recruitment is the foundation of population maintenance (Noy-Meir 1973). Survival of the seedlings is dependent on adequate moisture conditions. Sagebrush have a flexible generalized root system with development of both deep taproots and laterals near the surface (Dobrowolski et al. 1990). In general, these shrubs root to the full depth of the winter-spring soil moisture recharge, which ranges from 1 to over 3 m (3 to 10 ft) (Comstock and Ehleringer 1992). Root length of mature sagebrush plants was measured to a depth of 2 m (6.5 ft) in alluvial soils in Utah (Richards and Caldwell 1987).

Antelope bitterbrush and Stansbury cliffrose, both in the *Purshia* genus, occur frequently, but not abundantly, on the ecological sites within this DRG. Hybridization is common among these species, making field identification challenging (Booth et al. 2008). The shrubs are drought tolerant and all provide high quality browse for domestic and wild ungulates (Bishop et al. 2001). In general, bitterbrush and cliffrose are moderately fire tolerant (McConnell and Smith 1977). These shrubs regenerate primarily by seed and may resprout (Blaisdell and Mueggler 1956, McArthur and Welch 1982), however sprouting ability is highly variable and has been attributed to genetics, plant age, phenology, soil moisture and texture and fire severity (Blaisdell and Mueggler 1956, Blaisdell et al. 1982, Clark et al. 1982, Cook et al. 1994). Rodent caching of seed has been identified as an important mechanism for establishment of new plants (Alexander et al. 1974).

Muttongrass is a tufted, multi-flowered, perennial bunchgrass that can grow between 8 and 30 in. tall and has narrow leaves, which range from 1 to 3 mm wide. It is found in lower elevations in the northern extent of its native range, and higher elevations in the south. Muttongrass is one of the most drought-tolerant bluegrasses and is useful for restoring communities disturbed by fire, grazing, or mining, but is limited in its use due to low seed viability. Muttongrass plants are most frequently pistillate, but staminate plants do occasionally occur, which are able to hybridize and crossbreed with other bluegrasses. Muttongrass is found throughout the western United States as a primary component of the understory of pinyon-juniper communities, aspen forests and pine forests (Tilley et al. 2007).

Letterman's needlegrass is a fine-stemmed, cool-season bunchgrass that reaches 12 to 24 in. tall. It forms large clumps and is found on dry soils in a variety of vegetation communities, including high elevation meadows, subalpine grasslands, open areas underneath aspen, and in sagebrush communities (Tisdale and Hironaka 1981). This densely tufted species is more drought tolerant than Columbia needlegrass and it is able to grow in a variety of soil qualities and textures (Banner et al. 2011). Columbia needlegrass, also known as Nelson's needlegrass, is characterized by fine leaves and slender stems. It is common from the upper sagebrush and woodland types to the dry, open parks and hillsides at subalpine elevations (USFS 1937).

Indian ricegrass is a long-lived, cool-season perennial bunchgrass that grows from 4 to 24 inches in height (Blaisdell and Holmgren 1984). Primarily adapted to coarse-textured soils, its deep, fibrous root system makes Indian ricegrass one of the most drought-tolerant native species (Booth et al. 1980). Unlike other cool-season species, Indian ricegrass does not require vernalization (exposure to cold) in order to produce flowers and flowering can continue into late fall with favorable environmental conditions. This allows the seeds in each panicle to ripen over a longer period of time than most other species thus providing a greater opportunity for successful seed production (Jones 1990).

The ecological sites in this Disturbance Response Group (DRG) have low to high resilience to disturbance and resistance to invasion. Resilience increases with elevation, aspect, increased precipitation and increased nutrient availability. Three possible stable states have been identified for this DRG.

Annual Invasive Species:

The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and depressed competition or can increase resource pools by the decomposition of dead plant material following disturbance. The presence of exotic annual plants within these ecosystems decreases ecosystem resilience and resistance to disturbance through competition for limited resources. Peters and Bunting (1994) cites multiple authors on the extent of the soil profile exploited by the competitive exotic annual cheatgrass. Specifically, the depth of rooting is dependent on the size the plant achieves, and in competitive environments, cheatgrass roots were found to penetrate only 15 cm (6 in.) whereas isolated plants and pure stands were found to root at least 1 m in depth (3.2 ft) with some plants rooting as deep as 1.5 to 1.7 m (5 to 5.5 ft).

The species most likely to invade these sites is cheatgrass. Cheatgrass is a cool-season annual grass that maintains an advantage over native plants in part because it is a prolific seed producer, can germinate in the autumn or spring, tolerates grazing, and increases with frequent fire (Klemmedson and Smith 1964, Miller 1999). Cheatgrass originated from Eurasia and was first reported in North America in the late 1800s. Pellant and Hall (1994) found 3.3 million acres of public lands dominated by cheatgrass and suggested that another 76 million acres were susceptible to invasion by winter annuals including cheatgrass and medusahead (*Taeniatherum caput-medusae*).

Recent modeling and empirical work by Bradford and Lauenroth (2006) suggest that seasonal patterns of precipitation input and temperature are also key factors determining regional variation in the growth, seed production, and spread of invasive annual grasses. The phenomenon of cheatgrass "die-off" provides opportunities for restoration of perennial and native species (Baughman et al. 2016, Baughman et al. 2017). The causes of these events are not fully understood, but there is ongoing work to try to predict where they occur, in the hopes of aiding conservation planning (Weisberg et al. 2017, Brehm 2019).

Methods to control cheatgrass include herbicide, fire, targeted grazing, and seeding. Mapping potential or current invasion vectors is a management method designed to increase the cost-effectiveness of control methods. Spraying with herbicide (imazapic or imazapic + glyphosate) and seeding with crested wheatgrass and Sandberg bluegrass has been found to be more successful at combating cheatgrass (and medusahead) than spraying alone (Sheley et al. 2012). To date, most seeding success has occurred with non-native wheatgrass species. Perennial grasses, especially crested wheatgrass, are able to suppress cheatgrass growth when mature (Blank et al. 2020). Where native bunchgrasses are missing from the site, revegetation of annual grass-invaded rangelands has been shown to have a higher likelihood of success when using introduced perennial bunchgrasses such as crested wheatgrass Butler et al. (2011), (Davies et al. 2015b, Clements et al. 2017) tested four herbicides (imazapic, imazapic + glyphosate, rimsulfuron, and sulfometuron + chlorsulfuron) for suppression of cheatgrass, medusahead, and North Africa grass (*Ventenata dubia*) within residual stands of native bunchgrass. Additionally, they tested the same four herbicides followed by seeding of six bunchgrasses (native and non-native) with varying success (Butler et al. 2011). Herbicide-only treatments appeared to remove competition for established bluebunch wheatgrass by providing 100% control of North Africa grass and medusahead and greater than 95% control of cheatgrass (Butler et al. 2011). Caution in using these results is advised, as only 1 year of data was reported.

In considering the combination of pre-emergent herbicide and prescribed fire for invasive annual grass control, it is important to assess the tolerance of desirable brush species to the herbicide being applied. Vollmer and Vollmer (2008) tested the tolerance of alderleaf mountain mahogany (*Cercocarpus montanus*), antelope bitterbrush, and multiple sagebrush species to three rates of imazapic with and without methylated seed oil as a surfactant. They found that a cheatgrass control program in an antelope bitterbrush community should not exceed imazapic at 8 oz/ac with or without surfactant. Sagebrush, regardless of species or rate of application, was not affected. However, many environmental variables were not reported in this study and managers should install test plots before broad-scale herbicide application is initiated.

Fire Ecology:

Limited data exists that describes fire histories across woodlands in the Great Basin. Pre-settlement fire return intervals in the Great Basin National Park, Nevada were found to have a mean range between 50 to 100 years with north-facing slopes burning every 15 to 20 years and rocky landscapes with sparse understory, fire-safe sites, burn very infrequently (Gruell 1999). Results were less conclusive in a similar study in the Bodie Hills; however, it was apparent that old (300+ years old) singleleaf pinyon primarily survived in protected, low-fuel areas. Woodland dynamics are largely attributed to long-term climatic shifts (temperature and amount and distribution of precipitation) and the extent and return intervals of fire (Miller and Tausch 2001, Miller et al. 2019). Historically, lightning-ignited fires were likely common but typically did not affect more than a few individual trees. Replacement fires were uncommon to rare (100 to 600 years) and occurred primarily during extreme fire behavior conditions.

Utah juniper is usually killed by fire, and is most vulnerable to fire when it is under 4 ft tall (Bradley et al. 1992). Larger trees, because they have foliage farther from the ground and thicker bark, can survive low severity fires but mortality does occur when 60% or more of the crown is scorched (Bradley et al. 1992). Singleleaf pinyons are also most vulnerable to fire when less than 4 ft tall, however mature trees do not self-prune their dead branches allowing for accumulated fuel in the crowns. This characteristic and the relative flammability of the foliage make individual mature trees susceptible to fire (Bradley et al. 1992). With the low production of the understory vegetation and low density of trees per acre, high severity fires within this plant community were not likely and rarely became crown fires (Bradley et al. 1992, Miller and Tausch 2001). However, both the infilling of younger trees into old-growth stands and the expansion of trees into surrounding sagebrush communities have increased the risk of loss of pre-settlement trees through the increased landscape level continuity of fuels (Miller et al. 2008b).

Utah juniper and singleleaf pinyon reestablish by seed from nearby seed sources or surviving seeds. Junipers have a long-lived seed bank due to delayed germination by impermeable seed coats, immature or dormant embryos, and germination inhibitors (Chambers et al. 1999, Schupp et al. 1999). Singleleaf pinyons have relatively short-lived seeds with little innate dormancy that form only temporary seed banks with most seeds germinating in the spring following dispersal (Meeuwig and Basset 1983). The density of pinyon seeds in the seed bank is dependent upon the current year's cone crop. Singleleaf pinyon is known to have favorable cone production every 2 to 3 years thus the potential for a large temporary seed bank is high during mast years and likely low during non-mast years (Chambers et al. 1999). The role of nurse plant requirements between the two-tree species is important to post-fire establishment. Chambers et al. (1999) found that singleleaf pinyon seedlings rarely establish in interspaces or open environments. In contrast, Utah juniper seedlings were found capable of establishing in interspace microhabitats as frequently as under sagebrush. Therefore, fire that removes both trees and understory shrubs in pinyon-juniper woodlands may have a relatively greater effect on the establishment of pinyon than juniper.

Mountain big sagebrush is killed by fire (Neuenschwander 1980, Blaisdell and Holmgren 1984), and does not re-sprout (Blaisdell 1953). Post-fire regeneration occurs from seed and will vary depending on site characteristics, seed source, and fire characteristics. Mountain big sagebrush seedlings can grow rapidly and may reach reproductive maturity within 3 to 5 years (Bunting et al. 1987). Mountain big sagebrush may return to pre-burn density and cover within 15 to 20 years following fire, but establishment after severe fires may proceed more slowly and can take up to 50 years (Bunting et al. 1987, Ziegenhagen 2003, Miller and Heyerdahl 2008).

Antelope bitterbrush and Stansbury cliffrose are moderately fire tolerant (McConnell and Smith 1977). These shrubs regenerate primarily by seed and may resprout (Blaisdell and Mueggler 1956, McArthur and Welch 1982), however, sprouting ability is highly variable and has been attributed to genetics, plant age, phenology, soil moisture and texture, and fire severity (Blaisdell and Mueggler 1956, Blaisdell et al. 1982, Clark et al. 1982, Cook et al. 1994). Bitterbrush sprouts from a region on the stem approximately 1.5 in. above and below the soil surface; the plant rarely sprouts if the root crown is killed by fire (Blaisdell and Mueggler 1956). Bitterbrush and cliffrose may resprout following a low-intensity fire however, sprouting response also depends on soil moisture levels at the time of fire (Murray 1983). Lower soil moisture allows more charring of the stem below ground level (Blaisdell and Mueggler 1956), thus sprouting will usually be more successful after a spring fire than after a fire in summer or fall (Murray 1983, Busse et al. 2000, Kerns et al. 2006). If cheatgrass is present, bitterbrush and cliffrose seedling success is much lower. The factor that most limits the establishment of these seedlings is competition for water resources with the invasive species cheatgrass (Clements and Young 2002).

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The initial condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species response. For most forbs and grasses the growing points are located at or below the soil surface providing relative protection from disturbances which decrease above ground biomass, such as grazing or fire. Thus, fire mortality is more correlated to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant and abundance of old growth (Wright 1971, Young 1983). However, season and severity of the fire will influence plant response. Plant response will vary depending on post-fire soil moisture availability.

Muttongrass, a dominant component in this group, is top killed by fire but will sprout after low to moderate severity fires. A study by Vose and White (1991) in an open saw timber site found minimal difference in the overall effect of burning on muttongrass.

In general, needlegrasses are slightly to moderately damaged by fire depending on the season of burn. They tend to be more susceptible when burned during mid-summer (Wright and Klemmedson 1965). At the time of this document's publication, very little research has been done on the effects of fire on Letterman's needlegrass. However, most bunchgrasses are harmed by fire, and fire typically causes a decrease in reproduction, density, and cover in bunchgrasses (Ellsworth and Kauffman 2010). Bates et al. (2011) applied a partial cutting and fall season prescribed fire to a juniper encroached rangeland once dominated with Letterman's needlegrass and Columbia needlegrass. Results indicate mortality of Columbia needlegrass exceeded 80% while mortality of Letterman's was near 50%. However, 3 years post fire Columbia needlegrass had recovered, exceeding pre-fire cover levels. Season, fire severity, and post-fire climate all intergrade to determine needlegrass response to fire.

Thurber's needlegrass is a subdominant grass on the PIMO-JUOS/ARTRV ecological site (F029XY095NV) and is highly susceptible to damage from fire. Fire can cause high mortality, in addition to reducing basal area and yield of Thurber's needlegrass (Britton et al. 1990). The fine leaves and densely tufted growth form make this grass susceptible to subsurface charring of the crowns (Wright and Klemmedson 1965). Although timing of fire highly influenced the response and mortality of Thurber's needlegrass, smaller bunch sizes were less likely to be damaged by fire (Wright and Klemmedson 1965). Needlegrass often survives fire and will continue growth or regenerate from tillers when conditions are favorable (Koniak 1985, Britton et al. 1990). Reestablishment on burned sites has been found to be relatively slow due to low germination and competitive ability (Koniak 1985). Cheatgrass has been found to be a highly successful competitor with seedlings of this needlegrass and may preclude reestablishment (Evans and Young 1978).

Indian ricegrass is fairly fire tolerant (Wright 1985), which is likely due to its low culm density and below-ground plant crowns. Vallentine (1989) cites several studies in the sagebrush zone that classified Indian ricegrass as being slightly damaged from late summer burning. Indian ricegrass has also been found to reestablish on burned sites through seeds dispersed from adjacent unburned areas (Young 1983, West 1994). Thus, the presence of surviving, seed-producing plants facilitates the reestablishment of Indian ricegrass. Grazing management following fire to promote seed production and establishment of seedlings is important (Booth et al. 1980).

Livestock/Wildlife Grazing Interpretations:

Pinyon-juniper woodlands provide a diversity of habitat for wildlife. Although the foliage of pinyon and juniper varies in palatability among fauna, pinyon nuts and juniper berries are preferred by many species. The understory species provide fruits and browse for large ungulates, small mammals, birds, and beavers (Wildlife Action Plan Team 2012).

Ungulates will use pinyon and juniper trees for cover and graze the foliage. The understory species also provide critical browse for deer (Odocoileus spp.). The trees provide important cover for mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis)* wild horses (*Equus ferus)*, mountain lion (*Puma concolor*), bobcat (*Lynx rufus*), and pronghorn antelope (*Antilocapra americana*) (Logan and Irwin 1985, Evans 1988, Coates and Schemnitz 1994, Gottfried and Severson 1994).

Mule deer is considered the dominant big game species in the pinyon-juniper woodland and depend heavily on these woodlands for cover, shelter, and emergency forage during severe winters (Frischknecht 1975). Mule deer will eat singleleaf pinyon and juniper foliage, using the foliage moderately in winter, spring, and summer (Kufeld et al. 1973). Deep snows in higher elevation forest zones force mule deer and elk down into pinyon-juniper habitats during winter. This change in habitat allows mule deer and elk to browse the dwarf trees and shrubs (Gottfried and Severson 1994).

The diet of pronghorn (*Antilocapra americana)* varies considerably; however, singleleaf pinyon was shown to comprise 1 to 2% of the winter diet of pronghorn antelope that occur in pinyon-juniper habitat. Desert bighorn sheep (*Ovis nelson*) may utilize pinyon-juniper habitat, but only where the terrain is rocky and steep (Gottfried et al. 2000). Gray foxes (*Urocyon cinereoargenteus*), bobcats, coyotes (*Canis latran*s), weasels (*Mustela frenata*), skunks (*Mephitis* spp.), badgers (*Taxidea taxus*), and ringtail cats (*Bassariscus astutus*) search for prey in pinyon-juniper habitat woodlands (Short and McCulloch 1977).

Juniper “berries” or berry-cones are eaten by black-tailed jackrabbits (*Lepus californicus*) and coyotes (Gese et al. 1988, Kitchen et al. 2000). A study by Kitchen et al. (2000) conducted in juniper-pinion habitat found vegetation in coyote scats was mainly grass seeds or juniper berries. Jackrabbits are a major dispenser of juniper seeds (Schupp et al. 1999). The pinyon mouse (*Peromyscus truei*) is a pinyon-juniper obligate and uses the woodlands for cover and food (Hoffmeister 1981). Other small mammals include the porcupine (*Hystricomorph hystricidae*), desert cottontail (*Sylvilagus audubonii*), Nuttall's cottontail (*S. nuttallii*), deer mouse (*Peromyscus maniculatus*), Great Basin pocket mouse (*Perognathus parvus*), chisel-toothed kangaroo rat (*Dipodomys microps*) and desert woodrat (*Neotoma lepida*) (Turkowski and Watkins 1976).

Many bird species are associated with the pinyon-juniper habitat; some are permanent residents, some summer residents, and some winter residents, depending upon location. For birds and bats, the woodland provides structure for nesting and roosting, and locations for foraging. Singleleaf pinyon provides a number of cavities and the stringy, fibrous bark provides quality nesting material as well as the food provided by the tree's seeds and berries (Short and McCulloch 1977). Many bird species depend on juniper berry-cones and pine nuts for fall and winter food (Balda and Masters 1980). Several bird species are obligates, including gray flycatcher (*Epidonax wrightii)*, scrub jay (*Aphelocoma californica)*, plain titmouse (*Parus inornatus ridgwayi*), and gray vireo (*Vireo vicinior)*; several species are semi-obligates including black-chinned hummingbird (*Archilochus alexandri*), ash-throated flycatcher (*Myiarchus cinerascens*), pinion jay, American bushtit (*Psaltriparus minimus*), Bewick's wren (*Thryomanes bewickii*), Northern mockingbird (*Mimus polyglottos*), blue-gray gnatcatcher (*Polioptila caerulea*), black-throated gray warbler (*Dendroica nigrescens*), house finch (*Haemorhous mexicanus*), spotted towhee (*Pipilo maculatus*), lark sparrow (*Chondestes grammacus*) and black-chinned sparrow (*Zonotrichia atricapilla)* (Balda and Masters 1980). Ferruginous hawk (*Buteo regalis*), a conservation priority species due to recent population declines in Nevada, nests in older trees of sufficient size and structure to support their large nest platforms (Holechek 1981).

Diurnal reptiles include the sagebrush swift (*Sceloporus graciosus)*, the western fence lizard (*Sceloporus occidentalis),* the Great Basin collard lizard (*Crotaphytus bicinctores)*, the western whiptail (*Aspidoscelis tigris*), Gilbert's skink (*Plestiodon gilberti*) and the western skink (*Plestiodon skiltonianus*), the Pacific rattlesnake (*Crotalus oreganus*), the Great Basin gopher snake (*Pituophis catenifer deserticola*), and desert horned lizard (*Phrynosoma platyrhinos)* also occur in Utah juniper habitat (Frischknecht 1975, Morrison and Hall 1999). However, the distribution of most of the herpetofauna present in pinyon-juniper woodlands is poorly understood and more research and management are needed.

The history of livestock grazing in the pinyon-juniper ecosystem goes back more than 200 years, depending on the particular locality within the ecosystem (Hurst 1975). Historically, pinyon-juniper woodlands were much more open, and they supported a diverse understory that provided forage for both livestock and wildlife. Historic livestock overuse and increased stand densities have reduced the carrying capacity of these pinyon-juniper stands and many current stands only provide shade and shelter for livestock.

Despite low palatability, mountain big sagebrush is eaten by domestic sheep, cattle, goats and horses. Chemical analysis indicates that the leaves of big sagebrush are equal to alfalfa meal (*Medicago sativa)* in protein, have a higher carbohydrate content, and yield twelvefold more fat (USFS 1937). Many wildlife species are dependent on the sagebrush ecosystem including the greater sage grouse (*Centrocercus urophasianus)*, sage sparrow (*Artemisiospiza nevadensis*), pygmy rabbit (*Brachylagus idahoensis)*, and the sagebrush vole (*Lemmiscus curtatus)*. Dobkin and Sauder (2004) identified 61 species, including 24 mammals and 37 birds, associated with the shrub-steppe habitats of the Intermountain West.

Antelope bitterbrush is critical browse for mule deer, as well as domestic livestock, pronghorn, and elk (Wood et al. 1995). Grazing tolerance of antelope bitterbrush is dependent on-site conditions (Garrison 1953). Cattle tend to graze bitterbrush in higher areas than sheep or deer and take off newer twig growth, keeping them shorter. Palatability varies between plants and stages of growth, degree of use, and location. Columbian black-tailed deer and pronghorn usually graze it in the spring and summer, mule deer in the winter, and livestock in the summer. It is rather shade intolerant (Hormay 1943). Antelope bitterbrush initiates growth in the spring and finishes by late summer. It grows large ephemeral leaves in the spring and then small overwintering leaves in the late summer. Antelope bitterbrush recovers vigorously with new growth after defoliation from grazing, and potential growth remains the same or is enhanced by browsing. Antelope bitterbrush will allocate additional resources to new growth to recover from browsing (Bilbrough and Richards 1993).

Muttongrass, a dominant component on this ecological site, is relatively grazing tolerant. It is rated as excellent forage for cattle and horses, and good for sheep, elk, and deer (USFS 1937). Muttongrass starts growth in late winter or early spring and provides excellent early feed. In addition, muttongrass foliage cures well and is good fall forage (Humphrey et al. 1952). Muttongrass persists well in open areas and under canopies of oak and other shrubs (Monsen et al. 2004a).

At the time of this document's publication, the effects of grazing on Letterman's needlegrass are not well documented. However, it is known to be palatable to many species of livestock and wildlife, including cattle, sheep, horses, pronghorns, elk, mule deer, white-tailed deer (*Odocoileus virginianus)*, small mammals, and birds. It typically is only palatable early in the season because as Letterman's needlegrass ages, it dries and becomes coarse and wiry, which can injure an animal's mouth and leads to it being avoided by most animals later in the season (Dittberner and Olson 1983).

Columbia needlegrass, also known as Nelson's needlegrass, palatability varies from fair to very good. Cattle and horses graze it a little more closely than do sheep, however it is typically not a preferred forage species. Columbia needlegrass exhibits higher resilience to grazing than many of the other preferred forage species. USFS (1937) states "this grass is among the last of the fairly good grasses to disappear from the range under serious overgrazing and is among the first to reappear with the improvement of badly depleted areas".

Indian ricegrass is a deep-rooted, cool-season perennial bunchgrass that is adapted primarily to coarse-textured soils. Indian ricegrass is a preferred forage species for livestock and wildlife (Cook 1962, Booth et al. 1980). This species is often heavily utilized in winter because it cures well (Booth et al. 1980). It is also readily utilized in early spring, being a source of green feed before most other perennial grasses have produced new growth (Quinones 1981). Booth et al. (1980) note that the plant does well when utilized in winter and spring. Cook and Child (1971), however, found that repeated heavy grazing reduced crown cover, which may reduce seed production, density, and basal area of these plants. Additionally, heavy early spring grazing reduces plant vigor and stand density (Stubbendieck et al. 1985). In eastern Idaho, productivity of Indian ricegrass was at least 10 times greater in undisturbed plots than in heavily grazed ones (Pearson 1965). Cook and Child (1971) found a significant reduction in plant cover after 7 years of rest from heavy (90%) and moderate (60%) spring use. The seed crop may be reduced where grazing is heavy (Bich et al. 1995). Tolerance to grazing increases after May, thus spring deferment may be necessary for stand enhancement (Pearson 1964, Cook and Child 1971); however, utilization of less than 60% is recommended. In summary, adaptive management is required to manage this bunchgrass well.

Bunchgrasses, in general, tolerate moderate grazing anytime of the year. Growing season grazing should not occur more than once every other year and once every third year is recommended. Britton et al. (1990) observed the effects of clipping date on the basal area of five bunchgrasses in eastern Oregon and found grazing from August to October (after seed set) has the least impact. Heavy grazing, year after year during the growing season, will reduce perennial bunchgrasses and increase sagebrush. Abusive grazing by cattle or horses will likely increase shallow-rooted, early season forbs and grasses including muttongrass and Sandberg bluegrass (*Poa secunda*).

State and Transition Model Narrative for Group 20:

Reference State 1.0:

The Reference State 1.0 is representative of the natural range of variability under pristine conditions. This Reference State has four general community phases: a mature woodland phase (1.1), a shrub-herbaceous phase (1.2), an immature woodland phase (1.3), and an over-mature woodland phase (1.4). State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire, periodic long-term drought, and/or insect or disease attack. Fires are typically small and patchy due to low fuel loads. This fire type will create a plant community mosaic that will include all/most of the following community phases within this state.

Community Phase 1.1:

This phase is characterized by widely dispersed mature singleleaf pinyon and Utah juniper trees with an understory of mountain big sagebrush and perennial bunchgrasses. The visual aspect is dominated by Utah juniper and singleleaf pinyon which make up 15% or more. Tree canopy cover ranges from 20 to 30%. Trees have reached maximal or near maximal heights for the site and many tree crowns may be flat- or round-topped. At fire-safe sites, dominant trees average greater than 15 inches in diameter at one-foot stump height. Muttongrass is the most prevalent grass. Mountain big sagebrush is the primary understory shrub. Forbs such as arrowleaf balsamroot (*Balsamorhiza sagittat*a), phlox (*Phlox* spp.), and tapertip hawksbeard (*Crepis acuminata*) are minor components.

PIMO-JUOS/ARTRV (F029XY066NV), Mature Woodland 1.1, T. Stringham, June 2023

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
A high severity-crown fire will eliminate or reduce the singleleaf pinyon and Utah juniper overstory and the shrub component. This allows for the perennial bunchgrasses to dominate the site. Sprouting shrubs may increase.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.4:
Time without disturbance such as fire, long-term drought, or disease will allow for the gradual infilling of singleleaf pinyon and Utah juniper.

Community Phase 1.2:
This community phase is characterized by a post-fire shrub and herbaceous community. Muttongrass and other perennial bunchgrasses dominate. Forbs may increase after a

fire but will likely return to pre-burn levels within a few years. Pinyon and juniper seedlings up to 4 ft in height may be present. Mountain big sagebrush may be present in unburned patches. Burned tree skeletons may be present; however, these have little or no effect on the understory vegetation.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.3:
Time without disturbance such as fire, long-term drought, or disease will allow for the gradual maturation of the singleleaf pinyon and Utah Juniper component. Mountain big sagebrush reestablishes.

Community Phase 1.3
This community phase is characterized as an immature woodland with pinyon, juniper trees averaging over 4.5 ft in height. Pinyon and juniper canopy cover is between 10 to 20%. Tree crowns are typically cone- or pyramidal-shaped. Understory vegetation is dominated by mountain big sagebrush and perennial bunchgrasses as well as smaller tree seedlings and saplings. Under a sparse canopy cover (10–20%), understory production ranges from 400 to 800 lb/ac.

Community Phase Pathway 1.3a, from Phase 1.3 to 1.1:
Time without disturbance such as fire, long-term drought, or disease will allow for the gradual maturation of singleleaf pinyon and Utah juniper. Infilling by younger trees continues.

Community Phase Pathway 1.3b, from Phase 1.3 to 1.2:
Fire reduces or eliminates tree canopy, allowing perennial grasses to dominate the site.

Community Phase 1.4 (At Risk):
This phase is dominated by over-mature singleleaf pinyon and Utah juniper that have reached their maximal heights. The stand exhibits mixed age classes and canopy cover may be over 30%. Dominant and co-dominant trees average greater than 15 inches in diameter at one-foot stump height. Upper crowns are typically irregularly flat-topped or rounded. Understory vegetation is sparse or absent due to tree competition, overstory shading and duff accumulation. Understory production, under a dense canopy cover (> 30%) ranges from 50 to 200 lb/ac.

Community Phase Pathway 1.4a, from Phase 1.4 to 1.1:
Low intensity fire, insect infestation, or disease kills individual trees within the stand reducing canopy cover to less than 20%. Over time young trees mature to replace and maintain the mature woodland. The mountain big sagebrush and perennial bunchgrass community increases in density and vigor.

Community Phase Pathway 1.4b, from Phase 1.4 to 1.2:
A high-severity crown fire will eliminate or reduce the singleleaf pinyon and Utah juniper overstory and the shrub component which will allow for the perennial bunchgrasses to dominate the site.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0:

Trigger: Introduction of non-native annual species.

Slow variables: Over time the annual non-native plants will increase within the community.

Threshold: Any amount of introduced non-native annual species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

T1B: Transition from Reference State 1.0 to Infilled Tree State 3.0

Trigger: Time and a lack of disturbance allow trees to dominate site resources; may be coupled with inappropriate herbivory and/or fire suppression that favors shrub and tree dominance.

Slow variables: Over time the abundance and size of trees will increase.

Threshold: Juniper and pinyon canopy cover is greater than 30%. Little understory vegetation remains due to competition with trees for site resources.

Current Potential State 2.0:

This state is similar to the Reference State 1.0, with four general community phases: a mature woodland phase (2.1), a shrub-herbaceous phase (2.2), an immature woodland phase (2.3), and an over-mature woodland phase (2.4). Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of non-native species. These non-natives, particularly cheatgrass, can be highly flammable and promote fire where historically fire had been infrequent. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal. Fires within this community with the small amount of non-native annual species present are likely still small and patchy due to low fuel loads. This fire type will create a plant community mosaic that will include all/most of the following community phases within this state.

Community Phase 2.1:
This phase is characterized by a widely dispersed mature Utah juniper and singleleaf pinyon trees with an understory of mountain big sagebrush and perennial bunchgrasses. The visual aspect is dominated by singleleaf pinyon and Utah juniper of 15% or more. Tree canopy cover ranges from 20 to 30%. Trees have reached maximal or near maximal heights for the site and many tree crowns may be flat- or round-topped. At fire-safe sites, dominant trees average greater than 15 inches in diameter at one-foot stump height. Muttongrass is the most prevalent grass in the understory, found primarily under tree canopies. Mountain big sagebrush is the primary understory shrub. Mat-forming forbs are present. Understory production ranges from 250 to 600 lb/ac under a medium canopy cover (20–30%). Non-native, annual weeds are a minor component.

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
A high-severity crown fire will eliminate or reduce the singleleaf pinyon and Utah juniper overstory and the shrub component. This allows for the perennial bunchgrasses to dominate. Sprouting shrubs may increase.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.4:
Time without disturbance such as fire, long-term drought, or disease will allow for the gradual infilling of singleleaf pinyon and Utah juniper.

Community Phase 2.2:
This community phase is characterized by a post-fire shrub and herbaceous community. Muttongrass and other perennial grasses dominate. Forbs may increase post-fire but will likely return to pre-burn levels within a few years. Pinyon and juniper seedlings up to 4 ft in height may be present. Mountain big sagebrush may be present in unburned patches. Burned tree skeletons may be present; however, these have little or no effect on the understory vegetation. Annual non-native species generally respond well after fire and may be stable or increasing within the community. Canopy cover of trees is less than 10%. Understory production ranges from 500 to 1,000 lb/ac.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.3:
Time without disturbance such as fire, long-term drought, or disease will allow for the gradual maturation of the singleleaf pinyon and Utah Juniper component. Mountain big sagebrush reestablishes. Excessive herbivory may also reduce perennial grass understory further facilitating sagebrush or tree establishment.

Community Phase 2.3:
This community phase is characterized by an immature woodland, with singleleaf pinyon and Utah juniper trees averaging over 4.5 ft in height. Tree canopy cover is between 10 to 20%. Tree crowns are typically cone- or pyramidal-shaped. Understory vegetation consists of smaller tree seedlings and saplings, as well as perennial

bunchgrasses and shrubs. Understory production ranges from 400 to 800 lb/ac under a sparse canopy cover (10–20%). Annual non-native species are present.

Community Phase Pathway 2.3a, from Phase 2.3 to 2.1:

Time without disturbances such as fire, drought, or disease will allow for the gradual maturation of singleleaf pinyon and Utah juniper. Infilling by younger trees continues. Excessive herbivory may reduce perennial grass density and facilitate tree and shrub establishment.

Community Phase Pathway 2.3b, from Phase 2.3 to 2.2:
Fire reduces or eliminates tree canopy, allowing perennial grasses to dominate the site.

Community Phase 2.4 (At-Risk):
This phase is dominated by over-mature singleleaf pinyon and Utah juniper. The stand exhibits mixed age classes and canopy cover may be over 30%. The density and vigor of the mountain big sagebrush and perennial bunchgrass understory is decreased. Understory production ranges from 50 to 200 lb/ac under a dense canopy (>30 %). Annual non-native species are present primarily under tree canopies.

PIMO-JUOS/PUST (F029XY058NV), Current Potential 2.4, T. Stringham, June 2023

Community Phase Pathway 2.4a, from Phase 2.4 to 2.1:
Low intensity fire, insect infestation, or disease kills individual trees within the stand, reducing canopy cover to 20% or less. Over time young trees mature to replace and maintain the old-growth woodland. The mountain big sagebrush and perennial bunchgrass community increases in density and vigor. Annual non-natives present in trace amounts.

Community Phase Pathway 2.4b, from Phase 2.4 to 2.2:
A high-severity crown fire will eliminate or reduce the singleleaf pinyon and Utah juniper overstory and the shrub component which will allow for the perennial bunchgrasses to dominate the site. Annual non-native grasses typically respond positively to fire and may increase in the post-fire community.

T2A: Transition from Current Potential State 2.0 to Infilled Tree State 3.0

Trigger: Time and a lack of disturbance allow trees to dominate site resources; may be coupled with inappropriate grazing management that favors shrub and tree dominance.

Slow variables: Over time the abundance and size of trees will increase.

Threshold: Juniper and pinyon canopy cover is greater than 30%. Little understory vegetation remains due to competition with trees for site resources.

Infilled Tree State 3.0

This state has two community phases that are characterized by the dominance of Utah juniper and singleleaf pinyon in the overstory. This state is identifiable by 35 to over 50% cover of Utah juniper and singleleaf pinyon. This stand exhibits a mixed age class. Older trees are at maximal height and upper crowns may be flat-topped or rounded. Younger trees are typically cone- or pyramidal-shaped. Understory vegetation is sparse due to increasing shade and competition from trees.

Community Phase 3.1:
Singleleaf pinyon and Utah juniper dominate the aspect. Understory vegetation is thinning. Perennial bunchgrasses are sparse and mountain big sagebrush skeletons are as common as live shrubs due to tree competition for soil water, overstory shading, and duff accumulation. Tree canopy cover is greater than 30%. Annual non-native species may be present. Bare ground areas are prevalent and soil redistribution is evident.

PIMO-JUOS/ARTRV/POFE (F029XY066NV), Infilled Tree State 3.1, T. Stringham, June 2023

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:
Time without disturbance such as fire, long-term drought, or disease will allow for the gradual maturation of singleleaf pinyon and Utah juniper. Infilling by younger trees continues.

Community Phase 3.2:
Singleleaf pinyon and Utah juniper dominate the aspect. Tree canopy cover exceeds 30% and may be as high as 50%. Understory vegetation is sparse to absent. Perennial bunchgrasses, if present exist in the dripline or under the canopy of trees. Mountain big sagebrush skeletons are common or the sagebrush has been extinct long enough that only scattered limbs remain. Mat-forming forbs or Sandberg's bluegrass may dominate interspaces. Annual non-native species may be present and are typically found under the trees. Bare ground areas are large and interconnected. Soil redistribution may be extensive.

R3A Restoration from Infilled Tree State 3.0 to Current Potential State 2.0:

Manual or mechanical thinning of trees coupled with seeding of native species. Prescribed fire during fall or winter coupled with seeding. Probability of success is highest from community phase 3.1.

States Not Observed in Group 20:

An Annual State was not observed during field work for this project, however cheatgrass was observed in the understory of some of the sites. Sites with lower resilience and resistance may convert to an Annual State after wildfire.

Potential Resilience Differences with Other Ecological Sites in this Group:

PIMO-JUOS/PUST (F029XY058NV):

This woodland site occurs on hill and mountain sideslopes on all exposures. Slopes range from 8 to 50%. Elevations are 6,500 to 7,500 ft and precipitation ranges from 10 to 14 in. The soils are very shallow to deep and well drained. Available water capacity is low. Overstory tree composition is about 20 to 40% Utah juniper and 60 to 80% singleleaf pinyon. Stansbury cliffrose and desert snowberry are the primary understory shrubs and muttongrass and Sandberg bluegrass are the primary understory grasses. Annual understory production under a medium canopy (21–35%) is 50 to 200 lb/ac. The site is less productive and has a lower tree site index than the modal. Resilience is low because of low production, less precipitation and a lower elevation range. This site will have the same ecological states as the modal site.

PIMO-JUOS/ARTRV/POFE (F029XY095NV):

This woodland site occurs on mountain summits and sideslopes on all aspects. Slopes range from 30 to 50%. Elevations are 6,000 to about 7,200 ft. Average annual precipitation is 12 to 16 in. The soils are shallow to very shallow and available water capacity is low or very low. Overstory tree composition is about 50 to 70% singleleaf pinyon and 30 to 50% Utah juniper. Mountain big sagebrush is the principal understory shrub and muttongrass is the principal understory grass. Annual understory production under a medium canopy (21–35%) is 150 to 350 lb/ac. This site is a less productive and has a lower tree site index than the modal. Resilience is low because of the low production and lower elevation range. This site will have the same ecological states as the modal site.

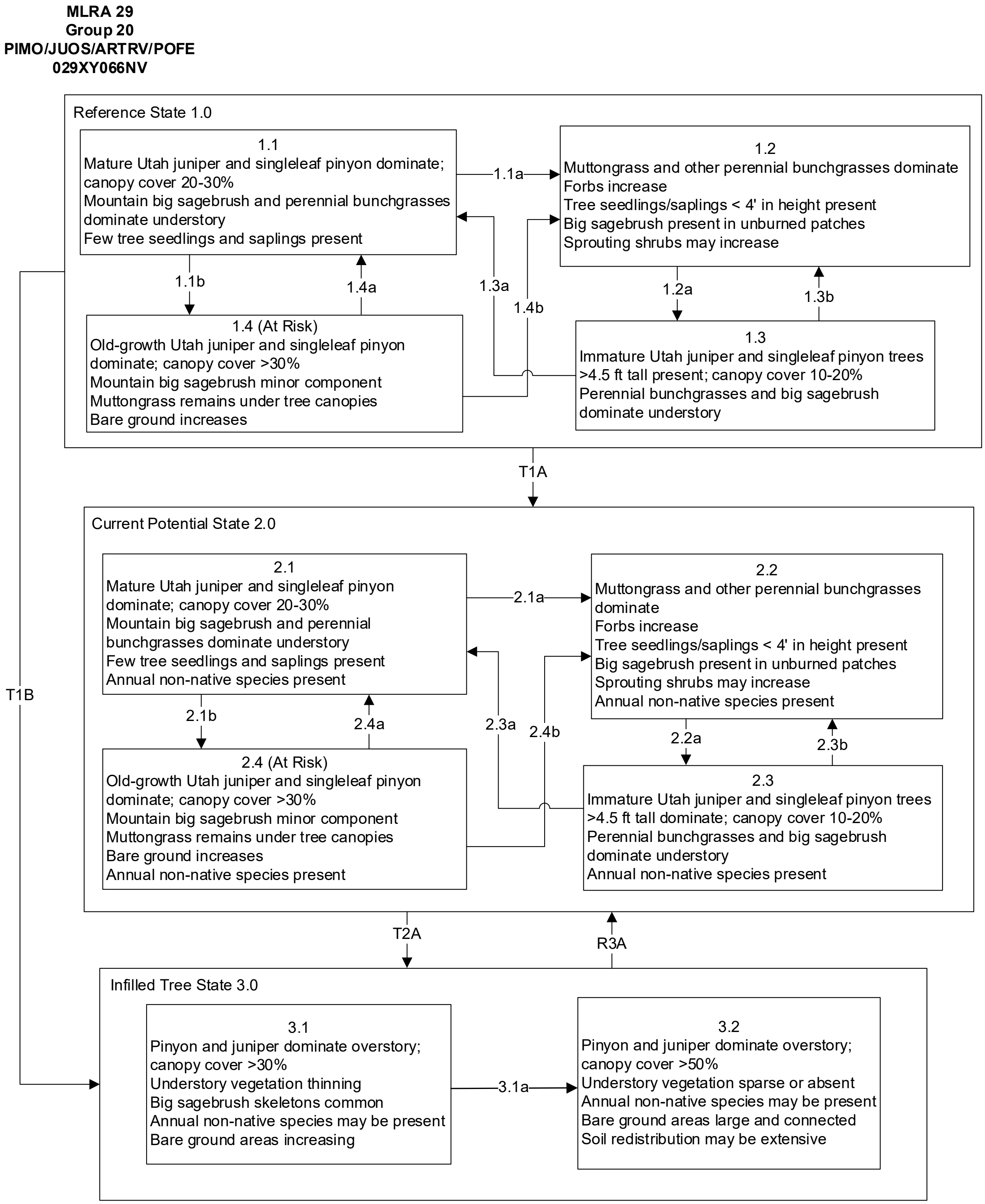
PIMO/ARTRV/POFE (F029XY102NV):

This woodland community occurs on mid- to upper mountain sideslopes of mostly northerly aspects. Slopes range from 15 to 75%, but are typically 30 to 50%. Elevations are 7,000 to over 9,000 ft. Average annual precipitation is 14 to 18 in. Soils are shallow to bedrock and well drained. Overstory tree composition is about 85 to 100% singleleaf pinyon with up to 15% curl-leaf mountain mahogany or Utah juniper. Annual understory production for a medium canopy (21–35%) is 150 to 350 lb/ac. Mountain big sagebrush and antelope bitterbrush are the principal understory shrubs. Muttongrass is the most prevalent understory grass. Tree site index and understory production are lower than the modal. Site resiliency is moderate to high primarily because of higher precipitation and elevation than the modal.

PIMO/ARTRV/POFE (F029XY103NV):

This woodland site occurs on mountain ridges, shoulders and upper sideslopes on all aspects. Slopes range from 4 to 75%, but slopes are generally 30 to 75%. Elevations are about 7,500 to over 9,000 ft. Average annual precipitation is about 14 to over 18 in. Soils are shallow to very shallow. Overstory tree canopy is over 95% singleleaf pinyon and up to 5% curl-leaf mountain mahogany or Utah juniper. Annual understory production for a sparse canopy (11–20%) is 75 to 250 lb/ac. Because of the broken terrain and inherently sparse productivity of the soils, naturally occurring wildfires probably did not greatly influence the structure and composition of the reference plant community. Mountain big sagebrush and antelope bitterbrush are the principal understory shrubs. Muttongrass, Sandberg's bluegrass, and Letterman's needlegrass are the most prevalent understory grasses. The site is less productive and has a lower tree site index than the modal. Resilience is low because of low production; however, an Annual State is unlikely due to the sparse vegetative cover.

Modal State and Transition Model for Group 20 in MLRA 29:



MLRA 29
Group 20
PIMO/JUOS/ARTRV/POFE
029XY066NV

Reference State 1.0 Community Pathways
1.1a: High severity crown fire reduces or eliminates tree cover, allowing sprouting shrubs and perennial bunchgrasses to dominate.
1.1b: Time and lack of disturbance such as fire, insect attack, disease, or drought allows younger trees to infill.
1.2a: Time and lack of disturbance such as fire, insect attack, disease, or drought facilitates establishment of trees and mountain big sagebrush. Excessive herbivory by wildlife may also reduce perennial grass understory.
1.3a: Time and lack of disturbance such as fire, insect attack, disease, or drought allows maturation of the woodland. Excessive herbivory by wildlife may also reduce perennial grass understory.
1.3b: Fire reduces or eliminates tree cover.
1.4a: Low severity fire, insect infestation, or disease removes individual trees and reduces total tree cover.
1.4b: High severity crown fire reduces or eliminates tree cover.

Transition T1A: Introduction of non-native annual species.

Transition T1B: Time and a lack of disturbance allows for trees to dominate site resources; may be coupled with inappropriate grazing management and/or fire suppression that favors shrub and tree dominance.

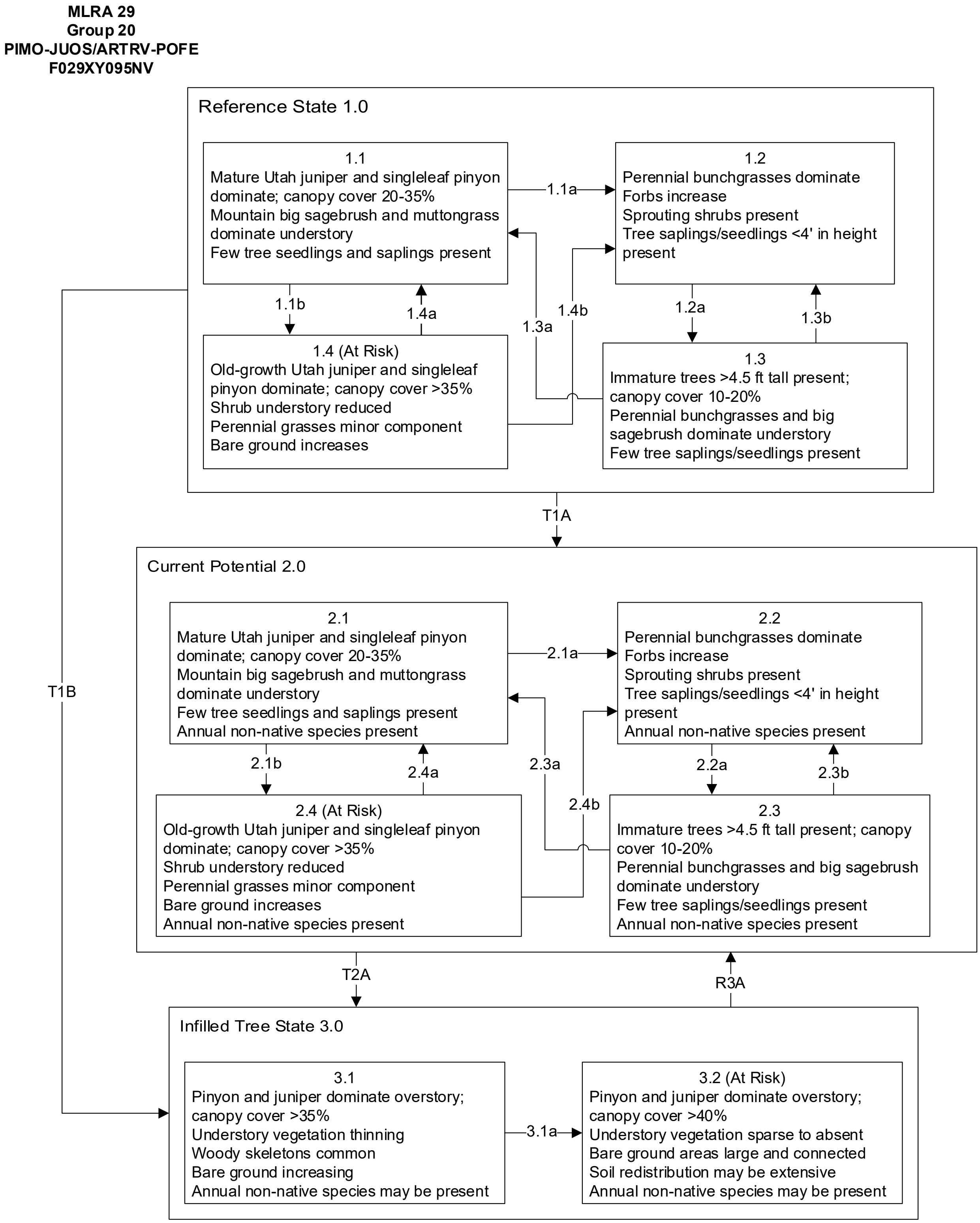
Current Potential State 1.0 Community Pathways
2.1a: High severity crown fire reduces or eliminates tree cover, allowing sprouting shrubs and perennial bunchgrasses to dominate.
2.1b: Time and lack of disturbance such as fire, insect attack, disease, or drought allows younger trees to infill.
2.2a: Time and lack of disturbance such as fire, insect attack, disease, or drought facilitates establishment of trees and mountain big sagebrush. Excessive herbivory by wildlife may also reduce perennial grass understory.
2.3a: Time and lack of disturbance such as fire, insect attack, disease or drought allows maturation of the woodland. Excessive herbivory may also reduce perennial grass understory.
2.3b: Fire reduces or eliminates tree cover.
2.4a: Low severity fire, insect infestation, or disease removes individual trees and reduces total tree cover.
2.4b: High severity crown fire reduces or eliminates tree cover.

Transition T2A: Time and a lack of disturbance allows for trees to dominate site resources; may be coupled with inappropriate grazing management and/or fire suppression that favors shrub and tree dominance.

Infilled Tree State 3.0 Community Pathways
3.1a: Time and lack of disturbance such as fire, insect attack, disease, or drought allows younger trees to infill.

Restoration R3A: Mechanical or hand thinning of trees coupled with seeding. Prescribed fire during fall or winter coupled with seeding. Success unlikely from phase 3.2.

Additional State and Transition Models for Group 20 in MLRA 29:



MLRA 29
Group 20
PIMO-JUOS/ARTRV-POFE
F029XY095NV

Reference State 1.0 Community Pathways
1.1a: High severity crown fire reduces or eliminates tree cover, allowing sprouting shrubs and perennial bunchgrasses to dominate.
1.1b: Time and lack of disturbance such as fire, insect attack, disease, or drought allows younger trees to infill.
1.2a: Time and lack of disturbance such as fire, insect attack, disease, or drought facilitates establishment of trees and mountain big sagebrush. Excessive herbivory by wildlife may also reduce perennial grass understory.
1.3a: Time and lack of disturbance such as fire, insect attack, disease, or drought allows maturation of the woodland. Excessive herbivory by wildlife may also reduce perennial grass understory.
1.3b: Fire reduces or eliminates tree cover.
1.4a: Low severity fire, insect infestation, or disease removes individual trees and reduces total tree cover.
1.4b: High severity crown fire reduces or eliminates tree cover.

Transition T1A: Introduction of non-native annual species.

Transition T1B: Time and a lack of disturbance allows for trees to dominate site resources; may be coupled with inappropriate grazing management and/or fire suppression that favors shrub and tree dominance.

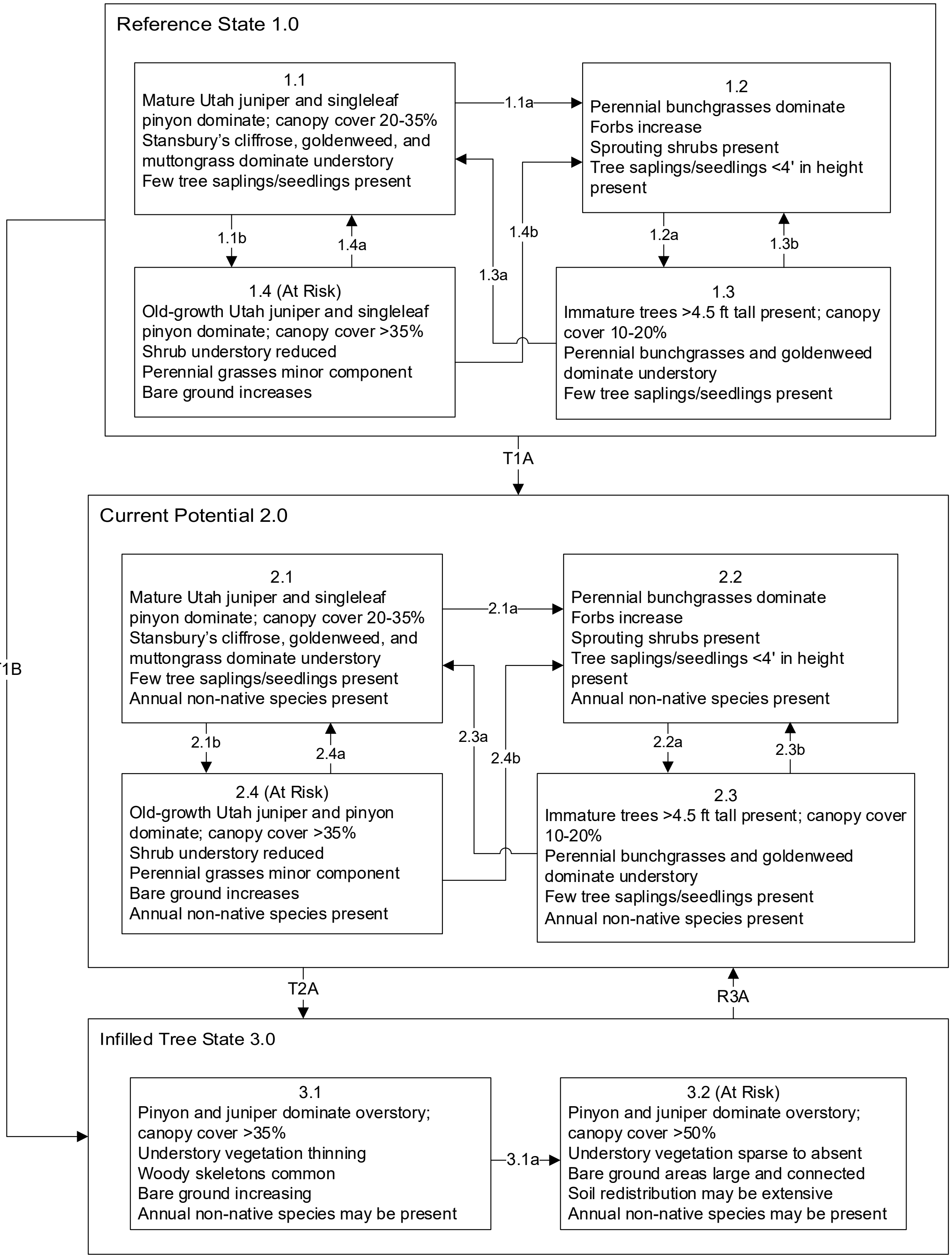
Current Potential State 1.0 Community Pathways
2.1a: High severity crown fire reduces or eliminates tree cover, allowing sprouting shrubs and perennial bunchgrasses to dominate.
2.1b: Time and lack of disturbance such as fire, insect attack, disease, or drought allows younger trees to infill.
2.2a: Time and lack of disturbance such as fire, insect attack, disease, or drought facilitates establishment of trees and mountain big sagebrush. Excessive herbivory by wildlife may also reduce perennial grass understory.
2.3a: Time and lack of disturbance such as fire, insect attack, disease or drought allows maturation of the woodland. Excessive herbivory may also reduce perennial grass understory.
2.3b: Fire reduces or eliminates tree cover.
2.4a: Low severity fire, insect infestation, or disease removes individual trees and reduces total tree cover.
2.4b: High severity crown fire reduces or eliminates tree cover.

Transition T2A: Time and a lack of disturbance allows for trees to dominate site resources; may be coupled with inappropriate grazing management and/or fire suppression that favors shrub and tree dominance.

Infilled Tree State 3.0 Community Pathways
3.1a: Time and lack of disturbance such as fire, insect attack, disease, or drought allows younger trees to infill.

Restoration R3A: Mechanical or hand thinning of trees coupled with seeding. Prescribed fire during fall or winter coupled with seeding. Success unlikely from phase 3.2.

MLRA 29
Group 20
PIMO-JUOS/PUST
F029XY058NV



MLRA 29
Group 20
PIMO-JUOS/PUST
F029XY058NV

Reference State 1.0 Community Phase Pathways
1.1a: High severity crown fire reduces or eliminates tree cover, allowing sprouting shrubs and perennial bunchgrasses to dominate.
1.1b: Time and lack of disturbance such as fire, insect attack, disease, or drought allows younger trees to infill.
1.2a: Time and lack of disturbance such as fire, insect attack, disease, or drought facilitates establishment of trees and goldenweed. Excessive herbivory by wildlife may also reduce perennial grass understory.
1.3a: Time and lack of disturbance such as fire, insect attack, disease, or drought allows maturation of the woodland. Excessive herbivory by wildlife may also reduce perennial grass understory.
1.3b: Fire reduces or eliminates tree cover.
1.4a: Low severity fire, insect infestation, or disease removes individual trees and reduces total tree cover.
1.4b: High severity crown fire reduces or eliminates tree cover.

Transition T1A: Introduction of non-native annual species.

Transition T1B:Time and a lack of disturbance allows for trees to dominate site resources; may be coupled with inappropriate grazing management and/or fire suppression that favors shrub and tree dominance.

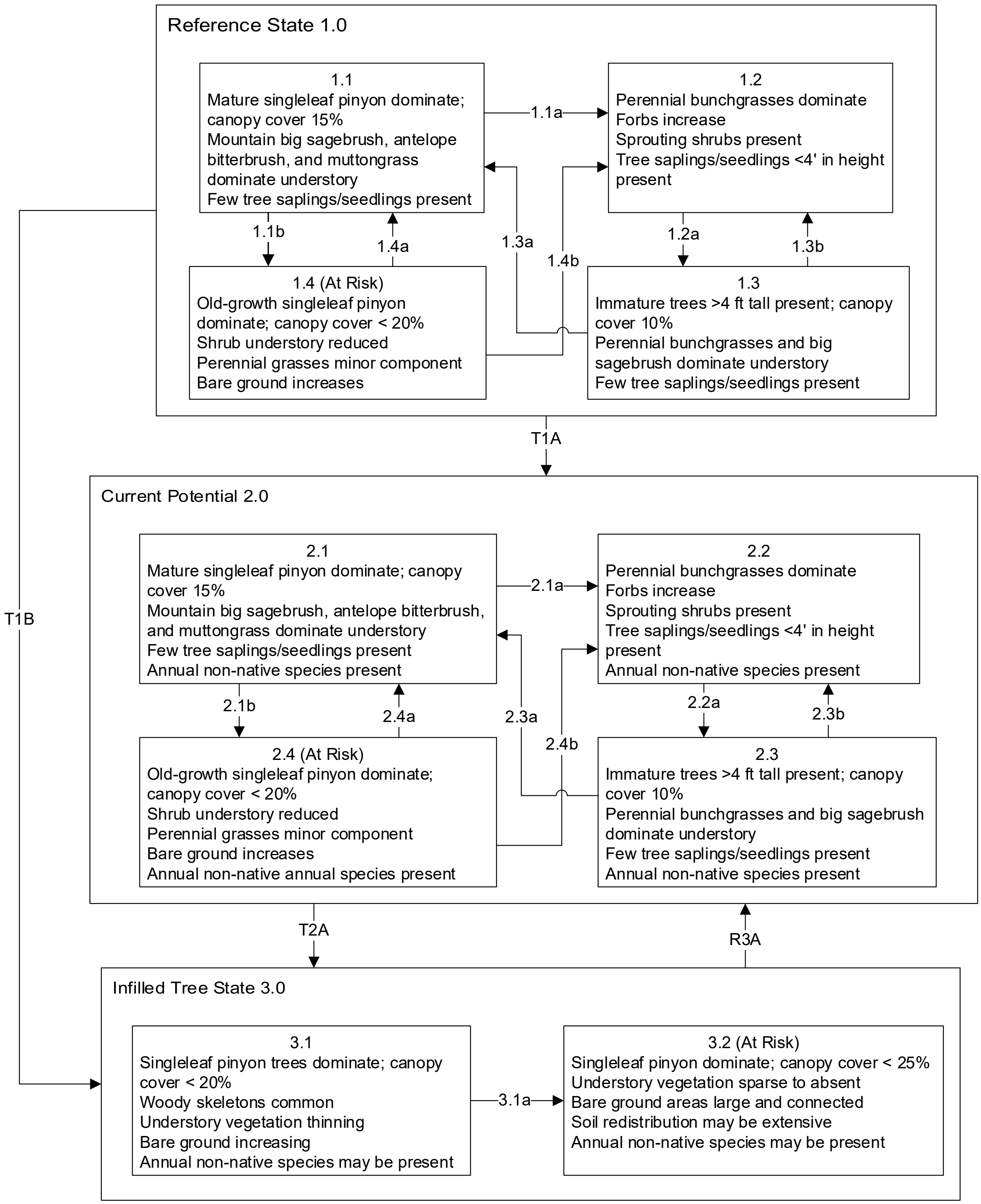
Current Potential 2.0 Community Phase Pathways
2.1a: High severity crown fire reduces or eliminates tree cover, allowing sprouting shrubs and perennial bunchgrasses to dominate.
2.1b: Time and lack of disturbance such as fire, insect attack, disease, or drought allows younger trees to infill.
2.2a: Time and lack of disturbance such as fire, insect attack, disease, or drought facilitates establishment of trees and goldenweed. Excessive herbivory by wildlife may also reduce perennial grass understory.
2.3a: Time and lack of disturbance such as fire, insect attack, disease, or drought allows maturation of the woodland. Excessive herbivory may also reduce perennial grass understory.
2.3b: Fire reduces or eliminates tree cover.
2.4a: Low severity fire, insect infestation, or disease removes individual trees and reduces total tree cover.
2.4b: High severity crown fire reduces or eliminates tree cover.

Transition T2A: Time and a lack of disturbance allows for trees to dominate site resources; may be coupled with inappropriate grazing management and/or fire suppression that favors shrub and tree dominance.

Infilled Tree State 3.0 Community Phase Pathways
3.1a: Time and lack of disturbance such as fire, insect attack, disease, or drought allows younger trees to infill.

Restoration R3A: Mechanical or hand thinning of trees coupled with seeding. Prescribed fire during fall or winter coupled with seeding. Success unlikely from phase 3.2.

MLRA 29
Group 20
PIMO/ARTRV/POFE
F029XY103NV



MLRA 29
Group 20
PIMO/ARTRV/POFE
F029XY103NV

Reference State 1.0 Community Phase Pathways
1.1a: High severity crown fire reduces or eliminates tree cover, allowing sprouting shrubs and perennial bunchgrasses to dominate.
1.1b: Time and lack of disturbance such as fire, insect attack, disease, or drought allows younger trees to infill.
1.2a: Time and lack of disturbance such as fire, insect attack, disease, or drought facilitates establishment of trees and big sagebrush. Excessive herbivory by wildlife may also reduce perennial grass understory.
1.3a: Time and lack of disturbance such as fire, insect attack, disease, or drought allows maturation of the woodland. Excessive herbivory by wildlife may also reduce perennial grass understory.
1.3b: Fire reduces or eliminates tree cover.
1.4a: Low severity fire, insect infestation, or disease removes individual trees and reduces total tree cover.
1.4b: High severity crown fire reduces or eliminates tree cover.

Transition T1A: Introduction of non-native annual species.

Transition T1B:Time and a lack of disturbance allows for trees to dominate site resources; may be coupled with inappropriate grazing management and/or fire suppression that favors shrub and tree dominance.

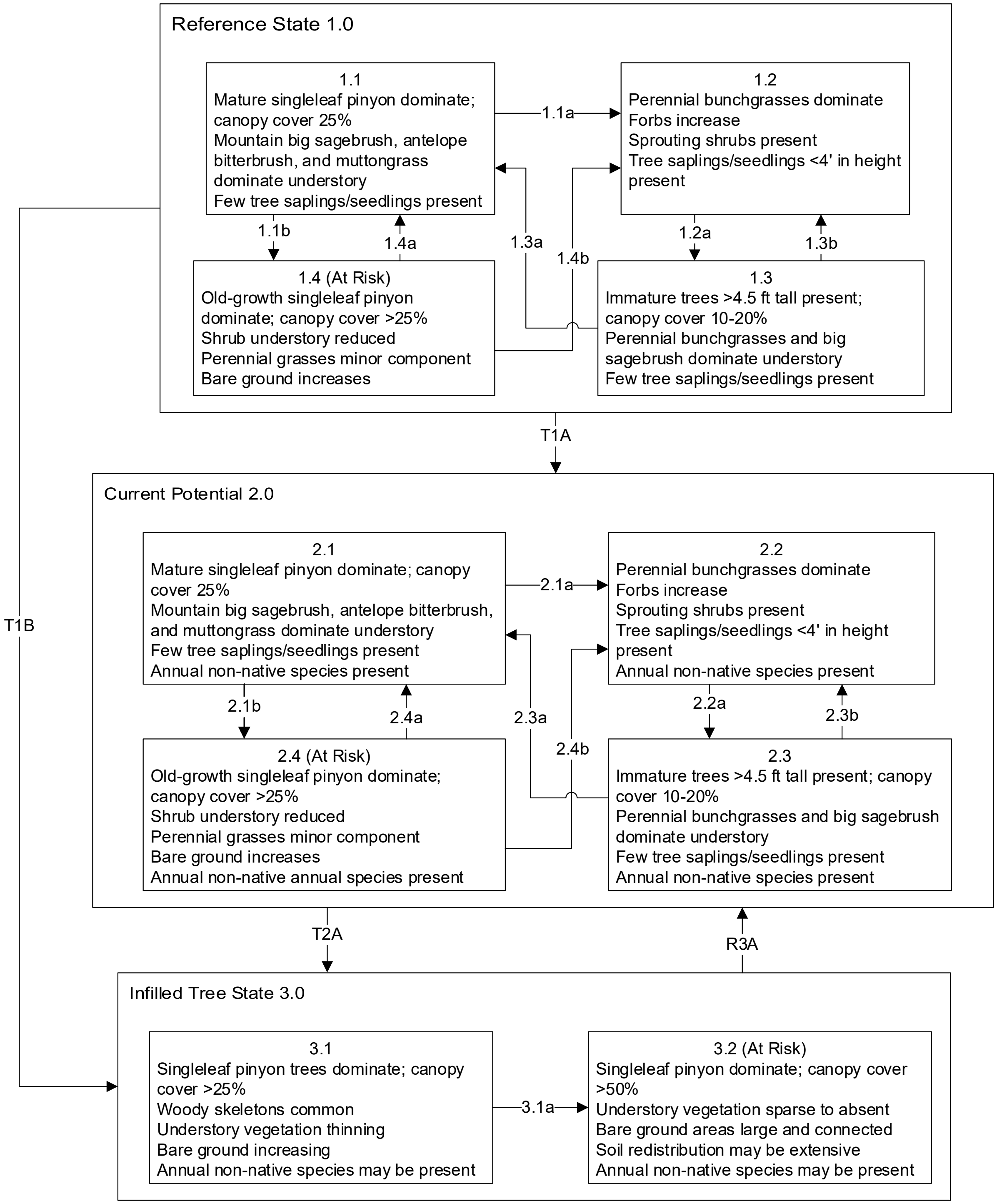
Current Potential 2.0 Community Phase Pathways
2.1a: High severity crown fire reduces or eliminates tree cover, allowing sprouting shrubs and perennial bunchgrasses to dominate.
2.1b: Time and lack of disturbance such as fire, insect attack, disease, or drought allows younger trees to infill.
2.2a: Time and lack of disturbance such as fire, insect attack, disease, or drought facilitates establishment of trees and big sagebrush. Excessive herbivory by wildlife may also reduce perennial grass understory.
2.3a: Time and lack of disturbance such as fire, insect attack, disease, or drought allows maturation of the woodland. Excessive herbivory may also reduce perennial grass understory.
2.3b: Fire reduces or eliminates tree cover.
2.4a: Low severity fire, insect infestation, or disease removes individual trees and reduces total tree cover.
2.4b: High severity crown fire reduces or eliminates tree cover.

Transition T2A: Time and a lack of disturbance allows for trees to dominate site resources; may be coupled with inappropriate grazing management and/or fire suppression that favors shrub and tree dominance.

Infilled Tree State 3.0 Community Phase Pathways
3.1a: Time and lack of disturbance such as fire, insect attack, disease, or drought allows younger trees to infill.

Restoration R3A: Mechanical or hand thinning of trees coupled with seeding. Prescribed fire during fall or winter coupled with seeding. Success unlikely from phase 3.2.

MLRA 29
Group 20
PIMO/ARTRV/POFE
F029XY102NV



MLRA 29
Group 20
PIMO/ARTRV/POFE
F029XY102NV

Reference State 1.0 Community Phase Pathways
1.1a: High severity crown fire reduces or eliminates tree cover, allowing sprouting shrubs and perennial bunchgrasses to dominate.
1.1b: Time and lack of disturbance such as fire, insect attack, disease, or drought allows younger trees to infill.
1.2a: Time and lack of disturbance such as fire, insect attack, disease, or drought facilitates establishment of trees and big sagebrush. Excessive herbivory by wildlife may also reduce perennial grass understory.
1.3a: Time and lack of disturbance such as fire, insect attack, disease, or drought allows maturation of the woodland. Excessive herbivory by wildlife may also reduce perennial grass understory.
1.3b: Fire reduces or eliminates tree cover.
1.4a: Low severity fire, insect infestation, or disease removes individual trees and reduces total tree cover.
1.4b: High severity crown fire reduces or eliminates tree cover.

Transition T1A: Introduction of non-native annual species.

Transition T1B:Time and a lack of disturbance allows for trees to dominate site resources; may be coupled with inappropriate grazing management and/or fire suppression that favors shrub and tree dominance.

Current Potential 2.0 Community Phase Pathways
2.1a: High severity crown fire reduces or eliminates tree cover, allowing sprouting shrubs and perennial bunchgrasses to dominate.
2.1b: Time and lack of disturbance such as fire, insect attack, disease, or drought allows younger trees to infill.
2.2a: Time and lack of disturbance such as fire, insect attack, disease, or drought facilitates establishment of trees and big sagebrush. Excessive herbivory by wildlife may also reduce perennial grass understory.
2.3a: Time and lack of disturbance such as fire, insect attack, disease, or drought allows maturation of the woodland. Excessive herbivory may also reduce perennial grass understory.
2.3b: Fire reduces or eliminates tree cover.
2.4a: Low severity fire, insect infestation, or disease removes individual trees and reduces total tree cover.
2.4b: High severity crown fire reduces or eliminates tree cover.

Transition T2A: Time and a lack of disturbance allows for trees to dominate site resources; may be coupled with inappropriate grazing management and/or fire suppression that favors shrub and tree dominance.

Infilled Tree State 3.0 Community Phase Pathways
3.1a: Time and lack of disturbance such as fire, insect attack, disease, or drought allows younger trees to infill.

Restoration R3A: Mechanical or hand thinning of trees coupled with seeding. Prescribed fire during fall or winter coupled with seeding. Success unlikely from phase 3.2.

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MLRA 29 Group 21: Pinyon and juniper woodland with fire-adapted shrub understory

Description of MLRA 29 Disturbance Response Group 21

Disturbance Response Group (DRG) 21 consists of four ecological sites. Precipitation is 12 to 18 in. (30–46 cm). Elevations range from 5,000 to 7,500 ft (1,520–2,286 m) and slopes are typically 35 to 75%. The soils in this group are typically shallow to moderately deep and available water holding capacity is low. These soils usually have high amounts of rock fragments at the soil surface which occupy plant growing space, yet help to reduce evaporation and provide a stabilizing effect on erosion conditions. This group is dominated by singleleaf pinyon (*Pinus monophylla*) and Utah juniper (*Juniperus osteosperma*) with Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) or mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*) as the primary understory shrub. Other shrubs in the group include Gambel oak (*Quercus gambelii*), Sonoran scrub oak (*Quercus turbinella*), greenleaf manzanita (*Arctostaphylos patula*), desert ceanothus (*Ceanothus greggii*), yellow silktassel (*Garrya flavescens*), and Utah serviceberry (*Amelanchier utahensis*). The understory grasses include Indian ricegrass *(Achnatherum hymenoides)*, prairie junegrass (*Koeleria macrantha*), muttongrass (*Poa fendleriana*), and bottlebrush squirreltail (*Elymus elymoides*). Under medium canopy cover of 20 to 35% understory production ranges from 200 to 1,300 lb/ac depending on ecological site.

Disturbance Response Group 21 Ecological Sites:

PIMO-JUOS/QUERC-AMUT-ARTRV – Modal (Shallow Ashy Loam 12-16" P.Z.)	F029XY078NV
PIMO-JUOS/ARTRV-AMUT-QUGA	F029XY084NV
PIMO/AMUT-ARTRV-QUTU2	F029XY100NV
PIMO-JUOS/ARTRV-AMUT-GAFL2	F029XY067NV

Modal Site:

The Shallow Ashy Loam 12-16" P.Z. (PIMO-JUOS/QUERC-AMUT-ARTRV, F029XY078NV) ecological site is the modal site that represents this group as it has the most acres mapped. This woodland community occurs on mountain sideslopes of mostly northerly aspects at the lower elevations of its range, and on all aspects at higher elevations. The site is found from 5,000 to about 6,500 ft (1,520–1,980 m) in elevation on slopes that range from 15 to over 100% but are typically 30 to 75%. Average annual precipitation is 12 to 16 in. (30–41 cm). The soils are typically shallow and well drained.

The soils are skeletal, with 35 to over 50% gravels, cobbles, or stones, by volume, distributed throughout their profile. Available water capacity is low, but trees and shrubs can extend their roots into fissures within the underlying material allowing them to utilize deep moisture. Runoff is medium to rapid and potential for sheet and rill erosion is moderate to severe depending on the slope. There are high amounts of rock fragments at the soil surface which occupy plant growing space, yet can also help to reduce evaporation and conserve soil moisture. These soils are skeletal with 35 to over 50% gravels, cobbles, or stones, by volume, distributed throughout their profile. An overstory canopy cover of about 25% is assumed to be representative of tree dominance on this site in the reference condition.

Wildfire is recognized as a natural disturbance that strongly influenced the structure and composition of the climax vegetation of this woodland site. This site is dominated by singleleaf pinyon and Utah juniper. Mountain big sagebrush, or Wyoming big sagebrush and Utah serviceberry are the principal understory shrubs. Overstory tree canopy composition is approximately 50 to 60% singleleaf pinyon and 40 to 50% Utah juniper. Sonoran scrub oak and Gambel oak, greenleaf manzanita, yellow silktassel, and desert ceanothus are also present and usually most prevalent following wildfire. Muttongrass is the most prevalent understory grass. Overstory tree canopy composition is about 50 to 60% singleleaf pinyon and 40 to 50% Utah juniper. Understory vegetative composition is about 35% grasses, 5% forbs, and 60% shrubs and young trees when the average overstory canopy is medium (20 to 30%). Average understory production ranges from 600 to 1,000 lb/ac with a medium canopy cover. Understory production includes the total annual production of all species within 4.5 ft (1.4 m) of the ground surface.

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development, and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasive species. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans across Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area, especially in eastern Nevada, when strong convection storms contribute significantly to annual precipitation. Moisture and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

Periodic drought regularly influences these ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West (Miller et al. 2008a). Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006).

Pinyon and juniper-dominated plant communities in the cold desert of the Intermountain West occupy over 18 million ha (44,600,000 ac) (Miller and Tausch 2001). In the mid to late 1900s, the number of pinyon and juniper trees established per decade began to increase compared to the previous several hundred years. The substantial increase in conifer establishment is attributed to a number of factors the most important being (1) cessation of the aboriginal burning (Tausch 1999), (2) change in climate with rising temperatures (Heyerdahl et al. 2006), (3) the reduced frequency of fire likely driven by the introduction of domestic livestock, (4) a decrease in wildfire frequency along with improved wildfire suppression efforts and (5) potentially increased CO2 levels favoring woody plant establishment (Bunting 1994, Tausch 1999). Miller et al. (2008b) found pre-settlement tree densities averaged 2 to 11 per acre in six woodlands studied across the Intermountain West. Current stand densities range from 80 to 358 trees/ac. In Utah, Nevada, and Oregon, trees established prior to 1860 accounted for only 2% or less of the total population of pinyon and juniper (Miller et al. 2008b). The research strongly suggests that for over 200 years prior to settlement, woodlands in the Great Basin were relatively low density with limited rates of establishment (Miller and Tausch 2001, Miller et al. 2008b). This evidence strongly suggests that tree canopy cover of 10 to 20% may be more representative of these sites in pristine condition. Increases in pinyon and juniper densities post-settlement were the result of both infill in mixed-age tree communities and expansion into shrub-steppe communities. However, the proportion of old-growth can vary depending on disturbance regimes, soils, and climate. Some ecological sites are capable of supporting persistent woodlands, likely due to specific soils and climate resulting in infrequent stand replacement disturbance regimes. In the Great Basin, old-growth trees have been found to typically grow on rocky shallow or sandy soils that support little understory vegetation to carry a fire (Holmes et al. 1986, Miller and Rose 1995, West et al. 1998).

Infilling by younger trees increases canopy cover causing a decrease in understory perennial vegetation and an increase in bare ground. As pinyon and juniper trees increase in density so has their litter. Phenolic compounds of juniper scales can have an inhibitory effect on grass growth (Jameson 1970). Furthermore, infilling shifts stand-level biomass from ground fuels to canopy fuels which has the potential to significantly impact fire behavior. The more tree-dominated pinyon and juniper woodlands become, the less likely they are to burn under moderate conditions, resulting in infrequent high-intensity fires (Gruell 1999, Miller et al. 2008b). Additionally, as the understory vegetation declines in vigor and density with increased canopy, the seed and propagules of the understory plant community also decrease significantly. The increase in bare ground allows for the invasion of non-native annual species such as cheatgrass and with intensive wildfire, the potential for conversion to annual exotics is a serious threat (Tausch 1999, Miller et al. 2008b).

Singleleaf pinyon and Utah juniper are long-lived tree species with wide ecological amplitudes (Tausch et al. 1981, West et al. 1998, Weisberg and Ko 2012). The maximum ages of pinyon and juniper exceed 1,000 years and stands with maximum age classes are only found on steep rocky slopes with no evidence of fire (West et al. 1975). Pinyon is slow-growing and very intolerant to shade with the exception of young plants, usually first-year seedlings (Tueller and Clark 1975). Singleleaf pinyon seedling establishment is episodic. Population age structure is affected by drought, which reduces seedling and sapling recruitment more than other age classes. The ecotones between singleleaf pinyon woodlands and adjacent shrublands and grasslands provide favorable microhabitats for singleleaf pinyon seedling establishment since they are active zones for seed dispersal, nurse plants are available, and singleleaf pinyon seedlings are only affected by competition from grass and other herbaceous vegetation for a couple of years.

Specific successional pathways after disturbance in pinyon and/or juniper stands are dependent on a number of variables, such as plant species present at the time of disturbance and their individual responses to disturbance, past management, type and size of disturbance, available seed sources in the soil or adjacent areas, and site and climatic conditions throughout the successional process.

Utah juniper can be killed by a fungus called juniper pocket rot (*Pyrofomes demidoffi*), also known as white trunk rot (Eddleman et al. 1994, Durham 2014). Pocket rot enters the tree through any wound or opening that exposes the heartwood. In an advanced stage, this fungus can cause high mortality (Durham 2014). Dwarf mistletoe (*Arceuthobium* spp.) a parasitic plant, may also affect Utah juniper and without treatment or pruning, may kill the tree 10 to 15 years after infection. Seedlings and saplings are most susceptible to the parasite (Christopherson 2014). Other diseases affecting juniper are: witches'-broom (*Gymnosporangium* spp.) that may girdle and kill branches; leaf rust (*Gymnosporangium* spp.) on leaves and young branches; and juniper blight (*Phomopsis* spp.). Flat-head borers (*Chrysobothris spp.*) attack the wood; long-horned beetles (*Methia juniper*, *Styloxus bicolor*) girdle limbs and twigs; and round-head borers (*Callidium* spp.) attack twigs and limbs (Tueller and Clark 1975).

Phillips (1909) recognized that pinyon are more resistant to disease than most of the conifers with which it associates. Hepting (1971) lists several diseases affecting pinyon including: foliage diseases, tarspot needle cast (*Davisomycella ampla*), stem diseases such as blister rust (*Cronartium ribicola*) and dwarf mistletoe, root diseases and trunk rots, red heart rot (caused by *Stereum sanguinolentum*), and butt rot (caused by *Polyporus schweinitzii)*. The pinyon ips beetle (*Ips confuses*) and pinyon needle scale (*Matsucoccus acalyptus*) are both native insects to Nevada that attack pinyon pines throughout their range. The pinyon needle scale weakens trees by killing needles older than 1 year. Sometimes small trees are killed by repeated feeding and large trees are weakened to the point that they are attacked by the pinyon ips beetle. The beetle typically kills weak and damaged trees (Phillips and Reboletti 2014). During periods of long-term drought, the impact of these two insects on singleleaf pinyon can be substantial.

The pinyon jay (*Gymnorhinus cyanocephalus*) and other members of the seed caching corvids play an important role in pinyon pine regeneration. These birds cache the seeds in the soil for future use. Those seeds that escape harvesting by the birds and rodents have the opportunity to germinate under favorable soil and climatic conditions (Lanner 1981). A mutualistic relationship exists between the trees that produce food and the animals that disperse the seeds, thereby ensuring the perpetuation of the trees. Large crops of seeds may stimulate reproduction in birds, especially the pinyon jay (Ligon 1974).

Pinyon and juniper growth is dependent mostly upon soil moisture stored from winter precipitation, mainly snow. Much of the summer precipitation is ineffective, being lost in runoff after summer convection storms or by evaporation and interception (Tueller and Clark 1975). Pinyon and juniper are highly resistant to drought which is common in the Great Basin. Tap roots of pinyon and juniper have a relatively rapid rate of root elongation and are thus able to persist until precipitation conditions are more favorable (Emerson 1932).

The understory of the ecological sites in this DRG are dominated by deep-rooted, cool season, perennial bunchgrasses, and long-lived shrubs (50+ years) with high root-to-shoot ratios. The dominant shrubs usually root to the full depth of the winter-spring soil moisture recharge, which ranges from 1 to over 3 m (3 to 10 ft) (Comstock and Ehleringer 1992). Root length of mature sagebrush plants was measured to a depth of 2 m (6.5 ft) in alluvial soils in Utah (Richards and Caldwell 1987). These shrubs have a flexible generalized root system with development of both deep taproots and laterals near the surface (Dobrowolski et al. 1990).

Mountain big sagebrush is generally long-lived; therefore, it is not necessary for new individuals to recruit every year for perpetuation of the stand. Infrequent large recruitment events and simultaneous low, continuous recruitment is the foundation of population maintenance (Noy-Meir 1973). The survival of the seedlings is dependent on adequate moisture conditions.

Utah serviceberry is a large shrub that grows from 2 to 4 m (6.5 to 13 ft) tall and typically grows in big sagebrush, pinyon-juniper, and aspen communities (Hammond 2012). Despite typically being found surrounded by other species, serviceberry seedlings can be outcompeted by dense stands of grasses and forbs. Utah serviceberry is top-killed by fire but resprouts from an underground crown, and its branches, leaves, and berries all provide forage for wildlife and livestock (Noller 2008). Utah serviceberry is more drought tolerant than other serviceberry species, and its root system is very deep and spreading and well adapted to coarse-textured soils (Hammond 2012). The only pest known to be a serious threat to Utah serviceberry is cedar-apple rust (*Gymnosporangium juniperi-virginianae*), which Utah serviceberry can host in its leaves and berries when growing in proximity to junipers (Wasser 1982).

Gambel oak is a deciduous small tree or shrub that is found in the foothills and lower mountains of western North America. It can occasionally grow as tall as 50 ft (15 m) but typically grows less than 30 ft (9 m) tall. Gambel oak has been known as a valuable resource for a long time, providing cover, habitat, and food for many different wildlife species. With the help of a healthy, productive understory, Gambel oak provides erosion protection over large areas (Kaufmann et al. 2016). Gambel oak is a sprouter, meaning that a Gambel oak plant can re-sprout from tissue underground, even when any of the plant above ground is killed from fire, grazing, or other forms of disturbance, as opposed to non-sprouters, which are killed by fire and rely on seed dispersal for post-dispersal colonization (Premoli and Steinke 2008). This makes Gambel oak a key component in restoring disturbed communities, because fresh, young plants will sprout, spread, and compete against invasive species.

Sonoran scrub oak is a long-lived, clonal evergreen shrub or small tree. It typically grows from 3 to 8 ft (91–244 cm) but can reach 15 ft (4.6 m) or more (Cable 1975). It reproduces both sexually and vegetatively. In wet years, it produces an abundance of acorns which usually germinate and establish from late July through mid-September (Tucker et al. 1961, Cable 1975). However, Sonoran scrub oak increases more through rhizome sprouting than seedling establishment and sprouts vigorously after fire, herbicide application or mechanical treatment (Saunier and Wagle 1967).

The perennial bunchgrasses that are sub-dominant to the shrubs include Indian ricegrass, muttongrass, and bottlebrush squirreltail. These species generally have somewhat shallower root systems than the shrubs, but root densities are often as high as or higher than those of shrubs in the upper 0.5 m (20 in.) of the soil profile. General differences in root depth distributions between grasses and shrubs result in resource partitioning in these shrub/grass systems.

Indian ricegrass, one of the dominant understory species of this group, is a hardy, cool-season, densely tufted, long-lived perennial bunchgrass that grows from 4 to 24 inches in height (Blaisdell and Holmgren 1984). Its deep, fibrous root system makes Indian ricegrass one of the most drought tolerant native species. Indian ricegrass can be found throughout MLRA 29, including on ridges, canyons, dunes, hills, plains, and mountains. Indian ricegrass is a key plant in recovering communities disturbed by grazing, mining, and fire because it is a hardy grass that is able to grow in rough, rocky, and coarse soils and still provides very valuable forage. When properly planted and managed, Indian ricegrass can help recover disturbed areas by competing with invasive species and providing cover and forage (Booth et al. 1980).

Muttongrass is a tufted, multi-flowered, perennial bunchgrass that can grow between 8 and 30 in. tall and has narrow leaves, which range from 1 to 3 mm (<1 in.) wide. It is found in lower elevations in the northern extent of its native range, and higher elevations in the south.

Muttongrass is one of the most drought-tolerant bluegrasses and is useful for restoring communities disturbed by fire, grazing, or mining, but is limited in its use due to low seed viability. Muttongrass plants are most frequently pistillate, but staminate plants do occasionally occur, which are able to hybridize and crossbreed with other bluegrasses. Muttongrass is found throughout the western United States as a primary component of the understory of pinyon-juniper communities and aspen and pine forests (Tilley et al. 2007).

Bottlebrush squirreltail is a short, cool-season bunchgrass that grows between 3 to 17 in. tall. It is an allotetraploid that can self-pollinate and is able to hybridize with other grasses, including other species of *Elymus* and some species of *Hordeum* (barley). Squirreltail is a very adaptable grass that has spread out all over western North America in the United States, Canada, and Mexico. Squirreltail can be found above 2,000 ft in elevation, and in areas that receive at least 5 in. of precipitation per year.

The ecological sites in this DRG have low to moderate resilience to disturbance and resistance to invasion. Resilience increases with elevation, aspect, increased precipitation, and increased nutrient availability. Five possible stable states have been identified for this DRG.

Annual Invasive Species:

The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and depressed competition or can increase resource pools by the decomposition of dead plant material following disturbance. The presence of non-native annual plants within these ecosystems decreases ecosystem resilience and resistance to disturbance through competition for limited resources. Peters and Bunting (1994) cites multiple authors on the extent of the soil profile exploited by the competitive exotic annual cheatgrass. Specifically, the depth of rooting is dependent on the size the plant achieves, and in competitive environments, cheatgrass (*Bromus tectorum*) roots were found to penetrate only 15 cm (6 in.) whereas isolated plants and pure stands were found to root at least 1 m in depth (3.2 ft) with some plants rooting as deep as 1.5 to 1.7 m (5 to 5.5 ft).

The species most likely to invade these sites is cheatgrass. Cheatgrass is a cool-season annual grass that maintains an advantage over native plants in part because it is a prolific seed producer, can germinate in the autumn or spring, tolerates grazing, and increases with frequent fire (Klemmedson and Smith 1964, Miller 1999). Cheatgrass originated from Eurasia and was first reported in North America in the late 1800s . Pellant and Hall (1994) found 3.3 million acres of public lands dominated by cheatgrass and suggested that another 76 million acres were susceptible to invasion by winter annuals including cheatgrass and medusahead.

Recent modeling and empirical work by Bradford and Lauenroth (2006) suggest that seasonal patterns of precipitation input and temperature are also key factors determining regional variation in the growth, seed production, and spread of invasive annual grasses. The phenomenon of cheatgrass "die-off" provides opportunities for restoration of perennial and native species (Baughman et al. 2016, Baughman et al. 2017). The causes of these events are not fully understood, but there is ongoing work to try to predict where they occur, in the hopes of aiding conservation planning (Weisberg et al. 2017, Brehm 2019).

Methods to control cheatgrass include herbicide application, prescribed fire, targeted grazing, and rangeland seeding. Mapping potential or current invasion vectors is a management method designed to increase the cost-effectiveness of control methods. Spraying with herbicide (imazapic or imazapic + glyphosate) and seeding with crested wheatgrass and Sandberg bluegrass has been found to be more successful at combating cheatgrass (and medusahead) than spraying alone (Sheley et al. 2012). To date, most seeding success has occurred with non-native wheatgrass species. Perennial grasses, especially crested wheatgrass, are able to suppress cheatgrass growth when mature (Blank et al. 2020). Where native bunchgrasses are missing from the site, revegetation of annual grass-invaded rangelands has been shown to have a higher likelihood of success when using introduced perennial bunchgrasses such as crested wheatgrass Butler et al. (2011), (Davies et al. 2015b, Clements et al. 2017) tested four herbicides (imazapic, imazapic + glyphosate, rimsulfuron, and sulfometuron + chlorsulfuron) for suppression of cheatgrass, medusahead (*Taeniatherum caput-medusae*), and North Africa grass (*Ventenata dubia*) within residual stands of native bunchgrass. Additionally, they tested the same four herbicides followed by seeding of six bunchgrasses (native and non-native) with varying success (Butler et al. 2011). Herbicide-only treatments appeared to remove competition for established bluebunch wheatgrass by providing 100% control of North Africa grass and medusahead and greater than 95% control of cheatgrass (Butler et al. 2011). Caution in using these results is advised, as only 1 year of data was reported.

In considering the combination of pre-emergent herbicide and prescribed fire for invasive annual grass control, it is important to assess the tolerance of desirable brush species to the herbicide being applied. Vollmer and Vollmer (2008) tested the tolerance of mountain mahogany (*Cercocarpus montanus*), antelope bitterbrush, and multiple sagebrush species to three rates of imazapic with and without methylated seed oil as a surfactant. They found that a cheatgrass control program in an antelope bitterbrush community should not exceed imazapic at 8 oz/ac with or without surfactant. Sagebrush, regardless of species or rate of application, was not affected. However, many environmental variables were not reported in this study and managers should install test plots before broad-scale herbicide application is initiated.

Fire Ecology:

Limited data exists that describes fire histories across woodlands in the Great Basin. Pre-settlement fire return intervals in Great Basin National Park, Nevada were found to have a mean range between 50 to 100 years with north-facing slopes burning every 15 to 20 years and rocky landscapes with sparse understory, considered fire-safe sites, burned very infrequently (Gruell 1999). Cable (1975) estimates that fire return intervals for interior chaparral, the understory of these sites, occurring in Arizona, Utah and Nevada, were likely 50 to 100 years

(Pase and Brown 1982). Woodland dynamics are largely attributed to long-term climatic shifts (temperature and amount and distribution of precipitation) and the extent and return intervals of fire (Miller and Tausch 2001, Miller et al. 2019). Both the infilling of younger trees into old growth stands and the expansion of trees into surrounding sagebrush communities have increased the risk of loss of pre-settlement trees through the increased landscape level continuity of fuels (Miller et al. 2008b).

Utah juniper is usually killed by fire and is most vulnerable to fire when it is under 4 ft (1.2 m) tall (Bradley et al. 1992). Larger trees, because they have foliage farther from the ground and thicker bark, can survive low severity fires but mortality does occur when 60% or more of the crown is scorched (Bradley et al. 1992). Singleleaf pinyons are also most vulnerable to fire when less than 4 ft (1.2 m) tall, however mature trees do not self-prune their dead branches allowing for accumulated fuel in the crowns. This characteristic and the relative flammability of the foliage make individual mature trees susceptible to fire (Bradley et al. 1992). With the low production of the understory vegetation and low density of trees per acre, high severity fires within this plant community were not likely and rarely became crown fires (Bradley et al. 1992, Miller and Tausch 2001).

Singleleaf pinyon and Utah juniper reestablish by seed from nearby seed sources or surviving seeds. Junipers have a long-lived seed bank due to delayed germination by impermeable seed coats, immature or dormant embryos, and germination inhibitors (Schupp et al. 1999). Singleleaf pinyon trees have relatively short-lived seeds with little innate dormancy that form only temporary seed banks with most seeds germinating in the spring following dispersal (Meeuwig and Basset 1983). The density of pinyon seeds in the seed bank is dependent upon the current year's cone crop. Singleleaf pinyon is known to have favorable cone production every 2 to 3 years thus the potential for a large temporary seed bank is high during mast years and likely low during non-mast years (Schupp et al. 1999). The role of nurse plant requirements between the two tree species is important to post-fire establishment. Schupp et al. (1999) found that singleleaf pinyon seedlings rarely establish in interspaces or open environments. In contrast, Utah juniper seedlings were found capable of establishing in interspace microhabitats as frequently as under sagebrush. Therefore, fire that removes both trees and understory shrubs in pinyon and/or juniper woodlands may have a relatively greater effect on the establishment of pinyon than juniper.

The initial response of native understory species following fire correlates closely with percent crown cover. In general, research indicates that understory response to disturbance is most productive when crown cover is at or below 20% while beyond 30% there is a rapid decline in understory species and soil seed reserves (Huber et al. 1999).

Mountain big sagebrush is killed by fire (Neuenschwander 1980, Blaisdell et al. 1982) and does not resprout (Blaisdell 1953). Post-fire regeneration occurs from seed and will vary depending on site characteristics, seed source, and fire characteristics. Mountain big sagebrush seedlings can grow rapidly and may reach reproductive maturity within 3 to 5 years (Bunting et al. 1987).

Mountain big sagebrush may return to pre-burn density and cover within 15 to 20 years following fire, but establishment after severe fires may proceed more slowly (Bunting et al. 1987).

Gambel oak is extremely fire tolerant due to it being a sprouting shrub (Kaufmann et al. 2016). When Gambel oak is killed by fire, most of the vegetative tissue underground is still alive, and the plant can sprout and grow from what is left. This gives Gambel oak and other sprouters an advantage over non-sprouters, or "obligate seeders" because they rely on seed dispersal in order to colonize an area after a fire or other disturbance (Premoli and Steinke 2008).

Sonoran scrub oak is top-killed by fire and the degree of damage and mortality depends on fire intensity and severity, site characteristics and climatic factors (Tiedmann and Schmutz 1966). Post-fire, this oak typically sprouts vigorously from the root crown and rhizomes and seed germination also occurs (Pase 1969, Cable 1975).

Utah serviceberry is a large, fire-tolerant shrub that is a major component of this DRG. It is top-killed by fire but sprouts from the underground root crown after disturbance. However, resprouting is reliant on the amount of moisture in the soil and Utah serviceberry is more adapted for drier soils, which will limit the potential for a sprout to successfully grow (Hammond 2012). It can also re-colonize an area after fire via seeds, but this may require up to 8 to 10 years for plants to be fully mature and productive (Noller 2008).

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The initial condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species' response. For most forbs and grasses, the growing points are located at or below the soil surface providing relative protection from disturbances that decrease above-ground biomass, such as grazing or fire. Thus, fire mortality is more correlated to duration and intensity of heat, which is related to culm density, culm-leaf morphology, size of plant, and abundance of old growth (Wright 1971, Young 1983). However, the season and severity of the fire will influence plant response. Plant response will vary depending on post-fire soil moisture availability.

Indian ricegrass, a common grass in this DRG, is fairly fire tolerant (Wright 1985), which is likely due to its low culm density and below-ground plant crowns. Vallentine (1989) cites several studies in the sagebrush zone that classified Indian ricegrass as being slightly damaged from late summer burning. Indian ricegrass has also been found to reestablish on burned sites through seeds dispersed from adjacent unburned areas (Young 1983, West 1994). Thus, the presence of surviving, seed-producing plants facilitates the reestablishment of Indian ricegrass. Grazing management following fire to promote seed production and establishment of seedlings is important. When properly planted and managed, Indian ricegrass can be a key factor in a community recovering from disturbance because it can grow in rough, rocky, coarse, and otherwise unattractive soils (Booth et al. 1980).

Muttongrass, a dominant understory grass in this group, is top-killed by fire but will sprout after low to moderate severity fires. A study by Vose and White (1991), in an open saw timber site found minimal difference in the overall effect of burning on muttongrass.

Bottlebrush squirreltail is considered one of the most fire-resistant bunchgrasses due to its small size, coarse stems, and sparse leafy material (Wright and Klemmedson 1965, Wright 1971, Britton et al. 1990). Post-fire regeneration occurs from surviving root crowns and from on- and off-site seed sources (Bradley et al. 1992). Bottlebrush squirreltail has the ability to produce large numbers of highly germinable seeds, with relatively rapid germination (Young and Evans 1977) when exposed to the correct environmental cues. Squirreltail is capable of facultative fall or spring germination, develops extensive roots at low temperatures, and produces seeds early in the season (Reynolds and Fraley 1989, Hironaka 1994, Monsen et al. 2004b). Recent research indicates that squirreltail is capable of relatively rapid natural selection to improve survival in low-water, competitive environments (Kulpa and Leger 2013). These traits and others make squirreltail competitive with cheatgrass and medusahead (Hironaka and Sindelar 1975, Hironaka 1994). Squirreltail reproduces primarily through seed. The long awns of the fruit allow for wind dispersal up to 130 ft (40 m) away from the parent plant (Hironaka and Tisdale 1963, Marlette and Anderson 1986).

Livestock/Wildlife Grazing Interpretations:

Pinyon-juniper woodlands provide a diversity of habitats for wildlife. Although the foliage of pinyon and juniper varies in palatability among fauna, pinyon nuts and juniper berries are preferred by many species. The understory species provide fruits and browse for large ungulates, small mammals, birds, and beavers (Wildlife Action Plan Team 2012).

Ungulates will use pinyon and juniper trees for cover and graze the foliage. The understory species also provide critical browsing for deer (Odocoileus spp.). The trees provide important cover for mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis*), wild horses (*Equus ferus*), mountain lion (*Puma concolor*), bobcat (*Lynx rufus*), and pronghorn (*Antilocapra americana*) (Logan and Irwin 1985, Evans 1988, Coates and Schemnitz 1994, Gottfried and Severson 1994).

Mule deer is considered the dominant big game species in the pinyon-juniper woodland and depend heavily on these woodlands for cover, shelter, and emergency forage during severe winters (Frischknecht 1975). Mule deer will eat singleleaf pinyon and juniper foliage, using the foliage moderately in winter, spring, and summer (Kufeld et al. 1973). Deep snow in higher elevation forest zones force mule deer and elk down into pinyon-juniper habitats during winter. This change in habitat allows mule deer and elk to browse the dwarf trees and shrubs (Gottfried and Severson 1994).

The diet of pronghorn antelope varies considerably; however, singleleaf pinyon was shown to comprise 1 to 2% of the winter diet of pronghorn that occur in pinyon-juniper habitat. Desert bighorn sheep (*Ovis nelson*) may utilize pinyon-juniper habitat, but only where the terrain is rocky and steep (Gottfried et al. 2000). Gray foxes (*Urocyon cinereoargenteus*), bobcats, coyotes (*Canis latran*s), weasels (*Mustela frenata*), skunks (*Mephitis* spp.), badgers (*Taxidea taxus*), and ringtail cats (*Bassariscus astutus*) search for prey in pinyon-juniper habitat woodlands (Short and McCulloch 1977).

Juniper "berries" or berry-cones are eaten by black-tailed jackrabbits, *Lepus californicus*, and coyotes (Gese et al. 1988, Kitchen et al. 2000). A study by Kitchen et al. (2000) conducted in juniper-pinion habitat found vegetation in coyote scats was mainly grass seeds or juniper berries. Jackrabbits are a major dispenser of juniper seeds (Schupp et al. 1999). The pinyon mouse (*Peromyscus truei*) is a pinyon-juniper obligate and uses the woodlands for cover and food (Hoffmeister 1981). Other small mammals include the porcupine (*Hystricomorph hystricidae*), desert cottontail (*Sylvilagus audubonii*), Nuttall's cottontail (*S. nuttallii*), deer mouse (*Peromyscus maniculatus*), Great Basin pocket mouse (*Perognathus parvus*), chisel-toothed kangaroo rat (*Dipodomys microps*) and desert woodrat (*Neotoma lepida*) (Turkowski and Watkins 1976).

Many bird species are associated with the pinyon-juniper habitat; some are permanent residents, some summer residents, and some winter residents, depending upon location. For birds and bats, the woodland provides structure for nesting and roosting, and locations for foraging. Singleleaf pinyon provides a number of cavities, and the stringy, fibrous bark provides quality nesting material as well as the food provided by the tree's seeds and berries (Short and McCulloch 1977). Many bird species depend on juniper berry-cones and pine nuts for fall and winter food (Balda and Masters 1980). Several bird species are obligates including gray flycatcher (*Epidonax wrightii),* scrub jay (*Aphelocoma californica)*, plain titmouse (*Parus inornatus ridgwayi*), and gray vireo (*Vireo vicinior)*; several species are semi-obligates including black-chinned hummingbird (*Archilochus alexandri*), ash-throated flycatcher (*Myiarchus cinerascens*), pinion jay (*Gymnorhinus cyanocephalus*), American bushtit (*Psaltriparus minimus*), Bewick's wren (*Thryomanes bewickii*), Northern mockingbird (*Mimus polyglottos*), blue-gray gnatcatcher (*Polioptila caerulea*), black-throated gray warbler (*Dendroica nigrescens*), house finch (*Haemorhous mexicanus*), spotted towhee (*Pipilo maculatus*), lark sparrow (*Chondestes grammacus*) and black-chinned sparrow (*Zonotrichia atricapilla)* (Balda and Masters 1980). Ferruginous hawk (*Buteo regalis*), a conservation priority species due to recent population declines in Nevada, nests in older trees of sufficient size and structure to support their large nest platforms (Holechek 1981).

Diurnal reptiles include the sagebrush swift (*Sceloporus graciosus)*, the blue-bellied lizard (*Sceloporus elongates),* the western collard lizard *(Crotaphytus collaris)*, the Great Basin rattlesnake *(Oreganus lutosus)*, the Great Basin gopher snake (*Pituophis catenifer*), and horned lizard *(Phrynosoma spp.)* also occur in Utah juniper habitat (Frischknecht 1975). However, the distribution of most of the herpetofauna present in pinyon-juniper woodlands is poorly understood and more research and management are needed.

The history of livestock grazing in the pinyon-juniper ecosystem goes back more than 200 years, depending on the particular locality within the ecosystem (Hurst 1975). Historically, pinyon-juniper woodlands were much more open, and they supported a diverse understory that provided forage for both livestock and wildlife. Historic livestock overuse and increased stand densities have reduced the carrying capacity of these pinyon-juniper stands and many current stands only provide shade and shelter for livestock.

Despite low palatability, mountain big sagebrush is eaten by sheep, cattle, goats, and horses. Chemical analysis indicates that the leaves of big sagebrush equal alfalfa meal in protein, have a higher carbohydrate content, and yield twelvefold more fat (USFS 1937). Many wildlife species are dependent on the sagebrush ecosystem including the greater sage grouse (*Centrocercus urophasianus*), sage sparrow (*Artemisiospiza nevadensis*), pygmy rabbit (*Brachylagus idahoensis*), and the sagebrush vole (*Lemmiscus curtatus*). Dobkin and Sauder (2004) identified 61 species, including 24 mammals and 37 birds, associated with the shrub-steppe habitats of the Intermountain West.

Gambel oak is considered an important species for wildlife forage, even though it is not highly palatable. This is due to how widespread and abundant it is, especially on winter ranges. Gambel oak leaves provide important forage for deer and elk year-round, and acorns are an extremely valuable mast crop, especially for black bears in the fall (Jester et al. 2008). Because it is a sprouting species, Gambel oak can provide valuable forage and cover in post-fire communities (Premoli and Steinke 2008).

Utah serviceberry is a very important plant because of the amount of food, cover, and habitat it provides to both livestock and wildlife. Its leaves, branches, and berries are used by many wildlife species, including big game, birds, and small animals (Noller 2008). It is highly palatable to wildlife and livestock and is a preferred forage for elk (McCulloch 1955).

Sonoran scrub oak provides little browse for wildlife and livestock but can be used heavily when other more palatable species are absent (Pond and Cable 1960). Acorns of scrub oak provide an important food source for many birds and small mammals (Pase 1969, Cable 1975).

Indian ricegrass is a deep-rooted, cool-season perennial bunchgrass that is adapted primarily to coarse-textured soils. Indian ricegrass is a preferred forage species for livestock and wildlife (Cook 1962, Booth et al. 2006). This species is often heavily utilized in winter because it cures well (Booth et al. 2006). It is also readily utilized in early spring, being a source of green feed before most other perennial grasses have produced new growth (Quinones 1981). Booth et al. (2006) note that the plant does well when utilized in winter and spring. Cook and Child (1971), however, found that repeated heavy grazing reduced crown cover, which may reduce seed production, density, and basal area of these plants. Additionally, heavy early spring grazing reduces plant vigor and stand density (Stubbendieck et al. 1985). In eastern Idaho, productivity of Indian ricegrass was at least 10 times greater in undisturbed plots than in heavily grazed ones (Pearson 1965). Cook and Child (1971) found a significant reduction in plant cover after 7 years of rest from heavy (90%) and moderate (60%) spring use. The seed crop may be reduced where grazing is heavy (Bich et al. 1995). Tolerance to grazing increases after May, thus spring deferment may be necessary for stand enhancement (Pearson 1964, Cook and Child 1971); however, utilization of less than 60% is recommended. In summary, adaptive management is required to manage this bunchgrass well.

Muttongrass is very palatable for wildlife and livestock and is rated as excellent forage for cattle and horses, and good for sheep. Muttongrass starts growth in late winter or early spring and provides excellent early feed. Muttongrass foliage cures well and is good fall forage, but not as good as spring or summer (Humphrey et al. 1952).

Squirreltail has the ability to produce large numbers of highly germinable seeds, with relatively rapid germination (Young and Evans 1977) when exposed to the correct environmental cues. Early spring growth and the ability to grow at low temperatures contribute to the persistence of bottlebrush squirreltail among cheatgrass-dominated ranges (Hironaka and Tisdale 1973). Squirreltail generally increases in abundance when moderately grazed or protected (Hutchings and Stewart 1953). In addition, moderate trampling by livestock in big sagebrush rangelands of central Nevada enhanced bottlebrush squirreltail seedling emergence compared to untrampled conditions. Heavy trampling however was found to significantly reduce germination sites (Eckert et al. 1987). Squirreltail is more tolerant of grazing than Indian ricegrass but all bunchgrasses are sensitive to overutilization within the growing season.

Bunchgrasses, in general, best tolerate light grazing after seed formation. Britton et al. (1990) observed the effects of clipping date on the basal area of five bunchgrasses in eastern Oregon and found grazing from August to October (after seed set) has the least impact. Heavy grazing, year after year during the growing season, will reduce perennial bunchgrasses and increase sagebrush. Abusive grazing by cattle or horses will likely increase sagebrush, rabbitbrush, and deep-rooted perennial forbs. Annual non-native weedy species such as cheatgrass and mustards, and may invade these sites.

State and Transition Model Narrative for Group 21:

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 29 disturbance response group 21.

Reference State 1.0:

The Reference State 1.0 is representative of the natural range of variability under pristine conditions. This reference state has four general community phases: a mature woodland phase (1.1), a shrub-herbaceous phase (1.2), an immature woodland phase (1.3), and an over-mature woodland phase (1.4). State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire, periodic drought, and/or insect or disease attack. Fires within this community are infrequent, with intervals in the range of 50 to 100 years or longer. This fire type will create a plant community mosaic that will include all/most of the following community phases within this state.

Community Phase 1.1:
This phase is characterized by widely dispersed mature pinyon and juniper trees with an understory of mountain or Wyoming big sagebrush, fire-adapted shrubs (oak, manzanita, ceanothus), and perennial bunchgrasses. The visual aspect is dominated by singleleaf pinyon and Utah juniper with about a 20 to 30% canopy cover. Trees have reached maximal or near maximal heights for the site and many tree crowns may be flat- or round-topped. At fire-safe sites, dominant trees average greater than 15 in. (38 cm) in diameter at one-foot stump height and are over 150 years of age. Big sagebrush and Utah serviceberry are the primary understory shrubs. Muttongrass is the dominant perennial grass and perennial forbs such as phlox and buckwheat are minor components. Understory production ranges between 600 to 1,100 lb/ac.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
A high-severity crown fire will eliminate or reduce the singleleaf pinyon and Utah juniper overstory and the fire-intolerant shrub component. This allows for the perennial bunchgrasses and fire-adapted shrubs to dominate the site.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.4:
Time without disturbances such as fire, drought, or disease will allow for the gradual infilling of singleleaf pinyon and Utah juniper.

Community Phase 1.2:
This community phase is characterized by a fire-adapted shrub and herbaceous community. Muttongrass and other perennial grasses dominate. Forbs may increase after a fire but will likely return to pre-burn levels within a few years. Pinyon and juniper seedlings up to 4 ft (1.2 m) in height may be present. Big sagebrush may be present in unburned patches. Burned tree skeletons may be present; however, these have little or no effect on the understory vegetation.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.3:
Time without disturbances such as fire, drought, or disease will allow for the gradual maturation of the singleleaf pinyon and Utah Juniper component. Big sagebrush reestablishes. Excessive herbivory may also reduce perennial grass understory.

Community Phase 1.3:
This community phase is characterized by an immature woodland, with pinyon and juniper trees averaging over 4.5 ft (1.4 m) in height. Tree canopy cover is between 10 to

20%. Tree crowns are typically cone- or pyramidal-shaped. Understory vegetation is dominated by big sagebrush, Utah serviceberry, and perennial bunchgrasses as well as smaller tree seedlings and saplings.

Community Phase Pathway 1.3a, from 1.3 to 1.4:
Time without disturbances such as fire, drought, or disease will allow for the gradual maturation of singleleaf pinyon and Utah juniper. Infilling by younger trees continues. Excessive herbivory may also reduce the perennial grass understory.

Community Phase Pathway 1.3b, from Phase 1.3 to 1.2:
Fire reduces or eliminates tree canopy, allowing perennial grasses and fire-adapted shrubs to dominate the site.

Community Phase 1.4 (At Risk):
This phase is dominated by singleleaf pinyon and Utah juniper that have reached maximal heights for the site. Upper crowns are typically irregularly flat-topped or rounded. The stand exhibits mixed age classes and canopy cover may be 30% or greater. The density and vigor of the big sagebrush and perennial bunchgrass understory is decreased. Bare ground areas are likely to increase. Mat-forming forbs such as phlox may increase. This community is at risk of crossing a threshold; without proper management this phase will transition to the Infilled Tree State 3.0.

Community Phase Pathway 1.4a, from Phase 1.4 to 1.1:
Low intensity fire, insect infestation, or disease kills individual trees within the stand reducing canopy cover to less than 30%. Over time young trees mature to replace and maintain the old-growth woodland. The big sagebrush, Utah serviceberry and perennial bunchgrass community increases in density and vigor.

Community Phase Pathway 1.4b, from Phase 1.4 to 1.2:
A high-severity crown fire will eliminate or reduce the singleleaf pinyon and Utah juniper overstory and the shrub component which will allow for the fire-adapted shrubs and perennial bunchgrasses to dominate the site.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0:

Trigger: Introduction of non-native annual species.

Slow variables: Over time the annual non-native plants will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

T1B: Transition from Reference State 1.0 to Infilled Tree State 3.0

Trigger: Time and a lack of disturbance allow trees to dominate site resources; may be coupled with inappropriate herbivory that favors shrub and tree dominance.

Slow variables: Over time the abundance and size of trees will increase.

Threshold: Pinyon and juniper canopy cover is greater than 40%. Little understory vegetation remains due to competition with trees for site resources.

Current Potential State 2.0:

This state is similar to the Reference State 1.0, with four general community phases: a mature woodland phase (2.1), a shrub-herbaceous phase (2.2), an immature woodland phase (2.3), and an over-mature woodland phase (2.4). Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of non-native species. These non-natives, particularly cheatgrass, can be highly flammable and promote fire where historically fire had been infrequent. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal. Fires within this community with the small amount of non-native annual species present are likely still small and patchy due to low fuel loads. This fire type will create a plant community mosaic that will include all/most of the following community phases within this state.

Community Phase 2.1:
This phase is characterized by widely dispersed mature pinyon and juniper trees with an understory of mountain or Wyoming big sagebrush, fire-adapted shrubs (oak, manzanita, ceanothus), and perennial bunchgrasses. The visual aspect is dominated by singleleaf pinyon and Utah juniper with about a 20 to 30% canopy cover. Trees have reached maximal or near maximal heights for the site and many tree crowns may be flat- or round-topped. At fire-safe sites, dominant trees average greater than 15 in. (38 cm) in diameter at one-foot stump height and are over 150 years of age. Big sagebrush and Utah serviceberry are the primary understory shrubs. Muttongrass is the dominant perennial grass and perennial forbs such as phlox and buckwheat are minor components. Understory production ranges between 600 to 1,100 lb/ac.

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
A high-severity crown fire will eliminate or reduce the singleleaf pinyon and Utah juniper overstory and the fire-intolerant shrub component. This allows for the perennial bunchgrasses and fire-tolerant shrubs to dominate the site.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.4:
Time without disturbances such as fire, drought, or disease will allow for the gradual infilling of singleleaf pinyon and Utah juniper.

Community Phase 2.2:
This community phase is characterized by a post-fire shrub and herbaceous community. Muttongrass and other perennial grasses dominate. Forbs may increase post-fire but will likely return to pre-burn levels within a few years. Pinyon and juniper seedlings up to 4 ft (1.2 m) in height may be present. Big sagebrush may be present in unburned patches. Burned tree skeletons may be present; however, these have little or no effect on the understory vegetation. Annual non-native species generally respond well after fire and may be stable or increasing within the community.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.3:

Time without disturbances such as fire, drought, or disease will allow for the gradual maturation of the singleleaf pinyon and Utah Juniper component. Big sagebrush reestablishes. Excessive herbivory may also reduce perennial grass understory.

Community Phase 2.3:

This community phase is characterized by an immature woodland, with pinyon and juniper trees averaging over 4.5 ft (1.4 m) in height. Tree canopy cover is between 10 to 20%. Tree crowns are typically cone- or pyramidal-shaped. Understory vegetation is dominated by big sagebrush, fire-adapted shrubs, and perennial bunchgrasses as well as smaller tree seedlings and saplings. Annual non-native species are present.

Community Phase Pathway 2.3a, from Phase 2.3 to 2.4:

Time without disturbances such as fire, drought, or disease will allow for the gradual maturation of singleleaf pinyon and Utah juniper. Infilling by younger trees continues.

Community Phase Pathway 2.3b, from Phase 2.3 to 2.2:

Fire reduces or eliminates tree canopy, allowing fire-adapted shrubs and perennial grasses to dominate the site.

Community Phase 2.4 (At Risk):

This phase is dominated by singleleaf pinyon and Utah juniper. The stand exhibits mixed age classes and canopy cover exceeds 30%. The density and vigor of the big sagebrush and perennial bunchgrass understory is decreased. Bare ground areas are likely to increase. Mat-forming forbs may increase. Annual non-native species are present primarily under tree canopies. This community is at risk of crossing a threshold, without proper management this phase will transition to the Infilled Tree State 3.0.

PIMO-JUOS/ARTRV-AMUT-QUERC (F029XY078NV), Current Potential 2.4, T. Stringham, June 2022

PIMO-JUOS/ARTRV-AMUT-QUGA (F029XY084NV), Current Potential 2.4, T. Stringham, May 2022

Community Phase Pathway 2.4a, from Phase 2.4 to 2.1:

Low intensity fire, insect infestation, or disease kills individual trees within the stand reducing canopy cover to less than 30%. Over time young trees mature to replace and maintain the old-growth woodland. The big sagebrush and perennial bunchgrass community increases in density and vigor. Annual non-natives present in trace amounts.

Community Phase Pathway 2.4b, from Phase 2.4 to 2.2:

A high-severity crown fire will eliminate or reduce the singleleaf pinyon and Utah juniper overstory and the non-sprouting shrub component which will allow for the fire-adapted shrubs and perennial bunchgrasses to dominate the site. Annual non-native grasses typically respond positively to fire and may increase in the post-fire community.

T2A: Transition from Current Potential State 2.0 to Infilled Tree State 3.0:

Trigger: Time and a lack of disturbance allow trees to dominate site resources; may be coupled with inappropriate grazing management that favors shrub and tree dominance.

Slow variables: Over time the abundance and size of trees will increase.

Threshold: Singleleaf pinyon and Utah juniper canopy cover is greater than 40%. Little understory vegetation remains due to competition with trees for site resources

T2B: Transition from Current Potential State 2.0 to Annual State 5.0:

Trigger: Catastrophic crown fire facilitates the rapid colonization of non-native, annual species, especially at lower elevations and southern exposures of this site.

Slow variables: Increase in tree crown cover, loss of perennial understory and an increase in annual non-native species.

Threshold: Cheatgrass or other non-native annuals dominate understory. Loss of deep-rooted perennial bunchgrasses changes spatial and temporal nutrient cycling and nutrient redistribution, and reduces soil organic matter. Increased canopy cover of trees allows severe stand-replacing fire. The increased seed bank of non-native, annual species responds positively to post-fire conditions facilitating the transition to an Annual State.

Infilled Tree State 3.0:

This state has two community phases that are characterized by the dominance of Utah juniper and singleleaf pinyon in the overstory. This state is identifiable by over 40% cover of Utah juniper and singleleaf pinyon, exhibiting a mixed age class. Older trees are at maximal height and upper crowns may be flat-topped or rounded. Younger trees are typically cone- or pyramidal-shaped. Understory vegetation is sparse due to increasing shade and competition from trees.

Community Phase 3.1:
Singleleaf pinyon and Utah juniper dominate the aspect. Understory vegetation is thinning. Perennial bunchgrasses are sparse and big sagebrush skeletons are as common as live shrubs due to tree competition for soil water, overstory shading, and duff accumulation. Tree canopy cover is greater than 40%. Annual non-native species are present or co-dominant in the understory. Bare ground areas are prevalent.

PIMO-JUOS/ARTRV-AMUT-QUERC (F029XY078NV), Infilled State 3.1, T. Stringham, May 2022

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:
Time without disturbances such as fire, drought, or disease will allow for the gradual maturation of singleleaf pinyon and Utah juniper. Infilling by younger trees continues.

Community Phase 3.2 (At Risk):
Singleleaf pinyon and Utah juniper dominate the aspect. Tree canopy cover exceeds 40%. Understory vegetation is sparse to absent. Perennial bunchgrasses, if present exist in the drip line or under the canopy of trees. Big sagebrush skeletons are common or the sagebrush has been extinct long enough that only scattered limbs remain. Mat-forming forbs, bottlebrush squirreltail and/or Sandberg bluegrass (*Poa secunda*) may dominate interspaces. Annual non-native species are present and are typically found under the trees. Bare ground areas are large and interconnected. Soil redistribution may be extensive.

T3A: Transition from Infilled Tree State 3.0 to Annual State 5.0:

Trigger: Repeated wildfires, in late summer when soils are dry, reduce the pinyon and juniper overstory and allows for the rapid colonization of annual non-native species.

Slow variables: Increase in tree crown cover, loss of perennial understory and an increase in annual non-native species.

Threshold: Cheatgrass or other non-native annuals dominate understory. Loss of deep-rooted perennial bunchgrasses changes spatial and temporal nutrient cycling and nutrient redistribution, and reduces soil organic matter. Increased canopy cover of trees allows severe stand-replacing fire. The increased seed bank of non-native, annual species responds positively to post-fire conditions facilitating the transition to an Annual State.

T3B: Transition from Infilled Tree State 3.0 to Sprouting Shrub State 4.0:

Trigger: Stand-replacing crown fire, when soils are moist, reduces the pinyon and juniper overstory and facilitates the fire-adapted shrubs in the understory to dominate the site.

Slow variables: Long fire-return intervals (50 to 100+ years) allow for the re-establishment of fire-adapted shrub seed banks and the development of the fuel loads and spatial continuity necessary for fire to occur.

Threshold: Increased canopy cover of trees increases the risk for severe stand-replacing crown fire. Loss of deep-rooted perennial bunchgrasses and shrubs changes temporal and spatial nutrient capture and cycling within the community.

R3A: Restoration from Infilled Tree State 3.0 to Current Potential State 2.0:

Manual or mechanical thinning of trees coupled with seeding of native species. Probability of success is highest from community phase 3.1.

Sprouting Shrub State 4.0:

This state has two community phases – an early seral phase dominated by fire-adapted shrubs, perennial grasses and non-native species and a mature fire-adapted shrub phase with a sparse understory of perennial grasses and non-native species. Time since fire may facilitate the maturation of fire-adapted shrubs. Large Gambel oak shrub fields can persist for many years because of its ability to resprout post-fire, competitive advantages over conifer species, and drought resilience (Guiterman et al. 2018). Annual non-native species create a highly combustible fuel bed that shortens the fire return interval. Nutrient cycling is spatially and temporally truncated as annual plants contribute significantly less to deep soil carbon.

Community Phase 4.1:
Fire-adapted shrubs such as oak, manzanita, Utah serviceberry, and silktassel dominate the overstory. Perennial bunchgrasses and forbs are common. Annual non-native species may be present. Bare ground areas are prevalent.

PIMO-JUOS/ARTRV-AMUT-QUERC (F029XY078NV), Sprouting Shrub State 4.1, T. Stringham, August 2021

Community Phase Pathway 4.1a, from Phase 4.1 to 4.2:
Time without disturbances such as fire, drought, or disease will allow for the maturation of the fire-adapted shrubs. Fire return intervals exceed 100 years.

Community Phase 4.2 (At Risk):
Fire-adapted shrubs such as oak, manzanita and silktassel dominate the overstory. Perennial grasses and forbs are sparse. Annual non-native species dominate the understory. Bare ground areas are prevalent. Pinyon and juniper seedlings/saplings present.

Community Phase Pathway 4.2a, from Phase 4.2 to 4.1:
Wildfires, with a fire-return interval less than 100 years, or other disturbances create a mosaic of late seral unburned patches and early seral burned patches dominated by annual non-natives.

T4A: Transition from Sprouting Shrub State 4.0 to Annual State 5.0:

Trigger: Frequent wildfires (less than 20 years) carried by oak and manzanita, when soils are dry, that facilitates the annual non-native species in the understory to dominate the site.

Slow variables: Over time, cover, production and seed bank of annual non-native species increases. Sprouting shrub seed bank is diminished with shortened fire return intervals of less than 20 years.

Threshold: Loss of deep-rooted perennial bunchgrasses and shrubs changes temporal and spatial nutrient capture and cycling within the community. The increased seed bank of non-native, annual species responds positively to post-fire conditions facilitating the transition to an Annual State.

R4A: Restoration from Sprouting Shrub State 4.0 to Current Potential State 2.0:

Periodic prescribed burns, or manual or mechanical thinning of shrubs coupled with seeding and planting of native species. Herbicide treatment of non-native annual species. Probability of success is highest from community phase 4.1.

Annual State 5.0:

This state has two community phases that are characterized by the dominance of annual non-native species such as cheatgrass and tumblemustard (*Sisymbrium altissimum*) in the understory. Time since fire may facilitate the maturation of fire-adapted shrubs (5.2). Ecological dynamics are significantly altered in this state. Annual non-native species create a highly combustible fuel bed that shortens the fire return interval. Nutrient cycling is spatially and temporally truncated as annual plants contribute significantly less to deep soil carbon.

Community Phase 5.1:
Cheatgrass, mustards and other non-native annual species dominate the site. Trace amounts of perennial bunchgrasses may be present. Fire-adapted shrubs may increase. Burned tree skeletons present.

PIMO-JUOS/ARTRV-AMUT-QUERC (F029XY078NV), Annual State 5.1, T. Stringham, June 2022

Community Phase Pathway 5.1a, from Phase 5.1 to 5.2:
Time and infrequent wildfires or other disturbances creates a mosaic of fire-adapted shrub patches and early seral burned patches dominated by annual non-natives.

Community Phase 5.2:
Sprouting and non-sprouting shrubs increase with time and lack of fire. Cheatgrass, mustards and other non-native annual species dominate the understory. Trace amounts of perennial bunchgrasses may be present. Burned tree skeletons present.

PIMO-JUOS/ARTRV-AMUT-QUERC (F029XY078NV), Annual State 5.2, T. Stringham, June 2022

Community Phase Pathway 5.2a, from Phase 5.2 to 5.1:
Frequent wildfires reduce shrub overstory. The understory is dominated by annual non-natives.

R5A: Restoration from Annual State 5.0 to Current Potential State 2.0:

Seeding and planting of native species that occur on the ecological site. Herbicide treatment of non-native annual species. Probability of success is highest from community phase 5.2.

Potential Resilience Differences with Other Ecological Sites in this Group:

PIMO-JUOS/ARTRV-AMUT-QUGA (F029XY084NV):

This site occurs on 15 to 75% slopes and elevations from 5,500 to 7,500 ft (1,676–2,286 m). Precipitation ranges from 10 to 13 in. (25–33 cm). This site has an overstory tree canopy of 65 to 85% singleleaf pinyon and 15 to 35% Utah juniper. This site has a higher site index of trees and lower understory production (300–700 lb/ac under a canopy cover of 21–35%) than the modal. Utah serviceberry, Gambel oak and big sagebrush (Wyoming and mountain) are the primary understory shrubs. Muttongrass is the most prevalent understory grass. This site will have the same five states as the modal.

PIMO-JUOS/ARTRV-AMUT-QUGA (F029XY084NV), Sprouting Shrub State 4.2, T. Stringham, June 2022

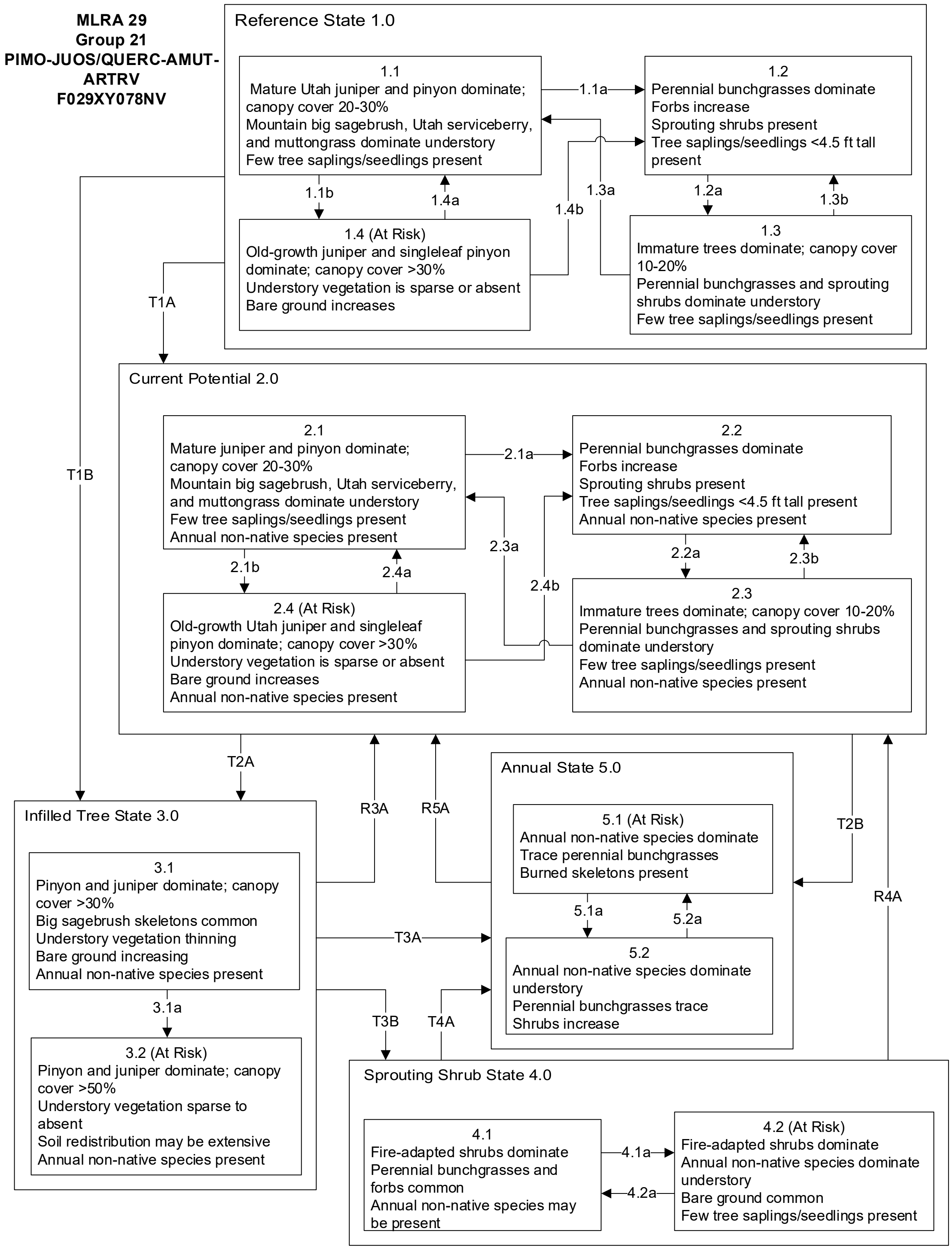
PIMO/AMUT-ARTRV-QUTU2 (F029XY100NV):

This site occurs on 15 to over 100% slopes but are typically 30 to 75%. Elevations range from 5,800 to 7,200 ft (1,768–2,195 m). Precipitation ranges from 14 to 18 in. (36–46 cm). This site has an overstory tree canopy of 95 to 100% singleleaf pinyon with less than 5% Utah juniper. This site has a lower site index of trees and a similar understory production as the modal (600–1,300 lb/ac under canopy cover 21–35%). Utah serviceberry, Sonoran scrub oak and mountain big sagebrush are the primary understory shrubs. Muttongrass is the most prevalent understory grass. This site will have the same five states as the modal.

PIMO-JUOS/ARTRV-AMUT-GAFL2 (F029XY067NV):

This site occurs on 30 to 75% slopes and elevations from 5,500 to 7,000 ft (1,676–2,134 m). Precipitation ranges from 13 to 15 in. (33–38 cm). This site has an overstory tree canopy of 60 to 80% singleleaf pinyon and 20 to 40% Utah juniper. This site has a lower site index of trees and a lower understory production as the modal (200–500 lb/ac) under canopy cover 21 to 35%. Mountain big sagebrush, Utah serviceberry, and yellowleaf silktassel are the principal understory shrubs. Wyoming big sagebrush occurs at lower elevations on this site. Muttongrass is the most prevalent understory grass. This site will have the same five states as the modal.

Modal State and Transition Model for Group 21 in MLRA 29:



MLRA 29
Group 21
PIMO-JUOS/QUERC-AMUT-ARTRV
F029XY078NV

Reference State 1.0 Community Phase Pathways
1.1a: High severity crown fire will eliminate/reduce singleleaf pinyon and Utah juniper overstory, allowing sprouting shrubs and perennial bunchgrasses to dominate.
1.1b: Time, lack of disturbance allows for infilling of singleleaf pinyon and Utah juniper.
1.2a: Time, lack of disturbance allows for maturation of trees. Mountain big sagebrush reestablishes.
1.3a: Time, lack of disturbance allows for maturation of singleleaf pinyon and Utah juniper. Infilling by younger trees, reduction of perennial grass understory.
1.3b: Fire reduces or eliminates tree canopy, allows perennial grasses to dominate the site.
1.4a: Low intensity fire, insect infestation, or disease kills individual trees, reducing the canopy cover to less than 30 percent. Mountain big sagebrush and perennial bunchgrass community increases.
1.4b: High severity crown fire will reduce or eliminate singleleaf pinyon and Utah juniper overstory, allowing sprouting shrubs and perennial bunchgrasses to dominate the site.

Transition T1A: Introduction of non-native annual species.

Transition T1B: Time, lack of disturbance allows trees to dominate the site.

Current Potential State 2.0 Community Phase Pathways
2.1a: High severity crown fire will eliminate or reduce singleleaf pinyon or Utah juniper overstory and shrub component, allowing sprouting shrubs and perennial bunchgrasses to dominate the site.
2.1b: Time, lack of disturbance allows for infilling of singleleaf pinyon and Utah juniper.
2.2a: Time, lack of disturbance allows maturation of trees. Mountain big sagebrush reestablishes.
2.3a: Time, lack of disturbance allows for maturation of singleleaf pinyon and Utah juniper. Infilling by younger trees.
2.3b: Fire reduces or eliminates tree canopy, allows perennial grasses to dominate the site.
2.4a: Low intensity fire, insect infestation, or disease reduces tree canopy cover to less than 30 percent. Mountain big sagebrush and perennial bunchgrasses increase.
2.4b: High-severity crown fire eliminates/reduces singleleaf pinyon and Utah juniper overstory, allowing sprouting shrubs and perennial bunchgrasses to dominate the site.

Transition T2A: Time, lack of disturbance allows trees to dominate the site.

Transition T2B: High-severity crown fire facilitates the establishment of non-native, annual species.

Infilled Tree State 3.0 Community Phase Pathways
3.1a: Time, lack of disturbance allows for gradual maturation of singleleaf pinyon and Utah juniper.

Transition T3A: Frequent wildfires reduce pinyon and juniper overstory, allows non-native species in the understory to dominate the site.

Transition T3B: Stand-replacing fire reduces pinyon and juniper overstory, allows sprouting shrubs in the understory to dominate the site.

Restoration R3A: Manual or mechanical thinning of trees coupled with seeding. Recovery of understory species.

Sprouting Shrub State 4.0 Community Phase Pathways
4.1a: Time, lack of disturbance allows for sprouting shrubs to recover. Pinyon/juniper seedlings/saplings present.
4.2a: Infrequent wildfire creates mosaic of burned and unburned shrub patches.

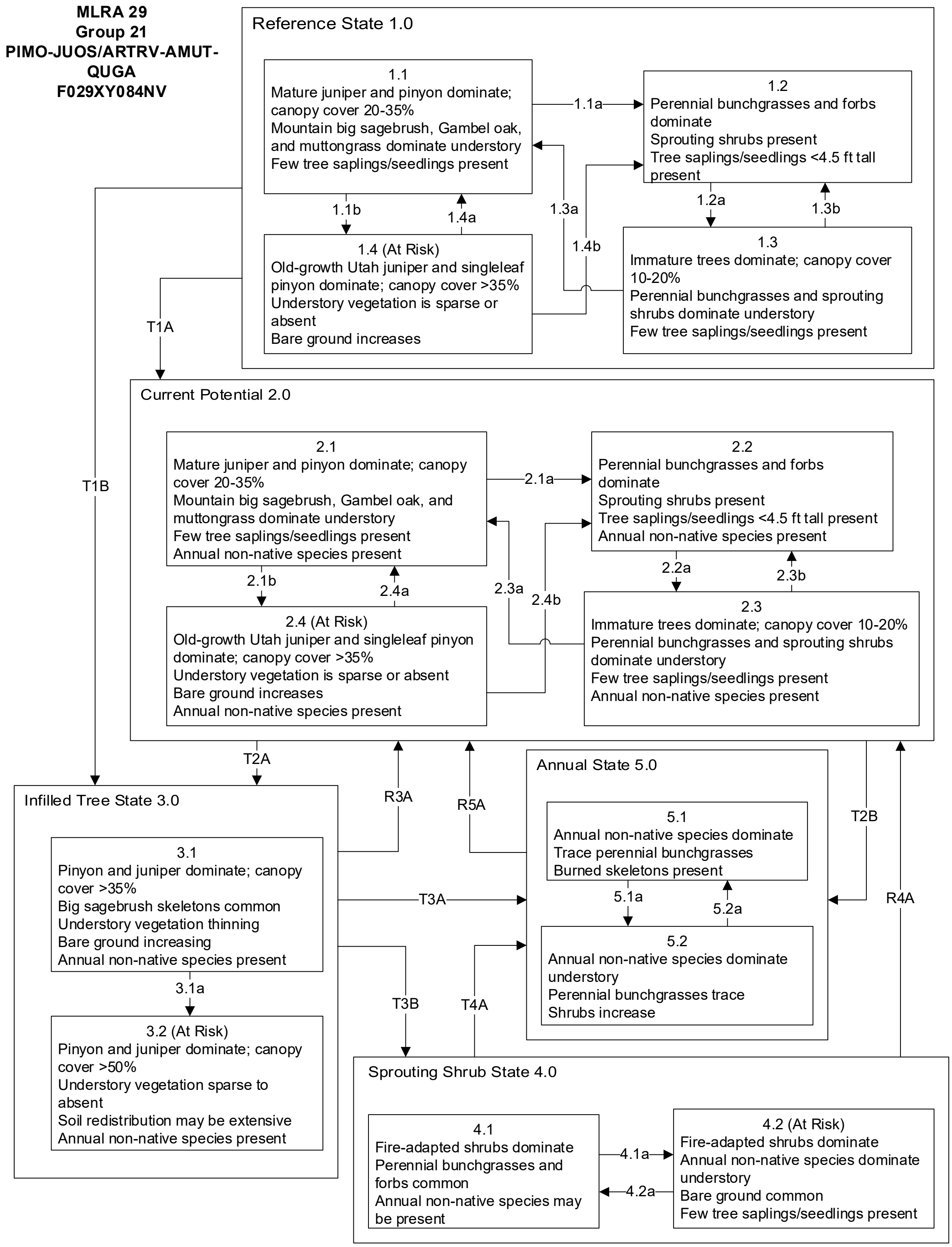
Transition T4A: Frequent wildfires reduce shrub canopy and allow annual non-native species to dominate the site.

Restoration R4A: Manual or mechanical thinning of shrubs coupled with herbicide treatment and tree seeding. Highest success likely from phase 4.1.

Annual State 5.0 Community Phase Pathways
5.1a. Time allows for sprouting shrubs to recover.
5.2a Frequent wildfires.

Restoration R5A: Herbicide treatment and seeding of native grass, shrub, and tree species. Highest success likely from phase 5.2.

Additional State and Transition Models for Group 21 in MLRA 29:



MLRA 29
Group 21
PIMO-JUOS/ARTRV-AMUT-QUGA
F029XY084NV

Reference State 1.0 Community Phase Pathways
1.1a: High severity crown fire will eliminate/reduce singleleaf pinyon and Utah juniper overstory, allowing sprouting shrubs and perennial bunchgrasses to dominate.
1.1b: Time, lack of disturbance allows for infilling of singleleaf pinyon and Utah juniper.
1.2a: Time, lack of disturbance allows for maturation of singleleaf pinyon and Utah juniper. Mountain big sagebrush reestablishes.
1.3a: Time, lack of disturbance allows for maturation of singleleaf pinyon and Utah juniper. Infilling by younger trees, reduction of perennial grass understory.
1.3b: Fire reduces or eliminates tree canopy, allows perennial grasses to dominate the site.
1.4a: Low intensity fire, insect infestation, or disease kills individual trees, reducing the canopy cover to less than 50 percent. Mountain big sagebrush and perennial bunchgrass community increases.
1.4b: High severity crown fire will reduce or eliminate singleleaf pinyon and Utah juniper overstory, allowing sprouting shrubs and perennial bunchgrasses to dominate the site.

Transition T1A: Introduction of non-native annual species.

Transition T1B: Time, lack of disturbance allows trees to dominate the site.

Current Potential State 2.0 Community Phase Pathways
2.1a: High severity crown fire will eliminate or reduce singleleaf pinyon or Utah juniper overstory and shrub component, allowing sprouting shrubs and perennial bunchgrasses to dominate the site.
2.1b: Time, lack of disturbance allows for infilling of singleleaf pinyon and Utah juniper.
2.2a: Time, lack of disturbance allows maturation of singleleaf pinyon and Utah juniper. Mountain big sagebrush reestablishes.
2.3a: Time, lack of disturbance allows for maturation of singleleaf pinyon and Utah juniper. Infilling by younger trees.
2.3b: Fire reduces or eliminates tree canopy, allows perennial grasses to dominate the site.
2.4a: Low intensity fire, insect infestation, or disease reduces tree canopy cover to less than 50 percent. Mountain big sagebrush and perennial bunchgrasses increase.
2.4b: High-severity crown fire eliminates/reduces singleleaf pinyon and Utah juniper overstory, allowing sprouting shrubs and perennial bunchgrasses to dominate the site.

Transition T2A: Time, lack of disturbance allows trees to dominate the site.

Transition T2B: High-severity crown fire facilitates the establishment of non-native, annual species.

Infilled Tree State 3.0 Community Phase Pathways
3.1a: Time, lack of disturbance allows for gradual maturation of singleleaf pinyon and Utah juniper.

Transition T3A: Frequent wildfires reduce pinyon and juniper overstory, allows non-native species in the understory to dominate the site.

Transition T3B: Stand-replacing fire reduces pinyon and juniper overstory, allows sprouting shrubs in the understory to dominate the site.

Restoration R3A: Manual or mechanical thinning of trees coupled with seeding. Recovery of understory species.

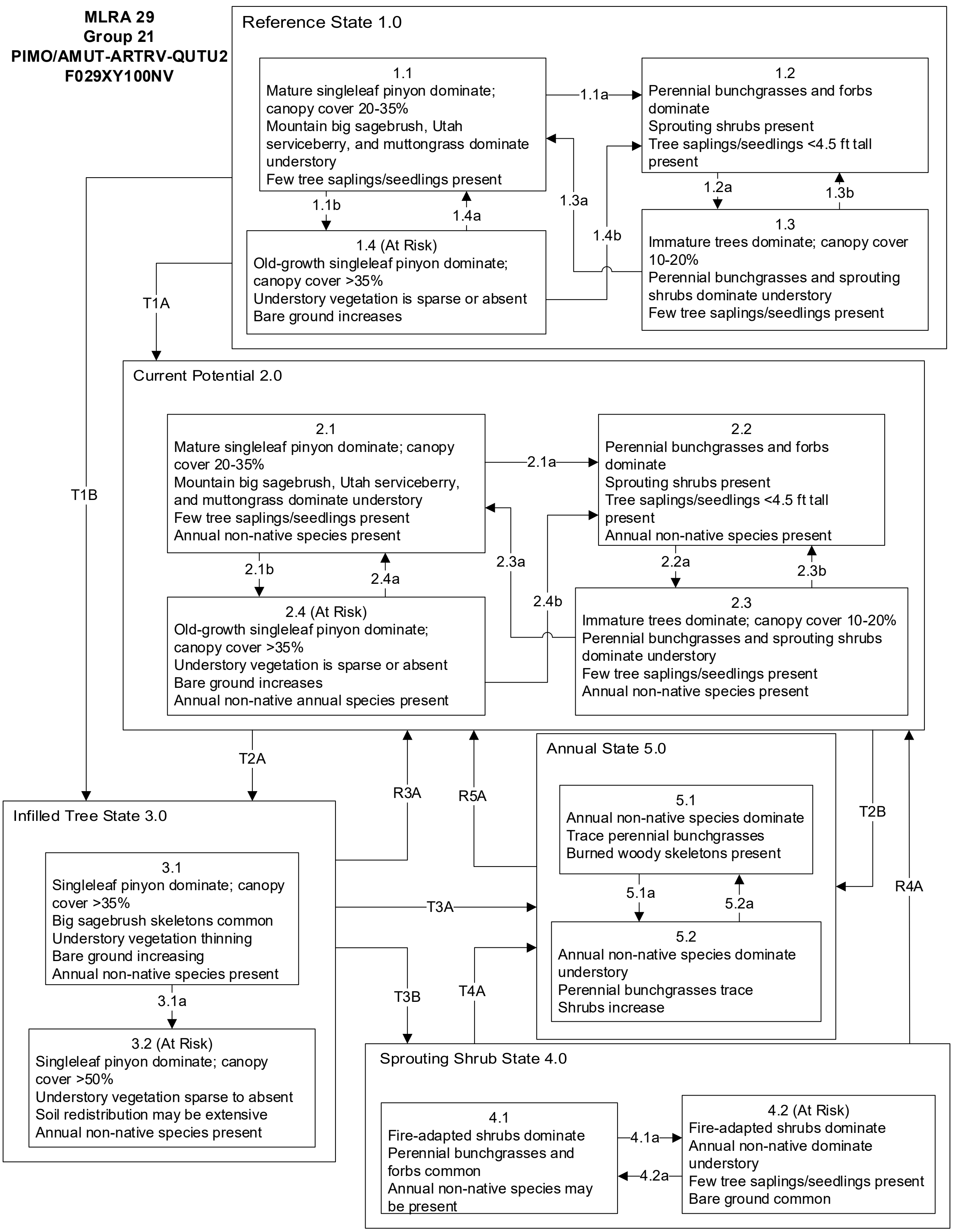
Sprouting Shrub State 4.0 Community Phase Pathways
4.1a: Time, lack of disturbance allows for sprouting shrubs to recover. Pinyon/juniper seedlings/saplings present.
4.2a: Infrequent wildfire creates mosaic of burned and unburned shrub patches.

Transition T4A: Frequent wildfires reduce shrub canopy and allow annual non-native species to dominate the site.

Restoration R4A: Manual or mechanical thinning of shrubs coupled with herbicide treatment and tree seeding. Highest success likely from phase 4.1.

Annual State 5.0 Community Phase Pathways
5.1a. Time allows for sprouting shrubs to recover.
5.2a Frequent wildfires.

Restoration R5A: Herbicide treatment and seeding of native grass, shrub, and tree species. Highest success likely from phase 5.2.


MLRA 29
Group 21
PIMO/AMUT-ARTRV-QUTU2
F029XY100NV
Reference State 1.0
1.1
Mature singleleaf pinyon dominate; canopy cover 20-35%
Mountain big sagebrush, Utah serviceberry, and muttongrass dominate understory
Few tree saplings/seedlings present
1.1a
1.2
Perennial bunchgrasses and forbs dominate
Sprouting shrubs present
Tree saplings/seedlings <4.5 ft tall present
1.1b
1.4a
1.3a
1.4b
1.2a
1.3b
1.4 (At Risk)
Old-growth singleleaf pinyon dominate; canopy cover >35%
Understory vegetation is sparse or absent
Bare ground increases
1.3
Immature trees dominate; canopy cover 10-20%
Perennial bunchgrasses and sprouting shrubs dominate understory
Few tree saplings/seedlings present
T1A
T1B
Current Potential 2.0
2.1
Mature singleleaf pinyon dominate; canopy cover 20-35%
Mountain big sagebrush, Utah serviceberry, and muttongrass dominate understory
Few tree saplings/seedlings present
Annual non-native species present
2.1a
2.2
Perennial bunchgrasses and forbs dominate
Sprouting shrubs present
Tree saplings/seedlings <4.5 ft tall present
Annual non-native species present
2.1b
2.4a
2.3a
2.4b
2.2a
2.3b
2.4 (At Risk)
Old-growth singleleaf pinyon dominate; canopy cover >35%
Understory vegetation is sparse or absent
Bare ground increases
Annual non-native annual species present
2.3
Immature trees dominate; canopy cover 10-20%
Perennial bunchgrasses and sprouting shrubs dominate understory
Few tree saplings/seedlings present
Annual non-native species present
T2A
R3A
R5A
Annual State 5.0
5.1
Annual non-native species dominate
Trace perennial bunchgrasses
Burned woody skeletons present
T2B
R4A
5.1a
5.2a
5.2
Annual non-native species dominate understory
Perennial bunchgrasses trace
Shrubs increase
Infilled Tree State 3.0
3.1
Singleleaf pinyon dominate; canopy cover >35%
Big sagebrush skeletons common
Understory vegetation thinning
Bare ground increasing
Annual non-native species present
T3A
T3B
T4A
3.1a
3.2 (At Risk)
Singleleaf pinyon dominate; canopy cover >50%
Understory vegetation sparse to absent
Soil redistribution may be extensive
Annual non-native species present
Sprouting Shrub State 4.0
4.1
Fire-adapted shrubs dominate
Perennial bunchgrasses and forbs common
Annual non-native species may be present
4.1a
4.2a
4.2 (At Risk)
Fire-adapted shrubs dominate
Annual non-native dominate understory
Few tree saplings/seedlings present
Bare ground common

MLRA 29
Group 21
PIMO/AMUT-ARTRV-QUTU2
F029XY100NV

Reference State 1.0 Community Phase Pathways
1.1a: High severity crown fire will eliminate/reduce singleleaf pinyon and Utah juniper overstory, allowing sprouting shrubs and perennial bunchgrasses to dominate.
1.1b: Time, lack of disturbance allows for infilling of singleleaf pinyon and Utah juniper.
1.2a: Time, lack of disturbance allows for maturation of trees. Mountain big sagebrush reestablishes.
1.3a: Time, lack of disturbance allows for maturation of singleleaf pinyon and Utah juniper. Infilling by younger trees, reduction of perennial grass understory.
1.3b: Fire reduces or eliminates tree canopy, allows perennial grasses to dominate the site.
1.4a: Low intensity fire, insect infestation, or disease kills individual trees, reducing the canopy cover to less than 50 percent. Mountain big sagebrush and perennial bunchgrass community increases.
1.4b: High severity crown fire will reduce or eliminate singleleaf pinyon and Utah juniper overstory, allowing sprouting shrubs and perennial bunchgrasses to dominate the site.

Transition T1A: Introduction of non-native annual species.

Transition T1B: Time, lack of disturbance allows trees to dominate the site.

Current Potential State 2.0 Community Phase Pathways
2.1a: High severity crown fire will eliminate or reduce singleleaf pinyon or Utah juniper overstory and shrub component, allowing sprouting shrubs and perennial bunchgrasses to dominate the site.
2.1b: Time, lack of disturbance allows for infilling of singleleaf pinyon and Utah juniper.
2.2a: Time, lack of disturbance allows maturation of trees. Mountain big sagebrush reestablishes.
2.3a: Time, lack of disturbance allows for maturation of singleleaf pinyon and Utah juniper. Infilling by younger trees.
2.3b: Fire reduces or eliminates tree canopy, allows perennial grasses to dominate the site.
2.4a: Low intensity fire, insect infestation, or disease reduces tree canopy cover to less than 50 percent. Mountain big sagebrush and perennial bunchgrasses increase.
2.4b: High-severity crown fire eliminates/reduces singleleaf pinyon and Utah juniper overstory, allowing sprouting shrubs and perennial bunchgrasses to dominate the site.

Transition T2A: Time, lack of disturbance allows trees to dominate the site.

Transition T2B: High-severity crown fire facilitates the establishment of non-native, annual species.

Infilled Tree State 3.0 Community Phase Pathways
3.1a: Time, lack of disturbance allows for gradual maturation of singleleaf pinyon and Utah juniper.

Transition T3A: Frequent wildfires reduce pinyon and juniper overstory, allows non-native species in the understory to dominate the site.

Transition T3B: Stand-replacing fire reduces pinyon and juniper overstory, allows sprouting shrubs in the understory to dominate the site.

Restoration R3A: Manual or mechanical thinning of trees coupled with seeding. Recovery of understory species.

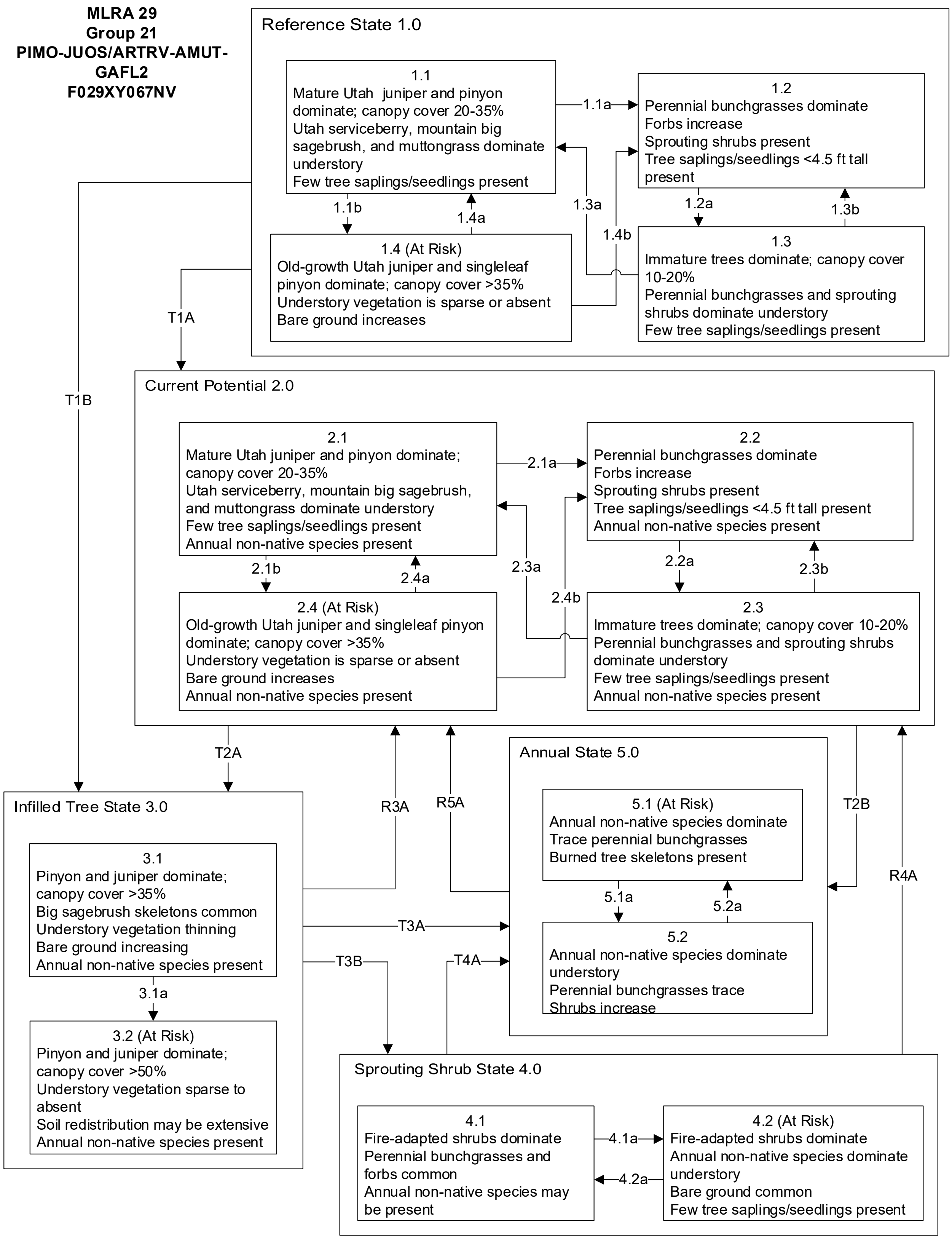
Sprouting Shrub State 4.0 Community Phase Pathways
4.1a: Time, lack of disturbance allows for sprouting shrubs to recover. Pinyon/juniper seedlings/saplings present.
4.2a: Infrequent wildfire creates mosaic of burned and unburned shrub patches.

Transition T4A: Frequent wildfires reduce shrub canopy and allow annual non-native species to dominate the site.

Restoration R4A: Manual or mechanical thinning of shrubs coupled with herbicide treatment and tree seeding. Highest success likely from phase 4.1.

Annual State 5.0 Community Phase Pathways
5.1a. Time allows for sprouting shrubs to recover.
5.2a Frequent wildfires.

Restoration R5A: Herbicide treatment and seeding of native grass, shrub, and tree species. Highest success likely from phase 5.2.


MLRA 29
Group 21
PIMO-JUOS/ARTRV-AMUT-GAFL2
F029XY067NV
Reference State 1.0
1.1
Mature Utah juniper and pinyon dominate; canopy cover 20-35%
Utah serviceberry, mountain big sagebrush, and muttongrass dominate understory
Few tree saplings/seedlings present
1.1a
1.2
Perennial bunchgrasses dominate
Forbs increase
Sprouting shrubs present
Tree saplings/seedlings <4.5 ft tall present
1.1b
1.4a
1.3a
1.2a
1.3b
1.4b
1.4 (At Risk)
Old-growth Utah juniper and singleleaf pinyon dominate; canopy cover >35%
Understory vegetation is sparse or absent
Bare ground increases
1.3
Immature trees dominate; canopy cover 10-20%
Perennial bunchgrasses and sprouting shrubs dominate understory
Few tree saplings/seedlings present
T1A
T1B
Current Potential 2.0
2.1
Mature Utah juniper and pinyon dominate; canopy cover 20-35%
Utah serviceberry, mountain big sagebrush, and muttongrass dominate understory
Few tree saplings/seedlings present
Annual non-native species present
2.1a
2.2
Perennial bunchgrasses dominate
Forbs increase
Sprouting shrubs present
Tree saplings/seedlings <4.5 ft tall present
Annual non-native species present
2.1b
2.4a
2.3a
2.2a
2.3b
2.4b
2.4 (At Risk)
Old-growth Utah juniper and singleleaf pinyon dominate; canopy cover >35%
Understory vegetation is sparse or absent
Bare ground increases
Annual non-native species present
2.3
Immature trees dominate; canopy cover 10-20%
Perennial bunchgrasses and sprouting shrubs dominate understory
Few tree saplings/seedlings present
Annual non-native species present
T2A
R3A
R5A
T2B
R4A
Annual State 5.0
5.1 (At Risk)
Annual non-native species dominate
Trace perennial bunchgrasses
Burned tree skeletons present
5.1a
5.2a
5.2
Annual non-native species dominate understory
Perennial bunchgrasses trace
Shrubs increase
Infilled Tree State 3.0
3.1
Pinyon and juniper dominate; canopy cover >35%
Big sagebrush skeletons common
Understory vegetation thinning
Bare ground increasing
Annual non-native species present
3.1a
3.2 (At Risk)
Pinyon and juniper dominate; canopy cover >50%
Understory vegetation sparse to absent
Soil redistribution may be extensive
Annual non-native species present
T3A
T3B
T4A
Sprouting Shrub State 4.0
4.1
Fire-adapted shrubs dominate
Perennial bunchgrasses and forbs common
Annual non-native species may be present
4.1a
4.2a
4.2 (At Risk)
Fire-adapted shrubs dominate
Annual non-native species dominate understory
Bare ground common
Few tree saplings/seedlings present

MLRA 29
Group 21
PIMO-JUOS/ARTRV-AMUT-GAFL2
F029XY067NV

Reference State 1.0 Community Phase Pathways
1.1a: High severity crown fire will eliminate/reduce singleleaf pinyon and Utah juniper overstory, allowing sprouting shrubs and perennial bunchgrasses to dominate.
1.1b: Time, lack of disturbance allows for infilling of singleleaf pinyon and Utah juniper.
1.2a: Time, lack of disturbance allows for maturation of trees. Mountain big sagebrush reestablishes.
1.3a: Time, lack of disturbance allows for maturation of singleleaf pinyon and Utah juniper. Infilling by younger trees, reduction of perennial grass understory.
1.3b: Fire reduces or eliminates tree canopy, allows perennial grasses to dominate the site.
1.4a: Low intensity fire, insect infestation, or disease kills individual trees, reducing the canopy cover to less than 35 percent. Mountain big sagebrush and perennial bunchgrass community increases.
1.4b: High severity crown fire will reduce or eliminate singleleaf pinyon and Utah juniper overstory, allowing sprouting shrubs and perennial bunchgrasses to dominate the site.

Transition T1A: Introduction of non-native annual species.

Transition T1B: Time, lack of disturbance allows trees to dominate the site.

Current Potential State 2.0 Community Phase Pathways
2.1a: High severity crown fire will eliminate or reduce singleleaf pinyon or Utah juniper overstory and shrub component, allowing sprouting shrubs and perennial bunchgrasses to dominate the site.
2.1b: Time, lack of disturbance allows for infilling of singleleaf pinyon and Utah juniper.
2.2a: Time, lack of disturbance allows maturation of trees. Mountain big sagebrush reestablishes.
2.3a: Time, lack of disturbance allows for maturation of singleleaf pinyon and Utah juniper. Infilling by younger trees.
2.3b: Fire reduces or eliminates tree canopy, allows perennial grasses to dominate the site.
2.4a: Low intensity fire, insect infestation, or disease reduces tree canopy cover to less than 35 percent. Mountain big sagebrush and perennial bunchgrasses increase.
2.4b: High-severity crown fire eliminates/reduces singleleaf pinyon and Utah juniper overstory, allowing sprouting shrubs and perennial bunchgrasses to dominate the site.

Transition T2A: Time, lack of disturbance allows trees to dominate the site.

Transition T2B: High-severity crown fire facilitates the establishment of non-native, annual species.

Infilled Tree State 3.0 Community Phase Pathways
3.1a: Time, lack of disturbance allows for gradual maturation of singleleaf pinyon and Utah juniper.

Transition T3A: Frequent wildfires reduce pinyon and juniper overstory, allows non-native species in the understory to dominate the site.

Transition T3B: Stand-replacing fire reduces pinyon and juniper overstory, allows sprouting shrubs in the understory to dominate the site.

Restoration R3A: Manual or mechanical thinning of trees coupled with seeding. Recovery of understory species.

Sprouting Shrub State 4.0 Community Phase Pathways
4.1a: Time, lack of disturbance allows for sprouting shrubs to recover. Pinyon/juniper seedlings/saplings present.
4.2a: Infrequent wildfire creates mosaic of burned and unburned shrub patches.

Transition T4A: Frequent wildfires reduce shrub canopy and allow annual non-native species to dominate the site.

Restoration R4A: Manual or mechanical thinning of shrubs coupled with herbicide treatment and tree seeding. Highest success likely from phase 4.1.

Annual State 5.0 Community Phase Pathways
5.1a. Time allows for sprouting shrubs to recover.
5.2a Frequent wildfires.

Restoration R5A: Herbicide treatment and seeding of native grass, shrub, and tree species. Highest success likely from phase 5.2.

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MLRA 29 Group 22: Silty soils with Bonneville saltbush and Indian ricegrass

Description of MLRA 29 Disturbance Response Group 22

Disturbance Response Group (DRG) 22 consists of three ecological sites. The sites occur on basin floors, lake plains and inset fans that are often subject to periodic flooding. The precipitation ranges from 5 to 8 in. (13–20 cm). Slopes range from 0 to 4%. Elevations range from 4,500 to about 5,650 ft (1,372–1,722 m). Production ranges from 250 to 1,000 lb/ac for a normal year. The soils on these sites are typically very deep and well drained. They formed in alluvium and lacustrine deposits from mixed limestone and welded tuff. Surface textures are silt loams to loams. The soils are moderately to strongly alkaline. Water holding capacity is moderate and runoff is negligible or very low. The reference plant communities are dominated by Bonneville saltbush (*Atriplex bonnevillensis*) or fourwing saltbush (*Atriplex canescens*), winterfat (*Krascheninnikovia lanata*), Indian ricegrass (*Achnatherum hymenoides*) and basin wildrye (*Leymus cinereus*). Other important species include shadscale (*Atriplex confertifolia*), green molly, (*Bassia americana*), and bottlebrush squirreltail (*Elymus elymoides*).

Disturbance Response Group 22 Ecological Sites:

Silty Plain – Modal	R029XY117NV
Deep Silty 5-8" P.Z.	R029XY159NV
Outwash Plain	R029XY048NV

Modal Site:

The Silty Plain ecological site is the modal site that represents this DRG, as it has the most acres mapped. This site occurs on basin floors with slopes from 0 to 2%. Elevations are 4,600 to approximately 4,700 ft (1,402–1,433 m). Surface soils are typically fine-textured. The soils of this site are very deep and well drained. The soils are moderately to very strongly alkaline and calcareous throughout the profile. The soil temperature regime is mesic and the soil moisture regime is typic aridic. Potential for sheet and rill erosion is slight. The reference plant community is dominated by Bonneville saltbush, winterfat and Indian ricegrass. Other important species include shadscale, green molly, and bottlebrush squirreltail.

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasives. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans a unique area in Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area. Flashy summer storm events contribute significantly to annual precipitation. Air and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species within MLRA 29 (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations, combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

Periodic drought regularly influences salt-desert shrub ecosystems, with drought duration and severity increasing throughout the 20th century in much of the Intermountain West (Miller et al. 2008a). Major shifts away from historical precipitation patterns have the potential to alter ecosystem function, vegetative composition and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006).

Large scale shrub die-off in the Great Basin since 1983 has been linked to above-average precipitation years (Ewing and Dobrowolski 1992). Elevated water tables and prolonged soil waterlogging in the lower portions of basins may have led to periods of excessive oxygen deprivation to which the shrub roots could not adjust either physiologically or by formation of more tolerant roots (Dobrowolski et al. 1990). Anoxia and/or salinity also may predispose the shrubs to pathogen attacks.

The ecological sites in this DRG are dominated by deep-rooted, cool-season perennial bunchgrasses and drought tolerant shrubs with high root to shoot ratios. Native bunchgrasses generally have somewhat shallower root systems than the shrubs, but root densities are often as high, or higher, than those of the shrubs in the upper 0.5 m (20 in.) of the soil profile (Dobrowolski et al. 1990). General differences in root depth distributions between grasses and shrubs results in resource partitioning in these shrub – grass systems. Although not dominant, warm-season grasses are present within all of these sites.

Saltbush (*Atriplex*) species are considered medium to short-lived shrubs and possess a number of morphological and physiological traits that enable them to cope with drought. Some of these traits include: a) photosynthesis through the C_4 carboxylation pathway; b) production of leaf trichomes (hair) and accumulation of salt crystals on the leaf surface to increase reflectance; c) accumulation and synthesis of inorganic and organic solutes to maintain turgor; and 4) root association with endomycorrhizae that allows absorption of soil moisture at very low water potentials (Newton and Goodin 1989, Dobrowolski et al. 1990, Cibils et al. 1998) .

Bonneville saltbush is a long-lived, drought tolerant shrub, up to 30 in. (0.76 cm) tall. Bonneville saltbush is a subsidiary species of fourwing saltbush but has different habitat requirements from fourwing saltbush (McArthur and Monsen 2004). Hanson (1962) determined that Bonneville saltbush is a cross between fourwing saltbush and sickle saltbush (*Atriplex gardneri var. falcata, A. falcata*). Bonneville saltbush tolerates greater salinity and has shorter leaves than either of the parents (Holmgren et al. 2012).

Fourwing saltbush is the most widely distributed and abundant saltbush in the southwest United States (Mozingo 1987c). It is a native, long-lived woody shrub that grows on a variety of soils, landforms, and climatic conditions from sand dunes, sand sheets, alluvial fans and plains, hills and mountains, and washes. It tolerates salinity but is not restricted to saline soils (Henrickson 1977). It is a polymorphic species and is evergreen or deciduous depending on climate (Ogle et al. 2012a). Fourwing saltbush has a long taproot of depths of 5–15 m (16 to 49 ft). and many small lateral roots (Van Dersal 1938, Barrow 1997). It has been found that the roots compose 40% of the total mass of adult plants (Wallace et al. 1974). *Atriplex* species are considered medium to short-lived shrubs and possess a number of morphological and physiological traits that enable them to cope with drought. Some of these traits include: a) photosynthesis through the C_4 carboxylation pathway; b) production of leaf trichomes and accumulation of salt crystals on the leaf surface to increase reflectance; c) accumulation and synthesis of inorganic and organic solutes to maintain turgor; and 4) root association with endomycorrhizae that allows absorption of soil moisture at very low water potentials (Newton and Goodin 1989, Dobrowolski et al. 1990, Cibils et al. 1998). Fourwing saltbush is not particularly resilient to fire but may resprout in some instances when fire intensity is not too severe (Ogle et al. 2020).

Winterfat, a common shrub of this group, is a native, long-lived and drought tolerant species (Mozingo 1987c). It has a woody base from which annual branchlets grow (Welsh et al. 1987). The most common variety is a low growing dwarf form (less than 38.1 cm), which is most often found on desert valley floors (Stevens et al. 1977). Winter precipitation and plentiful spring moisture is a primary growth driver for winterfat. Winterfat has a long growth period from April to September, and heavy August-September rain can cause a second late-season flowering (West and Gasto 1978). Winterfat reproduces from seed and primarily pollinates via wind (Stevens et al. 1977). Seed production, especially in desert regions, is dependent on precipitation (West and Gasto 1978) with good seed years occurring when there is appreciable summer precipitation and little browsing (Stevens et al. 1977). In years of low winter precipitation, winterfat greatly reduces seed production (West and Gasto 1978). Winterfat has multiple dispersal mechanisms: diaspores are shed in the fall or winter, dispersed by wind, rodent-cached, or carried on animals (Majerus 2003). Diaspores take advantage of available moisture, tolerating freezing conditions as they progress from imbibed seeds to germinants to nonwoody seedlings (Booth 1989). Under some circumstances, the degree of reproduction may be dependent on mature plant density (Freeman and Emlen 1995).

Green molly is a halophytic C3 subshrub that is most often found in soils with high alkalinity and salinity at around 1.4% (Kadereit and Freitag 2011, Bradbury and Parrot 2020). It is a half-shrub that typically reaches heights of 5–20 cm (2–8 in.), with unbranched vertical stems that lignify and die each fall, being removed by new spring growth (Clark and Wagner 1984). It is adapted to arid environments and is commonly found growing in the same areas as shadscale and greasewood (Clark and Wagner 1984). They tend to dominate regions with minimal vegetative competition due to their relative tolerance to high pH soils (Clark and Wagner 1984, Bradbury and Parrot 2020). A study of plant communities around the Great Salt Lake in Utah found that green molly grows primarily in clay loam soils (Bradbury and Parrot 2020). Green molly has deep, fibrous roots and can alter its root zone to create a higher ratio of sand to improve water infiltration and nutrient availability. It is also effective in erosion control and can be an ecologically significant species for stabilizing disturbed landscapes (Bradbury and Parrot 2020).

Indian ricegrass is a long-lived, cool-season perennial bunchgrass that grows from 10–60 cm (4–24 in.) in height (Blaisdell and Holmgren 1984). Primarily adapted to coarse-textured soils, its deep, fibrous root system makes Indian ricegrass one of the most drought-tolerant native species (Booth et al. 1980). Unlike other cool-season species, Indian ricegrass does not require vernalization (exposure to cold) in order to produce flowers and flowering can continue into late fall with favorable environmental conditions. This allows the seeds in each panicle to ripen over a longer period of time than most other species thus providing a greater opportunity for successful seed production (Jones 1990).

Basin wildrye is the largest of the native grasses commonly found on western ranges. It is a coarse, robust plant with stems up to 12 ft (3.7 m) high, growing in large bunches, often several feet in diameter. This grass usually grows in moist or wet saline situations in bottomlands and basins, where spring water tables are within its rooting zone. The species is weakly rhizomatous and has been found to root to depths of 1 m (39 in.) or more and to exhibit greater lateral root spread than many other grass species (Abbott et al. 1991).

Seasonally high water tables have also been found necessary for maintenance of productivity and reestablishment of basin wildrye following disturbances such as fire, drought or excessive herbivory (Eckert Jr et al. 1973). The sensitivity of basin wildrye seedling establishment to reduced soil water availability is increased as soil pH increases (Stuart et al. 1971). Lowering of the water table through extended drought or water pumping will decrease basin wildrye production and establishment while black greasewood, basin big sagebrush, rubber rabbitbrush, and invasive weeds will increase. Drought will initially cause a decline in bunchgrasses. Prolonged drought may cause a decline in black greasewood, while annual weedy species and bare ground will increase.

These communities often exhibit the formation of microbiotic crusts within the interspaces between shrubs. The effects of biological soil crusts are variable and dependent on ecosystem type and the composition of the crust's functional group. Faist et al. (2017) concludes that intact, light colored microbiotic crusts exhibited higher runoff and more sediment loss than the trampled or scraped crusts. Furthermore, the authors report the trampled dark colored microbiotic crusts shed slightly more water, after 30 minutes of intense rainfall (9 in. per hour) than the intact comparison. Other authors report a reduction in microbiotic crust integrity with inappropriate grazing management, wildland fire and cheatgrass (*Bromus tectorum*) invasion (Belnap 2006, Ponzetti et al. 2007).

Annual Invasive Species:

The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species resulting in reduced competition while simultaneously increasing resource pools through the decomposition of dead plant material. Historically, winterfat communities were free of exotic invaders; however, excessive grazing pressure during settlement and into the 20th century has increased the overall presence of cheatgrass, red brome (*Bromus rubens*), halogeton (*Halogeton glomeratus*), Russian thistle (*Salsola tragus*) and weedy mustard species (Brassicaceae family) (Pellant and Reichert 1984, Peters and Bunting 1994). The presence of non-native annual plants within these ecosystems decreases ecosystem resilience and resistance to disturbance through competition for limited resources. Cheatgrass and halogeton are the species most likely to invade the ecological sites contained within this DRG. Cheatgrass is a cool-season annual grass that maintains an advantage over native plants, in part, because it is a prolific seed producer, can germinate in the autumn or spring, tolerates grazing, and increases with frequent fire (Klemmedson and Smith 1964, Miller 1999). Cheatgrass originated from Eurasia and was first reported in North America in the late 1800s (Furbush 1953, Mack and Pyke 1983). Bradley et al. (2018) found that cheatgrass has expanded to greater than 15% cover over 210,000 km^2 – roughly 31% of the Intermountain West. In the Great Basin, cheatgrass is expanding at a rate of expansion of 3,700 km^2 annually and is a land management issue that will require creative solutions (Smith et al. 2022).

Methods to control cheatgrass include herbicide application, prescribed fire, targeted grazing, and rangeland seeding. The majority of research on cheatgrass control has focused on Wyoming big sagebrush (*Artemisia tridentata ssp. wyomingensis*) dominated rangelands. Control options include spraying with herbicide (imazapic or imazapic + glyphosate, indaziflam) and seeding with desired perennial species (Sheley et al. 2012). Indaziflam, a relatively new herbicide for rangeland applications, is showing promise in its ability to control cheatgrass, red brome, medusahead (*Taeniatherum caput-medusae*), North Africa grass (*Ventenata dubia*), and halogeton. Approved for rangelands in 2016, this pre-emergent herbicide works by inhibiting cell wall biosynthesis and therefore seed germination and root elongation (Kaapro and Hall 2012, Clark et al. 2019). Indaziflam effectively reduces the seed bank of invasive annuals with little to no effect on aboveground plant communities (Courkamp et al. 2022). It also has been proven to control invasive annuals longer than other herbicides, providing three or more years of control (Sebastian et al. 2017b). Sebastian et al. (2017b) found that indaziflam selectively controlled cheatgrass without impacting perennial grass and forb biomass as well. This led to significant increases in biomass of desirable species due to reductions in cheatgrass presence and competition (Sebastian et al. 2017b). Clark et al. (2019) found a similar result on plots in Colorado suggesting that indaziflam may be the best new herbicide on the market for invasive annual control.

Targeted grazing during the fall and winter can also control cheatgrass on invaded sites. Fall and winter grazing decreases standing dead biomass and reduces fuel continuity with minimal risk to native perennial herbaceous plants (Davies et al. 2016). This alters fire risk and severity by reducing fuel loads, flame height, rate of spread and area burned in Great Basin sagebrush systems (Davies et al. 2015a). Repetitive fall grazing can also reduce cheatgrass seed banks, however, the seed bank can rapidly recover if fall grazing efforts cease (Perryman et al. 2020).

Halogeton is a non-competitive plant that tends to invade areas that are susceptible to repeated disturbance such as; livestock trails, roadsides, trampled areas near watering holes or corrals and rangeland areas stripped of the natural vegetation by excessive grazing or other soil disturbing activities (Young 2002). It was first introduced into the western U.S. during the 20th century with the first collection being made near Wells, Nevada in 1934. Halogeton is highly toxic to sheep and has been responsible for thousands of sheep deaths throughout the western U.S., which triggered a massive effort to eradicate the introduced species in the late 1900s (Young 2002).

Halogeton has two distinct seed forms; a black form which consists of the achene only and a brown form which consists of the achene and attached sepals (Tisdale and Zappetini 1953, Robocker et al. 1969). The black form of halogeton seed germinate readily under a wide range of pH and salt concentrations within the first year. The brown form of seed was found to be 100% viable at the end of 2 years and 15% viable at the end of 10 years, proving that halogeton seed may remain viable in the soil for up to 10 years (Robocker et al. 1969). Eradication of this species is problematic, therefore, appropriate range management practices focused on soil and rangeland integrity are necessary to control the species.

Russian thistle is a tap-rooted, C4 photosynthesis (warm-season) annual forb, introduced from southeastern Europe and central Asia. The seeds have a remarkable capability to germinate in a variety of soil temperatures and in areas with very little precipitation, and even move back into dormancy after initial germination (Wallace et al. 1968). The seeds however, are not persistent and generally remain viable in the seedbank for less than 2 years (Boerboom 1993, Young et al. 1995). Russian thistle has been observed to provide initial establishment in completely de-vegetated sites and create microsite habitat which may allow increased establishment of other species (Allen and Allen 1988). The successful establishment of other species, particularly later seral species which forms mycorrhizal associations may reduce cover of Russian thistle as mycorrhizal inoculation has been observed to reduce the size and vigor of Russian thistle, while encouraging later seral species such as perennial bunchgrasses (Johnson 1998a).

Fire Ecology:

Historically, salt-desert shrub communities had sparse understories and bare soil in intershrub spaces, making these communities somewhat resistant to fire (Young 1983, Paysen et al. 2000). They may burn only during high fire hazard conditions; for example, years with high precipitation can result in almost continuous fine fuels, increasing fire hazard (West 1994, Paysen et al. 2000).

Fourwing saltbush's ability to sprout following fire may depend on the population and fire severity. A study by Parmenter (2008) showed a 58% mortality rate of fourwing saltbush following fire in New Mexico, the surviving shrubs produced sprouts shortly after fire. While fourwing saltbush is able to resprout after fire, it primarily reestablishes from seed (Stutz 1979, Wasser 1982)

Little fire effects information is available on Bonneville saltbush, however the parent genera, fourwing saltbush and sickle saltbush both resprout following fire, therefore Bonneville saltbush has some fire adaptions.

Winterfat is able to tolerate environmental stress, extremes of temperature and precipitation, and competition from other perennials, however it does not tolerate fire or overgrazing well (Ogle et al. 2001). Fire was historically rare within these communities due to low fuel loads. There are conflicting reports in the literature about the response of winterfat to fire. In one of the first published descriptions, Dwyer and Pieper (1967) reported that winterfat sprouts vigorously after fire. This observation was frequently cited in subsequent literature, but recent observations have suggested that winterfat can be completely killed by fire (Pellant and Reichert 1984). The response is apparently dependent on fire severity. Winterfat is able to sprout from buds near the base of the plant. However, if these buds are destroyed, winterfat will not sprout. Research has shown that winterfat seedling growth is depressed in growth by at least 90% when growing in the presence of cheatgrass (Hild et al. 2007). Repeated, frequent fires will increase the likelihood of conversion to a non-native, annual plant community with trace amounts of winterfat or other desirable species.

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species' response. Thus, fire mortality is correlated to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant, and abundance of old growth (Wright 1971, Young 1983). Boyd et al. (2015) found soil color and depth of burn to be accurate predictors of bunchgrass mortality in post-fire landscapes. They also found that bunchgrasses in close proximity of shrubs had up to five-fold higher mortality than bunchgrasses located in the interspaces (Boyd et al. 2015).

Indian ricegrass is fairly fire tolerant (Wright 1985), which is likely due to its low culm density and below-ground plant crowns. Vallentine (1989) cites several studies in the sagebrush zone that classified Indian ricegrass as being slightly damaged from late summer burning. Indian ricegrass has also been found to reestablish on burned sites through seeds dispersed from adjacent unburned areas (Young 1983, West 1994). Thus, the presence of surviving, seed-producing plants facilitates the reestablishment of Indian ricegrass. Grazing management following fire to promote seed production and establishment of seedlings is important. When properly managed, Indian ricegrass can be a key factor in a community recovering from disturbance because it can grow in rough, rocky, coarse, and otherwise unproductive soils (Booth et al. 1980). Green molly and squirreltail will resprout following fire (West 1994).

Basin wildrye is relatively resistant to fire, particularly dormant season fire, as plants sprout from surviving root crowns and rhizomes (Zschaechner 1985). Miller et al. (2013) reports fall and spring burning increased total shoot and reproductive shoot densities in the first year, although live basal areas were similar between burn and unburned plants. By year two, there was little difference between burned and control treatments.

Livestock/Wildlife Grazing Interpretations:

Fourwing saltbush is one of the most important forage shrubs in arid sites. Its importance is due to its abundance, accessibility, size, large volume of forage, evergreen habit, high palatability, and nutritive value (USFS 1937, Crofts and Epps 1975). The palatability rates from fairly good to good for cattle, and as good for sheep and goats. Deer (Odocoileus spp.) usually consume it as a winter browse (USFS 1937). It has similar protein, fat, and carbohydrate levels as alfalfa (*Medicago sativa*) (Catlin 1925). Fourwing saltbush is especially valuable as winter forage. It was noted in a study by Otsyina et al. (1982) that sheep readily grazed fourwing saltbush when introduced into a new pasture. Saltbush species are vital sources of non-protein nitrogen and essential nutrients; however, most are sensitive to browsing, with the exception of shadscale saltbush, which may be preferentially grazed under favorable conditions (Cibils et al. 1998). Defoliation typically impairs root growth, crown cover, and seed production in saltbush, thereby disrupting the photosynthetic processes that regulate biomass accumulation and carbohydrate synthesis (Mohebby et al. 2012).

Winterfat is a valuable forage species for livestock and wildlife, with an average of 14% crude protein during winter and 21% during the spring and early summer months (Clements et al. 2010). However, excessive grazing throughout the West has negatively impacted survival of winterfat stands (Hilton 1941, Statler 1967, Stevens et al. 1977). Domestic sheep and cattle diets on Great Basin rangelands greatly overlap, with a similarity of 78% (Johnson 1979). Time of grazing is critical for winterfat with the active growing period being most critical (Romo et al. 1995). Winterfat is a highly nutritious winter feed and shows significant declines in density with late winter or early spring grazing (Harper et al. 1990). Stevens et al. (1977) found that both vigor and reproduction of winterfat were reduced in Steptoe Valley, Nevada by improper season of use, and he recommended no more than 25% utilization during periods of active growth and up to 75% utilization during dormant season use. Rasmussen and Brotherson (1986) found significantly greater foliar cover and density of winterfat in areas ungrazed for 26 years versus winter grazed areas in Utah. In exclosures protected from grazing for between 5 and 16 years, Rice and Westoby (1978) found that winterfat increased in foliar cover but not in density where it was dominant, and in both foliar cover and density in shadscale-perennial grass communities where it was not dominant.

In addition to grazing by sheep and cattle, winterfat is browsed by rabbits (*Leporidae*), antelope (*Antilocapra americana*), and other wildlife species (Stevens et al. 1977, Ogle et al. 2001). Winterfat and perennial grasses average 80% of jackrabbits' diet in southeastern Idaho, with shrubs being grazed in fall and winter particularly (Johnson and Anderson 1984). Pronghorn and rabbits browse stems, leaves, and seed stalks of winterfat year round, especially during periods of active growth (Stevens et al. 1977). Management of wildlife browse is difficult and browse may be harmful to winterfat reestablishment as seed production and regrowth are curtailed if grazing occurs as the plant begins to grow (Eckert 1954).

Indian ricegrass is a preferred forage species for livestock and wildlife and cures well, providing nutritious winter feed (Cook 1962, Booth et al. 1980). It is also readily utilized in early spring, being a source of green feed before most other perennial grasses have produced new growth (Quinones 1981). Booth et al. (1980) note that the plant does well when utilized in winter and spring. In eastern Idaho, productivity of Indian ricegrass was at least 10 times greater in undisturbed plots than in heavily (60% utilization) grazed ones (Pearson 1965). Cook and Child (1971) found significant reduction in crown cover, plant vigor and herbage yield of Indian ricegrass when the species was utilized at 90% during any season. However, they found no reductions at 30% utilization during any season and no reductions at 60% utilization during winter and early spring grazing (Cook and Child 1971). The seed crop may be reduced where grazing is heavy (Bich et al. 1995). Tolerance to grazing increases after May, thus spring deferment may be necessary for stand enhancement (Pearson 1964, Cook and Child 1971); however, utilization of less than 60% is recommended. In summary, adaptive management is required to manage this bunchgrass well.

Spring defoliation of basin wildrye and/or consistent, heavy grazing during the growing season has been found to significantly reduce basin wildrye production and density (Krall et al. 1971). Basin wildrye is valuable forage for livestock (Ganskopp et al. 2007) and wildlife, but is intolerant of heavy, repeated, spring grazing (Krall et al. 1971). Basin wildrye is used often as a winter feed for livestock and wildlife; not only providing roughage above the snow but also cover in the early spring months (Majerus 1992).

State and Transition Model Narrative for Group 22:

Reference State 1.0:

The Reference State 1.0 is a representative of the natural range of variability under pristine conditions. This state has three community phases, a shrub-grass phase, a shrub phase and sparsely vegetated phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. This site is very stable, with little variation in plant community composition. Plant community changes would be reflected in production in response to drought, soil waterlogging from above-average precipitation events, and/or insect attacks. Wet years will increase grass production, while drought years will reduce production. Shrub production will also increase during wet years; however, recruitment of winterfat is episodic.

Community Phase 1.1:
The reference plant community is dominated by Bonneville saltbush, winterfat and Indian ricegrass. Shadscale, green molly and squirreltail are also important species on this site. Potential vegetative composition by air-dry weight is approximately 20% grasses, 5% forbs and 75% shrubs. Approximate ground cover (basal and crown) is 15 to 20%. Total annual air-dry production ranges from 100 to 350 lb/ac.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
Prolonged drought, soil waterlogging from above-average precipitation events, and/or insect attack reduces deep-rooted perennial grasses and shrubs while bare ground increases. Fires would also decrease vegetation on these sites but would be infrequent and patchy due to low fuel loads.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.3:
Soil waterlogging from above-average precipitation events, and/or insect attack reduces deep-rooted perennial grasses and shrubs while bare ground increases.

Community Phase 1.2:
Bonneville saltbush and winterfat dominate the site. Indian ricegrass is reduced and bare ground has increased. Drought will favor shrubs over perennial bunchgrasses. However, long-term drought will result in an overall decline in the plant community, regardless of functional group.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
Time, lack of disturbance and recovery from drought and/or insect attack would allow the vegetation to increase and bare ground would eventually decrease.

Community Phase 1.3 (At Risk):
Remnant shrubs and grasses are present on the fringes of the waterlogged basin. Bare ground is widespread. Wind erosion may be common.

Community Phase Pathway 1.3a, from Phase 1.3 to 1.1:
Time, lack of disturbance and recovery from soil waterlogging and/or insect attack would allow the vegetation to reestablish. Bare ground would eventually decrease.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0:

Trigger: Introduction of non-native annual plants such as cheatgrass, Russian thistle, mustards, and/or halogeton.

Slow variables: Over time the annual non-native plants will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

This state has three community phases, a shrub-grass phase, a shrub phase and a sparsely vegetated phase. In this state, ecological function has not changed, however the resiliency of the state has been reduced by the presence of invasive non-native annual species and the introduction of domestic grazers and feral horses and burros. Non-natives annuals may increase in abundance but will not become dominant within this State. These non-natives can be highly flammable and can promote fire where historically fire had been infrequent. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These feedbacks include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal.

Community Phase 2.1:
This community phase is dominated by Bonneville saltbush, winterfat and Indian ricegrass. Green molly, shadscale and bottlebrush squirreltail are also important species on this site. Non-native annual species are present.

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
Drought will favor shrubs over perennial bunchgrasses. However, long-term drought or long-term flooding will result in an overall decline in the plant community, regardless of functional group. Inappropriate livestock and/or horse and burro grazing will favor unpalatable shrubs such as shadscale and Douglas rabbitbrush, and cause a decline in Bonneville saltbush, winterfat, green molly and Indian ricegrass.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.3:
Soil waterlogging from above-average precipitation events, and/or insect attack reduces deep-rooted perennial grasses and shrubs while bare ground increases.

Community Phase 2.2 (At-Risk):
Bonneville saltbush, winterfat and other shrubs dominate this community phase. Indian ricegrass and other deep rooted perennial bunchgrasses are a minor component. Annual non-natives are present. This community phase is at risk of crossing a threshold to a Shrub State 3.0.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1
Release from long-term drought, long-term flooding and/or growing season livestock and/or horse and burro grazing allows recovery of bunchgrasses, Bonneville saltbush, winterfat, and green molly.

Community Phase 2.3 (At Risk):
Remnant shrubs and grasses are present on the fringes of the waterlogged basin. Bare ground is widespread. Wind erosion may be common. This community phase is at risk of crossing a threshold to a Shrub State 3.0.

Community Phase Pathway 2.3a, from Phase 2.3 to 2.1:
Time, lack of disturbance and recovery from soil waterlogging and/or insect attack would allow the vegetation to reestablish. Bare ground would eventually decrease.

T2A: Transition from Current Potential State 2.0 to Shrub State 3.0:

Trigger: Inappropriate, long-term grazing of Indian ricegrass and palatable shrubs during the growing season will favor unpalatable shrubs and initiate a transition to Community Phase 3.1. Long-term drought will also favor shrubs over grasses.

Slow variables: Long-term decrease in deep-rooted perennial grass density.

Threshold: Loss of deep-rooted Indian ricegrass and other perennial bunchgrasses changes nutrient cycling, nutrient redistribution, and reduces soil organic matter.

Shrub State 3.0:

This state consists of two community phases. This site has crossed a biotic threshold and site processes are being controlled by shrubs. Bare ground has increased.

Community Phase 3.1:
Long-term drought reduces perennial bunchgrasses and shrubs become more dominant. Annual non-native species are present and bare ground has increased.

Community Phase Pathway 3.1a from Phase 3.1 to 3.2:
Inappropriate or excessive grazing reduces Bonneville saltbush, winterfat and green molly and allows for sprouting and non-palatable shrubs, such as Douglas rabbitbrush, to dominate the overstory.

Community Phase 3.2:
Rabbitbrush and/or other sprouting shrubs dominate the overstory. Annual non-native species may be increasing and bare ground is significant. Desirable species such as Indian ricegrass and/or winterfat may be present in trace amounts. This site is at risk for an increase in invasive non-native annual plants.

Silty Plain 5-8" P.Z. (R029XY117NV), Shrub State 3.2, T. Stringham, May 2020

Community Phase Pathway 3.2a from Phase 3.2 to 3.1:
Grazing and/or horse and burro management that favors the reestablishment and growth of Bonneville saltbush, winterfat and/or other palatable shrubs.

Potential Resilience Differences with Other Ecological Sites in this Group:

Outwash Plain (R029XY048NV):

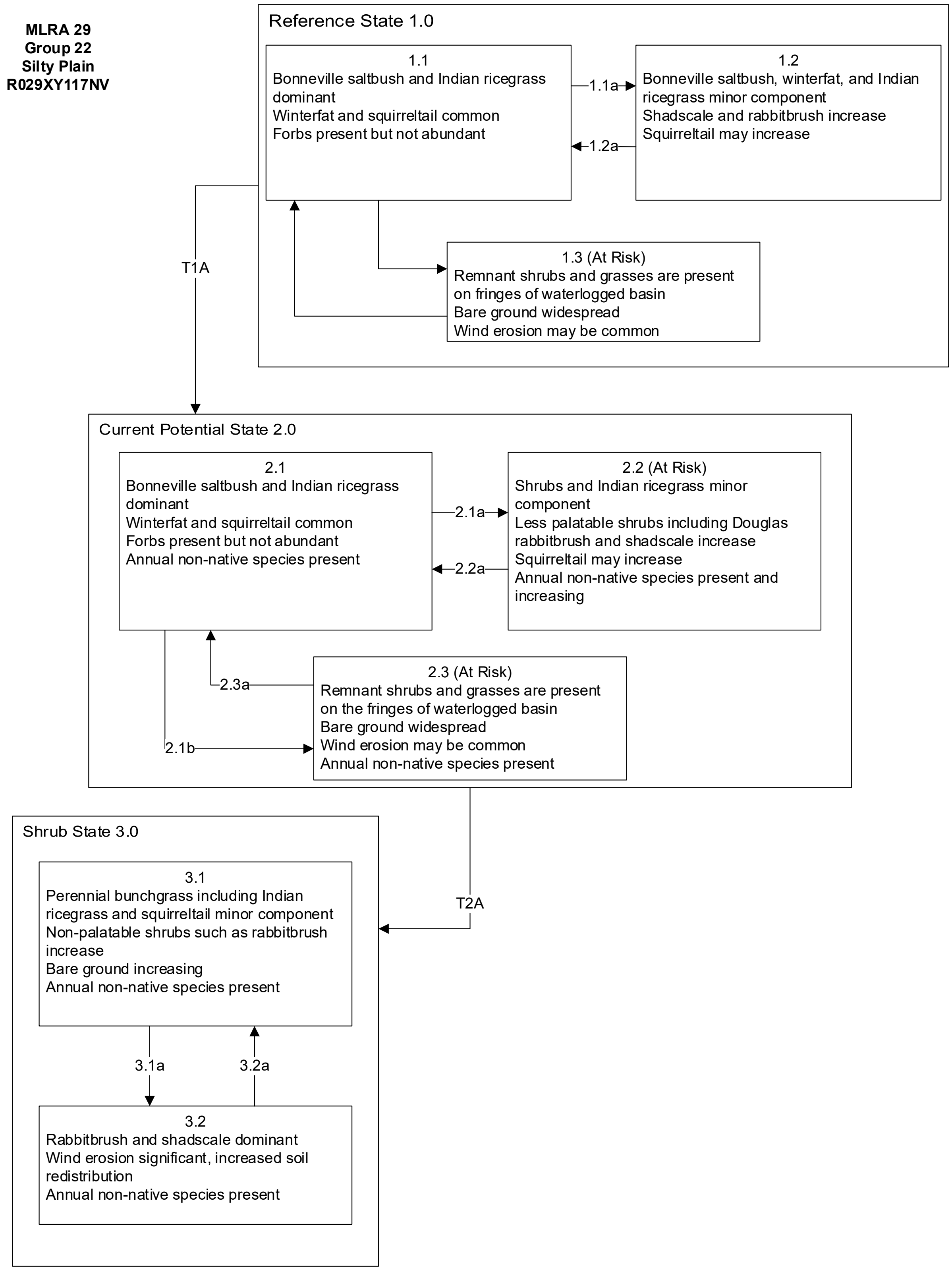
This site occurs on inset fans and lake plains with slopes from 0 to 4%. The soils are very deep and well drained from mixed rock sources. These soils are high in carbonates and are intermittently flooded. The plant community is dominated by fourwing saltbush and basin wildrye. Total annual production is 800 lb/ac in a normal year. The site is more productive than the modal but has the same three stable states.

Outwash Plain (R029XY048NV), Shrub State 3.1, T. Stringham, June 2023

Deep Silty 5-8" P.Z. (R029XY159NV):

This site occurs on basin floors and is dominated by Bonneville saltbush, shadscale, and green molly. Indian ricegrass and bottlebrush squirreltail dominate the understory. Total annual production is 300 lb/ac in a normal year. This site is more productive than the modal but has the same stable states.

Modal State and Transition Model for Group 22 in MLRA 29:



MLRA 29
Group 22
Silty Plain
R029XY117NV

Reference State 1.0 Community Phase Pathways
1.1a: Long term drought, time and/or herbivory favors increase of shrubs over deep-rooted perennial grasses.
1.1b: Soil waterlogging from above-average precipitation events and/or insect attack reduces deep-rooted perennial grasses and shrubs.
1.2a: Time, lack of disturbance allows Bonneville saltbush, winterfat, and Indian ricegrass to recover.
1.3a: Time, lack of disturbance and recovery from soil waterlogging and/or insect attack would allow the vegetation to reestablish.

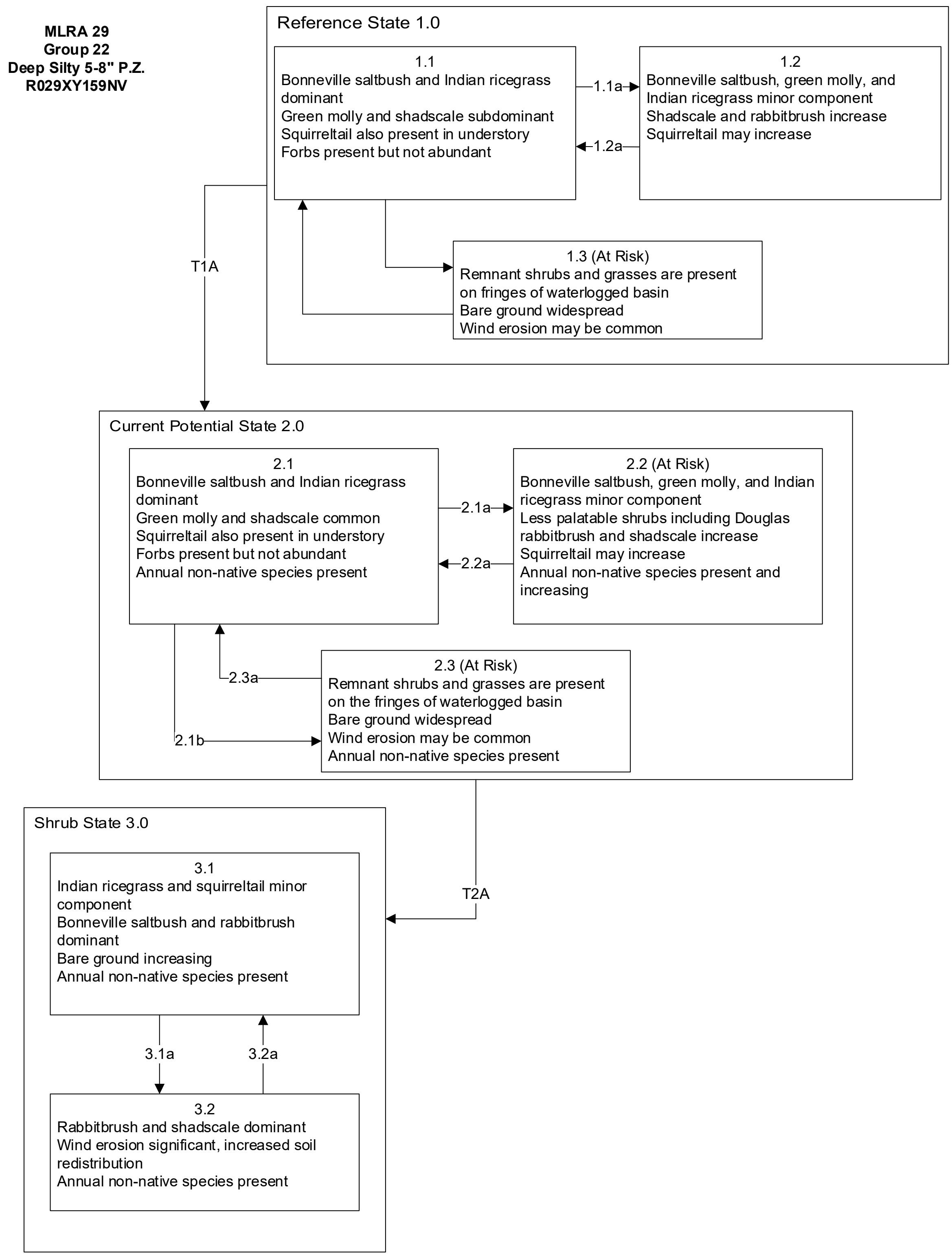
Transition T1A: Introduction of non-native annual species such as cheatgrass, halogeton, Russian thistle, and mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Inappropriate early season grazing reduces Bonneville saltbush and Indian ricegrass. Above-average precipitation will increase perennial grasses and episodic forbs. Long-term drought will reduce shrubs and perennial grasses.
2.1b: Soil waterlogging from above-average precipitation events and/or insect attack reduces deep-rooted perennial grasses and shrubs.
2.2a: Time, lack of disturbance and/or growing season grazing allows Bonneville saltbush, winterfat and Indian ricegrass to recover. Over time deeper-rooted shrubs and grasses will outcompete their shallower rooted counterparts.
2.3a: Time, lack of disturbance and recovery from soil waterlogging and/or insect attack would allow the vegetation to reestablish.

Transition T2A: Inappropriate, long-term grazing of Indian ricegrass and other palatable shrubs during the growing season and/or long-term drought.

Shrub State 3.0 Community Phase Pathways
3.1a: Inappropriate or excessive grazing increases non-palatable shrubs such as rabbitbrush.
3.2a: Time, lack of disturbance or grazing management favoring reestablishment of saltbush and other palatable shrubs.

Additional State and Transition Models for Group 22 in MLRA 29:



MLRA 29
Group 22
Deep Silty 5-8" P.Z.
R029XY159NV

Reference State 1.0 Community Phase Pathways
1.1a: Long term drought, time and/or herbivory favors increase of non-palatable shrubs over deep-rooted perennial grasses.
1.1b: Soil waterlogging from above-average precipitation events and/or insect attack reduces deep-rooted perennial grasses and shrubs.
1.2a: Time, lack of disturbance allows Bonneville saltbush, green molly, and Indian ricegrass to recover.
1.3a: Time, lack of disturbance and recovery from soil waterlogging and/or insect attack would allow the vegetation to reestablish.

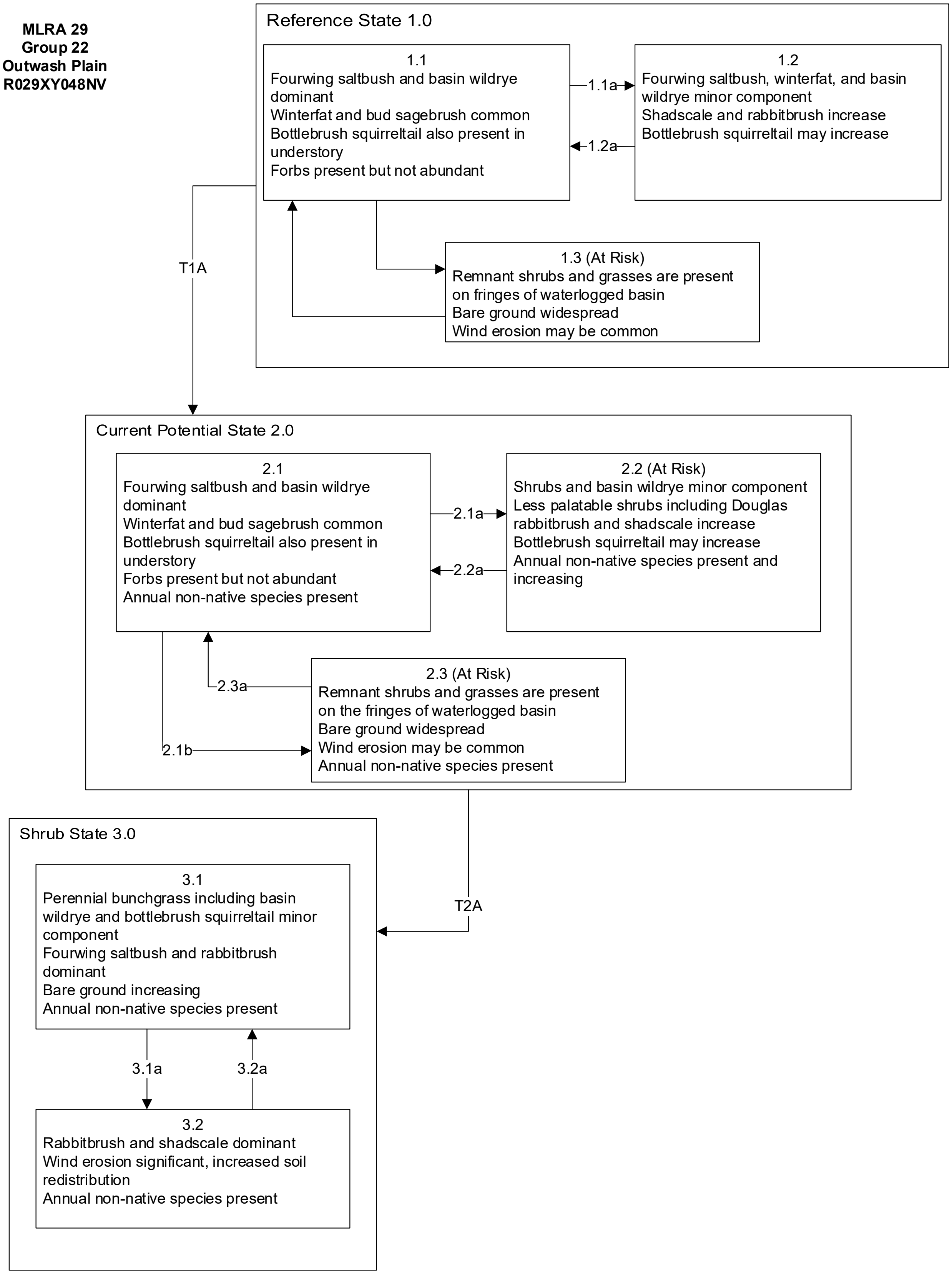
Transition T1A: Introduction of non-native annual species such as cheatgrass, halogeton, Russian thistle, and mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Inappropriate early season grazing reduces Bonneville saltbush and Indian ricegrass. Above average precipitation or prolonged drought reduce the shrub coverage, allowing perennial grasses and episodic forbs to increase.
2.1b: Soil waterlogging from above-average precipitation events and/or insect attack reduces deep-rooted perennial grasses and shrubs.
2.2a: Time, lack of disturbance and/or growing season grazing allows Bonneville saltbush and Indian ricegrass to recover. Over time deeper-rooted shrubs and grasses will outcompete their shallower rooted counterparts.
2.3a: Time, lack of disturbance and recovery from soil waterlogging and/or insect attack would allow the vegetation to reestablish.

Transition T2A: Inappropriate, long-term grazing of Indian ricegrass and other palatable shrubs during the growing season and/or long-term drought.

Shrub State 3.0 Community Phase Pathways
3.1a: Inappropriate or excessive grazing reduces Bonneville saltbush and green molly.
3.2a: Time, lack of disturbance or grazing management favoring reestablishment of saltbush and other palatable shrubs.

MLRA 29
Group 22
Outwash Plain
R029XY048NV



MLRA 29
Group 22
Outwash Plain
R029XY048NV

Reference State 1.0 Community Phase Pathways
1.1a: Long-term drought, time and/or herbivory favors increase of shrubs over deep-rooted perennial grasses.
1.1b: Soil waterlogging from above-average precipitation events and/or insect attack reduces deep-rooted perennial grasses and shrubs.
1.2a: Time, lack of disturbance allows fourwing saltbush, winterfat, and basin wildrye to recover.
1.3a: Time, lack of disturbance and recovery from soil waterlogging and/or insect attack would allow the vegetation to reestablish.

Transition T1A: Introduction of non-native annual species such as cheatgrass, halogeton, Russian thistle, and mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Inappropriate early-season grazing reduces fourwing saltbush and basin wildrye. Above-average precipitation would increase perennial grasses and episodic forbs. Prolonged drought would decrease perennial grasses and shrubs would increase.
2.1b: Soil waterlogging from above-average precipitation events and/or insect attack reduces deep-rooted perennial grasses and shrubs.
2.2a: Time, lack of disturbance and/or growing season grazing allows fourwing saltbush and basin wildrye to recover. Over time deeper-rooted shrubs and grasses will outcompete their shallower rooted counterparts.
2.3a: Time, lack of disturbance and recovery from soil waterlogging and/or insect attack would allow the vegetation to reestablish.

Transition T2A: Inappropriate, long-term grazing of basin wildrye and other palatable shrubs during the growing season and/or long-term drought.

Shrub State 3.0 Community Phase Pathways
3.1a: Inappropriate or excessive grazing reduces fourwing saltbush and winterfat.
3.2a: Time, lack of disturbance or grazing management favoring reestablishment of saltbush and other palatable shrubs.

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<u>MLRA 29 Group 23: Sites on hills and mountain sideslopes dominated by littleleaf mountain mahogany.</u>

Description of MLRA 29 Disturbance Response Group 23

Disturbance Response Group (DRG) 23 consists of one site. The precipitation ranges from 10 to 12(14) in. (25–36 cm). Slopes range from 8 to 75%, with 15 to 50% being typical. Elevation ranges from 5,800 to 7,000 ft (1,768–2,134 m). This site occurs on the summits and sideslopes of hills and lower mountains on all aspects. The soils in this site are very shallow to shallow and well drained. These soils have formed in residuum and colluvium from limestone and dolomite. The soil profile is modified with 50 to 75% rock fragments and more than half of these fragments are cobbles and stones. High amounts of rock fragments occur at the soil surface, stabilizing against erosion. The soil temperature regime is mesic, and the soil moisture regime is aridic bordering on xeric. Runoff is high, available water capacity is low or very low, and water intake rates are moderate. The reference plant community is dominated by littleleaf mountain mahogany *(Cercocarpus intricatus)* with black sagebrush *(Artemisia nova)* and needle-and-thread (*Hesperostipa comata*) as sub-dominant. Shrubs such as spiny greasebush *(Glossopetalon spinescens)* and ephedra (*Ephedra* spp.) may also be prevalent on site. Indian ricegrass *(Achnatherum hymenoides)* and other needlegrasses (*Achnatherum* spp.*)* may be a lesser component of the grass community. Annual production ranges from 300 to 600 lb/ac with 450 lb/ac on a normal year.

Disturbance Response Group 23 Ecological Sites:

Limestone Hill – Modal	R029XY040NV

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasive species. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.)(Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans a unique area in Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area. Flashy, summer storm events contribute significantly to annual precipitation as well. Air and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992).

The ecological site in this DRG is dominated by the long-lived littleleaf mountain mahogany, deep-rooted cool-season perennial bunchgrasses, and other long-lived shrubs (50+ years) with high root-to-shoot ratios. Littleleaf mountain mahogany roots in the cracks and crevices of exposed limestone and dolomite (Davis 1990). The perennial bunchgrasses generally have somewhat shallower root systems than the shrubs, but root densities are often as high as or higher than those of shrubs in the upper 0.5 m (1.6 ft). General differences in root depth distributions between grasses and shrubs result in resource partitioning in this system.

Littleleaf mountain mahogany is a long-lived, intricately branched, and occasionally tree-like evergreen shrub, which can grow 0.5 to 2.5 m (1.6 to 8 ft) tall. Littleleaf mahogany is found throughout most of Nevada and Utah, and parts of California, Arizona, and Colorado (Davis 1990). It is found mostly on rocky limestone slopes often in association with pinyon and juniper woodlands. Littleleaf mahogany may hybridize with curl-leaf mountain mahogany *(Cercocarpus ledifolius)* when the two species grow near each other (Brayton and Mooney 1966). Littleleaf mountain mahogany is very similar to curl-leaf mountain mahogany, but littleleaf earns its name by being shorter and having smaller leaves than curl-leaf mahogany. Littleleaf mahogany is typically found at lower elevations than curl-leaf, and its smaller size makes it more tolerant of drought (Mee et al. 2003).

Black sagebrush is generally long-lived; therefore, it is not necessary for new individuals to recruit every year for perpetuation of the stand. Infrequent large recruitment events and simultaneous low, continuous recruitment is the foundation of population maintenance (Noy-Meir 1973). Survival of the seedlings is dependent on adequate moisture conditions. Black sagebrush often hybridizes with other species of sagebrush, most commonly members of the section *Tridentatae*. This hybridization can result in patches of intermediate hybrid plants in between sagebrush communities. However, black sagebrush usually inhabits sites intolerable for other sagebrush species, forming unique communities (Tilley and St. John 2012a).

Needle-and-thread is a native, cool-season, perennial bunchgrass ranging from 1 to 4 ft (30–122 cm) in height (Magee 2002). It grows in the early spring and in the late fall if moisture is available, producing an abundance of basal leaves, which stay green during most seasons (Magee 2002). Maximum production and balance with associated grasses can be maintained through proper grazing use and periodic grazing deferments of at least 90 days (Magee 2002).

Needle-and-thread is an important forage source as it is grazed readily by all livestock, especially in early spring and late fall in which it cures well on the stem (Magee 2002).

Nevada ephedra, or Nevada jointfir, can be commonly found in small clumps or large, independent stands in a variety of plant communities, including sagebrush, desert shrub, and pinyon-juniper communities (Stanton 1973). Nevada ephedra is a common plant in Nevada (West et al. 1998) and can be found in a variety of communities, including sagebrush, desert shrub, and pinyon-juniper communities (Stanton 1973). Nevada ephedra reproduces by both seed (Welsh et al. 1987) and root sprouting in response to disturbance such as fire or herbicide (Hunter et al. 1978).

Spiny greasebush is a low, densely and intricately branched, rounded, spinescent shrub ranging from matted to 2 m (6.5 ft) high (Perryman 2014a). Spiny greasebush's new growth is characterized by somewhat grayish-green leaves, green stems that become light orangish-tan, gray and tannish-range bark, and finely puberulent herbage (Perryman 2014a). Spiny greasewood is widespread throughout Nevada occurring on summits, side slopes, and backslopes of lower mountains, hills, plateaus, and fan piedmonts (Perryman 2014a). It primarily occurs on very shallow to shallow soils from dolomitic limestone residuum and igneous residuum within the 6 to 14 in. (15–36 m) precipitation zone and at elevations between 2,000 and 7,800 ft (610–2,377 m) (Perryman 2014a).

Indian ricegrass is a hardy, cool-season, densely tufted, long-lived perennial bunchgrass that grows from 4 to 24 in. (10–61 cm) in height (Blaisdell and Holmgren 1984). Primarily adapted to coarse-textured soils, its deep, fibrous root system makes Indian ricegrass one of the most drought-tolerant native species (Booth et al. 1980). Unlike other cool-season species, Indian ricegrass does not require vernalization (exposure to cold) in order to produce flowers and flowering can continue into late fall with favorable environmental conditions. This allows the seeds in each panicle to ripen over a longer period of time than most other species thus providing a greater opportunity for successful seed production (Jones 1990). Indian ricegrass can be found in low deserts associated with shadscale *(Atriplex confertifolia)* and winterfat *(Krascheninnikovia lanata)* and in elevations up to 10,000 ft (3,048 m). It can be found throughout MLRA 29, including on ridges, canyons, dunes, hills, plains, and mountains. Indian ricegrass is a key plant in recovering communities disturbed by grazing, mining, and fire because it is a hardy grass that can grow in rough, rocky, and coarse soils and still provides very valuable forage. When properly planted and managed, Indian ricegrass can help recover disturbed areas by competing with invasive grasses and providing cover and forage (Booth et al. 1980).

Annual Invasive Species:

The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and depressed competition or can increase resource pools by the decomposition of dead plant material following disturbance. Historically, Great Basin plant communities were free of exotic invaders; however, excessive grazing pressure during settlement and into the 20th century has increased the overall presence of cheatgrass (*Bromus tectorum*), halogeton (*Halogeton glomeratus*), Russian thistle (*Salsola tragus*) and weedy mustard species (Brassicaceae family) (Peters and Bunting 1994). The presence of exotic annual plants within these ecosystems decreases ecosystem resilience and resistance to disturbance through competition for limited resources. Cheatgrass is a cool-season annual grass that maintains an advantage over native plants in part because it is a prolific seed producer, can germinate in the autumn or spring, tolerates grazing, and increases with frequent fire (Klemmedson and Smith 1964, Miller et al. 1999). Cheatgrass originated from Eurasia and was first reported in North America in the late 1800s (Furbush 1953, Mack and Pyke 1983). (Pellant and Hall 1994) found 3.3 million acres of public lands dominated by cheatgrass and suggested that another 76 million acres were susceptible to invasion by winter annuals including cheatgrass and medusahead. The species most likely to invade this site is cheatgrass, however dominance was not observed in field data and is not expected on this ecological site.

Fire Ecology:

Wildfire is infrequent and occurs due to the natural buildup of woody fuels. Ignitions commonly occur during lightning storms associated with summer monsoonal storms. Fires have long lasting effects on the structure and composition of this plant community, due to the long recovery periods. Post-fire plant communities will be characterized by a decrease in mature littleleaf mountain mahogany and a release of suppressed mahogany plants present in the understory. Invasive non-native annuals will also increase following wildfire. The historic fire regime of littleleaf mountain mahogany communities probably varied with community type and structure. The estimated fire return interval is greater than 100 years. Littleleaf mountain mahogany is moderately damaged by fire and there is very little sprouting following fire.

Historically, black sagebrush plants have no morphological adaptations for surviving fire and must reestablish from seed (Wright et al. 1979). Fire return intervals in black sagebrush ecosystems have been estimated at 100 to 200 years (Kitchen and McArthur 2007); however, fires were probably patchy and very infrequent due to the low productivity of these sites. The ability of black sagebrush to establish after fire is mostly dependent on the amount of seed deposited in the seed bank the year before the fire. Seeds typically do not persist in the soil for more than one growing season (Beetle 1960). A few seeds may remain viable in soil for 2 years (Meyer 2008a); however, even in dry storage, black sagebrush seed viability has been found to drop rapidly over time, from 81% to 1% viability after 2 and 10 years of storage, respectively (Stevens et al. 1981). Thus, repeated frequent fires can eliminate black sagebrush from a site, however black sagebrush in zones receiving 12 to 16 in. (30–41 cm) of annual precipitation has been found to have greater fire survival (Boltz 1994).

Ephedra vigorously sprouts after fire from extensive woody crowns (Young and Evans 1978, Koniak 1985). Sprouting after fire may vary by season of burn and fire severity, however. After fire, these sprouting shrubs can produce significant new growth if there is enough moisture available (Shaw 1992).

Livestock/Wildlife Grazing Interpretations:

Littleleaf mountain mahogany is browsed by wild ungulates and domestic sheep where it is within reach (Francis 2004), however, (Clary and Beale 1983) noted that pronghorn *(Antilocapra americana)* appeared to make little use of this plant when other forage, such as black sagebrush, was available.

Black sagebrush palatability has been rated as moderate to high depending on the ungulate and the season of use (Horton 1989, Wambolt 1996). The palatability of black sagebrush increases the potential negative impacts on remaining black sagebrush plants from grazing or browsing pressure following fire (Wambolt 1996). Pronghorn utilize black sagebrush heavily (Beale and Smith 1970). Domestic livestock will also utilize black sagebrush. The domestic sheep industry that emerged in the Great Basin in the early 1900s was largely based on wintering domestic sheep in black sagebrush communities (Mozingo 1987c). Domestic sheep will browse black sagebrush during all seasons of the year depending on the availability of other forage species with greater amounts being consumed in fall and winter. Black sagebrush is generally less palatable to cattle than to domestic sheep and wild ungulates (McArthur et al. 1979); however, cattle use of black sagebrush has also been shown to be greatest in fall and winter (Schultz and McAdoo 2002), with only trace amounts being consumed in summer (Van Vuren 1984).

Inappropriate grazing management during the growing season will cause a decline in needle-and-thread and Indian ricegrass. Growing season grazing by cattle may initially cause a decrease in the bunchgrass component and give a competitive advantage to shrub species including black sagebrush (Eckert et al. 1972). Needle-and-thread grass is most commonly found on warm/dry soils (Miller et al. 2013) and is not grazing tolerant and will be one of the first grasses to decrease under heavy grazing pressure (Smoliak et al. 1972, Tueller and Blackburn 1974). With the reduction in competition from deep-rooted perennial bunchgrasses, the rhizomatous galleta grass and short-statured Sandberg bluegrass will likely increase (Jameson 1962, Smoliak et al. 1972). Needle-and-thread is considered desirable for elk in winter and spring and deer in spring (NRCS 2013).

Indian ricegrass is a preferred forage species for livestock and wildlife (Cook 1962, Booth et al. 1980). It is often heavily utilized in winter because it cures well (Booth et al. 2006). It is also readily utilized in early spring, being a source of green feed before most other perennial grasses have produced new growth (Quinones 1981). In eastern Idaho, productivity of Indian ricegrass was at least 10 times greater in undisturbed plots than in heavily grazed ones (Pearson 1965). Cook and Child (1971) also found a significant reduction in plant cover after 7 years of rest from heavy (90%) and moderate (60%) spring use, indicating some level of grazing is necessary for stand maintenance. Tolerance to grazing increases after May, thus spring deferment may be necessary for stand enhancement (Pearson 1964, Cook and Child 1971); however, utilization of less than 60% is recommended. In summary, adaptive management is required to manage this bunchgrass well.

State and Transition Model Narrative for Group 23:

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 29 Disturbance Response Group 23.

Reference State 1.0:

The Reference State 1.0 represents the natural range of variability under pristine conditions. The reference state has two general community phases; shrub dominant with needlegrass sub-dominant phase and a perennial bunchgrass dominant with shrub sub-dominant phase. Plant community phase changes are triggered by infrequent wildlife and prolonged drought. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients.

Community Phase 1.1:
The reference plant community is dominated by mature littleleaf mountain mahogany trees. Black sagebrush and needle-and-thread are sub-dominant within the understory. *Ephedra* spp., spiny greasebush, Indian ricegrass, and needlegrasses are minor components. Potential vegetative composition is about 15% grasses, 5% forbs and 80% shrubs, however field observations indicated the forb component may be upward of 10%. Singleleaf pinyon and Utah juniper may be present in small amounts. Approximate ground cover (basal and crown) is 10 to 20%. Total annual air-dry production ranges from 300 to 600 lb/ac.

Community Phase Pathway 1.1a, from phase 1.1 to 1.2:
A mosaic pattern created by low severity fire or drought-induced death, reduces shrub cover allowing perennial bunchgrasses to increase.

Community Phase 1.2:
This is a post-fire phase. Perennial bunchgrasses and forbs are increased in cover whereas littleleaf mountain mahogany, black sagebrush and other non-sprouting shrubs are reduced. Sprouting shrubs, such as ephedra, Nevada greasebush and Douglas rabbitbrush increase in cover.

Community Phase Pathway 1.2a, from phase 1.2 to 1.1:
Time without disturbances such as wildfire, long-term drought, heavy browsing of mountain mahogany seedlings, seed predation by small mammals, or disease will allow regeneration of littleleaf mountain mahogany and black sagebrush.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0:

Trigger: Introduction of non-native annual plants, such as cheatgrass and annual mustards.

Slow variables: Over time the annual non-native species will increase within the community and compete with native species for resources.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:
This state is similar to the Reference State 1.0, with two similar community phases. Ecological function of the state remains unchanged; however, the resiliency and stability of the state has been reduced by the presence of non-native annual species. These species possess high seed output, persistent seed banks, rapid growth rates, ability to cross pollinate and the ability to adapt seed dispersal methods. They may increase in abundance but will not become dominant within this state.

Community Phase 2.1:
This community phase is dominated by mature littleleaf mountain mahogany trees. Black sagebrush, ephedra, and spiny greasebush are the dominant understory shrubs. Needle-and-thread is subdominant. Indian ricegrass and needlegrasses are also present. Perennial forbs comprise a minor component. Annual non-native species are present. Singleleaf pinyon and Utah juniper may be present in small amounts.

Community Phase Pathway 2.1a, from phase 2.1 to 2.2:
A mosaic pattern created by low severity fire or drought-induced death, reduces shrub cover allowing perennial bunchgrasses to increase.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.3:
Time and lack of disturbance, such as fire, allow for littleleaf mahogany and/or black sagebrush to increase in density. Inappropriate growing season grazing from domestic livestock and/or wild horses/burros reduces deep-rooted perennial bunchgrasses facilitating shrub dominance.

Limestone Hill (R029XY040NV), Current Potential 2.1, T. Stringham, June 2020

Community Phase 2.2:
This is a post-fire phase. Perennial bunchgrasses and forbs are increased in cover whereas littleleaf mountain mahogany, black sagebrush and other non-sprouting shrubs are reduced. Sprouting shrubs, such as ephedra, spiny greasebush and Douglas rabbitbrush increase in cover. Annual invasive grasses and/or forbs are present and increasing.

Community Phase Pathway 2.2a, from phase 2.2 to 2.1:
Time and a reduction in disturbances such as fire, drought, improper grazing of perennial bunchgrasses, browsing of mountain mahogany seedlings, seed predation by small mammals or disease allows for regeneration of littleleaf mountain mahogany and black sagebrush.

Community Phase Pathway 2.2b, from phase 2.2 to 2.3:
Time and lack of disturbance such as fire or inappropriate browsing of mahogany seedlings and an increase in improper grazing of perennial bunchgrasses leads to a reduction in bunchgrasses and a regeneration of littleleaf mountain mahogany and associated shrubs.

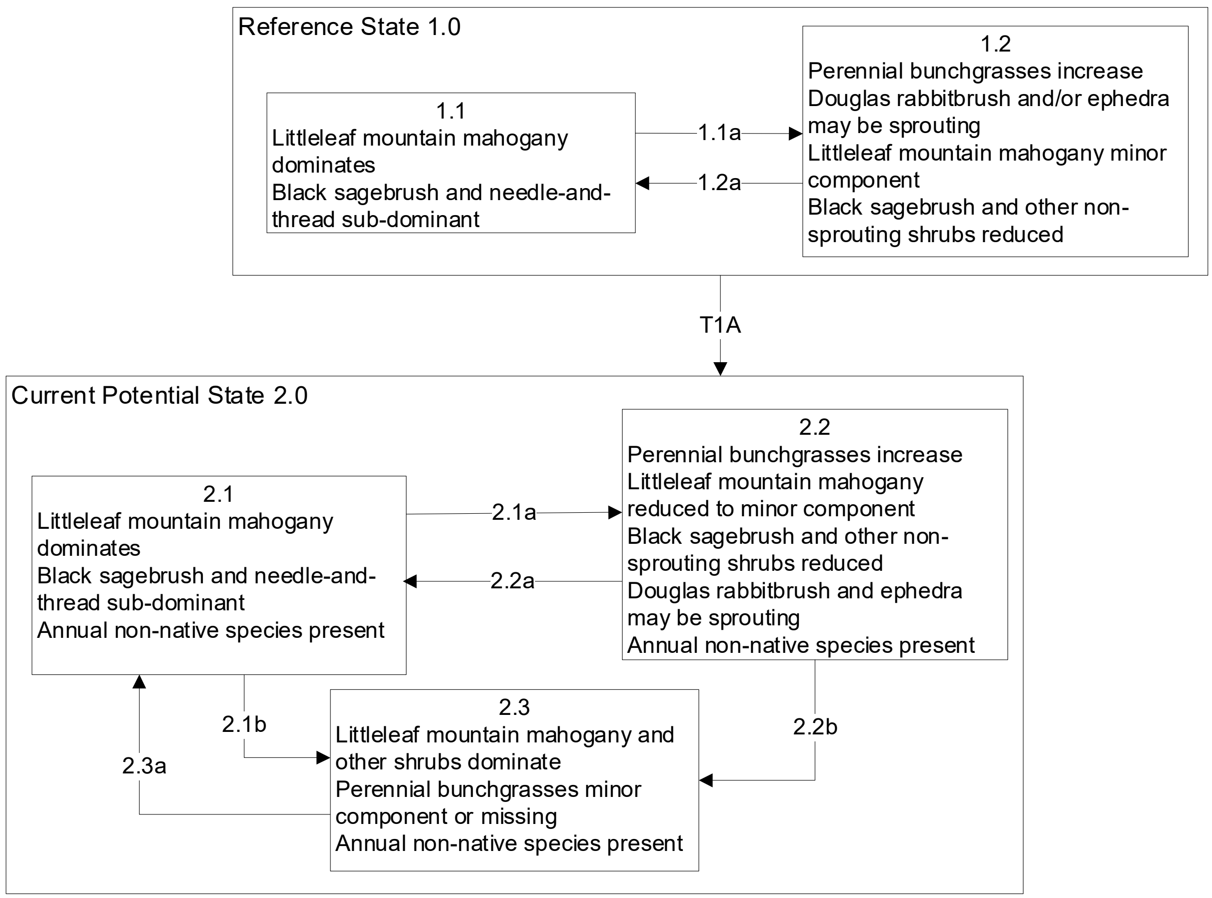
Community Phase 2.3:
Littleleaf mountain mahogany along with other shrubs dominate site aspect and resources. Perennial bunchgrasses reduced. Mat forming forbs (phlox, goldenweed) may be increasing. Bare ground interspaces increased.

Community Phase Pathway 2.3a, from phase 2.3 to 2.1:
Low intensity fire and/or long-term drought combined with appropriate grazing / herbivory management facilitates a decrease in the shrub component and an increase in perennial bunchgrass.

Limestone Hill (R029XY040NV), Current Potential 2.3, D. Snyder, September 2020

Modal State and Transition Model for Group 23 in MLRA 29:

MLRA 29
Group 23
Limestone Hill
R029XY040NV



MLRA 29
Group 23
Limestone Hill
R029XY040NV

Reference State 1.0 Community Phase Pathways
1.1a: A mosaic pattern created by low severity fire or drought-induced death, reduces shrub cover allowing perennial bunchgrasses to increase.
1.2a: Time and lack of disturbance such as fire, drought, or heavy browsing of mountain mahogany seedlings allows for regeneration of littleleaf mountain mahogany and black sagebrush.

Transition T1A: Introduction of non-native annual species.

Current Potential State 2.0 Community Phase Pathways
2.1a: A mosaic pattern created by low severity fire or drought-induced death, reduces shrub cover allowing perennial bunchgrasses to increase.
2.1b: Time and lack of disturbance, such as fire, allow for littleleaf mahogany and/or black sagebrush to increase in density.
2.2a: Time and a reduction in disturbances such as fire, drought, improper grazing of perennial bunchgrasses, browsing of mountain mahogany seedlings, seed predation by small mammals or disease allows for regeneration of littleleaf mountain mahogany and black sagebrush.
2.2b: Decrease in prevalence of fire or heavy browsing of seedlings or increase in improper grazing leads to reduction in perennial bunchgrasses and regeneration of littleleaf mountain mahogany and shrubs.
2.3a: Drought or low intensity fire, coupled with appropriate grazing leads to decrease in shrub component and increase in perennial bunchgrasses.

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MLRA 29 Group 24: Rocky soils with mountain mahogany, mountain big sagebrush, and needlegrass

Description of MLRA 29 Disturbance Response Group 24

Disturbance Response Group (DRG) 24 consists of two sites. The precipitation ranges from 14 to over 20 in. (36–51 cm). Slopes range from 2 to 50%. Elevation ranges from 7,000 to over 9,500 ft (2,134–2,896 m). The soils on these sites are typically shallow to deep to bedrock and well-drained. These soils are normally neutral to slightly acidic in reaction and often modified by high volumes of rock fragments throughout the profile. Available water holding capacity and permeability are moderate. The reference plant community is dominated by curl-leaf mountain mahogany *(Cercocarpus ledifolius)*. Other important species are mountain big sagebrush *(Artemisia tridentata ssp. vaseyana)*, basin wildrye *(Leymus cinereus)*, snowberry *(Symphoricarpos spp.)*, muttongrass *(Poa fendleriana)*, and multiple species of needlegrass, including western needlegrass *(Achnatherum occidentale ssp. occidentale)*, Letterman's needlegrass *(Achnatherum lettermanii)*, Thurber's needlegrass *(Achnatherum thurberianum)*, and Columbia needlegrass *(Achnatherum nelsonii ssp. nelsonii)*. Singleleaf pinyon *(Pinus monophylla)* and Utah juniper *(Juniperus osteosperma)* trees may also be present on these sites. Total annual production, in normal precipitation years, for all shrubs, herbaceous plants and trees less than 4 ft (1.2 m) tall, is 300 to 900 lb/ac. Total annual production for all vegetation, irrespective of height, ranges from 1,800 to 2,400 lb/ac in normal years.

Disturbance Response Group 24 Ecological Sites:

Mahogany Thicket – Modal	R029XY027NV
Mahogany Savanna	R029XY043NV

Modal Site:

The Mahogany Savanna (R029XY043NV) ecological site is the modal site that represents this DRG. This site occurs on mountain summits and sideslopes on all aspects. Slopes range from 4 to 50%, but slope gradients of 4 to 15% are typical. Elevations are 7,500 to 9,500 ft (2,283–2,896 m). The soils on this site are typically shallow and well drained. These soils are typically modified with high volumes of rock fragments throughout the soil profile, and stones or boulder are often present on the soil surface. The subsoil is neutral or slightly acidic in reaction. The soil temperature regime is frigid, and the soil moisture regime is xeric. Available water holding capacity is moderate, soil permeability is moderate, and runoff is medium to rapid. The reference plant community is dominated by curl-leaf mountain mahogany. Basin wildrye, muttongrass, and a suite of needlegrasses are important understory species. A few singleleaf pinyons and Utah junipers may be scattered throughout the stand. The total overstory canopy, including mahogany, pinyon, and juniper, exceeds 35%. Total annual production by air-dry weight on this site is approximately 1,800 lb/ac in normal years, with 900 lb/ac in the understory (trees, shrubs, and herbaceous plants shorter than 4.5 ft (1.4 m)).

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasives. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans a unique area in Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area. Flashy, summer storm events contribute significantly to annual precipitation as well. Air and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant(Everett et al. 1980).

Periodic drought regularly influences these ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West (Miller et al. 2008b). Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006).

The ecological sites in this DRG are dominated by long-lived curl-leaf mountain mahogany, deep-rooted cool-season perennial bunchgrasses, and long-lived shrubs (50+ years) with high root-to-shoot ratios. As tree canopy increases, needlegrasses and basin wildrye will decline while muttongrass – the more shade tolerant grass – will increase. The dominant shrubs usually root to the full depth of the winter-spring soil moisture recharge, which ranges from 1.0 to over 3.0 m (3.3–9.84 ft) (Comstock and Ehleringer 1992). Root length of mature sagebrush plants was measured to a depth of 2 m (6.56 ft) in alluvial soils in Utah (Richards and Caldwell 1987).

These shrubs have a flexible generalized root system with development of both deep taproots and laterals near the surface (Comstock and Ehleringer 1992). The perennial bunchgrasses generally have somewhat shallower root systems than the shrubs, but root densities are often as high as or higher than those of shrubs in the upper 0.5 m (1.64 ft). General differences in root depth distributions between grasses and shrubs result in resource partitioning in this system.

Curl-leaf mountain mahogany is a multi-branched, evergreen shrub or tree extending from 3 to over 20 ft (1–6 m) in height. The rooting of mountain mahogany is spreading and limited by the depth to bedrock. (Youngberg and Hu 1972) reported in an Oregon study that curl-leaf mountain mahogany produces nitrogen-fixing root nodules. They also reported that nodulated plants had the highest amounts of nitrogen in the leaves. It is the most widely distributed species of *Cercocarpus* and is the only species of the genus that extends as far north and west as Washington. Most often curl-leaf mountain mahogany stands occur on warm, dry, rocky ridges or outcrops where fire would be an infrequent occurrence (USFS 1937). Larger and older mahogany trees are found on fire-resistant rocky sites, and these trees are the source of new seeds if the non-rocky, fire-susceptible portions of the site are burned (Scheldt and Tisdale 1970, Dealy 1974).

Curl-leaf mahogany plants are long-lived and can reach 1,350+ years of age (Schultz et al. 1990). As mahogany stands increase in average age, average canopy volume and height of the individuals present also increase. As average canopy height and volume increase, stand density declines (Schultz et al. 1991). Stands with a closed, or nearly closed canopy often have few or no young curl-leaf mahogany (i.e., recruitment) in the understory (Schultz et al. 1990, Schultz et al. 1991), despite high seed density beneath trees (Russell and Schupp 1998, Ibáñez and Schupp 2002). Intraspecific competition reduces the growth rates of all age classes below the potential growth rates for the species. Competition may also increase mortality in the younger plants.

Curl-leaf mahogany plants are very self-compatible for pollination and most developing seed matures and is viable (Russell and Schupp 1998). The deep litter throughout stands with high canopy cover appears to facilitate seed germination but retard seedling survival due to poor contact between the root and the soil (Schultz et al. 1996, Ibáñez and Schupp 2002). Reproduction in large stands with high canopy cover occurs most often in either canopy gaps where a tree has died and increased exposure of bare ground or around the perimeter of the stand under sagebrush plants, where litter cover is less and seldom deep (Schultz et al. 1990, Schultz et al. 1991).

Mahogany seeds require bare mineral soil to germinate; litter depths over 0.25 in. can impede recruitment (Gruell et al. 1985, Schultz et al. 1991, Ibáñez et al. 1999, Ibáñez and Schupp 2002). Cheatgrass thus affects mahogany growth by competing for water resources and reducing the amount of bare soil in an area (Ross 1999). Multiple sources (Schultz et al. 1996, Ibáñez et al. 1999) found that mahogany seedlings germinate abundantly under the canopy of adult plants but rarely successfully establish there due to shading and higher litter amounts. In addition, (Schultz et al. 1996) found that seedlings had significantly higher long-term success in areas dominated by sagebrush canopy than in areas under mahogany canopy or in interspaces. Some hypothesize that the light shading and hydraulic lift provided by sagebrush may create a microsite facilitating mahogany recruitment (Gruell et al. 1985, Ibáñez et al. 1999).

Mountain big sagebrush is generally long-lived; therefore, it is not necessary for new individuals to recruit every year for perpetuation of the stand. Infrequent large recruitment events and simultaneous low, continuous recruitment is the foundation of population maintenance (Noy-Meir 1973). Survival of the seedlings is dependent on adequate moisture conditions.

The perennial bunchgrasses present on this site include needlegrasses *(Achnatherum*), muttongrass, and basin wildrye. These cool-season bunchgrasses generally have somewhat shallower root systems than the shrubs, but root densities are often as high as or higher than those of shrubs in the upper 0.5 m (1.64 ft) but taper off more rapidly than shrubs. However, basin wildrye is weakly rhizomatous and has been found to root to depths of 1 m or more and to exhibit greater lateral root spread than many other grass species (Abbott et al. 1991). Muttongrass may be more shade tolerant than other perennial bunchgrasses and will persist in the understory as the canopy closes (Erdman 1970).

Mahogany stands are susceptible to drought, frost, and invasion by non-native species, especially cheatgrass (*Bromus tectorum*). Cheatgrass affects mahogany seedling growth by competing for water resources and nutrients in an area (Ross 1999). It should be noted, cheatgrass was not found within the mahogany stands observed during field visits.

The ecological sites in this DRG have moderate to high resilience to disturbance and resistance to invasion. Resilience increases with elevation, aspect, precipitation, and nutrient availability. Long-term disturbance response may be influenced by small differences in landscape topography. Concave areas receive run-in from adjacent landscapes and consequently retain more moisture to support the growth of deep-rooted perennial grasses (i.e. basin wildrye) whereas convex areas are slightly less resilient and may have more shallow-rooted perennial grasses (i.e. muttongrass). North slopes are also more resilient than south slopes because lower soil surface temperatures operate to keep moisture content higher on northern exposures.

Annual Invasive Species:

The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and depressed competition or can increase resource pools by the decomposition of dead plant material following disturbance. The presence of non-native annual plants within these ecosystems decreases ecosystem resilience and resistance to disturbance through competition for limited resources. Peters and Bunting (1994) cites multiple authors on the extent of the soil profile exploited by the competitive exotic annual cheatgrass. Specifically, the depth of rooting is dependent on the size the plant achieves, and in competitive environments, cheatgrass roots were found to penetrate only 15 cm (6 in.) whereas isolated plants and pure stands were found to root at least 1 m in depth (3.2 ft) with some plants rooting as deep as 1.5 to 1.7 m (5 to 5.5 ft).

The species most likely to invade these sites is cheatgrass. Cheatgrass is a cool-season annual grass that maintains an advantage over native plants in part because it is a prolific seed producer, can germinate in the autumn or spring, tolerates grazing, and increases with frequent fire (Klemmedson and Smith 1964, Miller 1999). Cheatgrass originated from Eurasia and was first reported in North America in the late 1800s. Pellant and Hall (1994) found 3.3 million acres of public lands dominated by cheatgrass and suggested that another 76 million acres were susceptible to invasion by winter annuals including cheatgrass and medusahead (*Taeniatherum caput-medusae*).

Recent modeling and empirical work by Bradford and Lauenroth (2006) suggest that seasonal patterns of precipitation input and temperature are also key factors determining regional variation in the growth, seed production, and spread of invasive annual grasses. The phenomenon of cheatgrass "die-off" provides opportunities for restoration of perennial and native species (Baughman et al. 2016, Baughman et al. 2017). The causes of these events are not fully understood, but there is ongoing work to try to predict where they occur, in the hopes of aiding conservation planning (Weisberg et al. 2017, Brehm 2019).

Methods to control cheatgrass include herbicide application, prescribed fire, targeted grazing, and rangeland seeding. Mapping potential or current invasion vectors is a management method designed to increase the cost-effectiveness of control methods. Spraying with herbicide (imazapic or imazapic + glyphosate) and seeding with crested wheatgrass and Sandberg bluegrass has been found to be more successful at combating cheatgrass than spraying alone (Sheley et al. 2012). To date, most seeding success has occurred with non-native wheatgrass species. Perennial grasses, especially crested wheatgrass, are able to suppress cheatgrass growth when mature (Blank et al. 2020). Where native bunchgrasses are missing from the site, revegetation of annual grass-invaded rangelands has been shown to have a higher likelihood of success when using introduced perennial bunchgrasses such as crested wheatgrass Butler et al. (2011), (Davies et al. 2015b, Clements et al. 2017) tested four herbicides (imazapic, imazapic + glyphosate, rimsulfuron, and sulfometuron + chlorsulfuron) for suppression of cheatgrass, medusahead (*Taeniatherum caput-medusae*), and North Africa grass (*Ventenata dubia*) within residual stands of native bunchgrass. Additionally, they tested the same four herbicides followed by seeding of six bunchgrasses (native and non-native) with varying success (Butler et al. 2011). Herbicide-only treatments appeared to remove competition for established bluebunch wheatgrass (*Pseudoroegneria spicata*) by providing 100% control of North Africa grass and medusahead and greater than 95% control of cheatgrass (Butler et al. 2011). Caution in using these results is advised, as only 1 year of data was reported.

In considering the combination of pre-emergent herbicide and prescribed fire for invasive annual grass control, it is important to assess the tolerance of desirable brush species to the herbicide being applied. Vollmer and Vollmer (2008) tested the tolerance of alderleaf mountain mahogany (*Cercocarpus montanus*), antelope bitterbrush, and multiple sagebrush species to three rates of imazapic with and without methylated seed oil as a surfactant. They found that a cheatgrass control program in an antelope bitterbrush community should not exceed imazapic at 8 oz/ac with or without surfactant. Sagebrush, regardless of species or rate of application, was not affected. However, many environmental variables were not reported in this study and managers should install test plots before broad-scale herbicide application is initiated.

Fire Ecology:

The fire return interval in curl-leaf mountain mahogany-dominated sites is not well documented, however, a study by (Arno and Wilson 1986) suggested sites of curl-leaf mountain mahogany with ponderosa pine had fire return intervals of 13 to 22 years before 1900. Fire frequency most likely depends on surrounding vegetation. Mahogany will persist longest in rocky areas where it is protected from fire. Because of their thicker bark, mature trees can often survive low-severity fires (Gruell et al. 1985). Curl-leaf mountain mahogany is considered a weak sprouter after fire. It is usually moderately to severely damaged by severe fires and the recovery time of these sites is variable; some measurements show that stands lack recruitment for up to 30 years post-fire (Gruell et al. 1985).

Mountain big sagebrush is killed by fire (Neuenschwander 1980, Blaisdell et al. 1982) and does not resprout (Blaisdell 1953). Post-fire regeneration occurs from seed and will vary depending on site characteristics, seed source, and fire characteristics. Mountain big sagebrush seedlings can grow rapidly and may reach reproductive maturity within 3 to 5 years (Bunting et al. 1987). Mountain big sagebrush may return to pre-burn density and cover within 15 to 20 years following fire, but establishment after severe fires may proceed more slowly (Bunting et al. 1987).

Depending on fire severity, snowberry may increase after fire. Snowberry is top-killed by fire but resprouts from rhizomes (Leege and Hickey 1971, Noste and Bushey 1987). Snowberry has been noted to be fire tolerant (Miller et al. 2013); it regenerates well and may exceed pre-burn biomass in the third season after a fire (Merrill et al. 1982).

Basin wildrye is relatively resistant to fire, particularly dormant season fire, as plants sprout from surviving root crowns and rhizomes (Zschaechner 1985). Miller et al. (2013) report fall and spring burning increased total shoot and reproductive shoot densities in the first year, although live basal areas were similar between burn and unburned plants. By year two there was little difference between burned and control treatments.

Muttongrass, a sub-dominant component on this site, is top killed by fire but will sprout after low to moderate severity fires. A study by (Vose and White 1991) in an open sawtimber site found minimal difference in the overall effect of burning on muttongrass.

Needlegrasses are slightly to moderately damaged by fire depending on the season of burn. They tend to be more susceptible when burned during mid-summer (Wright and Klemmedson 1965).

At the time of this document's publication, very little research has been done on the effects of fire on Letterman's needlegrass. However, most bunchgrasses are harmed by fire, and fire typically causes a decrease in reproduction, density, and cover in bunchgrasses (Ellsworth and Kauffman 2010). Bates et al. (2011) applied a partial cutting and fall season prescribed fire to a juniper encroached rangeland once dominated with Letterman's needlegrass and Columbia needlegrass. Results indicate mortality of Columbia needlegrass exceeded 80% while mortality of Letterman's was near 50%. However, 3 years post fire Columbia needlegrass had recovered, exceeding pre-fire cover levels. Season, fire severity, and post-fire climate all intergrade to determine needlegrass response to fire.

Thurber's needlegrass is a subdominant grass on the Mahogany Savanna ecological site (R029XY043NV) and is highly susceptible to damage from fire. Fire can cause high mortality, in addition to reducing basal area and yield of Thurber's needlegrass (Britton et al. 1990). The fine leaves and densely tufted growth form make this grass susceptible to subsurface charring of the crowns (Wright and Klemmedson 1965). Although timing of fire highly influenced the response and mortality of Thurber's needlegrass, smaller bunch sizes were less likely to be damaged by fire (Wright and Klemmedson 1965). Needlegrass often survives fire and will continue growth or regenerate from tillers when conditions are favorable (Koniak 1985, Britton et al. 1990). Reestablishment on burned sites has been found to be relatively slow due to low germination and competitive ability (Koniak 1985). Cheatgrass has been found to be a highly successful competitor with seedlings of this needlegrass and may preclude reestablishment (Evans and Young 1978).

Infilling by singleleaf pinyon (*Pinus monophylla*) and Utah juniper (*Juniperus osteosperma*) may also occur with an extended fire return interval. Eventually, singleleaf pinyon and Utah juniper will dominate the site and out-compete sagebrush for water and sunlight severely reducing both the shrub and herbaceous understory (Miller et al. 2000, Lett and Knapp 2005). Bluegrasses may remain underneath trees on north-facing slopes. The potential for soil erosion increases as the Utah juniper woodland matures and the understory plant community cover declines (Pierson et al. 2010).

Livestock/Wildlife Grazing Interpretations:

Curl-leaf mountain mahogany is an important cover and browse species for big game such as elk (*Cervus canadensis)*, mule deer *(Odocoileus hemionus)*, and bighorn sheep *(Ovis canadensis)* (Lanner and Rasmuss 1984, Furniss et al. 1988). Sampson and Jespersen (1963) state that curl-leaf mountain mahogany is excellent browse for deer, and domestic livestock will browse this plant to varying degrees in all seasons except summer. It is not uncommon for these trees to develop a "hedged" appearance after years of regular browsing by wildlife.

Despite low palatability, mountain big sagebrush is eaten by domestic sheep, cattle, goats, and horses. Chemical analysis indicates that the leaves of big sagebrush equal alfalfa meal *(Medicago sativa)* in protein, have a higher carbohydrate content, and yield twelvefold more fat (USFS 1937). Many wildlife species are dependent on the sagebrush ecosystem including the greater sage grouse *(Centrocercus urophasianus)*, sage sparrow (*Artemisiospiza nevadensis*), pygmy rabbit *(Brachylagus idahoensis)*, and the sagebrush vole *(Lemmiscus curtatus)*. Dobkin and Sauder (2004) identified 61 species, including 24 mammals and 37 birds, associated with the shrub-steppe habitats of the Intermountain West.

Spring defoliation of basin wildrye and/or consistent, heavy grazing during the growing season has been found to significantly reduce basin wildrye production and density (Krall et al. 1971). Basin wildrye is valuable forage for livestock (Ganskopp et al. 2007) and wildlife but is intolerant of heavy, repeated, spring grazing (Krall et al. 1971). Basin wildrye is used often as a winter feed for livestock and wildlife; not only providing roughage above the snow but also cover in the early spring months (Majerus 1992)

At the time of this document's publication, the effects of grazing on Letterman's needlegrass are not well documented. However, it is known to be palatable to many species of livestock and wildlife, including cattle, sheep, horses, pronghorn (*Antilocapra americana*), elk, mule deer, white-tailed deer *(Odocoileus virginianus)*, small mammals, and birds. It typically is only palatable early in the season because as *A. lettermanii* ages, it dries and becomes coarse and wiry, which can injure an animal's mouth and leads to it being avoided by most animals later in the season (Dittberner and Olson 1983).

Western needlegrass, starts growth early, is slow in maturing, and remains green until late in the season. It produces a large amount of leafage which is fair to moderate forage for livestock. Forage value, relative to other grass species, is higher in the all than midsummer because it remains green after most of the other grasses have dried. Western needlegrass has a spreading and deep root system which increases its resilience to drought, trampling, and occasional heavy use (USFS 1937, Dyer and O'Beck 2006c).

Columbia needlegrass, also known as Nelson's needlegrass, palatability varies from fair to very good. Cattle and horses graze it a little more closely than do sheep, however it is typically not a preferred forage species. Columbia needlegrass exhibits higher resilience to grazing than many of the other preferred forage species. USFS (1937) states "this grass is among the last of the fairly good grasses to disappear from the range under serious overgrazing and is among the first to reappear with the improvement of badly depleted areas".

The Thurber's needlegrass component of this plant community is an important forage source for livestock and wildlife in the arid regions of the West (Ganskopp 1988). Although the seeds are apparently not injurious, grazing animals avoid them when they begin to mature. Domestic sheep, however, have been observed to graze the leaves closely, leaving stems untouched (Eckert and Spencer 1987). Heavy grazing during the growing season has been shown to reduce the basal area of Thurber's needlegrass (Eckert and Spencer 1987), suggesting that both seasonality and utilization are important factors in the management of this plant. A single defoliation, particularly during the boot stage, was found to reduce herbage production and root mass thus potentially lowering the competitive ability of this needlegrass (Ganskopp 1988).

Muttongrass, a minor component on this ecological site, is relatively grazing tolerant. It is palatable and nutritional forage for livestock and wildlife when it is in the early stages of growth. It is rated as excellent forage for cattle and horses, and good for domestic sheep, elk, and deer (USFS 1937). Muttongrass persists well in open areas and under canopies of oak and other shrubs (Monsen et al. 2004a).

State and Transition Model Narrative for Group 24:

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model (STM) for the MLRA 29 Disturbance Response Group 24. Note: Mahogany Thicket – R029XY027NV was not located or observed during fieldwork for this project. The MLRA 28B Mahogany Thicket (R028BY042NV) STM may be utilized for the MLRA 29 Mahogany Thicket.

Reference State 1.0:

The Reference State 1.0 is a representative of the natural range of variability under pristine conditions. The reference state has two general community phases; a tree-shrub dominant phase and a shrub dominant phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire, periodic long-term drought and/or insect attack. (This site has not been visited, so no pictures available)

Community Phase 1.1:
The reference plant community is dominated by curl-leaf mountain mahogany. Small disturbances that damage or kill individual trees open up areas in the canopy. Mountain big sagebrush and snowberry make up the shrub components of the understory. Needlegrasses, basin wildrye and muttongrass make up the perennial bunchgrasses. Forbs and other grasses are a small component of the understory. Singleleaf pinyon and Utah juniper are described in the site concept and may or may not be present. Total overstory canopy cover is less than 50%. Understory vegetation comprises approximately 50% of the total site production. Potential vegetation composition by air-dry weight is approximately 50% grasses, 10% forbs and 40% shrubs. Total annual production for all trees, shrubs, and herbaceous plants in the understory ranges from 600 to 1,300 lb/ac.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
Low-severity fire can reduce the mahogany overstory and allow for the understory species to dominate the site. Due to low fuel loads, fires will typically be low severity, resulting in a mosaic pattern. Heavy browsing by big game animals will also reduce the mahogany overstory.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.3:
Time and lack of disturbance such as fire allows the mountain mahogany to increase. The shrub and herbaceous understory components decline due to increased shading from the trees. Muttongrass and other shade-tolerant species increase.

Community Phase 1.2:
This community phase is characteristic of a post-disturbance, early-seral community. If resulting from fire, mahogany will be present in patches. Snowberry and rabbitbrush are sprouting or increasing in burned areas. Perennial bunchgrasses may dominate.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
Time and lack of disturbance such as fire allows the mountain mahogany to increase. The shrub and herbaceous understory components decline due to increased shading from the trees.

Community Phase 1.3:
Mahogany canopy cover increases in the absence of disturbance. Shrubs and deep-rooted perennial bunchgrasses are shaded out by the dense mahogany. Muttongrass is more shade tolerant, however, and is still found in the understory. Mountain big sagebrush is reduced or eliminated. Snowberry is the dominant shrub in the understory. Mahogany in dense stands will lose lower branches due to shading and/or herbivory, resulting in a more tree-like appearance. Singleleaf pinyon and Utah juniper are described in the site concept and may or may not be present.

Mahogany Savanna (R029XY043NV), Reference State 1.3, T. Stringham, June 2021

Mahogany Savanna (R029XY043NV), Reference State 1.3 At Risk of tree state T.Stringham, June 2021

Community Phase Pathway 1.3a:
Snow loading, low severity fire, or insect damage will decrease the overstory and allow for the shrubs and herbaceous plants in the understory to increase.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0:

Trigger: This transition is caused by the introduction of non-native annual plants, such as cheatgrass, mustards, and thistles.

Slow variables: Over time annual non-native species increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

T1B: Transition from Reference State 1.0 to Tree State 3.0:

Trigger: Time and lack of disturbance such as fire allows for pinyon and/or juniper trees to dominate.

Slow variables: Over time abundance and size of pinyon and/or juniper trees will increase.

Threshold: Pinyon pine and/or Utah juniper dominates ecological processes. Trees overtop and outcompete mountain mahogany and shrubs for water and sunlight. Shrub skeletons exceed live shrubs with minimal recruitment of new cohorts.

Current Potential State 2.0:

This state is similar to the Reference State 1.0. This state has the same three general community phases. Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of invasive weeds. These non-natives can be highly flammable, and can promote fire where historically fire had been infrequent. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal.

Community Phase 2.1:

This community phase is similar to the Reference State Community Phase 1.1, with the presence of non-native species in trace amounts. This community is dominated by curl-leaf mountain mahogany. Mountain big sagebrush and mountain snowberry make up the shrub components of the understory. Needlegrasses and muttongrass make up the perennial bunchgrasses. Forbs and other grasses are a small component of the understory. Utah juniper and singleleaf pinyon may be present.

Mahogany Savanna (R029XY043NV), Current Potential 2.1, T. Stringham, June 2021

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
Low-severity fire can reduce the mahogany overstory and allow for the understory species to dominate the site. Due to low fuel loads, fires will typically be low severity, resulting in a mosaic pattern. Non-native annual species present.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.3:
Time and lack of disturbance such as fire allows the mountain mahogany to increase. The shrub and herbaceous understory components decline due to increased shading from the trees. muttongrass and other shade-tolerant species increase.

Community Phase 2.2:
This community phase is characteristic of a post-disturbance, early-seral community. If resulting from fire, mahogany will be present in patches. Snowberry and rabbitbrush are sprouting or increasing in burned areas. Perennial bunchgrasses may dominate. Annual non-native species present.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Time and lack of disturbance such as fire allows the mountain mahogany to increase. The shrub and herbaceous understory components decline due to increased shading from the trees. Non-native species present.

Community Phase 2.3:
Curl-leaf mountain mahogany dominates the overstory. Mountain big sagebrush is reduced or eliminated. Snowberry and creeping barberry are the dominant shrubs in the understory. The understory of bluebunch wheatgrass and needlegrasses is reduced while the shade-tolerant muttongrass increases in the understory and may be the dominant grass on the site. Annual non-native species are stable to increasing. Bare ground may be increasing. Mahogany in dense stands will lose lower branches due to shading and/or herbivory, resulting in a more tree-like appearance. Singleleaf pinyon and Utah juniper may be present to increasing.


Mahogany Savanna (R029XY043NV), Current Potential 2.3 At Risk of Tree State, T. Stringham, June 2021


Mahogany Savanna (R029XY043NV), Current Potential 2.3. T. Stringham, June 2021

Community Phase Pathway 2.3a:

Snow loading, lightning, or insect damage will reduce the overstory and allow for the shrubs and herbaceous plants in the understory to increase. Fires may be likely following an unusually wet spring or a change in management favoring an increase in fine fuels. Annual non-native species generally respond well after fire and may be stable or increasing within the community

T2A: Transition from Current Potential State 2.0 to Tree State 3.0:

Trigger: Time and lack of disturbance such as fire allows for pinyon and juniper trees to dominate.

Slow variables: Over time abundance and size of pinyon and juniper will increase.

Threshold: Pinyon pine and Utah juniper dominate ecological processes. Trees overtop and outcompete mountain mahogany and shrubs for water and sunlight. Shrub skeletons exceed live shrubs with minimal recruitment of new cohorts.

Tree State 3.0:

This state is characterized by singleleaf pinyon and/or Utah juniper trees dominating site resources. Pinyon and/or juniper trees outcompete and overtop the mountain mahogany overstory. The understory is reduced due to shading and competition with tree overstory. This state may be compounded by grazing of livestock and wildlife further reducing perennial understory species. Annual non-native species may be increasing.

Community Phase 3.1:
Singleleaf pinyon and/or Utah juniper and mountain mahogany co-dominate the site. The understory of shrubs and grasses is nearly intact but shows signs of decadence and thinning (Miller et al. 2008b). Mountain big sagebrush and snowberry show signs of increased competition from tree canopy and are decreasing in the understory. Muttongrass increases with shading and may be the dominant bunchgrass in the understory. Annual non-native species are present and may be increasing.

Community Phase Pathway 3.1a:
Time and lack of disturbance allows for the maturation of pinyon pine and/or Utah juniper trees.

Community Phase 3.2:
Singleleaf pinyon pine and/or Utah juniper dominates the site. Trees dominate site resources and the understory is reduced (Miller et al. 2008b). Mountain mahogany is decadent and lacks recruitment. Muttongrass is present but reduced in density, found primarily under tree canopies. The shrub component of the understory is reduced, mountain big sagebrush skeletons may be present. Annual non-native species are present to increasing.

Restoration Pathway R3A:

Removal of pinyon and/or juniper from the site may allow mountain mahogany to reestablish and become dominant in the overstory (Abbott et al. 1991).

States Not Observed in Group 24:

Tree State: A Tree State was not observed for this group, however active singleleaf pinyon encroachment was observed. Without a tree removing or thinning disturbance, pinyon will dominate the site and eliminate or significantly reduce mahogany. A Tree State was added to the model to reflect this dynamic. In addition, this condition was observed in MLRA 28 (Stringham et al. 2015a).

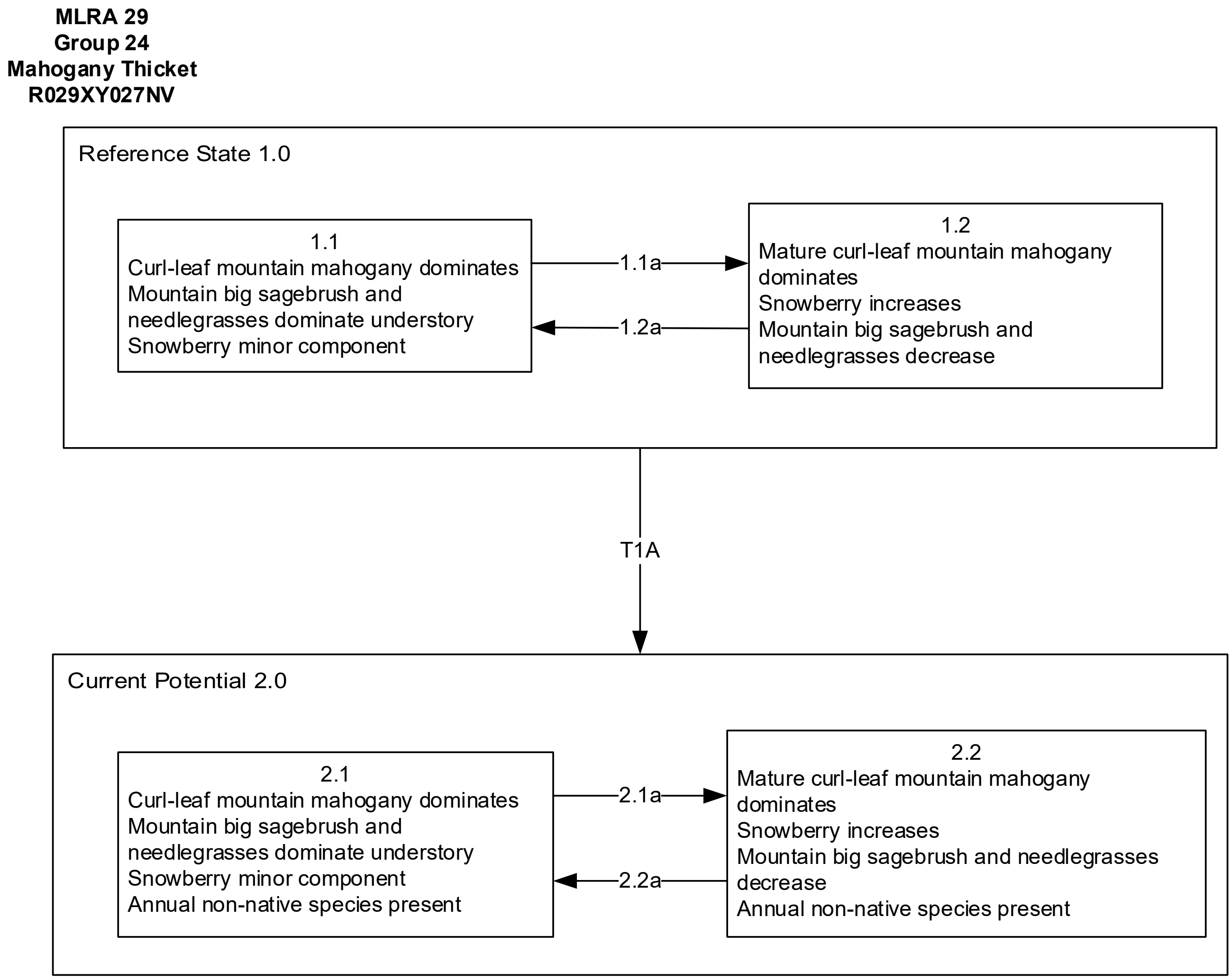
Annual State: An Annual State was not seen for this group, though such a state may be possible. An Annual State was found within another, similar, MLRA DRG: MLRA 28 Group 29AB (Stringham et al. 2015a).

Potential Resilience Differences with Other Ecological Sites in this Group:

Mahogany Thicket (R029XY027NV):

This site is less productive than the modal site. The dominant grasses on this site are needlegrasses such as Columbia needlegrass, western needlegrass, and Letterman's needlegrass. The site was not observed during fieldwork in MLRA 29. A similar site in MLRA 28A was observed to have two states: Reference and Current Potential.

Modal State and Transition Model for Group 24 in MLRA 29:



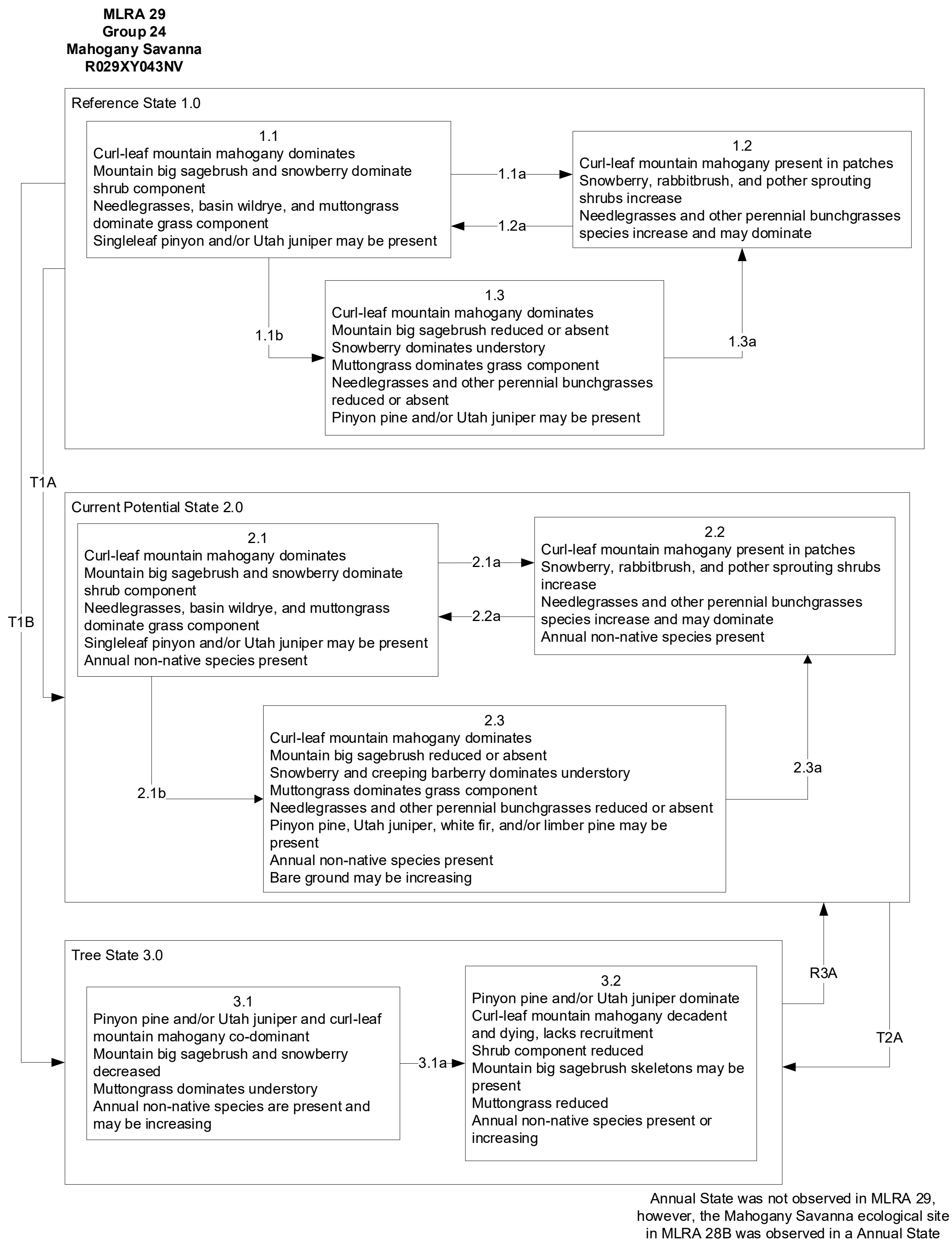
MLRA 29
Group 24
Mahogany Thicket
R029XY027NV

Reference State 1.0 Community Phase Pathways
1.1a: Time, lack of disturbance allows mountain mahogany to increase. The shrub and herbaceous understory decline.
1.2a: Snow loading, lightning, or insect damage will decrease mahogany overstory and allow the shrub and herbacous understory to increase.

Transition T1A: Introduction of non-native annual species.

Current Potential State 2.0 Community Pathways
2.1a: In the absence of disturbance, curl-leaf mountain mahogany matures and increases in canopy cover, reducing light availability and suppressing mountain big sagebrush and native grasses. Snowberry expands in the understory, while non-native annuals persist in open microsites.
2.2a: Reduction of mahogany canopy through disturbance (e.g., thinning or fire) can restore light and space, promoting the recovery of sagebrush and perennial grasses. This transition depends on the presence of a viable seed bank and effective management of invasive annuals.

Additional State and Transition Models for Group 24 in MLRA 29:



KEY
MLRA 29
Group 24
Mahogany Savanna
R029XY043NV

Reference State 1.0 Community Pathways
1.1a: Low severity fire creates mosaic pattern, reducing curl-leaf mountain mahogany cover and allowing understory species to dominate.
1.1b: Time and lack of disturbance such as fire, allows curl-leaf mountain mahogany to increase, reducing herbaceous understory. Muttongrass and other shade-tolerant species increase.
1.2a: Time and lack of disturbance such as fire, allows curl-leaf mountain mahogany to increase, reducing herbaceous understory.
1.3a: Low severity fire, snow loading, and/or insect damage will decrease the overstory and allow for the shrubs and herbaceous understory to increase.

Transition T1A: Introduction of non-native annual species.
Transition T1B: Time and lack of disturbance allows pinyon to increase and dominate.

Current Potential State 2.0 Community Pathways
2.1a: Low severity fire creates mosaic pattern, reducing curl-leaf mountain mahogany cover and allowing understory species to dominate. Non-native species present.
2.1b: Time and lack of disturbance such as fire, allows curl-leaf mountain mahogany to increase, reducing herbaceous understory. Muttongrass and other shade-tolerant species increase.
2.2a: Time and lack of disturbance such as fire, allows curl-leaf mountain mahogany to increase, reducing herbaceous understory. Non-native species present.
2.3a: Snow loading, lightning, and/or insect damage will decrease the overstory and allow for the shrubs and herbaceous understory to increase. Fire may be likely following change in management and/or unusually wet spring; annual non-natives will remain stable and may increase after fire.

Transition T2A: Time and lack of disturbance or fire suppression, allows pinyon to dominate.

Tree State 3.0 Community Pathways
3.1a: Time and lack of natural disturbance or fire suppression allows for maturation of the pinyon and/or Utah juniper community.

Restoration Pathway R3A: Removal of pinyon and/or Utah juniper from site will allow mountain mahogany to recover and dominate.

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<u>MLRA 29 Group 25: Loamy soils with spiny hopsage and cool-season grasses</u>

Description of MLRA 29 Disturbance Response Group 25

Disturbance Response Group (DRG) 25 consists of five ecological sites. These sites occur on piedmont slopes, summits and sideslopes of low hills, alluvial fans, and alluvial plains. Slopes range from 0 to 75%. Precipitation ranges from 5 to 8 in., and elevations range from 4,000 to 6,500 ft (1,220–1,830 m). The soils on these sites are typically shallow to deep and well drained. These soils are alluvium derived from volcanic rock sources and contain considerable amounts of gravel throughout the profile. Surface rock fragments protect the surface from erosion. Available water holding capacity is very low to moderate with slow to rapid runoff and moderately slow to moderately rapid permeability. The soil temperature regime is mesic and the soil moisture regime in typic aridic. Total annual production ranges from 200 to 700 lb/ac in a normal year. The reference plant communities are dominated by spiny hopsage (*Grayia spinosa*) and Indian ricegrass (*Achnatherum hymenoides*). Other important species include Nevada ephedra (*Ephedra nevadensis*), Anderson wolfberry (*Lycium andersonii*), spiny menodora (*Menodora spinescens*), galleta grass (*Pleuraphis jamesii*), and desert needlegrass (*Achnatherum speciosum*). Fourwing saltbush (*Atriplex canescens*), Joshua tree (*Yucca brevifolia*), winterfat (*Krascheninnikovia lanata*), and bud sagebrush (*Picrothamnus desertorum*) may also be present.

Disturbance Response Group 25 Ecological Sites:

Droughty Loam 5-8" P.Z. – Modal	R029XY079NV
Joshua Upland	R029XY007NV
Loamy Upland 5-8" P.Z.	R029XY016NV
Loamy Hill 5-8" P.Z.	R029XY021NV
Shallow Droughty Loam 5-8" P.Z.	R029XY031NV

Modal Site:

The Droughty Loam 5-8" P.Z. (R029XY079NV) ecological site is the modal site that represents this DRG. This site occurs on piedmont slopes with gradients of 2 to 15%. Precipitation ranges from 5 to 8 in., and elevations range from approximately 4,500 to 5,300 ft (1,370–1,615 m). The soils are typically moderately deep to deep and well drained. These soils are alluvium derived from volcanic rock sources and consist of loams and gravelly loams throughout the profile. Available water holding capacity is very low to moderate with slow runoff and moderately slow to moderately rapid permeability. The soil temperature regime is mesic and the soil moisture regime in typic aridic. Total annual production is approximately 700 lb/ac in a normal year. The reference plant community is dominated by spiny hopsage, Nevada ephedra, Indian ricegrass, and desert needlegrass. Potential vegetative composition (by air-dry weight) is about 45% grasses, 5% forbs and 50% shrubs.

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development, and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasives. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans a unique area in Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. Most of the annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area. Flashy, summer storm events contribute significantly to annual precipitation as well. Air and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

Periodic drought regularly influences these ecosystems, and drought duration, and severity has increased throughout the 20th century in much of the Intermountain West (Miller et al. 2008b). Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006).

The dominant bunchgrasses present on this site include Indian ricegrass, and desert needlegrass. These cool-season bunchgrasses have somewhat shallower root systems than the shrubs, but root densities are often as high or higher than those of shrubs in the upper 0.5 m (20 in.). Indian ricegrass, is a hardy, cool-season, densely tufted, long-lived perennial bunchgrass that grows from 4 to 24 in. (10–61 cm) in height (Blaisdell and Holmgren 1984). Primarily adapted to coarse-textured soils, its deep, fibrous root system makes Indian ricegrass one of the most drought-tolerant native species (Booth et al. 1980). Unlike other cool-season species, Indian ricegrass does not require vernalization (exposure to cold) to produce flowers and flowering can continue into late fall with favorable environmental conditions. This allows the seeds in each panicle to ripen over a longer period of time than most other species, thus providing a greater opportunity for successful seed production (Jones 1990). When properly planted and managed, Indian ricegrass can help recover disturbed areas by competing with invasive species and providing cover and forage (Booth et al. 1980). Indian ricegrass germination and establishment appears to occur in strong pulses, and the plant is known to prefer spring climactic conditions with early soil temperatures slightly higher than normal, yet lower than normal temperatures later in the growing season (Pearson 1979).

Desert needlegrass is a cool-season, perennial bunchgrass that grows 12 to 24 in. (30–61 cm) tall in large dense clumps (Sampson et al. 1951, Harrington 1954). It reproduces both sexually and asexually. This grass is pollinated by wind and is capable of producing large amounts of seeds (Sampson et al. 1951). Sexual reproduction is highly dependent on water availability; seed will not set if soil moisture is too low and air temperatures are too high (Bertiller et al. 1991). Vegetative reproduction occurs with the annual growth of new tillers (Evert 2006). Awns catch in animal fur, which may also disseminate seeds (Kearney et al. 1960).

Galleta is a mat-forming, rhizomatous, native grass that is 11 to 19 in. (28–48 cm) tall (Stubbendieck et al. 2003). This warm-season, perennial species is more water efficient than its cool-season counterparts. This allows galleta grass to survive in low precipitation zones where a significant portion of rainfall occurs during summer months (Banner et al. 2011). Everett et al. (1980) found that galleta grass initiated more than one phenological cycle with the presence of summer precipitation, allowing the species to grow and set seed more than once. This plant is typical of southern Nevada and the transition zone between the Great Basin and the Mojave Desert. It is most common in fine-textured soils (Stubbendieck et al. 2003).

Spiny hopsage is a rounded, summer-deciduous shrub standing 0.3 to 1.2 m (1–3 ft) tall that is widely distributed throughout the western United States. It is commonly associated with Wyoming big sagebrush, salt-desert shrub, pinyon-juniper, Mojave Desert, and Great Basin-Mojave Desert transition communities in elevations from 160 to 2,130 m (525 to 7,000 ft) (Shaw et al. 2008). Spiny hopsage typically grows in soils that are silty to sandy, neutral to strongly basic, and often high in calcium. It can provide soil stabilization on gentle to moderate slopes. The branches are divergent and thorn-tipped with whitish-gray to brownish bark that exfoliates in long strips. The leaves are alternate, entire, fleshly and gray-green in color. Spiny hopsage possesses prominent globose, gray-green overwintering leaf buds prior to summer leaf fall. The fruits mature in late spring to early summer (Shaw et al. 2008) Herbage, flower, and fruit production are dependent upon the availability of soil water and other environmental factors and vary widely among years, with drier years producing neither leaves nor flowers.

Nevada ephedra, or Nevada jointfir, can be commonly found in small clumps or large, independent stands in a variety of plant communities, including sagebrush, desert shrub, and pinyon-juniper communities (Stanton 1973). Nevada ephedra is a common plant species in

Nevada (West et al. 1998) and can be codominant with many species, including spiny menodora, winterfat, yellow rabbitbrush (*Chrysothamnus viscidiflorus*), bitterbrush (*Purshia* spp.), and others (Minnich 1999). Nevada ephedra primarily reproduces by seed (Welsh et al. 1987), but plants can produce clones in lateral roots in response to disturbances such as fire or herbicide (Hunter et al. 1978).

Fourwing saltbush is the most widely distributed and abundant saltbush in the southwest USA (Mozingo 1987c). It is a native, long-lived woody shrub that grows on a variety of landforms and soils from sand dunes, sand sheets, alluvial fans and plains, hills and mountains, and washes. It tolerates salinity but is not restricted to saline soils (Henrickson 1977). It is a polymorphic species and is evergreen or deciduous depending on climate (Ogle et al. 2012a). Fourwing saltbush has a long taproot of depths of 5 to 15 m (16 to 49 ft) and many small lateral roots (Van Dersal 1938, Barrow et al. 1997). It has been found that the roots compose 40% of the total mass of adult plants (Wallace et al. 1974). Fourwing saltbush is classified as a phreatophyte and has been documented at water tables occurring from 8 to 62 ft (2.4–19 m) in New Mexico (Meinzer 1927). *Atriplex* species are considered medium to short-lived shrubs and possess a number of morphological and physiological traits that enable them to cope with drought. Some of these traits include: a) photosynthesis through the C_4 carboxylation pathway; b) production of leaf trichomes (hair) and accumulation of salt crystals on the leaf surface to increase reflectance; c) accumulation and synthesis of inorganic and organic solutes to maintain turgor; and 4) root association with endomycorrhizae that allows absorption of soil moisture at very low water potentials (Newton and Goodin 1989, Dobrowolski et al. 1990, Cibils et al. 1998).

Anderson wolfberry is a drought-deciduous, spiny, rounded and many branched shrub typically found on sandy or gravelly ashes, sandy or alkali flats, mesas, and slopes from 1,500 to 6,000 ft (460–1,830 m) in elevation throughout the southwestern United States (Tesky 1992). It possesses an extensive, tough, and fibrous root system extending 25 to 30 ft from the plant and enabling it to reach depths of 1 to 9 ft (30–274 cm) (Tesky 1992). Wolfberry is characterized by its spiny light-barked twigs that harbor fleshy red berries and thick, fleshy, and flattened leaves. Germination either occurs late in the year following summer rains as a result of seed dispersal after ingestion by small mammals or through root sprouting from broken roots (Tesky 1992).

Spiny menodora is a dense, mounded shrub with forked branches that end in sharp thorns and grows about 3 ft tall. It is commonly found in dwarf shrublands of the Great Basin and Mojave Desert alongside Nevada ephedra, spiny hopsage, and other shrub species (Evens et al. 2020). Spiny menodora is typically found on rocky hills and dry washes in sparse plant communities (Sawyer and Keeler-Wolf 1995). It spreads through seed dispersal on the wind and by birds (Chumley 2007), but plants can sprout when top-killed by fire (Novak-Echenique 2020).

Joshua tree, a perennial tree-like succulent with dichotomous or pseudo-dichotomous branching (Lenz 2007). Joshua tree is a long-lived, slow growing species endemic to the Mojave Desert (Hickman 1993, Gilliland et al. 2006). Both the western Joshua tree (*Yucca brevifolia*) and

Jaeger's Joshua tree (*Yucca jaegeriana*) occur in MLRA 29. The species co-occur and hybridize in Tikaboo Valley, Lincoln County, Nevada (Sirchia et al. 2018). Joshua trees grow on hot, dry sites on upper piedmont slopes, alluvial flats, and low hills (Hickman 1993). They grow on well drained skeletal soils with sandy or loamy textures (Holland 1986, Brittingham 1998). Joshua tree establishes from seed or vegetatively by rhizomes. Most plants begin flowering and producing fruit when they reach 2 to 3 m tall (6.5–10 ft) (Sweet et al. 2019). Joshua tree seeds germinate in microhabitats under nurse plant canopies (Waitman et al. 2012).

The ecological sites in this DRG have moderate resilience to disturbance and resistance to invasion. Resilience increases with elevation, aspect, precipitation, and nutrient availability. Long-term disturbance responses may be influenced by slight differences in landscape topography. Concave areas receive run-in from adjacent landscapes and consequently retain more moisture to support the growth of deep-rooted perennial grasses, whereas convex areas are slightly less resilient and may have more shallow-rooted perennial grasses. North slopes are also more resilient than south slopes because lower soil surface temperatures operate to keep moisture content higher on northern exposures.

Annual Invasive Species:

The species most likely to invade these sites are cheatgrass (*Bromus tectorum*) and red brome (*Bromus rubens*). While red brome was not seen on this site during field work, it exists in close proximity to ecological sites in this group and is of regional concern. Both species are cool-season annual grasses that maintain an advantage over native plants in part because they are prolific seed producers, able to germinate in the autumn or spring, tolerant of grazing and increase with frequent fire (Klemmedson and Smith 1964, Miller 1999, USFS 2017b). Cheatgrass originated from Eurasia, and both were first reported in North America in the late 1800s (Furbush 1953, Mack and Pyke 1983). (Pellant and Hall 1994) found 3.3 million acres of public lands dominated by cheatgrass and suggested that another 76 million acres were susceptible to invasion by winter annuals including cheatgrass and red brome. By 2020, Smith et al. 2021, noted an eightfold increase in annual grass-dominated areas in the Great Basin equating to over 19 million acres (Smith et al. 2022). These grasses colonize interspaces between native perennial bunchgrasses and shrubs, increasing the amount and continuity of fine fuels (Davies et al. 2013). Consequently, annual grass-infested vegetation communities burn 2 to 4 times more frequently than relatively uninvaded communities (Balch et al. 2013, Davies et al. 2013), (Bradley et al. 2018). Post-fire reestablishment of native vegetation often proves exceedingly challenging due in part to pre-emptive resource use by early-germinating annual grasses (Melgoza et al. 1990, Eliason and Allen 1997, Davies et al. 2010). This cycle of invasion, fire and exclusion of native competitors can cause recipient communities to cross a threshold into an undesirable state of dominance by exotic annual grasses (Smith et al. 2022).

Methods to control red brome and cheatgrass include herbicide, fire, grazing, and seeding of primarily non-native wheatgrasses. Spraying with herbicide (imazapic or imazapic + glyphosate) and seeding with perennial grasses has been found to be more successful at combating red brome and cheatgrass than spraying alone (Sheley et al. 2012) . Where native bunchgrasses are missing from the site, revegetation of annual grass invaded rangelands has been shown to have a higher likelihood of success when using introduced perennial bunchgrasses such as crested wheatgrass (Davies et al. 2015b). Butler et al. (2011) tested four herbicides (imazapic, imazapic + glyphosate, rimsulfuron and sulfometuron + chlorsulfuron) only treatments for suppression of cheatgrass, medusahead and ventenata (North Africa grass, *Ventenata dubia*) within residual stands of native bunchgrass. Additionally, they tested the same four herbicides followed by seeding of six bunchgrasses (native and non-native) with varying success (Butler et al. 2011). Herbicide only treatments appeared to remove competition for established bluebunch wheatgrass by providing 100% control of ventenata and medusahead and greater than 95% control of cheatgrass (Butler et al. 2011), however caution in using these results is advised, as only 1 year of data was reported. Prescribed fire has also been utilized in combination with the application of pre-emergent herbicide to control medusahead and cheatgrass (Vollmer and Vollmer 2008). Mature medusahead or cheatgrass is very flammable, and fire can be used to remove the thatch layer, consume standing vegetation, and even reduce seed levels. Furbush (1953) reported that timing a burn while the seeds were in the milk stage effectively reduced medusahead the following year. He further reported that adjacent unburned areas became a seed source for reinvasion the following year (Furbush 1953). Although these results are relevant for cheatgrass and medusahead, effectiveness on red brome is unknown.

Fire Ecology:

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species' response. Thus, fire mortality is correlated to duration and intensity of heat, which is related to culm density, culm-leaf morphology, size of plant, and abundance of old growth (Wright 1971, Young 1983). Boyd et al 2015 (Boyd et al. 2015) found soil color and depth of burn to be accurate predictors of bunchgrass mortality in post-fire landscapes. For most forbs and grasses, the growing points are located at or below the soil surface providing relative protection from disturbances which decrease above ground biomass, such as grazing or fire. They also found that bunchgrasses in close proximity of shrubs had up to five-fold higher mortality than bunchgrasses located in the interspaces.

Indian ricegrass, a prominent grass in this DRG, is fairly fire tolerant (Wright 1985), which is likely due to its low culm density and below ground plant crowns. Several studies in the sagebrush zone that classified Indian ricegrass as being slightly damaged from late summer burning (Vallentine 1989). Indian ricegrass has also been found to reestablish on burned sites through seed dispersed from adjacent unburned areas (Young 1983, West 1994). Thus, the presence of surviving, seed producing plants facilitates the reestablishment of Indian ricegrass. Grazing management following fire to promote seed production and establishment of seedlings is important. When properly planted and managed, Indian ricegrass can be a key factor in a community recovering from disturbance because it can grow in rough, rocky, coarse, and otherwise unattractive soils (Booth et al. 1980).

Desert needlegrass has persistent dead leaf bases, making this species susceptible to burning. Fire removes this accumulation, and a rapid, cool fire will not result in death of the plants (Humphrey 1984). Field observations indicate that desert needlegrass survives and increases after most wildfires.

Nevada ephedra vigorously sprouts after fire from extensive woody crowns (Young and Evans 1978, Koniak 1985). Sprouting after fire may vary by season of burn and fire severity. Spiny hopsage is a sprouting shrub (Daubenmire 1970) that is fairly tolerant of fire due to its dormancy during the summer months (Rickard and McShane 1984). After fire, these sprouting shrubs can produce significant new growth if there is enough soil moisture available (Shaw 1992). Re-establishment from seed is determined by environmental conditions such as soil temperature and moisture conditions (Monsen et al. 2004a). Seedlings do not compete well with annual invasives (Monsen et al. 2004a).

Galleta grass has been found to increase following fire due to its rhizomatous root structure and ability to re-sprout (Jameson 1962). This sod-forming grass species may retard reestablishment of deeper-rooted bunchgrasses

Fourwing saltbush's ability to sprout following fire may depend on the population and fire severity. One study showed a 58% mortality rate of fourwing saltbush following fire in New Mexico, the surviving shrubs produced sprouts shortly after fire (Parmenter 2008). While fourwing saltbush is able to sprout after fire, it primarily reestablishes from seed (Stutz 1979, Wasser 1982).

Like many long-lived desert perennials, Anderson wolfberry is not strongly adapted to fire. Wolfberry's ability to sprout after a fire depends on the fire's severity; with high-severity fire reducing most plants to ash with very high levels of mortality while moderate or low severity fires allowing intermittent sprouting to occur after disturbance (Tesky 1992). However, it may take many years to reach pre-burn densities on disturbed sites (Tesky 1992).

Spiny menodora is tolerant to fire due to its morphology and sprouting ability. Plant communities dominated by spiny menodora are typically sparse, and individual plants are widely spaced (Sawyer and Keeler-Wolf 1995). In addition, the dense, woody branches of spiny menodora do not burn easily, and if the plant is top-killed by fire, it readily sprouts (Moody et al. 2010). These characteristics make spiny menodora tolerant of fire, and it is likely to dominate the site after low-severity fire.

Joshua trees are often killed or top-killed by fire and stand mortality is often over 70% (St. Clair et al. 2022). Persistent, dead leaves along the trunks can allow flames from surface fires to spread into their crowns which often kills them (Emming 2005). Young trees are more often killed than older plants (DeFalco et al. 2010). Surviving Joshua trees may sprout from the root crown (Borchert 2022), rhizomes, or canopy (Loik et al. 2000).

Livestock/Wildlife Grazing Interpretations:

The salt-desert shrub community is typically regarded as a browse-specific plant community. It is characterized by low productivity, which requires substantial acreage for grazing animals—about 1.5 to 3 acre per sheep per month and 10 to 20 acres per cow. Within this vegetation type, it is acknowledged that 65 to 90% of the available forage is browse (Costello 1944).

Spiny hopsage is palatable to livestock, especially sheep, during the spring and early summer (Phillips et al. 1996, Simmons 2003). However, the shrub goes to seed and loses its leaves in July and August so its usefulness in the fall and winter is limited (Sanderson and Stutz 1994). Two studies showed little to no utilization by sheep during the winter (Green et al. 1951, Harrison 1970). Some scientists are concerned about the longevity of the species. One study showed no change in cover or density when excluded from livestock and wildlife grazing for 10+ years (Rice and Westoby 1978), while another seldom observed seedling establishment (Daubenmire 1970). With poor recruitment rates, some are concerned that with repeated fires and excessive grazing, local populations of spiny hopsage may be lost (Simmons 2003). Spiny hopsage provides cover for birds and other small animals; spring and early summer forage for big game and livestock (Shaw et al. 2008).

Nevada ephedra is grazed by livestock and wildlife year-round. Its relative abundance in winter makes it very valuable forage when the production of other shrubs is decreased, and cattle, sheep, goats, and mule deer consume large amounts of ephedra in the winter (Dayton 1931). When new growth is available in spring and summer, ephedra is browsed by mule deer, bighorn sheep, and pronghorn (Beale and Smith 1970). Nevada ephedra provides cover for pronghorn, small mammals, and both game and nongame birds (Dittberner and Olson 1983). Small mammals and birds eat Nevada ephedra seeds (Meyer 2008b).

Fourwing saltbush is a dioecious plant, though nutrient levels have been shown not to significantly vary between male, female, and labile plants (Tiedemann et al. 1984). Differences were found seasonally, in the spring, when males tended to have higher levels of chlorophyll and nonstructural carbohydrate levels. Generally, the plant has appeared moderately or not affected by spring and fall or early summer utilization. Moderate utilization (60% defoliation of the current year growth) during rapid growth, seed set, and quiescence tended to stimulate twig growth. High intensity utilization however (≥ 90% defoliation of current year growth) at high frequency (4 or more times) could cause plant mortality (Buwai and Trlica 1977).

Anderson wolfberry plays a minor role as a browse species due to its fair to low palatability, resulting in being used as forage by livestock and feral burros, only when more desirable species are unavailable (Tesky 1992). Its red berries provide a small percentage of the diet for some birds and small mammals that it uses for seed distribution (Tesky 1992).

Yellow rabbitbrush is a native, perennial shrub that grows between 12 to 48 in. (30–122 cm) tall. It has a moderately deep taproot and is a vigorous seed producer. It reproduces via sprouting and seeds (Tilley and St. John 2012b). Rabbitbrush is not palatable and increases in areas where chronic, inappropriate grazing management of domestic livestock and/or feral horses or burros occurs (Tilley and St. John 2012b). Although the species is not palatable to livestock, it may see limited use by wildlife such as mule deer, pronghorn, jackrabbits, and other wildlife, especially in winter months (Tilley and St. John 2012b).

Indian ricegrass is a preferred forage species for livestock and wildlife and cures well, providing nutritious winter feed (Cook 1962, Booth et al. 1980). It is also readily utilized in early spring, being a source of green feed before most other perennial grasses have produced new growth (Quinones 1981). (Booth et al. 1980) note that the plant does well when utilized in winter and spring. In eastern Idaho, productivity of Indian ricegrass was at least 10 times greater in undisturbed plots than in heavily (60% utilization) grazed ones (Pearson 1965). Cook and Child 1971 found significant reduction in crown cover, plant vigor, and herbage yield of Indian ricegrass when the species was utilized at 90% during any season (Cook and Child 1971). However, they found no reductions at 30% utilization during any season and no reductions at 60% utilization during winter and early spring grazing (Cook and Child 1971). The seed crop may be reduced where grazing is heavy (Bich et al. 1995). Tolerance to grazing increases after May, thus spring deferment may be necessary for stand enhancement (Pearson 1964, Cook and Child 1971); however, utilization of less than 60% is recommended. In summary, adaptive management is required to manage this bunchgrass well.

Desert needlegrass response to grazing has not been well researched. The USDA, Natural Resource Conservation Service, Plant Fact Sheet, for this species indicates the grass is palatable to all classes of livestock, especially when young. However, after maturity palatability declines due to the prominent, sharp callus. Sheep generally avoid desert needlegrass after maturity while horses and cattle may use it moderately (NRCS 2008).

Galleta is a palatable forage species for cattle, sheep, deer (Odocoileus spp.), antelope (*Antilocapra americana*), and horses (*Equus ferus*) during late spring and summer while it is green (Stubbendieck et al. 2017). Due to its rhizomatous characteristics, galleta grass is particularly tolerant of heavy grazing and trampling (Pratt et al. 2002). This species will also initiate more than one phenological cycle if summer precipitation is present (Everett et al. 1980), allowing galleta to grow and propagate after defoliation.

Inappropriate grazing management during the growing season will cause a decline in understory plants such as Indian ricegrass and desert needlegrass. Chronic growing season grazing by livestock and/or feral horses and burros will cause a decrease in the bunchgrass component and give a competitive advantage to shrub species and galleta (Eckert et al. 1972).

State and Transition Model Narrative for Group 25:

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model (STM) for the MLRA 29 disturbance response group 25.

Reference State 1.0:

The Reference State 1.0 is a representative of the natural range of variability under pristine conditions. The reference state has three general community phases; a shrub-grass dominant phase, a grass-sprouting shrub phase, and a shrub dominant phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contributes to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire, periodic long-term drought, and/or insect attack.

Community Phase 1.1:
The reference plant community is dominated by spiny hopsage and Indian ricegrass and desert needlegrass are sub-dominant. Nevada ephedra, fourwing saltbush, winterfat, and bud sagebrush are common. Potential vegetative composition by air-dry weight is approximately 45% grasses, 5% forbs and 50% shrubs. Approximate ground cover (basal and crown) is 20 to 30%. Total annual air-dry production ranges from 450 to 900 lb/ac.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
Low severity fire creates grass/shrub mosaic which leads to an increase in dominance of perennial bunchgrasses and sprouting shrubs.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.3:
Time and lack of disturbance such as fire. Excessive herbivory or prolonged drought may also decrease perennial understory. Drought reduces herbaceous vigor and seed production, allowing shrubs to gain a competitive edge.

Community Phase 1.2:
Indian ricegrass, desert needlegrass, and other perennial bunchgrasses dominate. Shrubs may be present or sprouting while forbs may begin to increase.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
Time and lack of disturbance (fire, drought) and favorable moisture allow for shrub recruitment.

Community Phase 1.3:
Spiny hopsage and Nevada ephedra dominate site while perennial bunchgrasses are reduced.

Community Phase Pathway 1.3a:
Low severity fire and or reduced grazing pressure leads to an increase in perennial grasses.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0:

Trigger: This transition is caused by the introduction of non-native annual plants, such as cheatgrass, red brome, Russian thistle (*Salsola tragus*) and mustards.

Slow variables: Over time, the annual non-native species will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

This state is similar to the Reference State 1.0. This state has the same three general community phases. Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of invasive weeds. These non-native species can be highly flammable and can promote fire where historically fire had been infrequent. Negative feedbacks enhance ecosystem resilience and contributes to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-native species' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal.

Community Phase 2.1:
Spiny hopsage is codominant with Indian ricegrass and desert needlegrass. Nevada ephedra, fourwing saltbush, winterfat, and bud sagebrush are common. Annual non-natives are present in the understory.

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
Low severity fire that creates grass/shrub mosaic or managed herbivory.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.3
Time and lack of disturbance such as fire. Inappropriate grazing management and/or prolonged drought may also reduce perennial understory.

Community Phase 2.2:
Indian ricegrass, desert needlegrass and other perennial bunchgrasses dominate. Shrubs may be sprouting, and annual non-native species and forbs may increase.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Time and lack of disturbance and favorable moisture conditions allow for shrub regeneration.

Community Phase 2.3 (At-risk):
Spiny hopsage and Anderson wolfberry dominate. Perennial grasses are reduced. Yellow rabbitbrush, galleta, and other less palatable bunchgrasses may be increasing. Annual non-native species may also increase.

Loamy Upland 5-8" P.Z. (R029XY016NV), Current Potential 2.3, T. Stringham, June 2020

Community Phase Pathway 2.3a:
A low severity fire, reduced grazing pressure and/or restoration techniques like reseedings and shrub management.

T2A: Transition from Current Potential State 2.0 to Shrub State 3.0:

Trigger: Inappropriate grazing management will decrease or eliminate deep-rooted perennial bunchgrasses and favor shrub growth and establishment. Prolonged drought may also reduce deep-rooted perennial bunchgrasses.

Slow variables: Long-term decrease in deep-rooted perennial bunchgrasses density.

Threshold: Loss of deep-rooted perennial bunchgrasses changes nutrient cycling, nutrient redistribution, and reduces soil organic matter. Competition between deep-rooted perennial bunchgrasses and non-native annual species is also altered.

T2B: Transition from Current Potential State 2.0 to Annual State 4.0:

Trigger: Long-term inappropriate grazing management including wild horse and burro use. An unusually wet spring may also facilitate the increased germination and production of non-native annual species leading to their dominance within the community.

Slow variables: Increased production and cover of non-native annual species.

Threshold: Loss of deep-rooted perennial bunchgrasses and shrubs truncates, spatially and temporally, nutrient capture and cycling within the community.

Shrub State 3.0

This State is characterized by the dominance of shrubs, a reduced grass understory, and increased bare ground. This state has two community phases. This state has crossed a biotic threshold where deep-rooted perennial bunchgrasses have been removed from the system, and site resources are being controlled by shrubs. Shrub cover exceeds the site concept and may be decadent, reflecting stand maturity and lack of seedling establishment due to competition with mature plants. The shrub overstory dominates site resources such that soil water, nutrient capture, nutrient cycling and soil organic matter are temporally and spatially redistributed. Runoff and bare ground have increased.

Community Phase 3.1:
Spiny hopsage, Nevada ephedra and other shrubs dominate, reducing deep-rooted perennial bunchgrasses to a minor component. Galleta is common. Annual non-native species present and may be increasing. Wind erosion and soil crusting may increase. Soil pedestalling and redistribution indicate loss of stabilizing vegetation.

Droughty Loam 5-8" P.Z. (R029XY079NV), Shrub State 3.1, T. Stringham, May 2020

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:
Fire, brush management (i.e. mowing) with minimal soil disturbance, inappropriate grazing management, or prolonged drought.

Community Phase 3.2 (At Risk):
Sprouting shrubs, such as rabbitbrush dominate, reducing perennial bunchgrasses to a minor component. Galleta may be increasing. Annual non-native species may be increasing.

Loamy Upland 5-8" P.Z. (R029XY016NV), Shrub State 3.2, T. Stringham, May 2020

Community Phase Pathway 3.2a, from Phase 3.2 to 3.1:
Time and lack of disturbance and appropriate grazing management and several years of favorable precipitation may allow spiny hopsage and/or ephedra and some deep-rooted perennial grasses to reestablish.

T3A: Transition from Shrub State 3.0 to Annual State 4.0:

Increased disturbances such as catastrophic fire, soil disturbing treatments, extended drought, and/or increased grazing pressure.

Annual State 4.0

This state was not observed during field work but these sites have the potential to convert to an Annual State because of the presence of cheatgrass and red brome.

This state has two community phases, one dominated by non-native annual species, and one dominated by non-sprouting and sprouting shrubs and non-native annuals. In this state, a biotic threshold has been crossed, and state dynamics are driven by the dominance and persistence of the non-native annual species. Cheatgrass, red brome, Russian thistle, and/or tumble mustard (*Sisymbrium altissimum*) dominate the plant community. Bare ground may be common, and native vegetation is reduced in cover and density.

Community Phase 4.1:
Annual non-native species dominate the site with native perennial bunchgrasses present in lesser quantities. Sprouting shrubs may be present. Seeded species may be present.

Community Phase Pathway 4.1a, from Phase 4.1 to 4.2:
Time and lower frequency of disturbances like grazing or fire and/or failed restoration efforts.

Community Phase 4.2:
Annual non-native species dominate the site. Sprouting shrubs, rabbitbrush, Nevada ephedra, spiny hopsage increasing. Seeded species may be present.

Community Phase Pathway 4.2a, from Phase 4.2 to 4.1:
Fire, soil disturbance, or inappropriate grazing management, including wild horses and burros.

Potential Resilience Differences with Other Ecological Sites in this Group:

Loamy Hill 5-8" P.Z. (R029XY021NV):

This site occurs on summits and sideslopes of low hills on slopes typically from 30 to 50%. The soils are shallow to a hardpan or bedrock. The reference plant community is dominated by spiny hopsage, Anderson wolfberry and Indian ricegrass. Other important species on this site are Nevada dalea (*Psorothamnus polydenius*) and galleta. Potential vegetative composition (by air-dry weight) is approximately 40% grasses, 5% forbs and 55% shrubs. Annual air-dry production ranges from 100 to 300 lb/ac. This site may be a burned phase of the Loamy Slope 5-8" P.Z. ecological site (R029XY022NV) which is dominated by shadscale (*Atriplex confertifolia*). This site has similar resilience as the modal and has the same ecological states. An Annual State was not observed.

Loamy Upland 5-8" P.Z. (R029XY016NV):

This site occurs on piedmont slopes, alluvial fans and alluvial plains on slopes from 0 to 30%. The soils are moderately deep to deep and well drained. The reference plant community is dominated by spiny hopsage, Nevada ephedra and Indian ricegrass. Other important species are fourwing saltbush and galleta. Potential vegetative composition (by air-dry weight) is approximately 45% grasses, 5% forbs and 50% shrubs. Annual air-dry production ranges from

500 to 1,000 lb/ac. This site may be a burned phase of the Loamy Slope 5-8" P.Z. ecological site (R029XY022NV) which is dominated by shadscale (*Atriplex confertifolia*). This site has similar resilience as the modal and has the same ecological states. An Annual State was not observed.

Shallow Droughty Loam 5-8" P.Z. (R029XY031NV):

This site occurs on lower piedmont slopes on slopes typically from 2 to 15%. The soils are shallow to moderately deep and well drained. The reference plant community is dominated by spiny hopsage, spiny menodora and Indian ricegrass. Other important species are Nevada ephedra and galleta. Potential vegetative composition (by air-dry weight) is approximately 35% grasses, 5% forbs and 60% shrubs. Annual air-dry production ranges from 300 to 700 lb/ac. This site may be a burned phase of the Shallow Sandy Loam 5-8" P.Z. ecological site (R029XY080NV). This site has similar resilience as the modal and has the same ecological states. An Annual State was not observed.

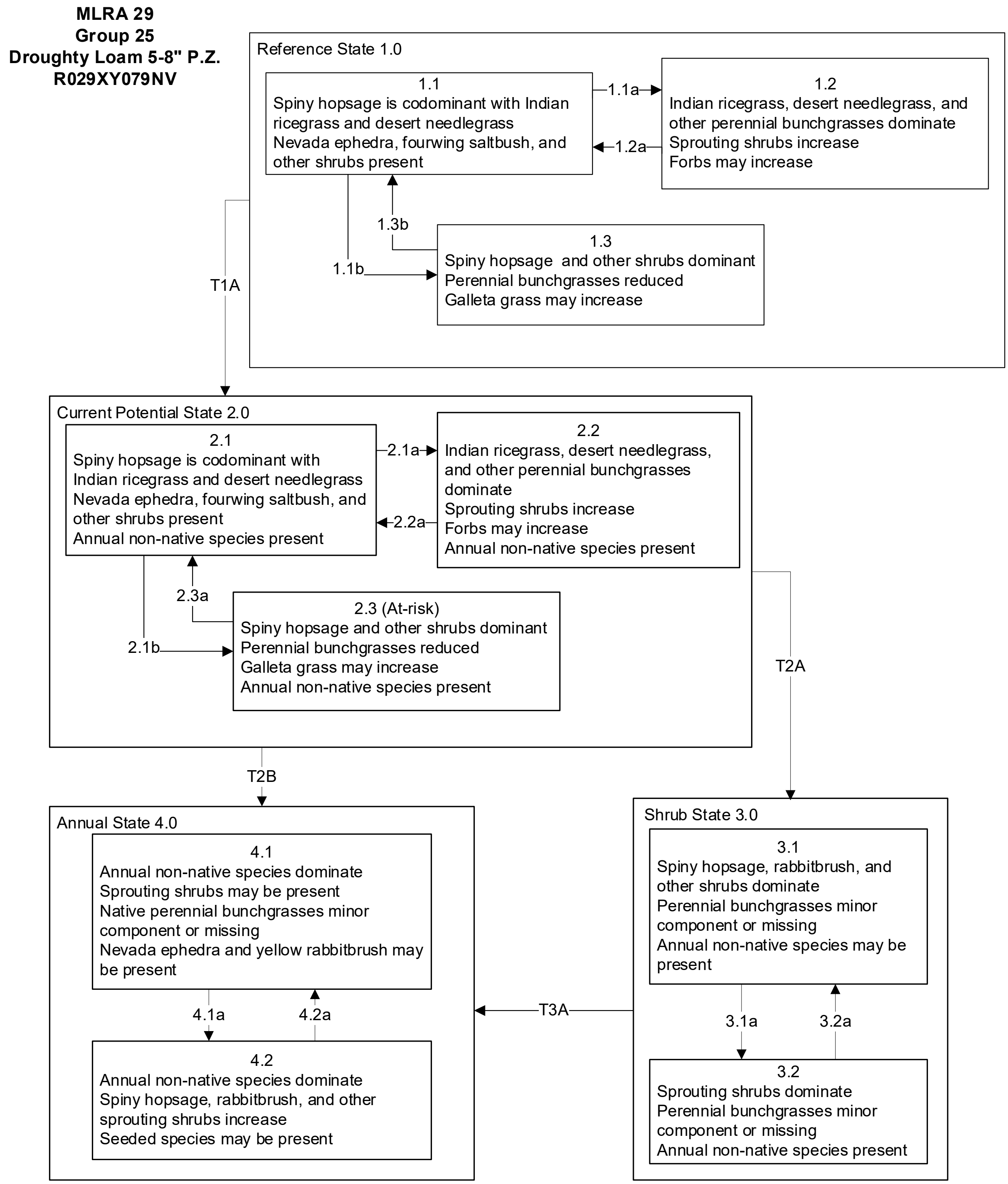
Shallow Droughty Loam 5-8" P.Z. (R029XY031NV), Shrub State, T. Stringham, April 2023

Joshua Upland (R029XY007NV):

This site occurs on upper piedmont slopes, rock pediments and hills on slopes typically from 2 to 30%. The soils are shallow to moderately deep and well drained. The reference plant community is dominated by Joshua tree, spiny hopsage, Nevada ephedra, fourwing saltbush and Indian ricegrass. Other important species are Anderson wolfberry, bud sagebrush and galleta. Potential vegetative composition (by air-dry weight) is approximately 40% grasses, 5% forbs and 55% shrubs and trees. Annual air-dry production ranges from 300 to 800 lb/ac. This site has similar resilience as the modal and has the same ecological states. An Annual State was not observed.

Joshua Upland (R029XY007NV), Shrub State, T. Stringham, June 2021

Modal State and Transition Model for Group 25 in MLRA 29:



MLRA 29
Group 25
Droughty Loam 5-8" P.Z.
R029XY079NV

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire creates grass/shrub mosaic or targeted shrub grazing
1.1b:Time and lack of disturbance such as fire. Excessive herbivory or drought may also decrease perennial understory.
1.2a:Time and lack of disturbance like reduced fire frequency allows for shrub regeneration.
1.3a: Low Severity fire, reduced grazing pressure and/or restoration techniques like reseedings and shrub management

Transition T1A: Introduction of non-native species.

Current Potential State 2.0 Community Phase Pathways
2.1a:Low severity fire that creates grass/shrub mosaic or managed herbivory; non-native annual species present
2.1b: Time and lack of disturbance such as fire. Inappropriate grazing management and/or drought may also reduce perennial understory.
2.2a:Time and lack of disturbance like reduced fire frequency allows for shrub regeneration.
2.3a:Low Severity fire, reduced grazing pressure and/or restoration techniques like reseedings and shrub management

Transition T2A:Inappropriate grazing management and/or drought favoring shrub dominance and reducing perennial bunchgrasses
Transition T2B:Increased disturbance such as high severity/high frequency fire or drought

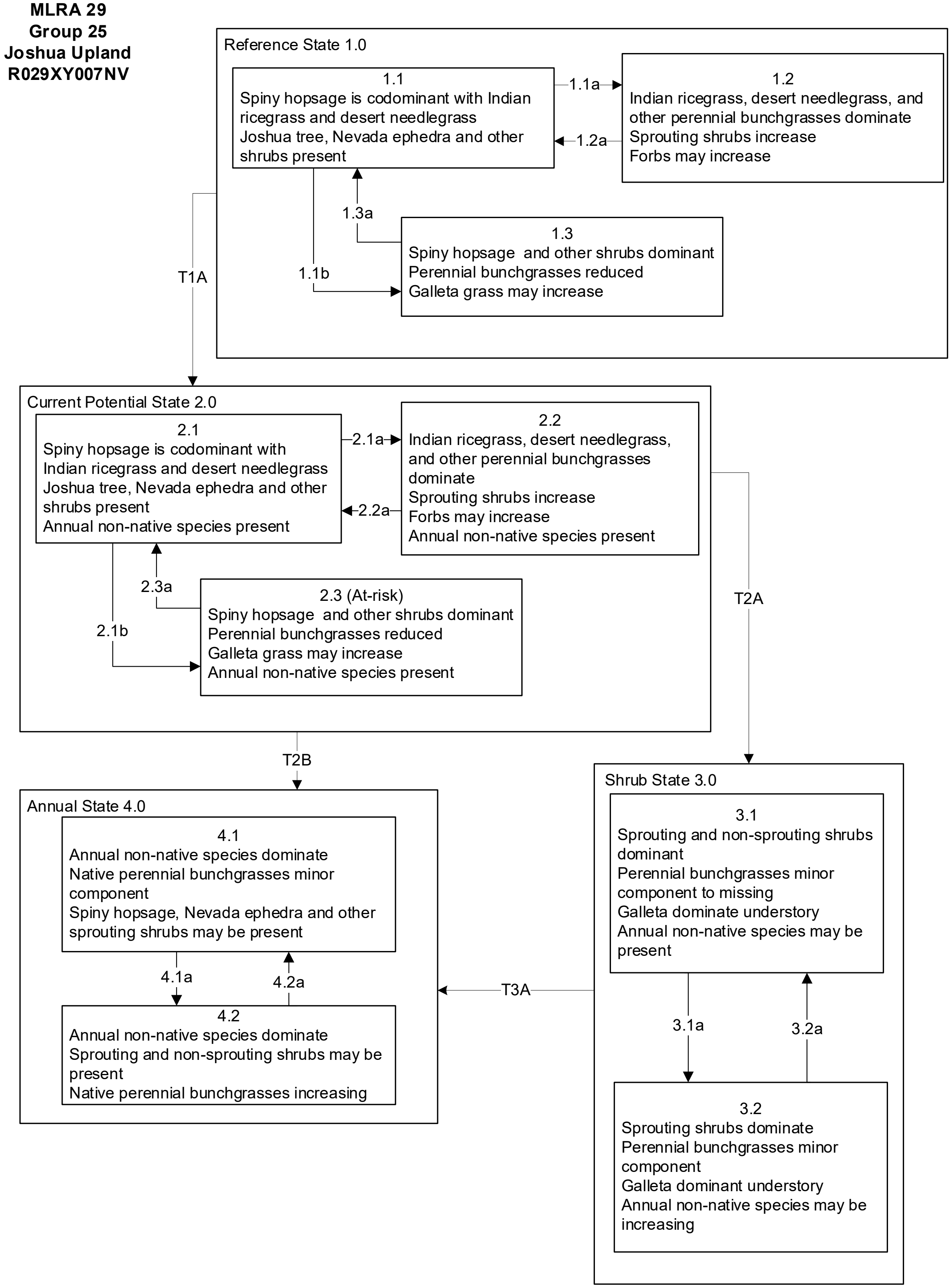
Shrub State 3.0 Community Phase Pathways
3.1a:Fire or brush management with minimal soil disturbance or prolonged drought
3.2a: Time and lack of disturbance: adjusting grazing practices

Transition T3A: Increased disturbance such as catastrophic fire, brush management (soil disturbing), extended drought and/or increased grazing pressure.

Annual State 4.0 Community Phase Pathways
4.1a:Time and lower frequency of disturbances like grazing or fire and/or active restoration efforts.
4.2a:Fire, soil disturbance or inappropriate grazing management

Annual State 4.0 – This state was not observed during field work but these sites have the potential to convert to an Annual State because of the presence of cheatgrass and red brome.

Additional State and Transition Models for Group 25 in MLRA 29:



MLRA 29
Group 25
Joshua Upland
R029XY007NV

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire creates grass/shrub mosaic or targeted shrub grazing.
1.1b: Time and lack of disturbance such as fire. Excessive herbivory or drought may also decrease perennial understory.
1.2a: Time and lack of disturbance like reduced fire frequency allows for shrub regeneration.
1.3a: Low Severity fire, reduced grazing pressure and/or restoration techniques like reseedings and shrub management.

Transition T1A: Introduction of non-native species.

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire that creates grass/shrub mosaic or managed herbivory; non-native annual species present.
2.1b: Time and lack of disturbance such as fire. Inappropriate grazing management and/or drought may also reduce perennial understory.
2.2a: Time and lack of disturbance like reduced fire frequency allows for shrub regeneration.
2.3a: Low Severity fire, reduced grazing pressure and/or restoration techniques like reseedings and shrub management.

Transition T2A: Inappropriate grazing management and/or drought favoring shrub dominance and reducing perennial bunchgrasses.
Transition T2B: Increased disturbance such as high severity/high frequency fire or drought.

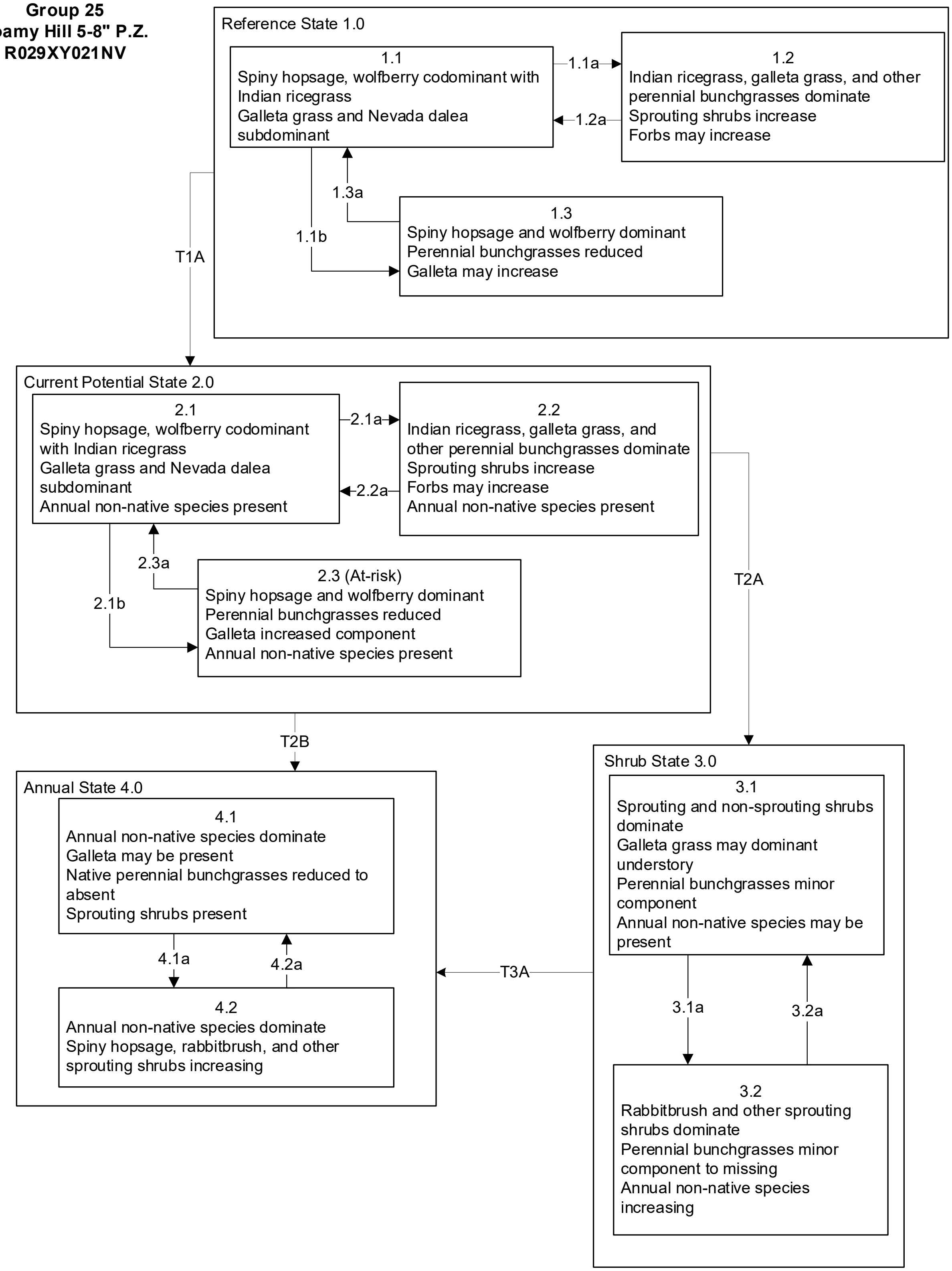
Shrub State 3.0 Community Phase Pathways
3.1a: Fire or brush management with minimal soil disturbance or prolonged drought.
3.2a: Time and lack of disturbance: adjusting grazing practices.

Transition T3A: Increased disturbance such as catastrophic fire, brush management (soil disturbing), extended drought and/or increased grazing pressure.

Annual State 4.0 Community Phase Pathways
4.1a: Time and lower frequency of disturbances like grazing or fire and/or active restoration efforts.
4.2a: Fire, soil disturbance or inappropriate grazing management.

NOTE: Annual State was not observed during field work but these sites have the potential to convert to an Annual State Because of the presence of cheatgrass and red brome.

MLRA 29
Group 25
Loamy Hill 5-8" P.Z.
R029XY021NV



MLRA 29
Group 25
Loamy Hill 5-8" P.Z.
R029XY021NV

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire creates grass/shrub mosaic or targeted shrub grazing.
1.1b:Time and lack of disturbance such as fire. Excessive herbivory or drought may also decrease perennial understory.
1.2a:Time and lack of disturbance like reduced fire frequency allows for shrub regeneration.
1.3a: Low Severity fire, reduced grazing pressure and/or restoration techniques like reseedings and shrub management.

Transition T1A: Introduction of non-native species.

Current Potential State 2.0 Community Phase Pathways
2.1a:Low severity fire that creates grass/shrub mosaic or managed herbivory; non-native annual species present.
2.1b: Time and lack of disturbance such as fire. Inappropriate grazing management and/or drought may also reduce perennial understory.
2.2a:Time and lack of disturbance like reduced fire frequency allows for shrub regeneration.
2.3a:Low Severity fire, reduced grazing pressure and/or restoration techniques like reseedings and shrub management.

Transition T2A:Inappropriate grazing management and/or drought favoring shrub dominance and reducing perennial bunchgrasses.
Transition T2B:Increased disturbance such as high severity/high frequency fire or drought.

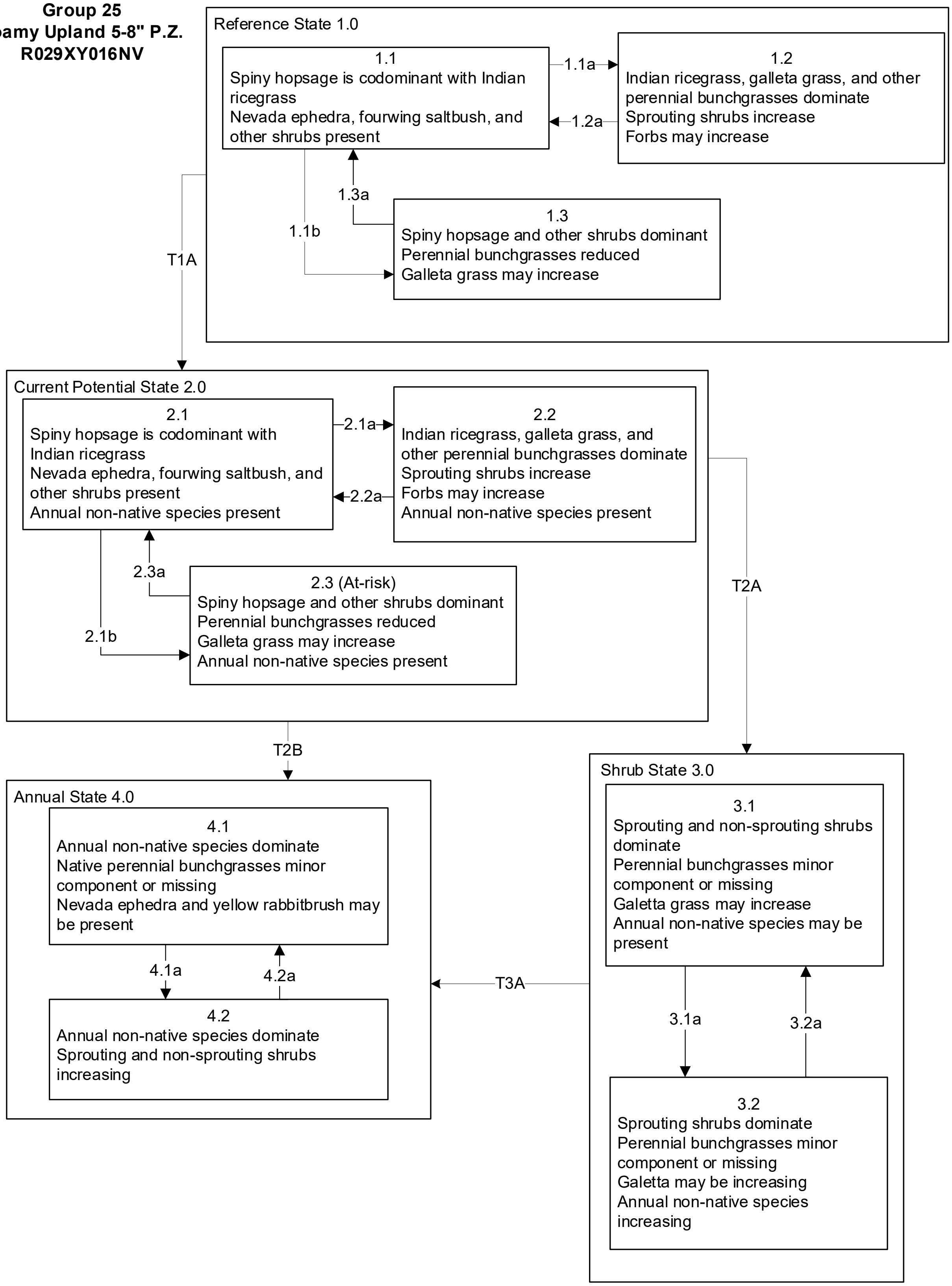
Shrub State 3.0 Community Phase Pathways
3.1a:Fire or brush management with minimal soil disturbance or prolonged drought.
3.2a: Time and lack of disturbance: adjusting grazing practices.

Transition T3A: Increased disturbance such as catastrophic fire, brush management (soil disturbing), extended drought and/or increased grazing pressure.

Annual State 4.0 Community Phase Pathways
4.1a:Time and lower frequency of disturbances like grazing or fire and/or active restoration efforts.
4.2a:Fire, soil disturbance or inappropriate grazing management.

Annual State 4.0 – This state was not observed during field work but these sites have the potential to convert to an Annual State because of the presence of cheatgrass and red brome.

MLRA 29
Group 25
Loamy Upland 5-8" P.Z.
R029XY016NV



MLRA 29
Group 25
Loamy Upland 5-8" P.Z.
R029XY016NV

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire creates grass/shrub mosaic or targeted shrub grazing.
1.1b:Time and lack of disturbance such as fire. Excessive herbivory or drought may also decrease perennial understory.
1.2a:Time and lack of disturbance like reduced fire frequency allows for shrub regeneration.
1.3a: Low Severity fire, reduced grazing pressure and/or restoration techniques like reseedings and shrub management.

Transition T1A: Introduction of non-native species.

Current Potential State 2.0 Community Phase Pathways
2.1a:Low severity fire that creates grass/shrub mosaic or managed herbivory; non-native annual species present.
2.1b: Time and lack of disturbance such as fire. Inappropriate grazing management and/or drought may also reduce perennial understory.
2.2a:Time and lack of disturbance like reduced fire frequency allows for shrub regeneration.
2.3a:Low Severity fire, reduced grazing pressure and/or restoration techniques like reseedings and shrub management.

Transition T2A:Inappropriate grazing management and/or drought favoring shrub dominance and reducing perennial bunchgrasses.
Transition T2B:Increased disturbance such as high severity/high frequency fire or drought.

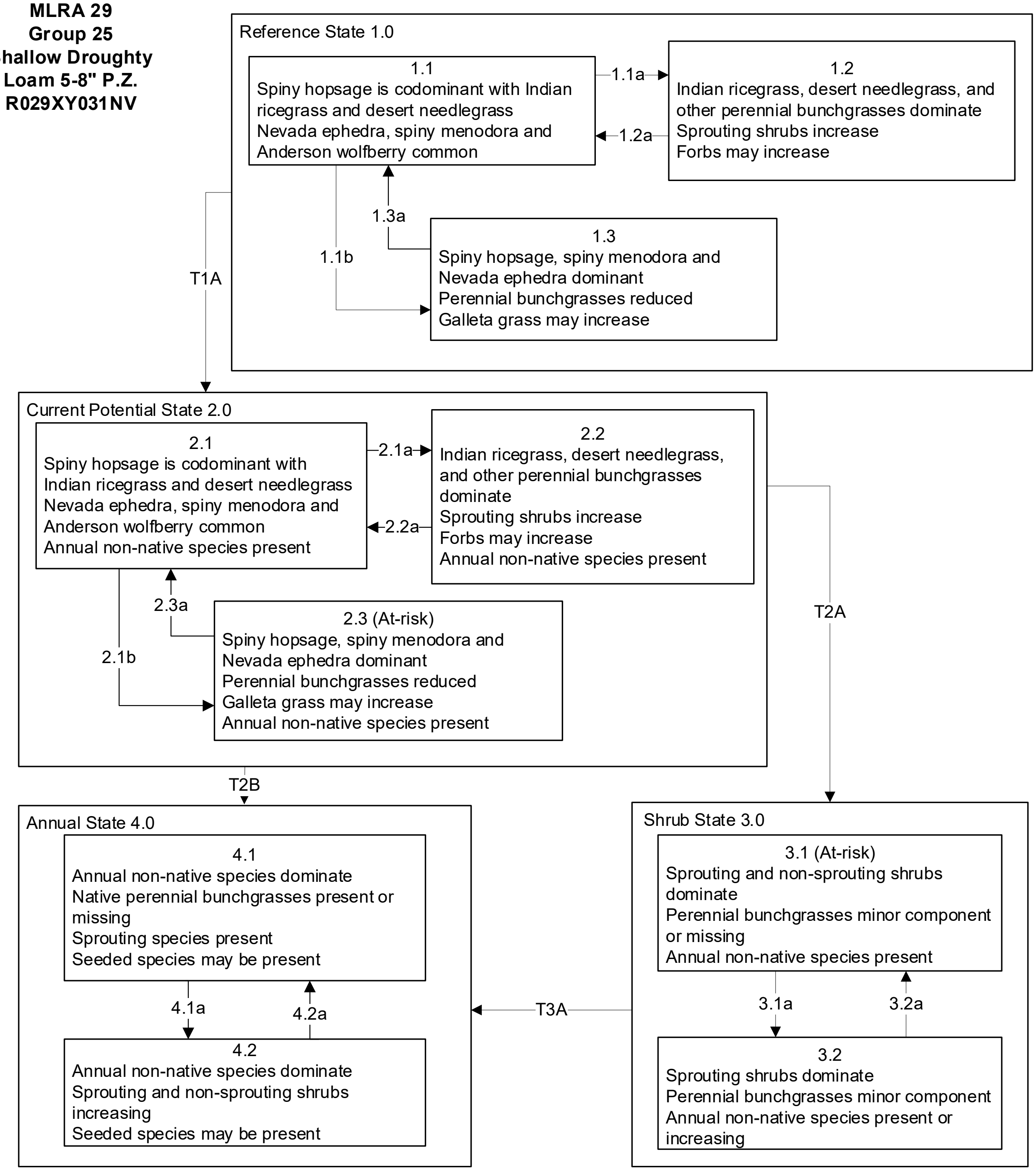
Shrub State 3.0 Community Phase Pathways
3.1a:Fire or brush management with minimal soil disturbance or prolonged drought.
3.2a: Time and lack of disturbance: adjusting grazing practices.

Transition T3A: Increased disturbance such as catastrophic fire, brush management (soil disturbing), extended drought and/or increased grazing pressure.

Annual State 4.0 Community Phase Pathways
4.1a:Time and lower frequency of disturbances like grazing or fire and/or active restoration efforts.
4.2a:Fire, soil disturbance or inappropriate grazing management.

Annual State 4.0 – This state was not observed during field work but these sites have the potential to convert to an Annual State because of the presence of cheatgrass and red brome.

MLRA 29
Group 25
Shallow Droughty
Loam 5-8" P.Z.
R029XY031NV



MLRA 29
Group 25
Shallow Droughty
Loam 5-8" P.Z.
R029XY031NV

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire, insect attack or drought creates grass/shrub mosaic.
1.1b:Time and lack of disturbance such as fire. Excessive herbivory or drought may also decrease perennial understory.
1.2a:Time and lack of disturbance like reduced fire frequency allows for shrub regeneration.
1.3a: Low severity fire, reduced grazing pressure and/or restoration techniques like reseedings and shrub management.

Transition T1A: Introduction of non-native species.

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire that creates grass/shrub mosaic or managed herbivory; non-native annual species present.
2.1b: Time and lack of disturbance such as fire. Inappropriate grazing management and/or drought may also reduce perennial understory.
2.2a:Time and lack of disturbance like reduced fire frequency allows for shrub regeneration.
2.3a: Low severity fire, reduced grazing pressure and/or restoration techniques like reseedings and shrub management.

Transition T2A:Inappropriate grazing management and/or drought favoring shrub dominance and reducing perennial bunchgrasses.
Transition T2B:Increased disturbance such as high severity/high frequency fire or drought.

Shrub State 3.0 Community Phase Pathways
3.1a:Fire or brush management with minimal soil disturbance or prolonged drought.
3.2a: Time and lack of disturbance and/or adjusted grazing practices.

Transition T3A: Increased disturbance such as catastrophic fire, brush management (soil disturbing), extended drought and/or increased grazing pressure.

Annual State 4.0 Community Phase Pathways
4.1a:Time and lower frequency of disturbances like grazing or fire and/or active restoration efforts.
4.2a: Fire, soil disturbance or inappropriate grazing management.

Annual State 4.0 – This state was not observed during field work but these sites have the potential to convert to an Annual State because of the presence of cheatgrass and red brome.

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<u>MLRA 29 Group 26: Shallow soils with blackbrush and cool-season grasses</u>

Description of MLRA 29 Disturbance Response Group 26

Disturbance Response Group (DRG) 26 consists of three ecological sites. The precipitation zone for these sites ranges from 5 to 10 in. (12–25 cm). Precipitation occurs primarily as snow and rain from October through April. Scattered summer convention storms occur from July through September but precipitation is rarely heavy enough to penetrate the soil to more than a few inches below the plant canopies. The elevation range for this group is approximately 3,600 to 6,300 ft (1,097–1,920 m). Slopes range from 15 to 40%. The soils on these sites are medium to coarse textured and are typically shallow to a restrictive layer. Available water holding capacity is low with a high volume of rock fragments which help to increase infiltration but reduces water holding capacity. The reference plant communities are dominated by an overstory of blackbrush (*Coleogyne ramosissima*) and an understory of desert needlegrass (*Achnatherum speciosum*) and/or Indian ricegrass (*Achnatherum hymenoides*). Other common shrubs include Nevada ephedra (*Ephedra nevadensis*), spiny hopsage (*Grayia spinosa)*, fourwing saltbush (*Atriplex canescens*) and desert bitterbrush (*Purshia glandulosa*). Warm-season grasses are also common and include galleta (*Pleuraphis jamesii),* threeawn (*Aristida purpurea*) and low woollygrass (*Dasyochloa pulchella*). Average annual production for a normal year ranges from 250 to 500 lb/ac.

Disturbance Response Group 26 Ecological Sites:

Shallow Gravelly Slope 8-10" P.Z. – Modal	R029XY019NV
Shallow Gravelly Loam 8-10" P.Z.	R029XY077NV
Shallow Gravelly Loam 5-8" P.Z.	R029XY013NV

Modal Site:

The Shallow Gravelly Slope 8-10" P.Z. (R029XY019NV) ecological site is the modal site for this group as it has the most acres mapped. This site occurs on fan remnants and sideslopes of hills and mountains on all exposures. Slopes range from 15 to 40%. Elevations range from approximately 3,000 to 6,300 ft (914–1,920 m). Mean annual precipitation is from 7 to 10 in. (18–25 cm). The soils on this site are typically shallow to a sub-surface duripan that limits root development within 20 in. (51 cm) of the soil surface. Surface soils are medium textured with gravels. The soils are well drained and infiltration and runoff are slow to medium. Available water capacity is low to moderate. The reference plant community is dominated by blackbrush, desert needlegrass, and Indian ricegrass. Nevada ephedra, fourwing saltbush, spiny hopsage (*Grayia spinosa*), and galleta are also common on this site. Average annual production ranges from 200 to 500 lb/ac.

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasives. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans a unique area in Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area. Flashy, summer storm events contribute significantly to annual precipitation as well. Air and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

The ecological sites in this DRG are dominated by a relatively high cover of blackbrush, a woody evergreen shrub. The blackbrush vegetation type occurs at the transitional zone between the Great Basin and Mojave deserts, from California, through Nevada, Arizona, Utah and southwestern Colorado (Bowns 1973) from elevations of approximately 3,500 to 6,500 ft (1,067–1,981 m). Blackbrush mixes with creosotebush (*Larrea tridentata*) and Joshua tree (*Yucca* spp.) at lower elevations and big sagebrush (*Artemisia tridentata*) and/or pinyon and Utah juniper (*Pinus* spp./*Juniperus occidentalis*) at the upper elevations (Brooks and Matchett 2001). Blackbrush is an exceptionally slow growing, long-lived shrub, is densely branched, and reaches heights of 1 to 2 m tall (3 to 6.5 ft) (Bowns 1973, Pendleton 2008).

Periodic drought regularly influences blackbrush communities and drought duration and severity has increased throughout the 20th century in much of the Intermountain West. Major shifts away from historic precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability with the soil profile (Bates et al. 2006). Considerable shrub growth can be made following a wet winter and spring, and during drought blackbrush frequently dies back by forming intercalary cork and isolating portions of the stem into separate vesicular traces. This is the main cause of the multi-stemmed nature of blackbrush (West 1983).

Blackbrush is a relatively long-lived shrub (100+ years) therefore, it is not necessary for individuals to recruit every year for perpetuation of the stand (Kitchen et al. 2015). Increasing in cover and density, this shrub becomes more dominant over time. Blackbrush is a mast-seeding plant that may go five or more years between significant seed crops. Flower and fruit production are highly variable from year to year (Beatley 1974). Seeds are gathered and cached by heteromyid rodents (Bowns and West 1976, Augur 2005). Germination requires wet, rainy or snowy conditions during the late winter (Pendleton et al. 1995). Survival of the seedlings is dependent on adequate summer moisture conditions and resistance to rodent predation (Meyer and Pendleton 2005). Seeds and seedlings are very palatable to heteromyid rodents and therefore, successful recruitment is primarily limited to periods following 1) a mast-seed crop when some of the cached seed may escape predation, and 2) 2 years of above-average precipitation (Bowns and West 1976, Augur 2005).

Soil organic matter, nitrogen and phosphorus are reportedly higher under blackbrush plants than in interspaces (Romney et al. 1973, Bowns and West 1976). Romney et al 1973 (Romney et al. 1973) attributed the increase in nitrogen to symbiotic nitrogen fixation within the shrub rhizosphere. Biological soil crusts, common in blackbrush communities, are the primary source of nitrogen in many arid ecosystems (Evans and Ehleringer 1993).

Nevada ephedra is a dioecious sprouting shrub. Male individuals tend to be found on steep hillsides, and female plants are sometimes found occupying concave sites where conditions may be more favorable to successful cone production (Freeman et al. 1976). Ephedra does not compete well with cheatgrass, and may exhibit reduced shoot growth when growing in areas dominated by cheatgrass (Pendleton et al. 2007).

The dominant cool-season perennial bunchgrasses in this group are desert needlegrass and Indian ricegrass. These species generally have shallower root systems than most shrubs, however, the majority of blackbrush roots occur at depths of 4 to 12 in. (10–30 cm) (Bowns 1973). The rooting pattern of blackbrush enables the plant to extract water more efficiently from shallow and sandy soils than from deep soil, thus competing directly with perennial grasses and forbs (Lei and Walker 1997).

Common warm-season grasses on these sites include purple threeawn and galleta. Purple threeawn is a relatively short-lived, warm-season, perennial bunchgrass with densely tufted culms averaging 30 to 60 in. (76–152 cm) tall. The plant prefers dry, coarse textured soils, and is an aggressive increaser on denuded rangelands (USFS 1937). Evans and Tisdale (1972), found purple threeawn to be a prolific seed producer, with highly viable seeds well adapted to wind and animal dispersal.

Galleta is a mat-forming, rhizomatous, native grass that is 11 to 19 in. (28–48 cm) tall (Stubbendieck et al. 2017). This warm-season, perennial species is more water efficient than its cool-season counterparts. This allows galleta grass to survive in low precipitation zones where a significant portion of rainfall occurs during summer months (Banner et al. 2011). Everett et al. (1980) found that galleta grass initiated more than one phenological cycle with the presence of summer precipitation, allowing the species to grow and set seed more than once. This plant is typical of southern Nevada and the transition zone between the Great Basin and the Mojave Desert. It is most common on fine-textured soils (Stubbendieck et al. 2017).

The ecological sites in this DRG have low resilience to disturbance and resistance to invasion. Increased resilience increases with elevation, aspect, increased precipitation and increased nutrient availability. Three possible alternative stable states along with the reference state have been identified for this DRG.

Annual Invasive Species:

Research on biological invasions indicates that the following factors can be correlated with the establishment and persistence of non-native plants: disturbance, connectivity to other invaded sites, disruption of ecological processes or regimes, and fluctuating resource levels ((Hobbs and Huenneke 1992, Maron and Connors 1996, Lonsdale 1999, Larson et al. 2001). Disturbance can decrease resource uptake due to damage or mortality of the native species and depressed competition or can increase resource pools by the decomposition of dead plant material following disturbance.

The species most likely to invade these sites are red brome (*Bromus rubens*) and cheatgrass (*B. tectorum*). Both species were introduced from the Mediterranean region. Red brome has been present in the Mojave Desert since the early 1900s, but appears to have increased in dominance since the 1970s (Hunter 1991). Cheatgrass was first reported in North America in the late 1800s (Furbush 1953, Mack and Pyke 1983). Both species have increased in desert plant communities coincident with increased human disturbance and a period of increased rainfall that predominated after the mid-century drought (Brown and Minnich 1986, Hunter 1991). Both species are cool-season annual grasses that maintain an advantage over native plants in part because they are prolific seed producers, able to germinate in the autumn or spring, tolerant of grazing and increase with frequent fire (Klemmedson and Smith 1964, Miller 1999). Where their productivity is high, these species can alter fuel loadings, fire behavior, and fire regimes, creating an invasive plant/fire regime cycle (Brooks et al. 2004, Brooks 2008).

Fire Ecology:

Natural fire return intervals of blackbrush communities appear to be on the order of centuries and long intervals without fire allowed late seral blackbrush stands to reestablish (Webb et al. 1987). Shrub cover was likely comprised of blackbrush at 30 to 50% total cover and there were low amounts of fine fuels in the interspaces due to root competition from blackbrush (Brooks et al. 2007). The low amounts of fine fuels in interspaces probably limited fire spread and only under extreme fire weather conditions (high winds, low relative humidity, low fuel moisture) did stand-replacing crown fires occur (Brooks et al. 2007). Recovery often occurred within several decades (Brooks and Matchett 2006, Brooks et al. 2016). Extensive burning of blackbrush stands from the 1940s to 1960s to improve livestock production mostly resulted in less desirable vegetation (Bowns and West 1976).

Response to fire is unpredictable and can vary depending on the climatic conditions at the time of fire, dynamic soil properties as well as varying land uses pre- and post-fire (Bowns and West 1976). Current knowledge indicates that the return of blackbrush may take many years. Succeeding communities after fire are variable and burn areas are usually dominated by native and non-native annual and perennial forb species the first few years following fire. Non-native invasive grasses, red brome and cheatgrass, are now present in most blackbrush stands which create fine fuels following years of high rainfall (Brooks and Matchett 2001, Brooks and Matchett 2006). The introduction of these non-native grasses is the greatest threat to the blackbrush community and large areas of the blackbrush community have burned since the 1990s, although primarily in the Mojave Desert. Natural recovery is very slow and the resulting vegetation then becomes dominated primarily by red brome, cheatgrass and other non-native annuals (Brooks and Matchett 2006).

Blackbrush is not fire-adapted and is typically killed however, when only a portion of a blackbrush plant is burned it may survive and resprout from the root crown (Brooks et al. 2007). Individual fires can kill the majority of seeds of all species in the seedbank and there are a few reports of seedling establishment after fire (Lei 1999a, Brooks et al. 2013b). If a fire occurs during the summer after seeds are cached, seeds may survive and germinate in the spring (Zitzer 2009). Most studies report that blackbrush does not reestablish after fire (Bowns 1973, Lei 1999b), however a recent study of two 2008 fires in Lincoln County, Nevada, report that blackbrush is reestablishing on these burned areas following several wet years (Gentilcore 2023). These fires were relatively small and surrounded by a dense stand of blackbrush which provided a potential seed source.

Several sprouting shrubs respond after fire and become dominant as a mid-seral community phase. Ephedra vigorously sprouts after fire from extensive woody crowns (Voth 1934, Young and Evans 1978, Koniak 1985). Spiny hopsage is a sprouting shrub (Simmons 2003) that is fairly tolerant of fire due its dormancy during the summer months (Rickard and McShane 1984). After fire, these sprouting shrubs can produce significant new growth if there is enough moisture available (Shaw 1992). Fourwing saltbush's ability to sprout following fire may depend on the population and fire severity. A study by Parmenter (2008) showed 58% mortality rate of fourwing saltbush following fire in New Mexico, the surviving shrubs produced sprouts shortly after fire. While fourwing saltbush is able to resprout after fire, it primarily reestablishes from seed (Stutz 1979, Wasser 1982, Howard 2003b). Anderson wolfberry (*Lycium andersonii*) has the ability to sprout from the root crown following disturbance but it may take several years to reach pre-burn densities (Tesky 1992).

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The initial condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species response. The perennial grasses are mostly top-killed by fire. With excessive litter buildup around the base, some plants will be killed by fire. For most forbs and grasses the growing points are located at or below the soil surface providing relative protection from disturbances which decrease above ground biomass, such as grazing or fire. Thus, fire mortality is more correlated to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant and abundance of old growth (Wright 1971, Young 1983).

Indian ricegrass is fairly fire tolerant, which is likely due to its low culm density and below-ground root crowns (Wright 1985). Vallentine (1989) cites several studies in the sagebrush zone that classified Indian ricegrass as being slightly damaged from late summer burning. Indian ricegrass has also been found to reestablish on burned sites through seed dispersed from adjacent unburned areas (Young 1983, West 1994). Thus, the presence of surviving, seed producing plants facilitates the reestablishment of Indian ricegrass. Grazing management following fire to promote seed production and establishment of seedlings is important.

Desert needlegrass has persistent dead leaf bases making this species susceptible to burning. Fire removes this accumulation and a rapid, cool fire will not result in death of the plants (Humphrey 1984). Field observations indicate that desert needlegrass survives and increases after most wildfires.

Purple threeawn has been found to increase, post-fire, on rangelands in poor condition prior to fire. Additionally, spring grazing after fire likely will favor purple threeawn over the cool-season bunchgrasses (Evans and Tisdale 1972). Purple threeawn basal area and tiller production is damaged by fire during the summer season, however mortality was found to be 10% or less. Fall burning appeared to have little detrimental effect (Strong et al. 2013). Purple threeawn depends upon seed for reproduction and the seeds, with three long, distinct awns, are well adapted for dissemination by animals and wind.

Galleta grass has been found to increase following fire likely due to its rhizomatous root structure and ability to resprout (Jameson 1962). This sod-forming grass species may retard reestablishment of deeper-rooted bunchgrasses.

Biological soil crusts, common in blackbrush communities, are negatively affected by fire. Callison et al. (1985) found little recovery of crust formation on blackbrush burned sites in southwestern Utah 19 years after fire.

Wildlife/Livestock Grazing Interpretations:

Blackbrush is considered poor forage for livestock, thus the reason for prescribed burns conducted by BLM in southern Nevada from the 1940s to the 1960s (Brooks et al. 2013a). Blackbrush is used as winter forage by bighorn sheep and mule deer (Bowns and West 1976). Blackbrush provides cover for upland game birds, nongame birds and small mammals (Pendleton et al. 2015).

Green ephedra is used as winter forage by wild ungulates and livestock (Jameson 1962, Kufeld et al. 1973). Keeler (1989) found green ephedra to be toxic to cattle and sheep, but not to calves and lambs. Ephedra is an important component of bighorn sheep diets in the eastern Sierra Nevada (McCullough and Schneegas 1966). Upland game birds, nongame birds and small mammals prefer the seeds of Nevada ephedra.

Fourwing saltbush is one of the most important forage shrubs in arid sites. Its importance is due to its abundance, accessibility, size, large volume of forage, evergreen habitat, high palatability, and nutritive value (USFS 1937, Van Epps 1975). The palatability rates range from fairly good to good for cattle, and is good for sheep *(Ovis aries)* and goats *(Capra hircus)*. Deer *(Odocoileus spp.)* usually consume it as a winter browse (USFS 1937). It has similar protein, fat, and carbohydrate levels as alfalfa (*Medicago sativa*) (Catlin 1925). Fourwing saltbush is especially valuable as winter forage. It was noted in a study by Otsyina et al. (1982) that sheep readily grazed fourwing saltbush when introduced into a new pasture.

Indian ricegrass is a preferred forage species for livestock and wildlife (USFS 1937, Cook 1962). This species is often heavily utilized in winter because it cures well (Quinones 1981). It is also readily utilized in early spring, being a source of green feed before most other perennial grasses have produced new growth (Quinones 1981). Cook and Child (1971) however, found that repeated heavy grazing reduced crown cover, which may reduce seed production, density, and basal area of these plants. Additionally, heavy early spring grazing reduces plant vigor and stand density (Stubbendieck et al. 1985). In eastern Idaho, productivity of Indian ricegrass was at least 10 times greater in undisturbed plots than in heavily grazed ones (Pearson 1965). Cook and Child (1971) found significant reduction in plant cover after 7 years of rest from heavy (90%) and moderate (60%) spring use. The seed crop may be reduced where grazing is heavy (Bich et al. 1995). Tolerance to grazing increases after May, thus spring deferment may be necessary for stand enhancement (Pearson 1964, Cook and Child 1971); however, utilization of less than 60% is recommended. Upland game birds, nongame birds and small mammals prefer the seeds of Indian ricegrass (Hafenrichter et al. 1968).

Desert needlegrass is palatable to all classes of livestock when young, however, after maturity it is avoided by sheep and moderately used by horses and cattle. The seed of desert needlegrass has a prominent, sharp callus that can injure the eyes and mouths of grazing animals, therefore grazing prior to seed set is typical. The plant tolerates light grazing in the growing season, however excessive use may reduce or eliminate desert needlegrass from the area (NRCS 2008).

Purple threeawn is not a preferred forage species and readily increases on poorly managed rangelands. Evans and Tisdale (1972) found the rate of root elongation to be three times greater than crested wheatgrass, indicating *Aristida* seedlings are well adapted for establishment on areas where soil moisture is depleted early in the growing season. Furthermore, *Aristida* begins growth much later in the growing season than cool-season bunchgrasses providing the plant protection from early growing season herbivory (Evans and Tisdale 1972). It is known to spread quickly into disturbed areas and its dominance may be indicative of poor grazing management (Brown and Archer 1989).

Galleta is a highly palatable forage species for cattle, sheep, deer *(Odocoileus spp.)*, antelope *(Antilocapra americana)*, and horses *(Equus ferus)* during late spring and summer while it is green (Stubbendieck et al. 2017). Due to its rhizomatous characteristics, galleta grass is particularly tolerant of heavy grazing and trampling (Pratt et al. 2002). This species will also initiate more than one phenological cycle if summer precipitation is present, allowing galleta to grow and propagate after defoliation (Everett et al. 1980). With inappropriate grazing of deep-rooted perennial grasses, galleta will increase but with further site degradation this grass will also decrease.

State and Transition Model Narrative for Group 26:

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 29 Disturbance Response Group 26.

Reference State 1.0:

The Reference State 1.0 is a representative of the natural range of variability under pristine conditions. The reference state has three general community phases: a shrub dominant phase, a forb and perennial grass phase and a sprouting shrub/perennial grass phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire and periodic drought.

Community Phase 1.1:
Blackbrush, desert needlegrass and Indian ricegrass dominate the site. Nevada ephedra and galleta are also common. Potential vegetative composition by weight is approximately 20% grasses, 5% forbs and 75% shrubs. Total foliar canopy cover is typically over 35%. Total annual air-dry production ranges from 200 to 500 lb/ac.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
Fire would decrease or eliminate the overstory of blackbrush and allow for forbs and perennial bunchgrasses to dominate the site. Fires would typically be small and patchy

due to low fine fuel loads. A fire following an unusually wet spring or a change in management may be more severe and reduce blackbrush cover to trace amounts.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.3:
Long-term drought, time and/or inappropriate grazing favor an increase in blackbrush over deep-rooted perennial bunchgrasses. Combinations of these would allow the blackbrush overstory to increase and dominate the site, causing a reduction in the perennial bunchgrasses.

Community Phase 1.2:
This community phase is characteristic of a post-disturbance, early seral community phase. This phase may persist up to 15+ years. Annual and perennial forbs and perennial bunchgrasses dominate this site. Desert needlegrass, Indian ricegrass and other perennial grasses are common. Blackbrush is killed by fire, therefore decreasing within the burned community, but could still be present in unburned patches.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.3:
Time and lack of disturbance allows for sprouting shrubs to increase, and perennial forbs and grasses would decrease.

Community Phase 1.3:
Sprouting shrubs such as Nevada ephedra, spiny hopsage and rabbitbrush are dominant. Shrubs stabilize the soil surface and allow shrubs islands to develop, eventually dominating the site. Blackbrush slowly increases in the absence of disturbance. This phase may last more than 50 years after fire.

Community Phase Pathway 1.3a, from Phase 1.3 to 1.2:
Wildfire or other disturbances would decrease shrubs and allow for increase in perennial forbs and grasses.

Community Phase Pathway 1.3b, from Phase 1.3 to 1.1:
Time and lack of disturbance allows for blackbrush to reestablish.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0

Trigger: This transition is caused by the introduction of non-native annual species; such as cheatgrass, red brome and stork's bill (*Erodium cicutarium*) with European settlement from the 1860s through the 1900s (Brooks and Chambers 2011).

Slow variables: Over time the annual non-native plants will increase within the community decreasing organic matter inputs from deep-rooted perennial bunchgrasses resulting in reductions in soil water availability for perennial bunchgrasses.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

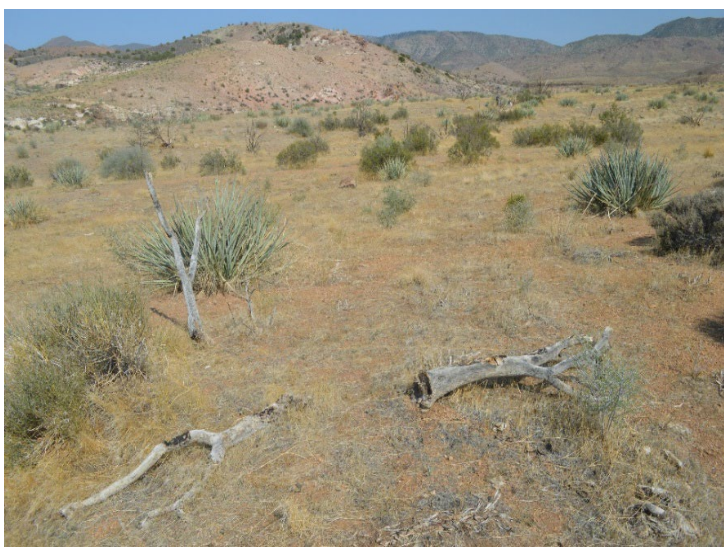
This state is similar to the Reference State 1.0. Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of non-native annual species. This state has the same three general community phases. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate and adaptations for seed dispersal. Additionally, the presence of highly flammable, non-native species reduces state resilience because these species can promote fire where historically fire has been infrequent leading to positive feedbacks that further the degradation of the system. Fire return intervals are shortened and may be from 50–100 years (Brooks et al. 2007).

Community Phase 2.1:
Blackbrush, desert needlegrass and Indian ricegrass dominate the site. Nevada ephedra and galleta are also common on this site. Non-native annual species are present in minor amounts.

Shallow Gravelly Slope 8-10" P.Z. (R029XY019NV), Current Potential 2.1, D. Snyder, June 2019

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
Fire would decrease or eliminate the overstory of blackbrush and allow for forbs and perennial bunchgrasses to dominate the site. Fires would typically be small and patchy due to low fine fuel loads. Annual non-native species generally respond well after fire and may be stable or increasing within the community.

Community Phase 2.2 (At-Risk):
This community phase is characteristic of a post-disturbance, early seral community phase. Annual and perennial forbs and perennial bunchgrasses dominate the site. Desert needlegrass, Indian ricegrass, and threeawn are common grasses. Perennial grasses and forbs may increase or dominate after fire for several years. Blackbrush is killed by fire, therefore decreasing within the burned community, but could still be present in unburned patches. Annual non-native species generally respond well after fire and may be stable or increasing within the community. This is an at-risk community phase. The loss of blackbrush cover allows interspaces to become occupied by a more continuous cover which can help spread fire (D'Antonio and Vitousek 1992, Brooks and Matchett 2003).



Shallow Gravelly Loam 8-10" P.Z. (R029XY077NV), Current Potential 2.2, T. Stringham, August 2021

Community Phase Pathway 2.2a, from Phase 2.2 to 2.3:
Absence of disturbance over time allows for the sprouting shrubs to recover.

Community Phase 2.3:
Sprouting shrubs such as Nevada ephedra, spiny hopsage and rabbitbrush are dominant. Blackbrush slowly increases in the absence of disturbance.

Community Phase Pathway 2.3a, from Phase 2.3 to 2.2:
Wildfire or other disturbances would decrease shrubs and allow for increase in perennial forbs and native and non-native grasses.

Community Phase Pathway 2.3b, from Phase 2.3 to 2.1:
Time, lack of disturbance over several years (>20+) and years of mast seed crops of blackbrush allows for blackbrush to reestablish.

T2A: Transition from Current Potential State 2.0 to Shrub State 3.0:

Trigger: Inappropriate, long-term grazing of perennial grasses during growing season would favor shrubs and initiate transition to Community Phase 3.1. Fire would cause a transition to Community Phase 3.2.

Slow variables: Long term decrease in perennial grass density resulting in a decrease in organic matter inputs and subsequent soil water decline.

Threshold: Loss of perennial bunchgrasses changes spatial and temporal nutrient cycling and redistribution, and reduces soil organic matter.

Shrub State 3.0:

This state has two community phases; a blackbrush dominated phase and a sprouting shrub phase. This state is a product of many years of heavy grazing during time periods harmful to perennial bunchgrasses. Galleta may increase with a reduction in deep-rooted perennial bunchgrass competition and become the dominant grass but with further site degradation this grass will also decrease. Blackbrush canopy cover is high and may be decadent, reflecting stand maturity and lack of seedling establishment due to competition with mature plants. The shrub overstory dominates site resources such that soil water, nutrient capture, nutrient cycling and soil organic matter are temporally and spatially redistributed.

Community Phase 3.1:
Blackbrush dominates the overstory. Annual non-native species may be present. Understory may be sparse, with few perennial grasses and forbs.

Shallow Gravelly Slope 8-10" P.Z. (R029XY019NV), Shrub State 3.1, T. Stringham, April 2023

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:
Fire would decrease or eliminate the overstory of blackbrush and allow for sprouting shrubs to dominate the site. Fires would typically be small and patchy due to low fine fuel loads. Annual non-native species generally respond well after fire and may be stable or increasing within the community.

Community Phase Pathway 3.2a, from Phase 3.2 to 3.1:
Over time (>20 years), lack of disturbance, and the occurrence of mast seed crops from remnant patches of blackbrush would allow for blackbrush and other shrubs to reestablish.

Community Phase 3.2:
Sprouting shrubs (*Gutierrezia spp*.), Nevada ephedra, *Hymenoclea salsola*) dominate the overstory. Annual non-native species may be present. Perennial grasses are sparse.


Shallow Gravelly Loam 8-10" P.Z. (R029XY077NV), Shrub State 3.2, D. Snyder, June 2019

T3A: Transition from Shrub State 3.0 to Annual State 4.0:

Trigger: Severe, large-scale fire, inappropriate grazing management, and years of above-average rainfall increase annual non-native species.

Slow variable: Increased seed production and cover of annual non-native species.

Threshold: Increased, continuous fine fuels modify the fire regime by changing intensity, size and spatial variability of fires. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and blackbrush truncate energy capture and impact the nutrient cycling and distribution.

Annual State 4.0:

This state has two community phases; one dominated by annual non-native species and the other a sprouting shrub dominated phase. This state is characterized by the dominance of annual non-native species such as cheatgrass, red brome, Russian thistle (*Salsola tragus*) and stork's bill in the understory. Several sprouting shrubs may dominate the overstory. Surface patchy fires are the regime and are carried by non-native annuals. Fire return intervals are less than 50 years. Blackbrush will likely not reestablish (Anjozian 2009).

Community Phase 4.1:
Annual non-native plants dominate the site. This phase may have seeded species present if resulting from a failed seeding attempt.

Shallow Gravelly Loam 8-10" P.Z. (R029XY077NV), Annual State 4.1, T. Stringham, August 2021

Community Phase Pathway 4.1a, from Phase 4.1 to 4.2:
Time and lack of disturbance allows for shrubs to reestablish. Sprouting shrubs such as ephedra and rabbitbrush will be the first to reappear after fire. Probability of blackbrush establishment is extremely low.

Community Phase 4.2:
Sprouting shrubs (snakeweed - *Gutierrezia* and banana yucca - *Yucca baccata*) remain in the overstory with annual non-native species such as cheatgrass, red brome and tumblemustard (*Sisymbrium altissimum*) dominating the understory. Trace amounts of desirable bunchgrasses may be present.

Shallow Gravelly Loam 5-8" P.Z. (R029XY013NV), Annual State 4.2, T. Stringham, May 2022

Community Phase Pathway 4.2a, from Phase 4.2 to 4.1:
Fire allows for annual non-native species to dominate site.

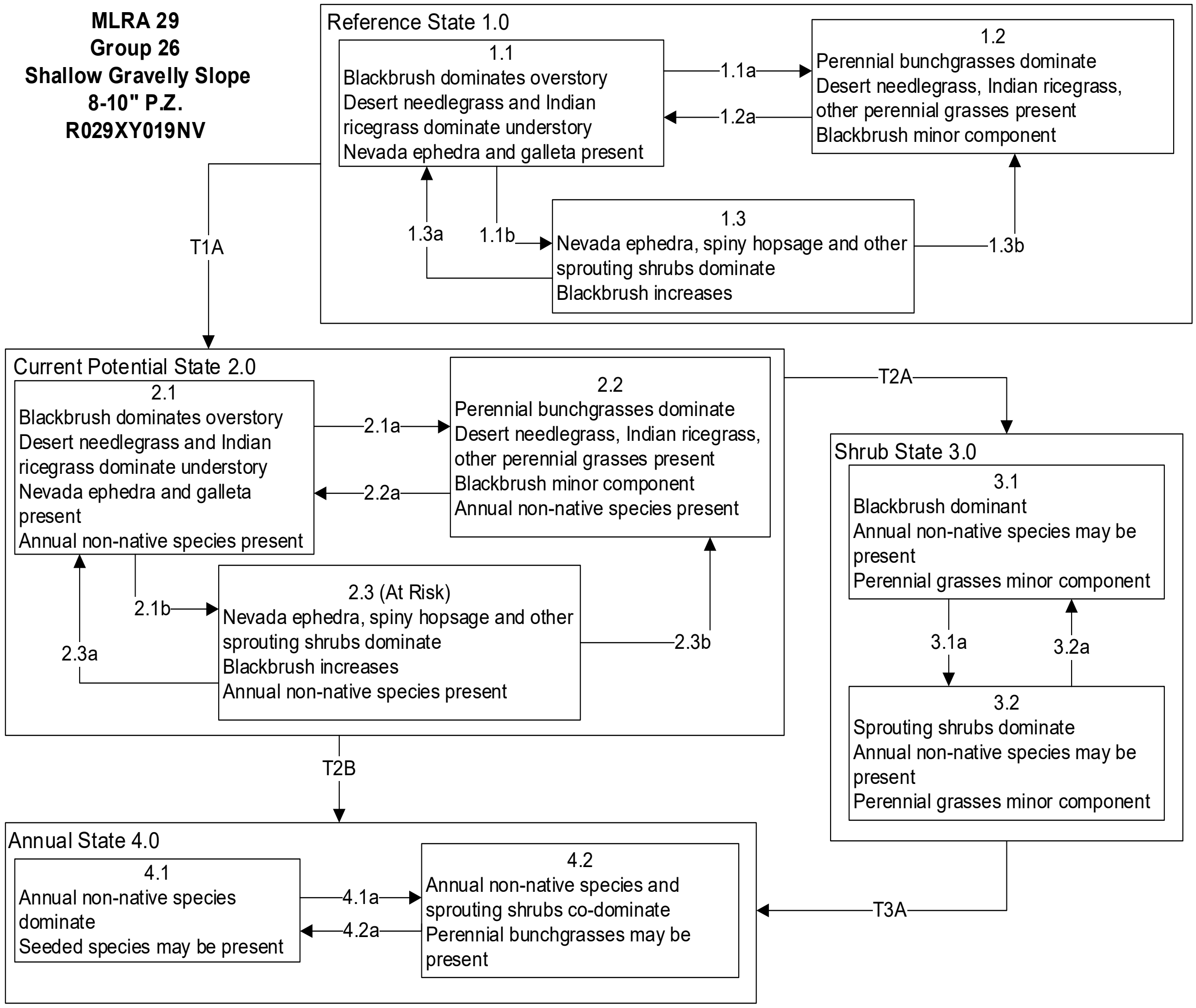
Potential Resilience Differences with Other Ecological Sites in this Group:

Shallow Gravelly Loam 5-8" P.Z. (R029XY013NV):
The vegetation community of this site is similar to the modal site but has Indian ricegrass as the dominant grass species. This site occurs from approximately 4,200 to 5,200 ft (1,280–1,585 m). Production is lower than the modal site with approximately 250 lb/ac in a normal year. This site occurs on summits and sideslopes of hills and lower mountains on all exposures. Soils are shallow to volcanic tuff bedrock at approximately 19 in. The soils are well drained, available water capacity is very low, and a calcic horizon occurs from 4 to 19 in. Nevada ephedra and Anderson wolfberry are common sprouting shrubs after fire.

Shallow Gravelly Loam 8-10" P.Z. (R029XY077NV):

The vegetation community is similar to the modal site but has desert needlegrass as the dominant grass species. This site occurs from approximately 4,400 ft to 5,500 ft (1,341–1,676 m). Production is higher than the modal site with approximately 500 lb/ac in a normal year. This site occurs on fan remnants, ballenas, and lower mountain and hill sideslopes from 2 to 50%. The soils are shallow to moderately deep and well drained with low available water capacity. Rooting is limited by a petrocalcic horizon or bedrock. A common shrub on this site is desert bitterbrush which is moderately fire tolerant (McConnell and Smith 1977). This shrub regenerates primarily by seed and may resprout (Blaisdell and Mueggler 1956, McArthur and Welch 1982), however sprouting ability is highly variable and has been attributed to genetics, plant age, phenology, soil moisture and texture and fire severity (Blaisdell and Mueggler 1956, Blaisdell et al. 1982, Clark et al. 1982). Rodent caching of seed has been identified as an important mechanism for establishment of new plants (Alexander et al. 1974). Rangeland seeding with non-native wheatgrass species, post-fire, has been attempted on this site with some success. Blackbrush transplants have also had success if seedlings are watered for successive years (Winkel and Ostler 1995). At higher elevations of this site, after wildfire a big sagebrush-bitterbrush community will replace the blackbrush community. Purple threeawn will often dominate the understory in these situations.

Modal State and Transition Model for Group 26 in MLRA 29:



MLRA 29
Group 26
Shallow Gravelly Slope
8-10" P.Z.
R029XY019NV

Reference State 1.0 Community Phase Pathways
1.1a: Fire decreases or eliminates the overstory of blackbrush and allow for perennial bunchgrasses and sprouting shrubs to dominate the site.
1.1b: Long-term drought, time and/or inappropriate grazing favor an increase in blackbrush over deep-rooted perennial bunchgrasses.
1.2a: Time and lack of disturbance allows for shrub regeneration.
1.3a: Wildfire or other disturbances decrease non-sprouting shrubs and allow for increase in perennial forbs and grasses.
1.3b: Time and lack of disturbance allows for blackbrush to reestablish.

Transition T1A: Introduction of non-native species such as cheatgrass, red brome or stork’s bill.

Current Potential State 2.0 Community Phase Pathways
2.1a: Fire decreases or eliminates the overstory of blackbrush and allow for sprouting shrubs and perennial bunchgrasses to dominate the site.
2.1b: Long-term drought, time and/or inappropriate grazing favor an increase in blackbrush over deep-rooted perennial bunchgrasses.
2.2a: Time and lack of disturbance allows for shrub regeneration.
2.3a: Wildfire or other disturbances decrease non-sprouting shrubs and allow for increase in sprouting shrubs, perennial forbs and grasses.
2.3b: Time and lack of disturbance allows for blackbrush to reestablish.

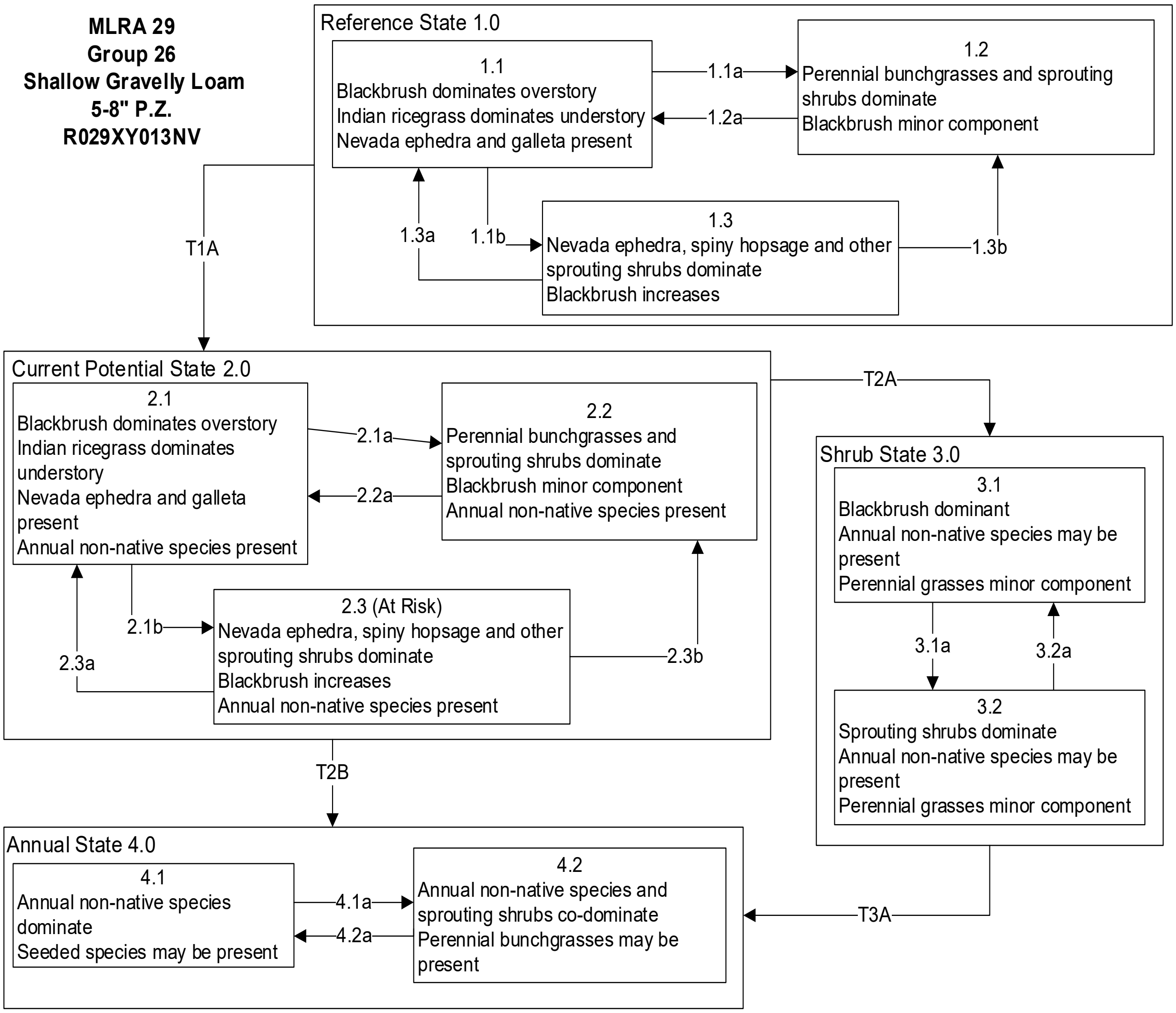
Transition T2A: Time and lack of disturbance and/or inappropriate grazing management (3.1). Fire (3.2).
Transition T2B: High severity fire and/or soil disturbance (4.1). Inappropriate grazing that favors shrubs in the presence of non-native annual species (4.2).

Shrub State 3.0 Community Phase Pathways
3.1a: Fire.
3.2a: Time and lack of fire allows some shrubs to reestablish.

Transition T3A: Catastrophic fire as well as inappropriate grazing management in the presence of non-native annual species.

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of disturbance allows for shrubs to reestablish.
4.2a: Fire allows for annual non-native species to dominate site.

Additional State and Transition Models for Group 26 in MLRA 29:



MLRA 29
Group 26
Shallow Gravelly Loam
5-8" P.Z.
R029XY013NV

Reference State 1.0 Community Phase Pathways
1.1a: Fire decreases or eliminates the overstory of blackbrush and allow for sprouting shrubs and perennial bunchgrasses to dominate the site.
1.1b: Long-term drought, time and/or inappropriate grazing favor an increase in blackbrush over deep-rooted perennial bunchgrasses.
1.2a: Time and lack of disturbance allows for shrub regeneration.
1.3a: Wildfire or other disturbances decrease non-sprouting shrubs and allow for increase in sprouting shrubs and perennial grasses.
1.3b: Time and lack of disturbance allows for blackbrush to reestablish.

Transition T1A: Introduction of non-native species such as cheatgrass, red brome or stork's bill.

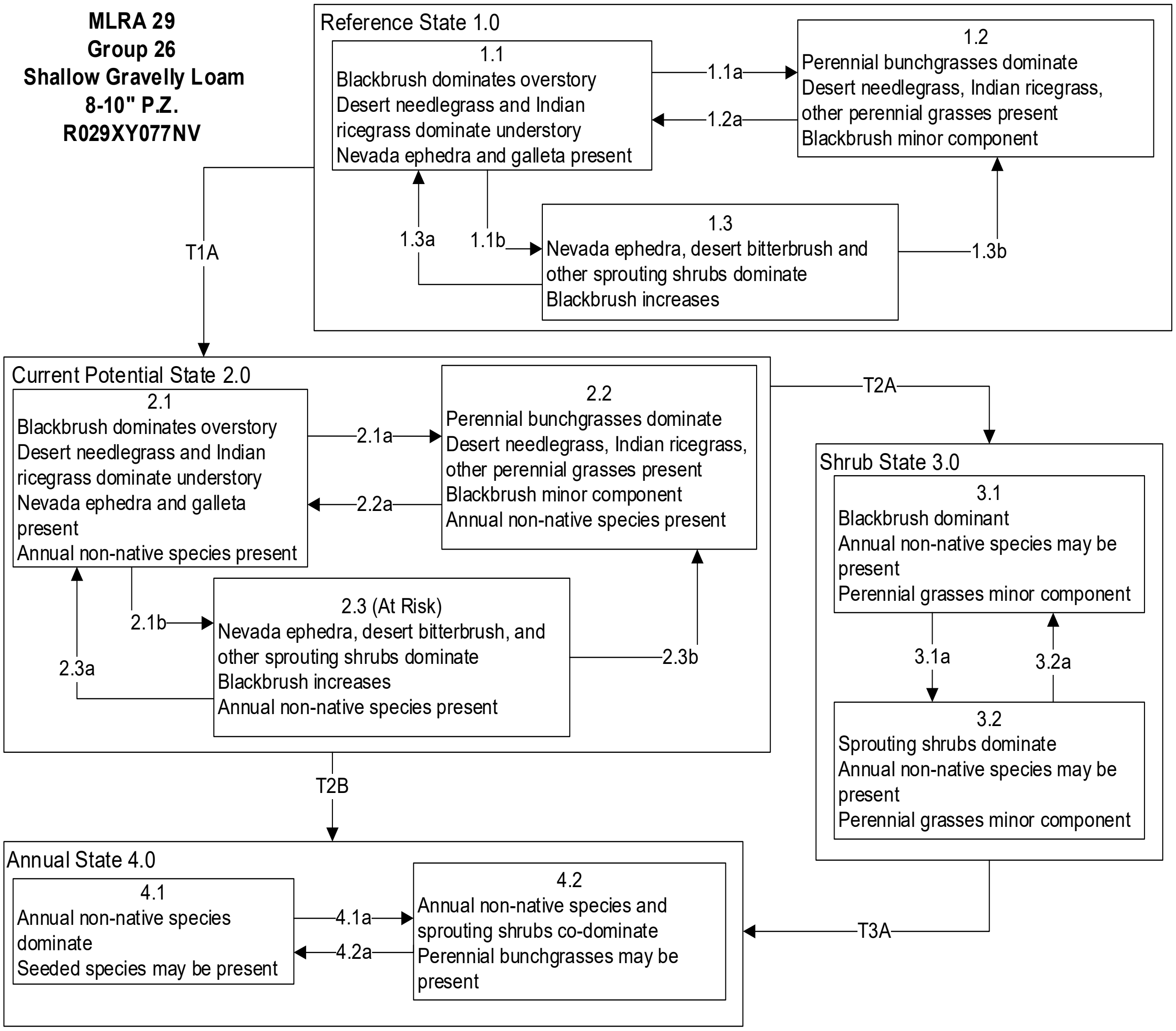
Current Potential State 2.0 Community Phase Pathways
2.1a: Fire decreases or eliminates the overstory of blackbrush and allow for sprouting shrubs and perennial bunchgrasses to dominate the site.
2.1b: Long-term drought, time and/or inappropriate grazing favor an increase in blackbrush over deep-rooted perennial bunchgrasses.
2.2a: Time and lack of disturbance allows for shrub regeneration.
2.3a: Wildfire or other disturbances decrease non-sprouting shrubs and allow for increase in sprouting shrubs and grasses.
2.3b: Time and lack of disturbance allows for blackbrush to reestablish.

Transition T2A: Time and lack of disturbance and/or inappropriate grazing management (3.1). Fire (3.2)
Transition T2B: High severity fire and/or soil disturbance (4.1). Inappropriate grazing that favors shrubs in the presence of non-native annual species (4.2).

Shrub State 3.0 Community Phase Pathways
3.1a: Fire.
3.2a: Time and lack of fire allows some shrubs to reestablish.

Transition T3A: Catastrophic fire as well as inappropriate grazing management in the presence of non-native annual species.

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of disturbance allows for shrubs to reestablish.
4.2a: Fire allows for annual non-native species to dominate site.


MLRA 29
Group 26
Shallow Gravelly Loam
8-10" P.Z.
R029XY077NV
Reference State 1.0
1.1
Blackbrush dominates overstory
Desert needlegrass and Indian ricegrass dominate understory
Nevada ephedra and galleta present
1.1a
1.2a
1.2
Perennial bunchgrasses dominate
Desert needlegrass, Indian ricegrass, other perennial grasses present
Blackbrush minor component
1.3a
1.1b
1.3
Nevada ephedra, desert bitterbrush and other sprouting shrubs dominate
Blackbrush increases
1.3b
T1A
Current Potential State 2.0
2.1
Blackbrush dominates overstory
Desert needlegrass and Indian ricegrass dominate understory
Nevada ephedra and galleta present
Annual non-native species present
2.1a
2.2a
2.2
Perennial bunchgrasses dominate
Desert needlegrass, Indian ricegrass, other perennial grasses present
Blackbrush minor component
Annual non-native species present
2.1b
2.3a
2.3 (At Risk)
Nevada ephedra, desert bitterbrush, and other sprouting shrubs dominate
Blackbrush increases
Annual non-native species present
2.3b
T2A
Shrub State 3.0
3.1
Blackbrush dominant
Annual non-native species may be present
Perennial grasses minor component
3.1a
3.2a
3.2
Sprouting shrubs dominate
Annual non-native species may be present
Perennial grasses minor component
T2B
Annual State 4.0
4.1
Annual non-native species dominate
Seeded species may be present
4.1a
4.2a
4.2
Annual non-native species and sprouting shrubs co-dominate
Perennial bunchgrasses may be present
T3A

MLRA 29
Group 26
Shallow Gravelly Loam
8-10" P.Z.
R029XY077NV

Reference State 1.0 Community Phase Pathways
1.1a: Fire decreases or eliminates the overstory of blackbrush and allows for sprouting shrubs and perennial bunchgrasses to dominate the site.
1.1b: Long-term drought, time and/or inappropriate grazing favor an increase in blackbrush over deep-rooted perennial bunchgrasses.
1.2a: Time and lack of disturbance allows for shrub regeneration.
1.3a: Wildfire or other disturbances decrease non-sprouting shrubs and allow for increase in perennial forbs and grasses.
1.3b: Time and lack of disturbance allows for blackbrush to reestablish.

Transition T1A: Introduction of non-native species such as cheatgrass, red brome or stork's bill.

Current Potential State 2.0 Community Phase Pathways
2.1a: Fire decreases or eliminates the overstory of blackbrush and allows for sprouting shrubs and perennial bunchgrasses to dominate the site.
2.1b: Long-term drought, time and/or inappropriate grazing favor an increase in blackbrush over deep-rooted perennial bunchgrasses.
2.2a: Time and lack of disturbance allows for shrub regeneration.
2.3a: Wildfire or other disturbances decrease non-sprouting shrubs and allow for increase in perennial forbs and grasses.
2.3b: Time and lack of disturbance allows for blackbrush to reestablish.

Transition T2A: Time and lack of disturbance and/or inappropriate grazing management (3.1). Fire (3.2)
Transition T2B: High severity fire and/or soil disturbance (4.1). Inappropriate grazing that favors shrubs in the presence of non-native annual species (4.2).

Shrub State 3.0 Community Phase Pathways
3.1a: Fire.
3.2a: Time and lack of fire allows some shrubs to reestablish.

Transition T3A: Catastrophic fire as well as inappropriate grazing management in the presence of non-native annual species.

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of disturbance allows for shrubs to reestablish.
4.2a: Fire allows for annual non-native species to dominate site.

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MLRA 29 Group 27: Bouldery slopes

Description of MLRA 29 Disturbance Response Group 27

Disturbance Response Group (DRG) 27 consists of two ecological sites. These sites occur on extremely bouldery sideslopes, hill summits, lower mountains, and mountain backslopes. The precipitation ranges from 5 to 10 in. Slopes range from 4 to 75% with less than 50% being typical. Elevation ranges from approximately 4,000 to 5,700 ft (1,219–1,737 m). The soils of this site are coarse, formed in residuum and colluvium from volcanic rock. Surface rock fragments cover may be as high as 90%, consisting of angular gravels, cobbles, and stones. Steep slopes and sparse vegetation subject thin, shallow soils beneath rock fragments to colluvial movement. Numerous cracks and crevices allow deep root penetration into areas where water remains available following the drying up of the shallow soil above. The available water holding capacity is very low to low. Permeability of the soils is moderately rapid, soils are well-drained, and runoff is very high. The soil moisture regime is typic aridic and the soil temperature regime is mesic. The reference plant community is dominated by green ephedra *(Ephedra viridis*) and Wyoming big sagebrush (*Artemisia tridentata var. wyomingensis*), with Eastern Mojave buckwheat (*Eriogonum fasciculatum*) and desert snowberry (*Symphoricarpos longiflorus*) making up minor components. The perennial grass community is dominated by desert needlegrass (*Achnatherum speciosum*) with needle and thread (*Hesperostipa comata*) being a minor component. These sites also carry a small amount of Utah Juniper (*Juniperus osteosperma*). Annual production for a normal year ranges from 350 to 600 lb/ac.

Disturbance Response Group 27 Ecological Sites:

Bouldery Slope 5-8" P.Z. – Modal	R029XY085NV
Scree Slope 8-10" P.Z.	R029XY169NV

Modal Site:

The Bouldery Slope 5-8" P.Z. (R029XY085NV) ecological site is the modal site that represents this DRG, as it has the most acres mapped. This site occurs on extremely bouldery sideslopes and summits of hills and lower mountains. Slopes range from 4 to 75%, but slope gradients of 15 to 50% are most typical. Elevations for this site range from 4,000 to about 5,500 ft (1,219–1,676 m). Annual production ranges from 400 to 800 lb/ac. Soils are coarse-textured, shallow and well drained. They are formed in residuum and colluvium from volcanic rocks. Following spring and summer thunderstorms, water will perch on the underlying bedrock of these soils. The numerous cracks and crevices of the parent material allow deep root penetration into areas where water remains available following the drying up of the shallow soil above. It is in these areas that the majority of the plants on this site flourish. The shrub component is dominated by green ephedra, and the herbaceous component is dominated by desert needlegrass. Needle- and-thread, Mojave buckwheat, and desert snowberry make up minor components. Utah juniper trees occur sporadically throughout the site. Potential vegetative composition (by air-dry weight) is approximately 45% grasses, 5% forbs and 50% shrubs and trees.

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasives. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans a unique area in Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area. Flashy, summer storm events contribute significantly to annual precipitation as well. Air and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

Periodic drought regularly influences these desert ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West (Miller et al. 2008a). Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006).

Green ephedra is typically codominant with other shrub species in lowland arid areas, and are more dominant in mid-elevations, acting as a sand binder to prevent hillside erosion. It is common on soils with a shallow restrictive layer, so it does not tend to form very deep root systems (Perryman 2014a). These shrubs photosynthesize through its green twigs instead of its reduced leaves, so it is green year-round. Flowering occurs from March to May, and seeds ripen and drop from June to September in several year intervals of mast-seeding events that follow periods of high precipitation (Meyer 2008b). Ephedra tends to be spatially differentiated by sex, with males mostly found on dry slopes, while females are found at the base of hillsides in run-off areas. The exact reason is unknown, but this could be due to the fact that these shrubs are wind pollinated, and this allows males to spread pollen easily and places female plants in areas with adequate resources for seed production (Freeman et al. 1976). Ephedra does not compete well with cheatgrass, and may exhibit reduced shoot growth when growing in areas dominated by cheatgrass (Pendleton et al. 2007).

Wyoming big sagebrush, the most drought tolerant of the big sagebrushes, is generally long-lived; therefore, it is not necessary for new individuals to recruit every year for perpetuation of the stand. Infrequent large recruitment events and simultaneous low, continuous recruitment is the foundation of population maintenance (Noy-Meir 1973). Survival of the seedlings is dependent on adequate moisture conditions.

Eastern Mojave buckwheat is a generally long-lived (five to over 50 years) drought tolerant and shade intolerant polycarpic subshrub. (Sawyer et al. 2009, Montalvo and Beyers 2010). It possesses woody, branched fibrous roots that typically spread laterally about three times the canopy spread with depths generally less than 1.5 m (5 ft) deep, although up to 2.46 m (8 ft) has been observed. (Hellmers et al. 1955, Kummerow et al. 1977). Eastern Mojave buckwheat prefers coarse, well-drained soils that are moderately acidic to slightly saline (Sawyer et al. 2009). Its emerging seedlings do not compete well with non-native grasses, although it can become very dense and outcompete other desirable species if planted at too high a proportion of a seeding mixture (Dyer and O'Beck 2006b, Montalvo and Beyers 2010). Eastern Mojave buckwheat is considered an important, fast-growing shrub that is used extensively in roadside revegetation, erosion control, post-fire mitigation, and habitat restoration, and on disturbed lands. (Reveal 1989, Newton and Claassen 2003, Montalvo 2004).

Desert snowberry is a native, long-lived, deciduous shrub with wide variations in leaf and twig pubescence (Monsen et al. 2004b). Desert snowberry occurs on deep, well-drained soils in desert-shrub, pinyon-juniper, sagebrush, mountain bush and ponderosa pine communities from Oregon to Colorado, and south from southern California to Texas (Monsen et al. 2004b). It has been shown to do poorly on severely disturbed sites, performing best on souls with well-developed, undisturbed horizons (Monsen et al. 2004b). Desert snowberry considered the most drought tolerant snowberry, can be seeded or transplanted, and traditionally grows intermixed with other species, but not in closed stands (Monsen et al. 2004b).

Desert needlegrass is a cool-season, perennial bunchgrass that grows 12 to 24 in. (30–61 cm) tall in large dense clumps (Sampson et al. 1951, Harrington 1954). It reproduces both sexually and asexually. This grass is pollinated by wind, and is capable of producing large amounts of seeds (Sampson et al. 1951). Sexual reproduction is highly dependent on water availability; seed will not set if soil moisture is too low and temperatures are too high (Bertiller et al. 1991).

Vegetative reproduction occurs with the annual growth of new tillers (Evert 2006). Awns catch on animal fur, which disseminates seeds (Kearney et al. 1960).

Needle-and-thread is a cool-season (Waller and Lewis 1979), native, perennial bunchgrass which reproduces through seed and tillers (Russell et al. 2017) with a medium to deep rooting depth. A study in New Mexico pinyon-juniper woodlands found a rooting depth range of 63 to 168 cm (24 to 66 in.) with a mean of 110 cm (43 in.), a mean depth of 26 cm (10 in.) deeper than Indian ricegrass (*Achnatherum hymenoides*) (Foxx and Tierney 1987), though Melgoza and Nowak (1991) in a study of in northern Nevada found that over 50% of the root biomass occurred in the first 0.2 m (8 in.) of soil. Needle-and-thread has moderate to high drought resistance (Mueller and Weaver 1942, Winkler et al. 2019), and recovers well from drought (Ellison and Woolfolk 1937). Analysis of NRCS soils data shows that needle-and-thread has a statistically significant preference for sand in the top 50 cm (20 in.) of the soil profile when compared to perennial grasses within Nevada (Soil Survey Staff 2024).

Annual Invasive Species:

The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species resulting in reduced competition while simultaneously increasing resource pools through the decomposition of dead plant material. Historically, desert shrub communities were free of exotic invaders; however, excessive grazing pressure during settlement and into the 20th century has increased the overall presence of cheatgrass (*Bromus tectorum*), red brome (*Bromus rubens*), halogeton (*Halogeton glomeratus*), Russian thistle (*Salsola tragus*) and weedy mustard species (Brassicaceae family) (Peters and Bunting 1994). The presence of non-native annual plants within these ecosystems decreases ecosystem resilience and resistance to disturbance through competition for limited resources.

The species most likely to invade the ecological sites in this DRG is cheatgrass. Cheatgrass is a cool-season annual grass that maintains an advantage over native plants, in part, because it is a prolific seed producer, can germinate in the autumn or spring, tolerates grazing, and increases with frequent fire (Klemmedson and Smith 1964, Miller and Rose 1999). Cheatgrass originated from Eurasia and was first reported in North America in the late 1800s (Furbush 1953, Mack and Pyke 1983). Bradley et al. (2018) found that cheatgrass has expanded to greater than 15% cover over 210,000 km^2 – roughly 31% of the Intermountain West. In the Great Basin, cheatgrass is expanding at a rate of expansion of 3,700 km^2 annually and is a land management issue that will require creative solutions (Smith et al. 2022).

Mapping potential or current invasion vectors is a management method designed to increase the cost-effectiveness of control methods. Recent modeling and empirical work by Bradford and Lauenroth (2006) suggest that seasonal patterns of precipitation input and temperature are also key factors determining regional variation in the growth, seed production, and spread of invasive annual grasses. The phenomenon of cheatgrass “die-off” provides opportunities for restoration of perennial native species (Baughman et al. 2016, Baughman et al. 2017). The causes of these events are not fully understood, but there is ongoing work to try to predict where they occur, in the hopes of aiding conservation planning (Weisberg et al. 2017, Brehm 2019).

Methods to control cheatgrass include herbicide application, prescribed fire, targeted grazing, and rangeland seeding. Spraying with herbicide (imazapic or imazapic + glyphosate) and seeding with crested wheatgrass (*Agropyron cristatum*) and Sandberg bluegrass (*Poa secunda*) has been found to be more successful at combating cheatgrass and medusahead (*Taeniatherum caput-medusae*) than spraying alone (Sheley et al. 2012). To date, most seeding success has occurred with non-native wheatgrass species. Perennial grasses, especially crested wheatgrass, are able to suppress cheatgrass growth when mature (Blank et al. 2020). Butler et al. (2011) tested four herbicides (imazapic, imazapic + glyphosate, rimsulfuron, and sulfometuron + chlorsulfuron) for suppression of cheatgrass, medusahead, and ventenata (North Africa grass, *Ventenata dubia*) within residual stands of native bunchgrass. Additionally, they tested the same four herbicides followed by seeding of six bunchgrasses (native and non-native) with varying success (Butler et al. 2011). Herbicide-only treatments appeared to remove competition for established bluebunch wheatgrass (*Pseudoroegneria spicata*) by providing 100% control of ventenata and medusahead and greater than 95% control of cheatgrass (Butler et al. 2011). Clements et al. 2022 found that imazapic successfully reduced cheatgrass on study plots by 95% and subsequent seeding efforts with native and non-native species produced an average of 4.8 perennial grasses/m^2.

Indaziflam, a relatively new herbicide for rangeland applications, is showing promise in its ability to control cheatgrass, red brome (*Bromus rubens*), medusahead, ventenata, and halogeton. Approved for rangelands in 2016, this pre-emergent herbicide works by inhibiting cell wall biosynthesis and therefore seed germination and root elongation (Kaapro and Hall 2012, Clark et al. 2019). Indaziflam effectively reduces the seed bank of invasive annuals with little to no effect on aboveground plant communities (Courkamp et al. 2022). It also has been proven to control invasive annuals longer than other herbicides, providing three or more years of control (Sebastian et al. 2017b). Sebastian et al. (2017b) found that indaziflam selectively controlled cheatgrass without impacting perennial grass and forb biomass as well (Sebastian et al. 2017b). This led to significant increases in biomass of desirable species due to reductions in cheatgrass presence and competition. Clark et al. 2019 found a similar result on plots in Colorado suggesting that indaziflam may be the best new herbicide on the market for invasive annual control (Clark et al. 2019).

Targeted cattle grazing during the fall and winter can also control cheatgrass on invaded sites. Fall and winter grazing decreases standing dead biomass and reduces fuel continuity with minimal risk to native perennial herbaceous plants (Davies et al. 2016). This alters fire risk and severity by reducing fuel loads, flame height, rate of spread and area burned in Great Basin sagebrush systems (Davies et al. 2015a). Repetitive fall grazing can also reduce cheatgrass seed banks, however, the seed bank can rapidly recover if fall grazing efforts cease (Perryman et al. 2020).

Fire Ecology:

Green ephedra has the ability to both resprout from belowground vegetation or the root crown after fire has destroyed the shrub, or recover from a seed bank in the soil (Condon and Weisberg 2016). It was found that green ephedra typically establishes quickly after fire events and makes up a considerable amount of the shrub population, but eventually is outcompeted by other shrub species like bitterbrush (*Purshia tridentata*) or big sagebrush (*Artemisia tridentata*) (Morris and Leger 2016). Sprouting after fire may vary by season of burn and fire severity. After fire, these sprouting shrubs can produce significant new growth if there is enough moisture available (Shaw 1992). Other environmental conditions also determine the level of re-establishment that occurs, such as the salinity and temperature of soil. In order to germinate, seeds need moist conditions (Monsen et al. 2004b). They do not compete well with annual invasives (Monsen et al. 2004b).

Wyoming big sagebrush is killed by fire and only regenerates from seed. Recovery time for Wyoming big sagebrush may require 50 to 120 or more years (Baker 2006). Post-fire regeneration will vary depending on site characteristics, seed source, and fire characteristics (Baker 2006).

Snowberry (*Symphoricarpos*) is also top-killed by fire, but resprouts after fire from rhizomes (Leege and Hickey 1971, Noste and Bushey 1987). Snowberry has been noted to regenerate well and exceed pre-burn biomass in the third season after a fire (Merrill et al. 1982).

Eastern Mojave buckwheat is a facultative seeder and has been found to resprout after fire and mowing (Montalvo and Beyers 2010). About 71% of seedlings were found to have emerged in the first-year post-fire, with 21% in the second and 5% in the subsequent. Additionally, in areas that burned two consecutive years, all previous year seedlings were killed in the second fire and new seedling recruitment has halved (Zedler et al. 1983), indicating that high fire frequency can devastate populations. Furthermore, it has been found to resprout more readily from above ground stems than below ground organs, making it vulnerable to high intensity fire (Westman et al. 1981).

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species' response. Thus, fire mortality is correlated to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant, and abundance of old growth (Wright 1971, Young et al. 1983). Boyd et al. 2015 found soil color and depth of burn to be accurate predictors of bunchgrass mortality in post fire landscapes (Boyd et al. 2015). They also found that bunchgrasses in close proximity of shrubs had up to five-fold higher mortality than bunchgrasses located in the interspaces (Boyd et al. 2015).

Needlegrasses are slightly to moderately damaged by fire depending on season of burn. They tend to be more susceptible when burned during mid-summer (Wright and Klemmedson 1965). Desert needlegrass is susceptible to and top killed by fire due to its persistent dead leaf bases (Pavek 1993). However, like many perennial grasses, it possesses root crowns that can survive fire, especially rapid, cool fires (Humphrey 1974, Koniak 1985). Desert needlegrass was shown to be one of the few perennial grasses that remained the same or increased in frequency 15 to 17 years after fires, indicating that its surviving tufts may sprout (Koniak 1985).

Needle-and-thread is a fine-leaf grass and is considered sensitive to fire (Akinsoji 1988, Bradley et al. 1992, Miller et al. 2013). In a study by Wright and Klemmedson (1965), season of burn rather than fire intensity seemed to be the crucial factor in mortality for needle-and-thread. Early spring season burning was seen to kill the plants while August burning had no effect. Thus, after wildfire needle-and-thread is often present in the post-burn community.

Livestock/Wildlife Grazing Interpretations:

Livestock use of these sites is minimized by steep slopes, low productivity and abundance of large surface rock fragments. Inappropriate grazing management, during the spring growing season, will cause a decline in understory plants such as Indian ricegrass and needle-and-thread. Growing season grazing by cattle several years in a row causes a decrease in the bunchgrass component and gives a competitive advantage to shrub species including black sagebrush (Eckert et al. 1972). Reduced bunchgrass vigor or density provides an opportunity for galleta and/or Sandberg bluegrass expansion and/or cheatgrass and other invasive species such as halogeton to occupy interspaces. Galleta (*Pleuraphis jamesii*) and/or Sandberg bluegrass increases under grazing pressure (Jameson 1962, Tisdale and Hironaka 1981) and is capable of co-existing with cheatgrass. Increased cheatgrass cover leads to increased fire frequency and potentially an annual plant community. Thus, depending on the season of use, the type of grazing animal, and site conditions, either galleta, Sandberg bluegrass or cheatgrass may become the dominant understory with inappropriate grazing management.

Green ephedra is an important browse species for domestic livestock and wildlife. Cattle usually will not preferentially choose ephedra as a food source, but will utilize about 50% of the stems. It is an important winter feed source for deer due to its abundance and numerous branching twigs that are accessible after snowfall. The shrub is fair to poorly palatable for cattle, sheep, and deer, and is rated good to fair for goats (Sampson and Jespersen 1963). Green ephedra is used as winter forage by wild ungulates and livestock (Jameson 1962, Kufeld et al. 1973). Keeler (1989) found green ephedra to be toxic to cattle and sheep, but not to calves and lambs. Ephedra is an important component of bighorn sheep diets in the eastern Sierra Nevada (McCullough and Schneegas 1966).

Eastern Mojave Buckwheat is eaten by many domestic livestock and browsed by big game; rated good to fair for deer, fair for goats, fair to poor for cattle and sheep, and poor to useless for horses (Sampson and Jespersen 1963). Additionally, its flowers provide an important food resource for many species of insects, among them wasps, butterflies, beetles, and bees, including the non-native honeybee (*Apis mellifera*) (Moldenke and Neff 1974, Kremen et al. 2002). In one study, 31 species of bees were identified as visitors, 8 of which were important to pollination of crops (Kremen et al. 2002).

The palatability of snowberries varies in different locations and with different plant associations (USFS 1988). In general, there is a tendency for *Symphoricarpos* species to have greater palatability in the Intermountain Region and on the drier eastern and southern ranges than the more northern and western areas (USFS 1988). However, in the desert regions of Utah and Nevada, the local desert/longflower snowberry is largely unpalatable to livestock (USFS 1988). However, it can be a fairly good and important browse plant for sheep and goats, and to a lesser extent for cattle with it being worthless for horses (USFS 1988, Monsen et al. 2004b). These shrubs are also fair to fairly good forage for deer and elk (USFS 1988). The relatively low, shrubby snowberries, whose foliage is mostly accessible to livestock, withstand grazing very well; often, because of their abundance, they are important factors in the forage supply on many ranges (USFS 1988). On many overgrazed sagebrush ranges in which the understory species have been eliminated, desert snowberry and sagebrush will remain (Monsen et al. 2004b). However, excessive use will result in death of plants (Monsen et al. 2004b).

Inappropriate grazing management during the growing season will cause a decline in understory plants such as needle-and-thread. Growing season grazing by cattle may initially cause a decrease in the bunchgrass component and give a competitive advantage to shrub species (Eckert et al. 1972). Needle-and-thread is not grazing tolerant and will be one of the first grasses to decrease under heavy grazing pressure (Smoliak et al. 1972, Tueller and Blackburn 1974). Heavy grazing is likely to reduce basal area of these plants (Smoliak et al. 1972). With the reduction in competition from deep rooted perennial bunchgrasses, the rhizomatous galleta grass and short-statured Sandberg bluegrass will likely increase (Jameson 1962, Smoliak et al. 1972).

Desert needlegrass is palatable to all classes of livestock when young, however, after maturity it is avoided by sheep and moderately used by horses and cattle (Perkins 2008). The seed of desert needlegrass has a prominent, sharp callus that can injure the eyes and mouths of grazing animals, therefore grazing prior to seed set is typical (Perkins 2008). The plant tolerates light grazing in the growing season, however, excessive use may reduce or eliminate desert needlegrass from the area (Perkins 2008).

State and Transition Model Narrative for Group 27:

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 29 Disturbance Response Group 27.

Reference State 1.0:

The Reference State is a representative of the natural range of variability under pristine conditions. The Reference State has three general community phases; a shrub-grass dominant phase, a shrub dominant phase and a grass dominant phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire, periodic drought and/or insect or disease attack. Due to the nature and extent of disturbance in this site, all three plant community phases would likely occur in a mosaic across the landscape. Utah juniper or singleleaf pinyon may be present on the site, but will only occur as scattered trees and will not dominate the site.

Community Phase 1.1:
The reference plant community is dominated by green ephedra and desert needlegrass. Needle-and-thread grass is a sub-dominant plant in the understory. Mojave Buckwheat and desert snowberry make up minor components of shrub cover. Scattered Utah juniper and singleleaf pinyon pine may be present on the site. Potential vegetative composition by air-dry weight is approximately 45% grasses, 5% forbs and 50% shrubs and trees. Approximate ground cover (basal and crown) is 10 to 25%. Total annual air-dry production ranges from 400 to 800 lb/ac.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
Low severity fire creates grass/shrub mosaic leads to an increase in dominance of perennial bunchgrasses on site. Green ephedra and other sprouting shrubs are likely to quickly recover.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.3:
Time and lack of disturbance such as fire allows shrub cover to increase and become dominant. Long-term drought, herbivory, or combinations of these will cause a decline in perennial bunchgrasses.

Community Phase 1.2:
This community phase is characteristic of a post-disturbance, early seral community phase. Desert needlegrass, needle-and-thread and other perennial bunchgrasses dominate. Sprouting shrubs such as green ephedra may recover quickly and increase. Scattered Utah juniper and singleleaf pinyon pine may be present on the site.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
Time and lack of disturbance will allow shrub cover to resprout and re-establish.

Community Phase 1.3:

Green ephedra increases in the absence of disturbance and dominates the overstory, reducing deep-rooted perennial bunchgrasses in the understory from competition with shrubs and/or herbivory. Scattered Utah juniper and singleleaf pinyon pine may be present on the site.

Community Phase Pathway 1.3a, from Phase 1.3 to 1.1:
A low severity fire, herbivory or combinations will reduce the shrub overstory and create a shrub/grass mosaic.

Community Phase Pathway 1.3b, from Phase 1.3 to 1.2:
High intensity fire will decrease or eliminate the shrub overstory and allow for perennial bunchgrasses to dominate the site. Sprouting shrubs are likely to recover quickly.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0

Trigger: Introduction of non-native annual plants.

Slow variables: Over time the annual non-native plants will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

This state is similar to the Reference State 1.0 with the same three community phases. Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of invasive weeds. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal. Additionally, the presence of highly flammable, non-native species reduces State resilience because these species can promote fire where historically fire has been infrequent, leading to positive feedbacks that further the degradation of the system**.**

Community Phase 2.1:

This community phase is compositionally similar to the Reference State Community Phase 1.1 but with the presence of non-native species in trace amounts. Green ephedra and desert needlegrass dominate the site. Needle-and-thread grass is a sub-dominant plant in the understory. Mojave buckwheat and desert snowberry make up minor components of shrub cover Scattered Utah juniper and singleleaf pinyon pine may be present on the site.

Scree Slope 8-10" P.Z. (R029XY169NV), Current Potential 2.1, T. Stringham, May 2022

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
Low severity fire creates grass/shrub mosaic or targeted shrub grazing leads to increase in dominance of bunchgrasses on site. Green ephedra and other sprouting shrubs are likely to quickly recover. Annual non-native species may increase.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.3:
Time and lack of disturbance such as fire allows shrub cover to increase and become dominant. Long-term drought, herbivory, or combinations of these will cause a decline in perennial bunchgrasses.

Community Phase 2.2:
This community phase is characteristic of a post-disturbance, early seral community phase. Desert needlegrass, needle-and-thread and other perennial bunchgrasses dominate. Sprouting shrubs such as green ephedra may recover quickly and increase. Annual non-natives are present and may be increasing. Scattered Utah juniper and singleleaf pinyon pine may be present on the site.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Time and lack of disturbance will allow shrub cover to resprout and re-establish.

Community Phase 2.3 (At Risk):

Green ephedra and yellow rabbitbrush (*Chrysothamnus viscidiflorus*) increases in the absence of disturbance and dominates the overstory, reducing deep-rooted perennial bunchgrasses in the understory from competition with shrubs and/or herbivory. Annual non-native species are present and may be increases due to reduced competition with perennial species. Scattered Utah juniper and singleleaf pinyon pine may be present on the site.

Bouldery Slope 5-8" P.Z. (R029XY085NV), Current Potential 2.3, T. Stringham, August 2021

Community Phase Pathway 2.3a, from Phase 2.3 to 2.1:
A low severity fire, herbivory or combinations will reduce the non-sprouting shrub overstory and create a shrub/grass mosaic. Annual non-native species are present and may be present in response to disturbance.

Community Phase Pathway 2.3b from Phase 2.3 to 2.2:
High intensity fire will decrease or eliminate the non-sprouting shrub overstory and allow for perennial bunchgrasses to dominate the site. Sprouting shrubs are likely to recover quickly. Annual non-native species are present and may be increasing.

States Not Observed in Group 27:

Shrub State: A Shrub State was not seen for this group, though such a state may be possible within this group. A Shrub State was found within another, similar, MLRA DRG: MLRA 29 Group 13.

Tree State: A Tree State was not seen for this group, though such a state may be possible within this group. A Tree State was found within another, similar, MLRA DRG: MLRA 29 Group 13.

Annual State: An Annual State was not seen for this group, though such a state may be possible within this group. An Annual State was found within another, similar, MLRA DRG: MLRA 29 Group 13.

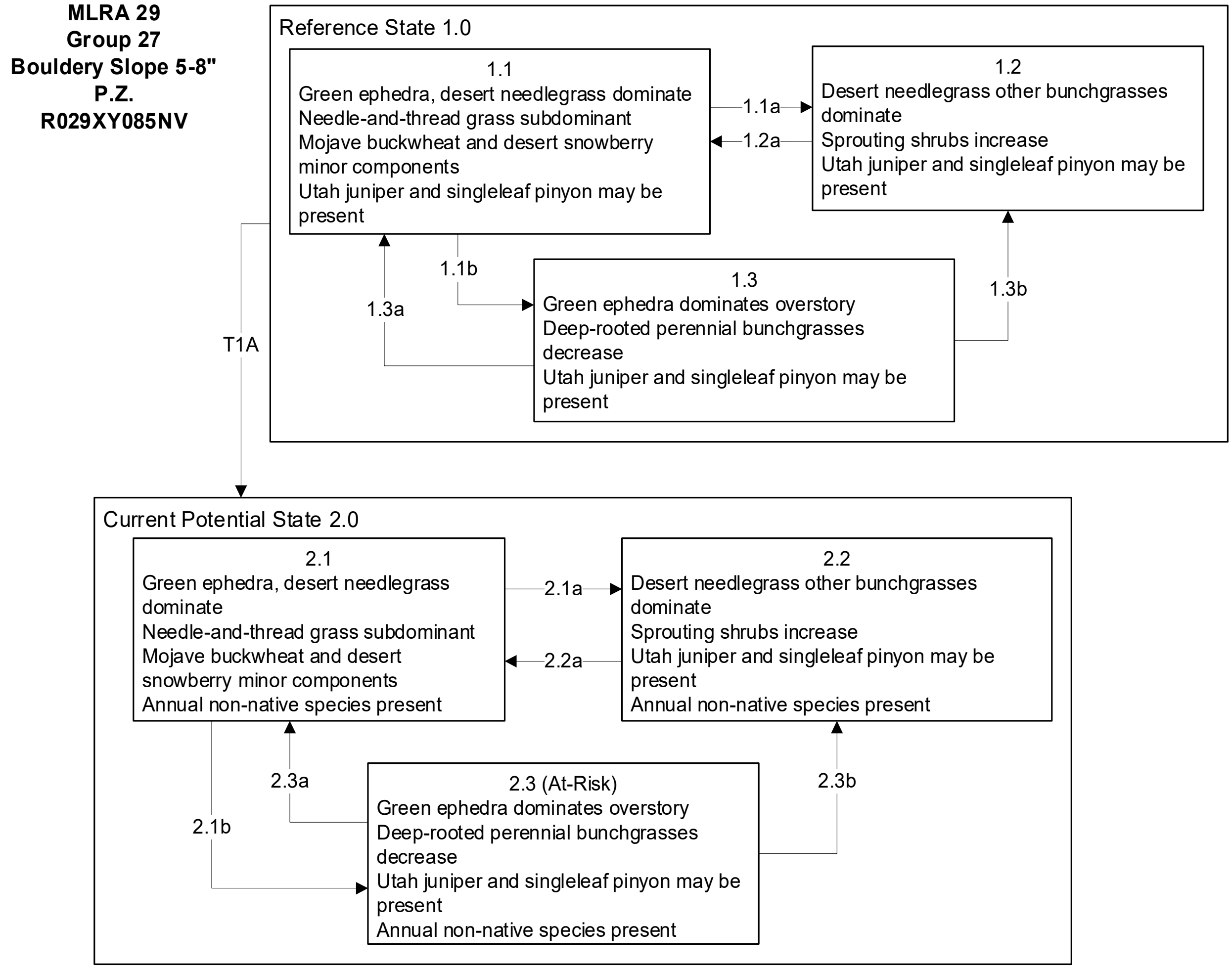
Seeded State: A Seeded State was not seen for this group, though such a state may be possible within this group. A Seeded State was found within another, similar, MLRA DRG: MLRA 29 Group 13.

Potential Resilience Differences with Other Ecological Sites in this Group:

Scree Slope 8-10" P.Z. (R029XY069NV):

The plant community is dominated by green ephedra *(Ephedra viridis)*, Wyoming big sagebrush *(Artemisia tridentata var. wyomingensis)* and desert needlegrass *(Achnatherum speciosum)*. This site is less productive (producing 350 lb/ac in a normal year) and has surface rock fragment cover greater than 90%. Slopes range from 30 to 75% The most productive areas within this site occur adjacent to areas of exposed bedrock. These areas provide plants with a relatively stable zone and additional moisture supplied by runoff from impervious rock. This site has the same two stable states as the modal.

Modal State and Transition Model for Group 27 in MLRA 29:



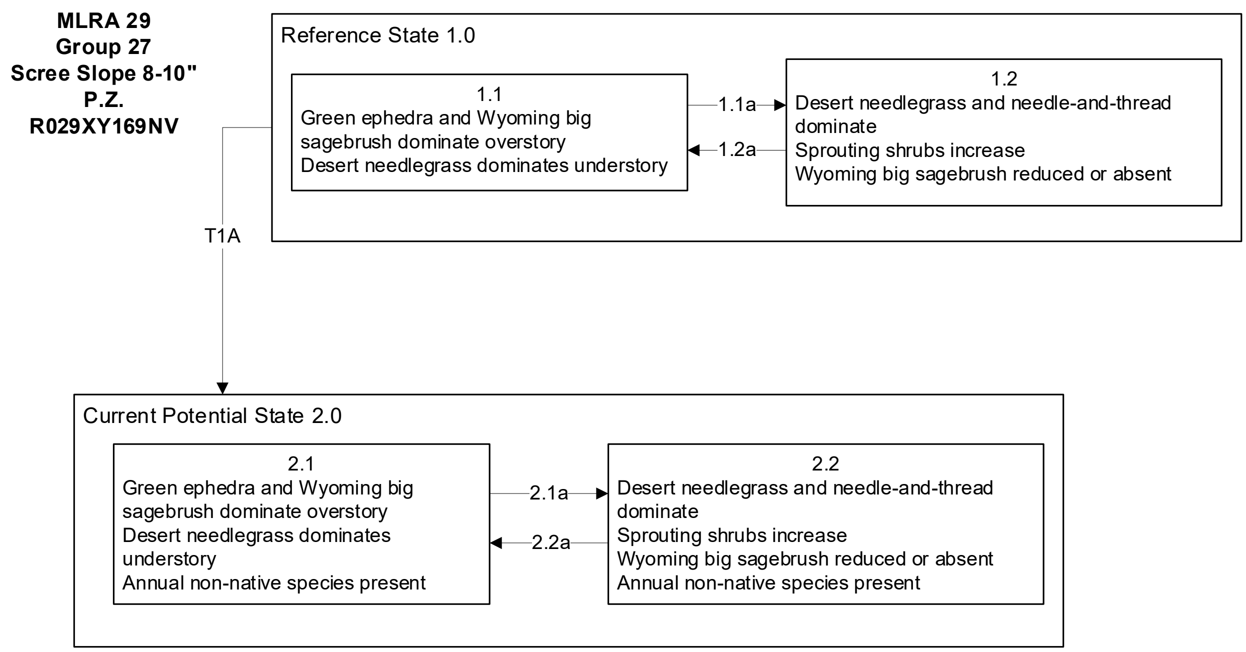
MLRA 29
Group 27
Bouldery Slope 5-8" P.Z.
R029XY085NV

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire creates grass/shrub mosaic increases bunchgrasses and sprouting shrubs.
1.1b: Time and lack of disturbance such as fire increases shrub cover. Long-term drought and herbivory can also decrease perennial bunchgrasses.
1.2a: Time and lack of disturbance will allow shrub cover to resprout and re-establish.
1.3a: A low severity fire, herbivory or combinations will reduce the shrub overstory and create a shrub/grass mosaic.
1.3b: High intensity fire will decrease or eliminate the shrub overstory and allow for perennial bunchgrasses to dominate the site.

Transition T1A: Introduction of non-native annual species

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire creates grass/shrub mosaic, targeting grazing increases bunchgrasses. Sprouting shrubs increase.
2.1b: Time and lack of disturbance such as fire increases shrub cover. Long-term drought and herbivory can also decrease perennial bunchgrasses.
2.2a: Time and lack of disturbance will allow shrub cover to resprout and re-establish.
2.3a: A low severity fire, herbivory or combinations will reduce the shrub overstory and create a shrub/grass mosaic. Annual non-native species are present and may be present in response to disturbance.
2.3b: High intensity fire will decrease or eliminate the shrub overstory and allow for perennial bunchgrasses to dominate the site. Annual non-native species are present and may be increasing.

Additional State and Transition Models for Group 27 in MLRA 29:



MLRA 29
Group 27
Scree Slope 8-10" P.Z.
R029XY169NV

Reference State 1.0 Community Phase Pathways
1.1a: Prolonged drought or insect infestation reduces shrub and grass cover.
1.2a: Release from drought or insect infestation.

Transition T1A: Introduction of non-native annual species such as cheatgrass and annual mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Prolonged drought or insect infestation reduces shrub and grass cover.
2.2a: Release from drought or insect infestation.

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MLRA 29 Group 28: Pinyon and juniper woodland with Wyoming big sagebrush understory

Description of MLRA 29 Disturbance Response Group 28

Disturbance Response Group (DRG) 28 consists of two ecological sites. The precipitation ranges from 10 to 14 in. Slopes range from 15 to 75%. Elevations range from 5,400 to 7,200 ft (1,646–2,195 m). The soils are range from very shallow to deep and well drained. They are typically skeletal and have 35 to over 50% gravels, cobbles, or stones distributed throughout the profile as well as coarse fragments at the soil surface. Potential for rill and sheet erosion is moderate to high depending on slope. The soil temperature regime is mesic and the soil moisture regime is aridic bordering on xeric. The reference plant communities are dominated by singleleaf pinyon *(Pinus monophylla).* Utah juniper *(Juniperus osteosperma)* is co-dominant with singleleaf pinyon on one ecological site. Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) is the dominant understory shrub species and other shrub species include desert bitterbrush (*Purshia glandulosa*), Stansbury cliffrose (*Purshia stansburiana*), green ephedra (*Ephedra viridis*), and Utah serviceberry (*Amelanchier utahensis*). The perennial grass component is dominated by muttongrass (*Poa fendleriana*). Other grass species important to these sites include Indian ricegrass *(Achnatherum hymenoides)*, Sandberg bluegrass (*Poa secunda*), prairie junegrass (*Koeleria macrantha*), and needleandthread *(Hesperostipa comata*). Understory production ranges from 50 to 500 lb/ac with canopy cover of 21 to 35%. Tree site indexes range from 25 to 55.

Disturbance Response Group 28 Ecological Sites:

PIMO-JUOS/ARTRW8 – Modal	F029XY065NV
JUOS/ARTRW8-PUGL2/ACHY (Shallow Loam 10-14" P.Z.)	F029XY070NV

Modal Site:

The singleleaf pinyon-Utah juniper/Wyoming big sagebrush/muttongrass (F029XY065NV) site is the modal for this DRG as it has the most acres mapped. This woodland site occurs on upper fan piedmonts, hills and low mountain summits and sideslopes on all aspects. Slopes range from 4 to over 50%, but are typically 30 to 50%. Elevations are 5,800 to about 7,200 ft. Average annual precipitation is 10 to about 14 in. Soils are shallow to moderately deep. These soils are typically skeletal with 35 to over 50% gravels, cobbles or stones, by volume, distributed throughout the profile. Available water holding capacity is low, but trees and shrubs extend their roots into fractures in the bedrock allowing them to utilize deep moisture. High amounts of rock fragments are present at the soil surface, occupying plant growing space, yet helping to reduce evaporation and conserve soil moisture. Coarse fragments on the surface help reduce evaporation thus conserving soil moisture. Runoff is medium to rapid and potential for erosion is moderate to severe depending on slope. This site is dominated by singleleaf pinyon and Utah juniper. Overstory tree canopy composition is about 50 to 70% Utah juniper and 30 to 50% singleleaf pinyon. An overstory canopy of average of 20 to 35% is assumed to be representative of tree dominance on this site in the pristine environment. However, current research indicates a canopy cover of 10 to 20% is likely more appropriate to represent this site condition in pre-European contact condition (Miller et al. 2008b). Wyoming big sagebrush is the principal understory shrub and muttongrass and Sandberg bluegrass are the prominent understory grasses. Utah serviceberry, Stansbury cliffrose, and desert bitterbrush are also important shrubs in this community. Mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*) may occur at the upper elevations of this site. Understory vegetative composition is about 30% grasses, 10% forbs and 60% shrubs and young trees in a mature woodland averaging 20 to 35% canopy cover. Average understory production ranges from 200 to 500 lb/ac with 300 pounds typical for a normal precipitation year. Understory production includes the total annual production of all species within 4.5 ft (1.4 m) of the ground surface. This woodland community is of low site quality for tree production.

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasive species. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans across Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area, especially in eastern Nevada, when strong convection storms contribute significantly to annual precipitation. Moisture and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

However, periodic drought regularly influences these ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West (Miller et al. 2008a). Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006).

Pinyon and juniper-dominated plant communities in the cold desert of the Great Basin and Colorado Plateau occupy over 18 million hectares (44.8 M ac) (Miller and Tausch 2001, Miller et al. 2019). Soils occupied by persistent woodlands are most commonly shallow to restrictive layers including claypans, calcareous horizons, and fractured bedrock (Miller et al. 2019). In addition, soil surfaces are typically very coarse-textured with gravelly to extremely cobbly material, often resulting in very low to low soil moisture storage (Miller et al. 2019). In the mid to late 1900s, the number of pinyon and juniper trees established per decade began to increase compared to the previous several hundred years. The substantial increase in conifer establishment is attributed to a number of factors the most important being (1) cessation of the aboriginal burning (Tausch 1999), (2) change in climate with rising temperatures (Heyerdahl et al. 2006), (3) the reduced frequency of fire likely driven by the introduction of domestic livestock, (4) a decrease in wildfire frequency along with improved wildfire suppression efforts and (5) potentially increased CO2 levels favoring woody plant establishment (Bunting 1994, Tausch 1999). Miller et al. (2008b) found pre-settlement tree densities averaged 2 to 11 per acre in six woodlands studied across the Intermountain West. Current stand densities range from 80 to 358 trees/ac. In Utah, Nevada, and Oregon, trees established prior to 1860 accounted for only 2% or less of the total population of pinyon and juniper (Miller et al. 2008b). The research strongly suggests that for over 200 years prior to settlement, woodlands in the Great Basin were relatively low density with limited rates of establishment (Miller and Tausch 2001, Miller et al. 2008b). This evidence strongly suggests that tree canopy cover of 10 to 20% may be more representative of these sites in pristine condition. Increases in pinyon and juniper densities post-settlement were the result of both infill in mixed-age tree communities and expansion into shrub-steppe communities. Pre-settlement trees accounted for less than 2% of the stands sampled in Nevada, Oregon, and Utah (Miller et al. 1999, Miller and Tausch 2001, Miller et al. 2008b). However, the proportion of old-growth can vary depending on disturbance regimes, soils, and climate. Some ecological sites are capable of supporting persistent woodlands, likely due to specific soils and climate resulting in infrequent stand replacement disturbance regimes. In the Great Basin, old-growth trees have been found to typically grow on rocky shallow or sandy soils that support little understory vegetation to carry a fire (Holmes et al. 1986, Miller and Rose 1995, West et al. 1998).

Infilling by younger trees increases canopy cover causing a decrease in understory perennial vegetation and an increase in bare ground. As pinyon and juniper trees increase in density so has their litter. Phenolic compounds of juniper scales can have an inhibitory effect on grass growth (Jameson 1970). Furthermore, infilling shifts stand-level biomass from ground fuels to canopy fuels which has the potential to significantly impact fire behavior. The more tree-dominated pinyon and juniper woodlands become, the less likely they are to burn under moderate conditions, resulting in infrequent high-intensity fires (Gruell 1999, Miller et al. 2008b). Additionally, as the understory vegetation declines in vigor and density with increased canopy, the seed and propagules of the understory plant community also decrease significantly. The increase in bare ground allows for the invasion of non-native annual species such as cheatgrass and with intensive wildfire, the potential for conversion to annual exotics is a serious threat (Tausch 1999, Miller et al. 2008b).

Singleleaf pinyon and Utah juniper are long-lived tree species with wide ecological amplitudes (Tausch et al. 1981, West et al. 1998, Weisberg and Ko 2012). The maximum ages of pinyon and juniper exceed 1,000 years and stands with maximum age classes are only found on steep rocky slopes with no evidence of fire (West et al. 1975). Pinyon is slow-growing and very intolerant to shade with the exception of young plants, usually first-year seedlings (Tueller and Clark 1975). Singleleaf pinyon seedling establishment is episodic. Population age structure is affected by drought, which reduces seedling and sapling recruitment more than other age classes. The ecotones between singleleaf pinyon woodlands and adjacent shrublands and grasslands provide favorable microhabitats for singleleaf pinyon seedling establishment since they are active zones for seed dispersal, nurse plants are available, and singleleaf pinyon seedlings are only affected by competition from grass and other herbaceous vegetation for a couple of years.

Specific successional pathways after disturbance in pinyon-juniper stands are dependent on a number of variables, such as plant species present at the time of disturbance and their individual responses to disturbance, past management, type and size of disturbance, available seed sources in the soil or adjacent areas, and site and climatic conditions throughout the successional process.

Insects and diseases of western juniper are not well understood or studied (Eddleman et al. 1994). Utah juniper can be killed by a fungus called Juniper Pocket Rot (*Pyrofomes demidoffi*), also known as white trunk rot (Eddleman et al. 1994, Durham 2014). Pocket rot enters the tree through any wound or opening that exposes the heartwood. In an advanced stage, this fungus can cause high mortality (Durham 2014). Dwarf mistletoe (*Phorandendron* spp.), a parasitic plant, may also affect Utah juniper and without treatment or pruning, may kill the tree 10 to 15 years after infection. Seedlings and saplings are most susceptible to the parasite (Christopherson 2014). Other diseases affecting juniper are: witches' broom (*Gymnosporangium* spp.) that may girdle and kill branches; leaf rust (*Gymnosporangium* spp.) on leaves and young branches; and juniper blight (*Phomopsis* spp.). Flat-head borers (*Chrysobothris spp.*) attack the wood; long-horned beetles (*Methia juniper*, *Styloxus bicolor*) girdle limbs and twigs; and round-head borers (*Callidium* spp.) attack twigs and limbs (Tueller and Clark 1975).

Phillips (1909) recognized that the pinyons are more resistant to disease than most of the conifers with which it associates. Hepting (1971) lists several diseases affecting pinyon including: foliage diseases, tarspot needle cast *(Davisomycella ampla)*, stem diseases such as blister rust *(Cronartium ribicola)* and dwarf mistletoe *(Arceuthobium spp.)*, root diseases and trunk rots, red heart rot, and butt rot (caused by *Polyporus schweinitzii)*. The pinyon ips beetle *(Ips confuses*) and pinyon needle scale (*Matsucoccus acalyptus*) are both native insects to Nevada that attack pinyon pines throughout their range. The pinyon needle scale weakens trees by killing needles older than 1 year. Sometimes small trees are killed by repeated feeding and large trees are weakened to the point that they are attacked by the pinyon ips beetle. The beetle typically kills weak and damaged trees (Phillips and Reboletti 2014). During periods of long-term drought, the impact of these two insects on singleleaf pinyon can be substantial.

The pinyon jay (*Gymnorhinus cyanocephalus)* and other members of the seed caching corvids play an important role in pinyon pine regeneration. These birds cache the seeds in the soil for future use. Those seeds that escape harvesting by the birds and rodents have the opportunity to germinate under favorable soil and climatic conditions (Lanner 1981). A mutualistic relationship exists between the trees that produce food and the animals that disperse the seeds, thereby ensuring the perpetuation of the trees. Large crops of seeds may stimulate reproduction in birds, especially the pinyon jay (Ligon 1974).

Pinyon and juniper growth is dependent mostly upon soil moisture stored from winter precipitation, mainly snow. Much of the summer precipitation is ineffective, being lost in runoff after summer convection storms or by evaporation and interception (Tueller and Clark 1975). Pinyon and juniper are highly resistant to drought which is common in the Great Basin. Tap roots of pinyon and juniper have a relatively rapid rate of root elongation and are thus able to persist until precipitation conditions are more favorable (Emerson 1932).

In the Great Basin, the majority of annual precipitation is received during the winter and early spring. This continental semiarid climate regime favors the growth and development of deep-rooted shrubs and herbaceous cool season plants using the C3 photosynthetic pathway (Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow results in deeper percolation of moisture into the soil profile. Herbaceous plants, more shallow-rooted than shrubs, grow earlier in the growing season and thrive on spring rains, while the deeper-rooted shrubs lag in phenological development because they draw from deeply infiltrating moisture from snowmelt the previous winter. Periodic drought regularly influences sagebrush ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West. Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006).

Wyoming big sagebrush, the dominant shrub of this group, is generally long-lived; therefore, it is not necessary for new individuals to recruit every year for perpetuation of the stand. Infrequent large recruitment events and simultaneous low, continuous recruitment is the foundation of population maintenance (Noy-Meir 1973). Survival of the seedlings is dependent on adequate moisture conditions. Sagebrush have a flexible generalized root system with development of both deep taproots and laterals near the surface (Dobrowolski et al. 1990). In general, these shrubs root to the full depth of the winter-spring soil moisture recharge, which ranges from 1.0 to over 3.0 m (3 to 10 ft) (Comstock and Ehleringer 1992). Root length of mature sagebrush plants was measured to a depth of 2 m (6.5 ft) in alluvial soils in Utah (Richards and Caldwell 1987).

Desert bitterbrush and Stansbury cliffrose, both in the *Purshia* genus, occur frequently, but not abundantly, on the ecological sites within this DRG. Hybridization is common among these species, making field identification challenging (Booth et al. 2008). The shrubs are drought tolerant and all provide high quality browse for domestic and wild ungulates (Bishop et al. 2001). In general, bitterbrush and cliffrose are moderately fire tolerant (McConnell and Smith 1977). These shrubs regenerate primarily by seed and may resprout (Blaisdell and Mueggler 1956, McArthur and Welch 1982), however sprouting ability is highly variable and has been attributed to genetics, plant age, phenology, soil moisture and texture and fire severity (Blaisdell and Mueggler 1956, Blaisdell et al. 1982, Clark et al. 1982, Cook et al. 1994). Rodent caching of seed has been identified as an important mechanism for establishment of new plants (Alexander et al. 1974).

The primary perennial bunchgrasses that are found on these sites include muttongrass, Sandberg bluegrass, Indian ricegrass, prairie junegrass and bottlebrush squirreltail. These species generally have somewhat shallower root systems than the shrubs, but root densities are often as high as or higher than those of shrubs in the upper 0.5 m (1.6 ft) of the soil profile. General differences in root depth distributions between grasses and shrubs result in resource partitioning in these shrub/grass systems.

Muttongrass is a tufted, multi-flowered, perennial bunchgrass that can grow between 8 and 30 in. tall and has narrow leaves, which range from 1 to 3 mm wide. It is found in lower elevations in the northern extent of its native range, and higher elevations in the south. Muttongrass is one of the most drought-tolerant bluegrasses and is useful for restoring communities disturbed by fire, grazing, or mining, but is limited in its use due to low seed viability. Muttongrass plants are most frequently pistillate, but staminate plants do occasionally occur, which are able to hybridize and crossbreed with other bluegrasses. Muttongrass is found throughout the western United States as a primary component of the understory of pinyon-juniper communities, aspen forests and pine forests (Tilley et al. 2007).

Indian ricegrass is a long-lived, cool-season perennial bunchgrass that grows from 4 to 24 inches in height (Blaisdell and Holmgren 1984). Primarily adapted to coarse-textured soils, its deep, fibrous root system makes Indian ricegrass one of the most drought-tolerant native species (Booth et al. 1980). Unlike other cool-season species, Indian ricegrass does not require vernalization (exposure to cold) in order to produce flowers and flowering can continue into late fall with favorable environmental conditions. This allows the seeds in each panicle to ripen over a longer period of time than most other species thus providing a greater opportunity for successful seed production (Jones 1990).

Annual Invasive Species:

The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and decomposition of dead plant material following disturbance further increases resource pools. The presence of exotic annual plants within these ecosystems decreases ecosystem resilience and resistance to disturbance through competition for limited resources. Dobrowolski et al. (1990) cite multiple authors on the extent of the soil profile exploited by the competitive exotic annual cheatgrass. Specifically, the depth of rooting is dependent on the size the plant achieves, and in competitive environments, cheatgrass roots were found to penetrate only 15 cm (6 in.) whereas isolated plants and pure stands were found to root at least 1 m in depth with some plants rooting as deep as 1.5 to 1.7 m (5 to 5.5 ft).

The species most likely to invade these sites is cheatgrass. Cheatgrass is a cool-season annual grass that maintains an advantage over native plants in part because it is a prolific seed producer, can germinate in the autumn or spring, tolerates grazing, and increases with frequent fire (Klemmedson and Smith 1964, Miller and Rose 1999). Cheatgrass originated from Eurasia and was first reported in North America in the late 1800s (Furbush 1953, Mack and Pyke 1983). Pellant and Hall (1994) found 3.3 million acres of public lands dominated by cheatgrass and suggested that another 76 million acres were susceptible to invasion by winter annuals including cheatgrass and medusahead.

Recent modeling and empirical work by Bradford and Lauenroth (2006) suggest that seasonal patterns of precipitation input and temperature are also key factors determining regional variation in the growth, seed production, and spread of invasive annual grasses. The phenomenon of cheatgrass “die-off” provides opportunities for restoration of perennial and native species (Baughman et al. 2016, Baughman et al. 2017). The causes of these events are not fully understood, but there is ongoing work to try to predict where they occur, in the hopes of aiding conservation planning (Weisberg et al. 2017, Brehm 2019).

Methods to control cheatgrass include herbicide application, prescribed fire, targeted grazing, and rangeland seeding. Mapping potential or current invasion vectors is a management method designed to increase the cost-effectiveness of control methods. Spraying with herbicide (imazapic or imazapic + glyphosate) and seeding with crested wheatgrass and Sandberg bluegrass has been found to be more successful at combating cheatgrass (and medusahead) than spraying alone (Sheley et al. 2012). To date, most seeding success has occurred with non-native wheatgrass species. Perennial grasses, especially crested wheatgrass, are able to suppress cheatgrass growth when mature (Blank et al. 2020). Where native bunchgrasses are missing from the site, revegetation of annual grass-invaded rangelands has been shown to have a higher likelihood of success when using introduced perennial bunchgrasses such as crested wheatgrass (Davies et al. 2015b, Clements et al. 2017). Butler et al. (2011) tested four herbicides (imazapic, imazapic + glyphosate, rimsulfuron, and sulfometuron + chlorsulfuron) for suppression of cheatgrass, medusahead (*Taeniatherum caput-medusae*), and ventenata (North

Africa grass, *Ventenata dubia*) within residual stands of native bunchgrass. Additionally, they tested the same four herbicides followed by seeding of six bunchgrasses (native and non-native) with varying success (Butler et al. 2011). Herbicide-only treatments appeared to remove competition for established bluebunch wheatgrass by providing 100% control of ventenata and medusahead and greater than 95% control of cheatgrass (Butler et al. 2011). Caution in using these results is advised, as only 1 year of data was reported.

In considering the combination of pre-emergent herbicide and prescribed fire for invasive annual grass control, it is important to assess the tolerance of desirable brush species to the herbicide being applied. Vollmer and Vollmer (2008) tested the tolerance of mountain mahogany (*Cercocarpus montanus*), antelope bitterbrush, and multiple sagebrush species to three rates of imazapic with and without methylated seed oil as a surfactant. They found that a cheatgrass control program, utilizing imazapic, in an antelope bitterbrush community should not exceed 8 oz/ac with or without surfactant. Sagebrush, regardless of species or rate of application, was not affected. However, many environmental variables were not reported in this study and managers should install test plots before broad-scale herbicide application is initiated.

The ecological sites in this Disturbance Response Group (DRG) have low to medium resilience to disturbance and resistance to invasion. Resilience increases with elevation, aspect, increased precipitation and increased nutrient availability. Four possible stable states have been identified for this DRG.

Fire Ecology:

Limited data exists that describes fire histories across woodlands in the Great Basin. Pre-settlement fire return intervals in the Great Basin National Park, Nevada were found to have a mean range between 50 to 100 years with north-facing slopes burning every 15 to 20 years and rocky landscapes with sparse understory, fire-safe sites, burn very infrequently (Gruell 1999). Results were less conclusive in a similar study in the Bodie Hills; however, it was apparent that old (300+ years old) singleleaf pinyon primarily survived in protected, low-fuel areas. Woodland dynamics are largely attributed to long-term climatic shifts (temperature and amount and distribution of precipitation) and the extent and return intervals of fire (Miller and Tausch 2001, Miller et al. 2019). Historically, lightning-ignited fires were likely common but typically did not affect more than a few individual trees. Replacement fires were uncommon to rare (100 to 600 years) and occurred primarily during extreme fire behavior conditions.

Utah juniper is usually killed by fire, and is most vulnerable to fire when it is under 4 ft tall (Bradley et al. 1992). Larger trees, because they have foliage farther from the ground and thicker bark, can survive low severity fires but mortality does occur when 60% or more of the crown is scorched (Bradley et al. 1992). Singleleaf pinyon are also most vulnerable to fire when less than 4 ft tall, however mature trees do not self-prune their dead branches allowing for accumulated fuel in the crowns. This characteristic and the relative flammability of the foliage make individual mature trees susceptible to fire (Bradley et al. 1992). With the low production of the understory vegetation and low density of trees per acre, high severity fires within this plant community were not likely and rarely became crown fires (Bradley et al. 1992, Miller and Tausch 2001). However, both the infilling of younger trees into old-growth stands and the expansion of trees into surrounding sagebrush communities have increased the risk of loss of pre-settlement trees through the increased landscape level continuity of fuels (Miller et al. 2008b).

Utah juniper and singleleaf pinyon reestablish by seed from nearby seed sources or surviving seeds. Junipers have a long-lived seed bank due to delayed germination by impermeable seed coats, immature or dormant embryos, and germination inhibitors (Chambers et al. 1999, Schupp et al. 1999). Singleleaf pinyons have relatively short-lived seeds with little innate dormancy that form only temporary seed banks with most seeds germinating in the spring following dispersal (Meeuwig and Basset 1983). The density of pinyon seeds in the seed bank is dependent upon the current year's cone crop. Singleleaf pinyon is known to have favorable cone production every 2 to 3 years thus the potential for a large temporary seed bank is high during mast years and likely low during non-mast years (Chambers et al. 1999). The role of nurse plant requirements between the two tree species is important to post-fire establishment. Chambers et al. (1999) found that singleleaf pinyon seedlings rarely establish in interspaces or open environments. In contrast, Utah juniper seedlings were found capable of establishing in interspace microhabitats as frequently as under sagebrush. Therefore, fire that removes both trees and understory shrubs in pinyon-juniper woodlands may have a relatively greater effect on the establishment of pinyon than juniper.

Wyoming big sagebrush is killed by fire and only regenerates from seed. Recovery time for Wyoming big sagebrush may require 50 to 120 or more years (Baker 2006). However, the introduction and expansion of cheatgrass has dramatically altered the fire regime (Balch et al. 2013) and restoration potential of Wyoming big sagebrush communities.

Mountain big sagebrush is killed by fire (Neuenschwander 1980, Blaisdell and Holmgren 1984), and does not re-sprout (Blaisdell 1953). Post fire regeneration occurs from seed and will vary depending on site characteristics, seed source, and fire characteristics. Mountain big sagebrush seedlings can grow rapidly and may reach reproductive maturity within 3 to 5 years (Bunting et al. 1987). Mountain big sagebrush may return to pre-burn density and cover within 15 to 20 years following fire, but establishment after severe fires may proceed more slowly and can take up to 50 years (Bunting et al. 1987, Ziegenhagen 2003, Miller and Heyerdahl 2008).

Desert bitterbrush and Stansbury cliffrose are moderately fire tolerant (Nord 1965, McConnell and Smith 1977). These shrubs regenerate primarily by seed and may resprout (Blaisdell and Mueggler 1956, McArthur and Welch 1982), however, sprouting ability is highly variable and has been attributed to genetics, plant age, phenology, soil moisture and texture, and fire severity (Blaisdell and Mueggler 1956, Blaisdell et al. 1982, Clark et al. 1982, Cook et al. 1994). Cliffrose may resprout following a low-intensity fire however, sprouting response also depends on soil moisture levels at the time of fire (Murray 1983). If cheatgrass is present, bitterbrush and cliffrose seedling success is much lower. The factor that most limits the establishment of these seedlings is competition for water resources with the invasive species cheatgrass (Clements and Young 2002).

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The initial condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species response. For most forbs and grasses the growing points are located at or below the soil surface providing relative protection from disturbances which decrease above ground biomass, such as grazing or fire. Thus, fire mortality is more correlated to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant and abundance of old growth (Wright 1971, Young 1983). However, season and severity of the fire will influence plant response. Plant response will vary depending on post-fire soil moisture availability.

Muttongrass, a dominant component in this group, is top killed by fire but will sprout after low to moderate severity fires. A study by Vose and White (1991) in an open saw timber site found minimal difference in the overall effect of burning on muttongrass.

Sandberg bluegrass, a minor component of this ecological site, has been found to increase following fire likely due to its low stature and productivity (Daubenmire 1975). Sandberg bluegrass may retard reestablishment of deeper-rooted bunchgrass. Reduced bunchgrass vigor or density provides an opportunity for Sandberg bluegrass expansion and/or cheatgrass and other invasive species to occupy interspaces, leading to increased fire frequency and potentially an annual plant community.

Indian ricegrass is fairly fire tolerant (Wright 1985), which is likely due to its low culm density and below-ground plant crowns. Vallentine (1989) cites several studies in the sagebrush zone that classified Indian ricegrass as being slightly damaged from late summer burning. Indian ricegrass has also been found to reestablish on burned sites through seeds dispersed from adjacent unburned areas (Young 1983, West 1994). Thus, the presence of surviving, seed-producing plants facilitates the reestablishment of Indian ricegrass. Grazing management following fire to promote seed production and establishment of seedlings is important (Booth et al. 1980).

Livestock/Wildlife Grazing Interpretations:

Pinyon-juniper woodlands provide a diversity of habitat for wildlife. Although the foliage of pinyon and juniper varies in palatability among fauna, pinyon nuts and juniper berries are preferred by many species. The understory species provide fruits and browse for large ungulates, small mammals, birds, and beavers (Wildlife Action Plan Team 2012).
Ungulates will use pinyon and juniper trees for cover and graze the foliage. The understory species also provide critical browse for deer *(Odocoileus spp.)*. The trees provide important

cover for mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis)* wild horses *(Equus ferus)*, mountain lion (*Puma concolor*), bobcat (*Lynx rufus*), and pronghorn antelope (*Antilocapra americana*) (Logan and Irwin 1985, Evans 1988, Coates and Schemnitz 1994, Gottfried and Severson 1994).

Mule deer is considered the dominant big game species in the pinyon-juniper woodland and depend heavily on these woodlands for cover, shelter, and emergency forage during severe winters (Frischknecht 1975). Mule deer will eat singleleaf pinyon and juniper foliage, using the foliage moderately in winter, spring, and summer (Kufeld et al. 1973). Deep snows in higher elevation forest zones force mule deer and elk down into pinyon-juniper habitats during winter. This change in habitat allows mule deer and elk to browse the dwarf trees and shrubs (Gottfried and Severson 1994).

The diet of pronghorn antelope varies considerably; however, singleleaf pinyon was shown to comprise 1 to 2% of the winter diet of pronghorn antelope that occur in pinyon-juniper habitat. Desert bighorn sheep (*Ovis nelson*) may utilize pinyon-juniper habitat, but only where the terrain is rocky and steep (Gottfried et al. 2000). Gray foxes (*Urocyon cinereoargenteus*), bobcats (*Lynx rufus*), coyotes (*Canis latran*s), weasels (*Mustela frenata*), skunks (*Mephitis* spp.), badgers (*Taxidea taxus*), and ringtail cats *(Bassariscus astutus*) search for prey in pinyon-juniper habitat woodlands (Short and McCulloch 1977).

Juniper "berries" or berry-cones are eaten by black-tailed jackrabbits (*Lepus californicus)* and coyotes (Gese et al. 1988, Kitchen et al. 2000). A study by Kitchen et al. (2000) conducted in juniper-pinion habitat found vegetation in coyote scats was mainly grass seeds or juniper berries. Jackrabbits are a major dispenser of juniper seeds (Schupp et al. 1999). The pinyon mouse *(Peromyscus truei*) is a pinyon-juniper obligate and uses the woodlands for cover and food (Hoffmeister 1981). Other small mammals include the porcupine (*Hystricomorph hystricidae*), desert cottontail (*Sylvilagus audubonii*), Nuttall's cottontail (*S. nuttallii*), deer mouse (*Peromyscus maniculatus*), Great Basin pocket mouse (*Perognathus parvus*), chisel-toothed kangaroo rat (*Dipodomys microps*) and desert woodrat (*Neotoma lepida*) (Turkowski and Watkins 1976).

Many bird species are associated with the pinyon-juniper habitat; some are permanent residents, some summer residents, and some winter residents, depending upon location. For birds and bats, the woodland provides structure for nesting and roosting, and locations for foraging. Singleleaf pinyon provides a number of cavities and the stringy, fibrous bark provides quality nesting material as well as the food provided by the tree's seeds and berries (Short and McCulloch 1977). Many bird species depend on juniper berry-cones and pine nuts for fall and winter food (Balda and Masters 1980). Several bird species are obligates, including gray flycatcher (*Epidonax wrightii)*, scrub jay (*Aphelocoma californica)*, plain titmouse (*Parus inornatus ridgwayi*), and gray vireo (*Vireo vicinior)*; several species are semi-obligates including black-chinned hummingbird (*Archilochus alexandri*), ash-throated flycatcher (*Myiarchus cinerascens*), pinion jay (*Gymnorhinus cyanocephalus*), American bushtit (*Psaltriparus minimus*), Bewick's wren (*Thryomanes bewickii*), Northern mockingbird (*Mimus polyglottos*), blue-gray gnatcatcher (*Polioptila caerulea*), black-throated gray warbler (*Dendroica nigrescens*), house finch (*Haemorhous mexicanus*), spotted towhee (*Pipilo maculatus*), lark sparrow (*Chondestes grammacus*) and black-chinned sparrow (*Zonotrichia atricapilla)* (Balda and Masters 1980). Ferruginous hawk (*Buteo regalis*), a conservation priority species due to recent population declines in Nevada, nests in older trees of sufficient size and structure to support their large nest platforms (Holechek 1981).

Diurnal reptiles include the sagebrush swift (*Sceloporus graciosus)*, the western fence lizard (*Sceloporus occidentalis),* the Great Basin collard lizard *(Crotaphytus bicinctores)*, the western whiptail (*Aspidoscelis tigris*), Gilbert's skink (*Plestiodon gilberti*) and the western skink (*Plestiodon skiltonianus*), the Pacific rattlesnake (*Crotalus oreganus*), the Great Basin gopher snake (*Pituophis catenifer deserticola*), and desert horned lizard *(Phrynosoma platyrhinos)* also occur in Utah juniper habitat (Frischknecht 1975, Morrison and Hall 1999). However, the distribution of most of the herpetofauna present in pinyon-juniper woodlands is poorly understood and more research and management are needed.

The history of livestock grazing in the pinyon-juniper ecosystem goes back more than 200 years, depending on the particular locality within the ecosystem (Hurst 1975). Historically, pinyon-juniper woodlands were much more open, and they supported a diverse understory that provided forage for both livestock and wildlife. Historic livestock overuse and increased stand densities have reduced the carrying capacity of these pinyon-juniper stands and many current stands only provide shade and shelter for livestock.

Despite low palatability, mountain big sagebrush is eaten by domestic sheep, cattle, goats (*Capra hircus*) and horses (*Equus ferus*). Chemical analysis indicates that the leaves of big sagebrush equal alfalfa meal (*Medicago sativa*) in protein, have a higher carbohydrate content, and yield twelvefold more fat (USFS 1937). Many wildlife species are dependent on sagebrush including the greater sage grouse (*Centrocercus urophasianus*), sage sparrow (*Artemisiospiza nevadensis*), pygmy rabbit (*Brachylagus idahoensis*), and the sagebrush vole (*Lemmiscus curtatus*). Wyoming big sagebrush is the least palatable of the big sagebrush taxa (Sheehy and Winward 1981, Bray et al. 1991), however it may receive light or moderate use depending upon the amount of understory cover (Tweit and Houston 1980).

Desert bitterbrush is an important forage species for livestock, deer and pronghorn, especially in winter when protein levels are high (Sampson and Jespersen 1963, Young and Evans 1981). This shrub also provides important cover for large and small mammals (Monsen et al. 2004b)

Muttongrass is relatively grazing tolerant. It is rated as excellent forage for cattle and horses, and good for sheep, elk, and deer (USFS 1937). Muttongrass starts growth in late winter or early spring and provides excellent early feed. In addition, muttongrass foliage cures well and is good fall forage (Humphrey et al. 1952). Muttongrass persists well in open areas and under canopies of oak and other shrubs (Monsen et al. 2004a).

Sandberg bluegrass increases under grazing pressure (Tisdale and Hironaka 1981) and is capable of co-existing with cheatgrass. Excessive domestic sheep grazing favors Sandberg bluegrass; however, where cattle are the dominant grazers, cheatgrass often dominates (Daubenmire 1970). Thus, depending on the season of use, the grazer and site conditions, either Sandberg bluegrass or cheatgrass may become the dominant understory with inappropriate grazing management. Repeated frequent fire in this community will eliminate big sagebrush and severely decrease or eliminate the deep-rooted perennial bunchgrasses from the site and facilitate the establishment of an annual weed community with varying amounts of Sandberg bluegrass and rabbitbrush.

Indian ricegrass is a preferred forage species for livestock and wildlife (Cook 1962, Booth et al. 1980). This species is often heavily utilized in winter because it cures well (Booth et al. 1980). It is also readily utilized in early spring, being a source of green feed before most other perennial grasses have produced new growth (Quinones 1981). Booth et al. (1980) note that the plant does well when utilized in winter and spring. Cook and Child (1971), however, found that repeated heavy grazing reduced crown cover, which may reduce seed production, density, and basal area of these plants. Additionally, heavy early spring grazing reduces plant vigor and stand density (Stubbendieck et al. 1985). In eastern Idaho, productivity of Indian ricegrass was at least 10 times greater in undisturbed plots than in heavily grazed ones (Pearson 1965). Cook and Child (1971) found a significant reduction in plant cover after 7 years of rest from heavy (90%) and moderate (60%) spring use. The seed crop may be reduced where grazing is heavy (Bich et al. 1995). Tolerance to grazing increases after May, thus spring deferment may be necessary for stand enhancement (Pearson 1964, Cook and Child 1971); however, utilization of less than 60% is recommended. In summary, adaptive management is required to manage this bunchgrass well.

Bunchgrasses, in general, tolerate moderate grazing anytime of the year. Growing season grazing should not occur more than once every other year and once every third year is recommended. Britton et al. (1990) observed the effects of clipping date on the basal area of five bunchgrasses in eastern Oregon and found grazing from August to October (after seed set) has the least impact. Heavy grazing, year after year during the growing season, will reduce perennial bunchgrasses and increase sagebrush. Abusive grazing by cattle or horses will likely increase shallow-rooted, early season forbs and grasses including muttongrass and Sandberg bluegrass.

State and Transition Model Narrative for Group 28:

Reference State 1.0:

The Reference State 1.0 is representative of the natural range of variability under pristine conditions. This Reference State has four general community phases: a mature woodland phase (1.1), a shrub-herbaceous phase (1.2), an immature woodland phase (1.3), and an over-mature woodland phase (1.4). State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire, periodic long-term drought, and/or insect or disease attack. Fires are typically small and patchy due to low fuel loads. This fire type will create a plant community mosaic that will include all/most of the following community phases within this state.

Community Phase 1.1:

This phase is characterized by widely dispersed mature singleleaf pinyon and Utah juniper trees with an understory of big sagebrush and perennial bunchgrasses. The visual aspect is dominated by Utah juniper and singleleaf pinyon which make up 15% or more. Tree canopy cover ranges from 20 to 35%. Trees have reached maximal or near maximal heights for the site and many tree crowns may be flat- or round-topped. At fire-safe sites, dominant trees average greater than 15 in. (38 cm) in diameter at one-foot stump height. Muttongrass is the most prevalent grass. Desert bitterbrush is a common understory shrub. Forbs such as buckwheat (*Eriogonum* spp.) and phlox (*Phlox* spp.) are minor components.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:

A high severity-crown fire, insect infestation, disease, long-term drought or combinations will eliminate or reduce the singleleaf pinyon and Utah juniper overstory and the non-sprouting shrub component. This allows for the perennial bunchgrasses to dominate the site. Sprouting shrubs may increase.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.4:

Time without disturbance such as fire, long-term drought, or disease will allow for the gradual infilling of singleleaf pinyon and Utah juniper.

Community Phase 1.2:

This community phase is characterized by a post-fire shrub and herbaceous community. Muttongrass and other perennial bunchgrasses dominate. Forbs may increase after a fire but will likely return to pre-burn levels within a few years. Pinyon and juniper seedlings up to 4 ft (1.2 m) in height may be present. Big sagebrush may be present in unburned patches. Burned tree skeletons may be present; however, these have little or no effect on the understory vegetation.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.3:

Time without disturbance such as fire, long-term drought, insect infestation or disease will allow for the gradual maturation of the singleleaf pinyon and Utah Juniper component. Big sagebrush reestablishes.

Community Phase 1.3
This community phase is characterized as an immature woodland with pinyon, juniper trees averaging over 4.5 ft (1.4 m) in height. Pinyon and juniper canopy cover is between 10 to 20%. Tree crowns are typically cone- or pyramidal-shaped. Understory vegetation is dominated by big sagebrush and perennial bunchgrasses as well as smaller tree seedlings and saplings.

Community Phase Pathway 1.3a, from Phase 1.3 to 1.1:
Time without disturbance such as fire, long-term drought, insect infestation, or disease will allow for the gradual maturation of singleleaf pinyon and Utah juniper. Infilling by younger trees continues.

Community Phase Pathway 1.3b, from Phase 1.3 to 1.2:
Fire reduces or eliminates tree canopy, allowing perennial grasses and sprouting shrubs to dominate the site.

Community Phase 1.4 (At-risk):
This phase is dominated by singleleaf pinyon and Utah juniper. The stand exhibits mixed age classes and canopy cover may be greater than 50%. The density and vigor of the big sagebrush and perennial bunchgrass understory is decreased. Bare ground areas are likely to increase. Mat-forming forbs may increase.

Community Phase Pathway 1.4a, from Phase 1.4 to 1.1:
Low intensity fire, drought, insect infestation, or disease kills individual trees within the stand reducing canopy cover to less than 20%. Over time young trees mature to replace and maintain the mature woodland. The big sagebrush and perennial bunchgrass community increases in density and vigor.

Community Phase Pathway 1.4b, from Phase 1.4 to 1.2:
A high-severity crown fire will eliminate or reduce the singleleaf pinyon and Utah juniper overstory and the non-sprouting shrub component which will allow for the perennial bunchgrasses and sprouting shrubs to dominate the site.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0:

Trigger: Introduction of non-native annual species.

Slow variables: Over time the annual non-native plants will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

T1B: Transition from Reference State 1.0 to Infilled Tree State 3.0

Trigger: Time and a lack of disturbance allow trees to dominate site resources; may be coupled with inappropriate herbivory and/or fire suppression that favors shrub and tree dominance.

Slow variables: Over time the abundance and size of trees will increase.

Threshold: Juniper and pinyon canopy cover is greater than 35%. Little understory vegetation remains due to competition with trees for site resources.

Current Potential State 2.0:

This state is similar to the Reference State 1.0, with four general community phases: a mature woodland phase (2.1), a shrub-herbaceous phase (2.2), an immature woodland phase (2.3) and an over-mature woodland phase (2.4). Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of non-native species. These non-natives, particularly cheatgrass, can be highly flammable and promote fire where historically fire had been infrequent. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal. Fires within this community with the small amount of non-native annual species present are likely still small and patchy due to low fuel loads. This fire type will create a plant community mosaic that will include all/most of the following community phases within this state.

Community Phase 2.1:

This phase is characterized by a widely dispersed mature Utah juniper and singleleaf pinyon trees with an understory of big sagebrush and perennial bunchgrasses. The visual aspect is dominated by singleleaf pinyon and Utah juniper of 15% or more. Tree canopy cover ranges from 20 to 35%. Trees have reached maximal or near maximal heights for the site and many tree crowns may be flat- or round-topped. At fire-safe sites, dominant trees average greater than 15 in. (38 cm) in diameter at one-foot stump height. Muttongrass is the most prevalent grass in the understory, found primarily under tree canopies. Desert bitterbrush and Stansbury cliffrose are common understory shrubs. Mat-forming forbs are present. Overall, the understory is sparse. Non-native, annual species such as cheatgrass and/or red brome (*Bromus rubens*) are a minor component.

PIMO-JUOS/ARTRW8 (F029XY065NV), Current Potential State 2.1, T. Stringham, May 2022

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
A high-severity crown fire, insect infestation, disease, long-term drought or combinations will eliminate or reduce the singleleaf pinyon and Utah juniper overstory and the non-sprouting shrub component. This allows for the perennial bunchgrasses to dominate. Sprouting shrubs may increase.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.4:
Time without disturbance such as fire, long-term drought, or disease will allow for the gradual infilling of singleleaf pinyon and Utah juniper.

Community Phase 2.2:
This community phase is characterized by a post-fire shrub and herbaceous community. Muttongrass and other perennial grasses dominate. Forbs may increase post-fire but will likely return to pre-burn levels within a few years. Pinyon and juniper seedlings up to 4 ft in height may be present. Big sagebrush may be present in unburned patches. Burned tree skeletons may be present; however, these have little or no effect on the understory vegetation. Annual non-native species generally respond well after fire and may be stable or increasing within the community.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.3:
Time without disturbance such as fire, long-term drought, or disease will allow for the gradual maturation of the singleleaf pinyon and Utah Juniper component. Big sagebrush reestablishes. Excessive herbivory may also reduce perennial grass understory further facilitating sagebrush or tree establishment.

Community Phase 2.3:
This community phase is characterized by an immature woodland, with singleleaf pinyon and Utah juniper trees averaging over 4.5 ft (1.4 m) in height. Tree canopy cover is between 10 to 20%. Tree crowns are typically cone- or pyramidal-shaped. Understory vegetation consists of smaller tree seedlings and saplings, as well as perennial bunchgrasses and shrubs. Annual non-native species are present.

Community Phase Pathway 2.3a, from Phase 2.3 to 2.1:

Time without disturbances such as fire, drought, insect infestation, or disease will allow for the gradual maturation of singleleaf pinyon and Utah juniper. Infilling by younger trees continues. Excessive herbivory may reduce perennial grass density and facilitate tree and shrub establishment.

Community Phase Pathway 2.3b, from Phase 2.3 to 2.2:
Fire reduces or eliminates tree canopy, allowing perennial grasses and sprouting shrubs dominate the site.

Community Phase 2.4 (At-risk):
This phase is dominated by singleleaf pinyon and Utah juniper. The stand exhibits mixed age classes and canopy cover may be over 50%. The density and vigor of the mountain big sagebrush and perennial bunchgrass understory is decreased. Bare ground areas are likely to increase. Mat-forming forbs may increase. Annual non-native species are present primarily under tree canopies. This community is at risk of crossing a threshold to an Infilled Tree State (3.0).

Community Phase Pathway 2.4a, from Phase 2.4 to 2.1:
Low intensity fire, insect infestation, drought, or disease kills individual trees within the stand, reducing canopy cover to 20% or less. Over time young trees mature to replace and maintain the old-growth woodland. The mountain big sagebrush and perennial bunchgrass community increases in density and vigor. Annual non-natives present in trace amounts.

Community Phase Pathway 2.4b, from Phase 2.4 to 2.2:
A high-severity crown fire will eliminate or reduce the singleleaf pinyon and Utah juniper overstory and the shrub component which will allow for the perennial bunchgrasses to dominate the site. Annual non-native grasses typically respond positively to fire and may increase in the post-fire community.

T2A: Transition from Current Potential State 2.0 to Infilled Tree State 3.0

Trigger: Time and a lack of disturbance allow trees to dominate site resources; may be coupled with inappropriate grazing management that favors shrub and tree dominance.

Slow variables: Over time the abundance and size of trees will increase.

Threshold: Juniper and pinyon canopy cover is greater than 30%. Little understory vegetation remains due to competition with trees for site resources.

T2B: Transition from Current Potential State 2.0 to Annual State 4.0

Trigger: Catastrophic crown fire facilitates the establishment of non-native, annual species.

Slow variables: Increase in tree crown cover, loss of perennial understory and an increase in annual non-native species.

Threshold: Cheatgrass or other non-native annuals dominate understory. Loss of deep-rooted perennial bunchgrasses changes spatial and temporal nutrient cycling and nutrient redistribution, and reduces soil organic matter. Increased canopy cover of trees allows severe stand-replacing fire. The increased seed bank of non-native, annual species responds positively to post-fire conditions facilitating the transition to an Annual State.

Infilled Tree State 3.0

This state has two community phases that are characterized by the dominance of Utah juniper and singleleaf pinyon in the overstory. This state is identifiable by 35 to over 50% cover of Utah juniper and singleleaf pinyon. This stand exhibits a mixed age class. Older trees are at maximal height and upper crowns may be flat-topped or rounded. Younger trees are typically cone- or pyramidal-shaped. Understory vegetation is sparse due to increasing shade and competition from trees.

Community Phase 3.1:
Singleleaf pinyon and Utah juniper dominate the aspect. Understory vegetation is thinning. Perennial bunchgrasses are sparse and big sagebrush skeletons are as common as live shrubs due to tree competition for soil water, overstory shading, and duff accumulation. Tree canopy cover is greater than 30%. Annual non-native species may be present. Bare ground areas are prevalent and soil redistribution is evident.

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:
Time without disturbance such as fire, long-term drought, insect infestation, or disease will allow for the gradual maturation of singleleaf pinyon and Utah juniper. Infilling by younger trees continues.

Community Phase 3.2:
Singleleaf pinyon and Utah juniper dominate the aspect. Tree canopy cover exceeds 35% and may be as high as 50%. Understory vegetation is sparse to absent. Perennial bunchgrasses, if present exist in the dripline or under the canopy of trees. Big sagebrush

skeletons are common or the sagebrush has been extinct long enough that only scattered limbs remain. Mat-forming forbs or Sandberg's bluegrass may dominate interspaces. Annual non-native species may be present and are typically found under the trees. Bare ground areas are large and interconnected. Soil redistribution may be extensive.

T3A: Transition from Infilled Tree State 3.0 to Annual State 4.0:

Trigger: Canopy fire reduces the pinyon and juniper overstory and facilitates the annual non-native species in the understory to dominate the site.

Slow variables: Over time, cover, production and seed bank of annual non-native species increases.

Threshold: Loss of deep-rooted perennial bunchgrasses and shrubs changes temporal and spatial nutrient capture and cycling within the community. Increase in canopy cover of trees increases rainfall interception and reduces soil moisture for understory species. Increased canopy cover of trees increases the risk for severe stand-replacing crown fire. The increased seed bank of non-native, annual species responds positively to post-fire conditions facilitating the transition to an Annual State.

R3A Restoration from Infilled Tree State 3.0 to Current Potential State 2.0:

Manual or mechanical thinning of trees coupled with seeding of native species. Prescribed fire during fall or winter coupled with seeding. Probability of success is highest from community phase 3.1.

Annual State 4.0:

This state has two community phases with an annual non-native species phase and a shrub/annual non-native species phase. Time since fire may facilitate the maturation of sprouting shrubs such as rabbitbrush. Ecological dynamics are significantly altered in this state. Annual non-native species create a highly combustible fuel bed that shortens the fire return interval. Nutrient cycling is spatially and temporally truncated as annual plants contribute significantly less to deep soil carbon.

Community Phase 4.1:
Cheatgrass, mustards and other non-native annual species dominate the site. Trace amounts of perennial bunchgrasses may be present. Sprouting shrubs may increase. Burned tree skeletons present.

Community Phase Pathway 4.1a, from Phase 4.1 to 4.2:
Time without disturbance such as fire, long-term drought, or disease will allow for the sprouting shrubs to mature and non-sprouting shrubs to reestablish.

Community Phase Pathway 4.2a, from Phase 4.2 to 4.1:
A wildfire will return this phase back to a non-native annual species phase dominated by cheatgrass and mustards. Sprouting shrubs will likely respond favorably to fire and non-sprouting shrubs will be reduced in cover.

Community Phase 4.2:
Sprouting and non-sprouting shrubs dominate the overstory. Cheatgrass, mustards and other non-native annual species dominate the understory. Trace amounts of perennial bunchgrasses may be present. Tree seedlings and saplings may be present.

States Not Observed in Group 28:

An Annual State was not observed for these sites, but cheatgrass was observed in the understory. Both sites have low resistance and resilience which may lead to an Annual State after wildfire at the lower elevations of these sites where Wyoming big sagebrush is the dominant understory shrub.

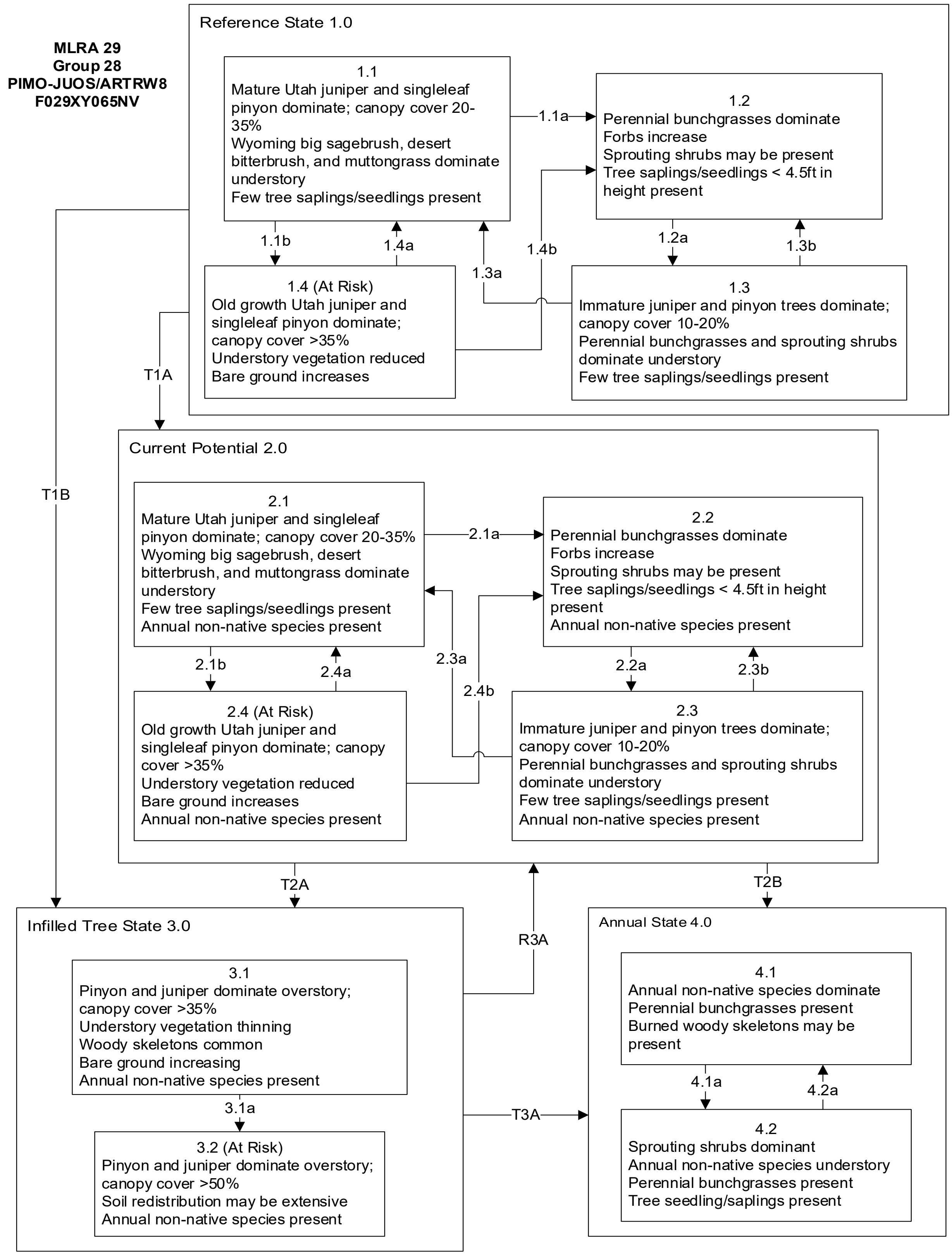
Potential Resilience Differences with Other Ecological Sites in this Group:

JUOS/ARTRW8-PUGL2/ACHY (F029XY070NV):

This woodland site occurs on summits and sideslopes of upper fan piedmonts, hills and lower mountains on all exposures. Slopes range are typically 15 to 50%. Elevations are 5,400 to 6,200 ft (1,646–1,890 m) and precipitation ranges from 10 to 14 in. (25–36 cm). The soils are shallow to moderately deep and well drained. Available water capacity is low. Overstory tree composition is about 95 to 100% Utah juniper and less than 5% singleleaf pinyon. Wyoming big sagebrush, desert bitterbrush and/or Stansbury cliffrose are the primary understory shrubs. Indian ricegrass, muttongrass and bottlebrush squirreltail are the primary understory grasses. Annual understory production under a medium canopy (21–35%) is 50 to 200 lb/ac. The site is less productive and has a similar tree site index as the modal. Resilience is low because of low production, less precipitation and a lower elevation range. This site will have the same ecological states as the modal site.

JUOS/ARTRW8-PUGL2/ACHY (F029XY070NV), Infilled Tree State 3.1, T. Stringham, May 2022

Modal State and Transition Model for Group 28 in MLRA 29:



MLRA 29
Group 28
PIMO-JUOS/ARTRW8
F029XY065NV

Reference State 1.0 Community Phase Pathways
1.1a: High severity crown fire, insect infestation, disease, drought, or combinations reduces or eliminates tree cover. Tree skeletons may be present post-fire.
1.1b: Time and lack of disturbance such as fire, insect infestation, disease, or drought allows for infilling of Utah juniper and singleleaf pinyon.
1.2a: Time and lack of disturbance such as fire or drought. Excessive herbivory by wildlife may reduce perennial grasses.
1.3a: Time and lack of disturbance such as fire, insect infestation, disease, or drought allows for maturation of trees. Excessive herbivory by wildlife may reduce perennial grasses.
1.3b: Fire reduces or eliminates tree cover.
1.4a: Low intensity fire, insect infestation, drought, or disease removes individual trees, reducing the total tree cover.
1.4b: High severity crown fire reduces or eliminates tree cover.

Transition Pathway T1A: Introduction of non-native annual species.

Transition Pathway T1B: Time and lack of disturbance allows trees to dominate the site resources. Inappropriate grazing will favor shrub and woody species as a dominant component.

Current Potential 2.0 Community Phase Pathways
2.1a: High severity crown fire, insect infestation, disease, drought or combinations reduces or eliminates tree cover. Tree skeletons may be present post-fire.
2.1b: Time and lack of disturbance such as fire, insect infestation, disease, or drought allows for infilling of Utah juniper and singleleaf pinyon.
2.2a: Time and lack of disturbance such as fire or drought. Excessive herbivory by wildlife may reduce perennial grasses.
2.3a: Time and lack of disturbance such as fire, insect infestation, disease, or drought allows for maturation of trees. Excessive herbivory by wildlife may reduce perennial grasses.
2.3b: Fire reduces or eliminates tree cover.
2.4a: Low intensity fire, insect infestation, or disease removes individual trees, reducing the total tree cover.
2.4b: High severity crown fire reduces or eliminates tree cover.

Transition Pathway T2A: Time and lack of disturbance allows trees to dominate the site resources. Inappropriate grazing will favor shrub and woody species as a dominant component.

Transition Pathway T2B: High-severity crown fire facilitates the establishment of non-native, annual species.

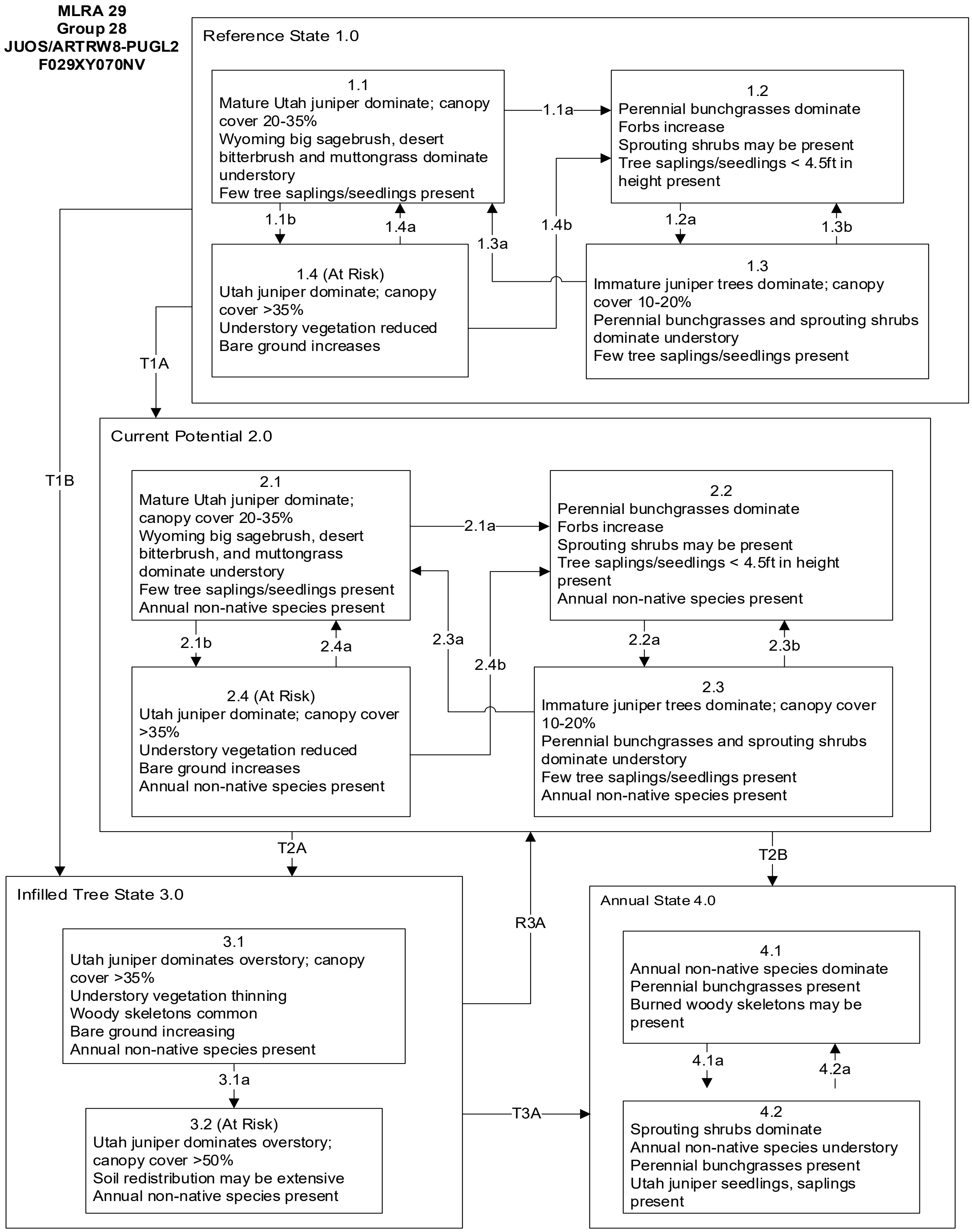
Infilled Tree State 3.0 Community Phase Pathways
3.1a: Time and lack of disturbance allows for infilling of Utah juniper and singleleaf pinyon.

Transition Pathway T3A: Canopy fire reduces pinyon and juniper overstory, allows non-native species in the understory to dominate the site.

Restoration Pathway R3A: Manual or mechanical thinning of trees coupled with seeding. Recovery of understory species. Success unlikely from phase 3.2.

Current Potential 4.0 Community Phase Pathways
4.1a: Time allows sprouting shrubs to recover.
4.2a: Fire.

Additional State and Transition Models for Group 28 in MLRA 29:



MLRA 29
Group 28
JUOS/ARTRW8-PUGL2
F029XY070NV

Reference State 1.0 Community Phase Pathways
1.1a: High severity crown fire, insect infestation, disease, drought or combinations reduces or eliminates tree cover. Tree skeletons may be present post-fire.
1.1b: Time and lack of disturbance such as fire, insect infestation, disease, or drought allows for infilling of Utah juniper.
1.2a: Time and lack of disturbance such as fire or drought. Excessive herbivory by wildlife may reduce perennial grasses.
1.3a: Time and lack of disturbance such as fire, insect infestation, disease, or drought allows for maturation of trees. Excessive herbivory by wildlife may reduce perennial grasses.
1.3b: Fire reduces or eliminates tree cover.
1.4a: Low intensity fire, insect infestation, drought, or disease removes individual trees, reducing the total tree cover.
1.4b: High severity crown fire or other disturbances reduces or eliminates tree cover.

Transition Pathway T1A: Introduction of non-native annual species.

Transition Pathway T1B: Time and lack of disturbance allows trees to dominate the site resources. Inappropriate grazing will favor shrub and woody species as a dominant component.

Current Potential 2.0 Community Phase Pathways
2.1a: High severity crown fire, insect infestation, disease, drought or combinations reduces or eliminates tree cover. Tree skeletons may be present post-fire.
2.1b: Time and lack of disturbance such as fire, insect infestation, disease, or drought allows for infilling of Utah juniper.
2.2a: Time and lack of disturbance such as fire or drought. Excessive herbivory may reduce perennial grasses.
2.3a: Time and lack of disturbance such as fire, insect attack, disease, or drought allows for maturation of trees. Excessive herbivory may reduce perennial grasses.
2.3b: Fire reduces or eliminates tree cover.
2.4a: Low intensity fire, insect infestation, drought, or disease removes individual trees, reducing the total tree cover.
2.4b: High severity crown fire reduces or eliminates tree cover.

Transition Pathway T2A: Time and lack of disturbance allows trees to dominate the site resources. Inappropriate grazing will favor shrub and woody species as a dominant component.

Transition Pathway T2B: High-severity crown fire facilitates the establishment of non-native, annual species.

Infilled Tree State 3.0 Community Phase Pathways
3.1a: Time and lack of disturbance allows for infilling of Utah juniper.

Transition Pathway T3A: Canopy fire reduces pinyon and juniper overstory, allows non-native species in the understory to dominate the site.

Restoration Pathway R3A: Manual or mechanical thinning of trees coupled with seeding. Recovery of understory species. Success unlikely from phase 3.2.

Current Potential 4.0 Community Phase Pathways
4.1a: Time allows sprouting shrubs to recover.
4.2a: Fire.

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MLRA 29 Group 29: Well drained soils dominated by oak

Description of MLRA 29 Disturbance Response Group 29

Disturbance Response Group (DRG) 29 consists of two ecological sites. The precipitation ranges from 12 to 16 in. Slopes range from 2 to 50% and elevations range from 4,500 to about 7,000 ft (1,372–2,134 m). These sites occur on north and east exposure sideslopes and concave mountain sideslopes. The soils on these sites are typically shallow to moderately deep and well-drained. These soils are highly modified by rock fragments, with cobbles and gravels comprising up to 80 to 90% of the profile. They have argillic horizons and mollic epipedons, typically ranging from 6 to 10 in. (15–25 cm) deep and 7 to 40 in. (18–102 cm) thick, respectively. The soil temperature regime is xeric and the soil moisture regime is mesic. Runoff is very high; water holding capacity is moderately high to high; and permeability is moderate. The reference plant communities are dominated by Sonoran scrub oak (*Quercus turbinella*), Gambel oak (*Quercus gambelii*), Utah serviceberry (*Amelanchier utahensis*), and muttongrass (*Poa fendleriana*). Production ranges from 800 to 7,000 lb/ac with an average of 1,100 to 5,000 lb/ac in a normal year.

Disturbance Response Group 29 Ecological Sites:

North Slope 12-14" P.Z. – Modal	R029XY172NV
Oak Thicket	R029XY171NV

Modal Site:

The North Slope 12-14" P.Z. ecological site (R029XY172NV) is the modal site that represents this DRG, as it has the most acres mapped. The precipitation ranges from 12 to 16 in. (30–41 cm). Slopes range from 0 to 50%, with slope gradients of 15 to 30% most typical. This site occurs on mountain sideslopes on generally north and east exposures from 4,500 to 6,000 ft (1.4–1.8 km). The soils on this site are typically shallow and well drained. They are modified by rock fragments with up to 80 to 90% cobbles and gravels, have an argillic horizon with an abrupt textural boundary at 8 in. (20 cm) in depth, and a mollic epipedon of 7 to 17 in. (18–43 cm) in depth. The soil temperature regime is xeric and the soil moisture regime is mesic. Runoff is very high; water holding capacity is moderately high to high; and permeability is moderate. The reference plant community is dominated by Sonoran scrub oak, Utah serviceberry, and muttongrass.

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasive species. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans a unique area in Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area. Flashy, summer storm events contribute significantly to annual precipitation as well. Air and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

Periodic drought regularly influences these desert ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West (Miller and Heyerdahl 2008). Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006).

Sonoran scrub oak has been found to root over 30 ft (9 m) deep and also exhibits extensive lateral rooting (Saunier 1964). Stands tend to thicken gradually by sprouting from root crowns or lateral root buds, however the species is also capable of producing an abundance of acorns (Saunier 1964). It is a drought-resistant species that inhabit sandy, gravelly, or rocky soils, typically at elevations of 4,000 to 6,500 ft (1.2–2.0 m) (USFS 1988). Sonoran scrub oak is common in the semidesert shrub type, extending into woodland types, and is commonly associated with catclaw, manzanita, mountain mahogany, and silktassel (USFS 1988). Large areas of what are now chaparral types were once open brushland with sizable grass cover that were then supplanted by less palatable shrubs, such as Sonoran scrub oak, after severe and continued livestock overuse (USFS 1988). Proper management of similar areas should focus on maintaining the original herbaceous vegetative stand (USFS 1988).

Utah serviceberry is a large shrub that grows from 2 to 15 ft (0.6–4.6 m) tall, with a canopy spreading up to 15 ft (4.6 m), and typically grows in big sagebrush, pinyon-juniper, and aspen communities (Hammond 2012, Larese-Casanova 2012b). It is more drought tolerant than other serviceberry species, occupying drier mountain ridges and sideslopes, due to its very deep and spreading root system (Wasser et al. 1982, Hammond 2012). However, Utah serviceberry has been found to be intolerant of high water tables and grows largest on north exposures with moist, well drained soils (Larese-Casanova 2012b). It can reproduce from seed, stolons, or sprouting from the root crown, and despite typically being found surrounded by other species, serviceberry seedlings can be outcompeted by dense stands of grasses and forbs (Larese-Casanova 2012b). The only pest known to be a serious threat to Utah serviceberry is cedar-apple rust (*Gymnosporangium juniperi-virginianae*), which it can host in its leaves and berries when growing in proximity to juniper trees (*Juniperus* spp.) (Wasser et al. 1982).

Gambel oak is a deciduous small tree or shrub that is found in the foothills and lower mountains of western North America, and tolerates a wide range of environmental and soil conditions (Kaufmann et al. 2016). It possesses abundant lignotubers and rhizomes in the below-ground root systems, providing protection against extreme fire events, herbicide and mechanical treatments (Kaufmann et al. 2016). Gambel oak has been known as a valuable resource for a long time, providing cover, habitat, and food for many different wildlife species. With the help of a healthy, productive understory, Gambel oak provides erosion protection and soil stability over large areas (Larese-Casanova 2012a, Kaufmann et al. 2016). Gambel oak is a sprouter, meaning that a Gambel oak plant can re-sprout from tissue underground, even when any of the plant above ground is killed from fire, grazing, or other forms of disturbance, as opposed to non-sprouters, which are killed by fire and rely on seed dispersal for post-dispersal colonization (Premoli and Steinke 2008). This makes Gambel oak a key component in restoring disturbed communities, because fresh, young plants will sprout, spread, and compete against invasive species. Furthermore, its deep taproots and xeromorphic leaves make it a drought tolerant species (Larese-Casanova 2012a).

Mountain big sagebrush, a dominant shrub in this group, is generally long-lived; therefore, it is not necessary for new individuals to recruit every year for perpetuation of the stand. Infrequent large recruitment events and simultaneous low, continuous recruitment is the foundation of population maintenance (Noy-Meir 1973). Survival of the seedlings is dependent on adequate moisture conditions. Sagebrush has a flexible generalized root system with development of both deep taproots and laterals near the surface (Dobrowolski et al. 1990). In general, these shrubs root to the full depth of the winter-spring soil moisture recharge, which ranges from 1 to over 3 m (3 to 9+ ft) (Comstock and Ehleringer 1992). Root length of mature sagebrush plants was measured to a depth of 2 m (6.5 ft) in alluvial soils in Utah (Richards and Caldwell 1987).

Muttongrass is a tufted, multi-flowered, perennial bunchgrass that can grow between 8 and 30 in. (76 cm) tall and has narrow leaves, which range from 1 to 3 mm (<1 in.) wide. It is found in lower elevations in the northern extent of its native range, and higher elevations in the south. Muttongrass is one of the most drought-tolerant bluegrasses and is useful for restoring communities disturbed by fire, grazing, or mining, but is limited in its use due to low seed viability. Muttongrass plants are most frequently pistillate, but staminate plants do occasionally occur, which are able to hybridize and crossbreed with other bluegrasses. Muttongrass is found throughout the western United States as a primary component of the understory of pinyon-juniper communities and aspen and pine forests, indicating a high tolerance for shade (Tilley et al. 2007). Analysis of NRCS soils data shows that muttongrass has a preference for more clay rich soils when compared to perennial grasses as a whole in Nevada (Soil Survey Staff 2024). Analysis of terrestrial monitoring data in MLRA 29 shows primary woody co-occurrence with singleleaf pinyon (*Pinus monophylla*) and Utah juniper (*Juniperus osteosperma*), and primary associated shrubs being Mormon tea (*Ephedra viridis*), yellow rabbitbrush (*Chrysothamnus viscidiflorus),* Utah serviceberry, and Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*). Perennial grasses commonly co-occurring with muttongrass are squirreltail (*Elymus elymoides*), Sandberg bluegrass (*Poa secunda*), and Indian ricegrass (BLM 2024a).

The ecological sites in this DRG have moderate to high resilience to disturbance and resistance to invasion. Resilience increases with elevation, aspect, precipitation, and nutrient availability. Long-term disturbance response may be influenced by small differences in landscape topography. Concave areas receive run-in from adjacent landscapes and consequently retain more moisture to support the growth of deep-rooted perennial grasses (i.e. basin wildrye) whereas convex areas are slightly less resilient and may have more shallow-rooted perennial grasses (i.e. muttongrass). North slopes are also more resilient than south slopes because lower soil surface temperatures operate to keep moisture content higher on northern exposures.

Fire Ecology:

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The initial condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species response. For most forbs and grasses the growing points are located at or below the soil surface providing relative protection from disturbances which decrease above ground biomass, such as grazing or fire. Thus, fire mortality is more correlated to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant and abundance of old growth (Wright 1971, Young 1983). However, season and severity of the fire will influence plant response. Plant response will vary depending on post-fire soil moisture availability.

Sonoran scrub oak sprouts strongly in response to fire, with a study by Pond and Cable (1962) reporting that it responded vigorously and dominated the plant cover after a wildfire. Furthermore, this tree demonstrates a high level of fire resilience, with post-burn stem densities exceeding pre-burn levels following each of four consecutive annual prescribed burns and burning intervals of 2 or more year failing to reduce sprouting (Pond and Cable 1960).

Utah serviceberry is a large, fire-tolerant shrub which is top-killed by fire, but sprouts from the underground root crown after disturbance (Bradley 1984). It does not report high fire-caused mortality, however if fire exclusion leads to increased shade, Utah serviceberry is likely to decrease (Zlatnik 1999a). Heavy litter accumulations and moisture conditions may increase the likelihood of fire-caused mortality and harm (Debyle 1975, Crane 1982). Utah serviceberry is drought tolerant, exhibiting greater tolerance to dehydration than western serviceberry (*A. alnifolia*), a trait that should enhance the potential for crown sprouting following summer fire (Bradley 1984). Utah serviceberry can also re-colonize an area after fire via seeds, but this can require up to 8 to 10 years for plants to be fully matured and productive (Noller 2008).

Gambel oak is extremely fire tolerant due to its lignotubers/rhizomes (Kaufmann et al. 2016). When Gambel oak is killed by fire, most of the vegetative tissue underground is still alive, and the plant can sprout and grow from what remains. This gives Gambel oak and other sprouters an advantage over non-sprouters, or "obligate seeders" because they rely on seed dispersal in order to colonize an area after a fire or other disturbance (Premoli and Steinke 2008). However, an individual Gambel oak plant is not resistant to fire.

Mountain big sagebrush is killed by fire and does not resprout (Blaisdell 1953). Post-fire regeneration occurs from seed and will vary depending on site characteristics, seed source, and fire characteristics. Mountain big sagebrush seedlings can grow rapidly and may reach reproductive maturity within 3 to 5 years. Mountain big sagebrush may return to pre-burn density and cover within 15 to 20 years following fire, but establishment after severe fires may proceed more slowly (Bunting et al. 1987).

Muttongrass is top-killed by fire but will re-sprout after low to moderate severity fires; however, it appears to be killed by with slow, little to no recovery from severe fire (Erdman 1970, Moody et al. 2010). A study by Vose and White (1991) in an open saw timber site found minimal difference in the overall effect of burning on muttongrass. Furthermore, muttongrass was shown to recover vigorously and abundantly in some locales within ponderosa zones after fire, without requiring seeding (Hughes 2008).

The introduction of annual non-native species, like cheatgrass (*Bromus tectorum*) may cause an increase in fire frequency and eventually lead to an annual-dominated community. Conversely, infilling by singleleaf pinyon and Utah juniper may also occur with an extended fire return interval. Without fire or changes in management, pinyon and juniper may dominate the site and mountain big sagebrush will be severely reduced. The herbaceous understory will also be reduced; however, muttongrass (higher elevations) and Sandberg bluegrass may be found in trace amounts.

Annual Invasive Species:

The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and depressed competition or can increase resource pools by the decomposition of dead plant material following disturbance. Excessive grazing pressure during settlement and into the 20th century has increased the overall presence of cheatgrass, halogeton (*Halogeton glomeratus*), Russian thistle (*Salsola tragus*), and weedy mustard species (*Brassicaceae* genera) (Peters and Bunting 1994). The presence of exotic annual plants within these ecosystems decreases ecosystem resilience and resistance to disturbance through competition for limited resources. Dobrowolski et al. (1990) cite multiple authors on the extent of the soil profile exploited by the competitive exotic annual cheatgrass. Specifically, the depth of rooting is dependent on the size the plant achieves, and in competitive environments, cheatgrass roots were found to penetrate only 15 cm (6 in.) whereas isolated plants and pure stands were found to root at least 1 m (3+ ft) in depth with some plants rooting as deep as 1.5 to 1.7 m (5 to 5.5 ft).

Cheatgrass is a cool-season annual grass that maintains an advantage over native plants in part because it is a prolific seed producer, can germinate in the autumn or spring, tolerates grazing, and increases with frequent fire (Klemmedson and Smith 1964, Miller et al. 1999).

Methods to control cheatgrass include herbicide application, prescribed fire, targeted grazing, and rangeland seeding of primarily non-native wheatgrasses. Mapping potential or current invasion vectors is a management method designed to increase the cost-effectiveness of control methods. Spraying with herbicide (imazapic or imazapic + glyphosate) and seeding with crested wheatgrass and Sandberg bluegrass has been found to be more successful at combating cheatgrass than spraying alone (Sheley et al. 2012). Where native bunchgrasses are missing from the site, revegetation of cheatgrass-invaded rangelands has been shown to have a higher likelihood of success when using introduced perennial bunchgrasses such as crested wheatgrass (Davies et al. 2015b). Butler et al. (2011) tested four herbicides (imazapic, imazapic + glyphosate, rimsulfuron and sulfometuron + chlorsulfuron) only treatments for suppression of cheatgrass, medusahead (*Taeniatherum caput-medusae)* and North Africa grass (*Ventenata dubia*) within residual stands of native bunchgrass (Butler et al. 2011). Additionally, they tested the same four herbicides followed by seeding of six bunchgrasses (native and non-native) with varying success (Butler et al. 2011). Herbicide-only treatments appeared to remove competition for established bluebunch wheatgrass (*Pseudoroegneria spicata*) by providing 100% control of North Africa grass and medusahead and greater than 95% control of cheatgrass (Butler et al. 2011), however, caution in using these results is advised, as only 1 year of data was reported. Prescribed fire has also been utilized in combination with the application of pre-emergent herbicide to control medusahead and cheatgrass (Vollmer and Vollmer 2008). Mature medusahead or cheatgrass is very flammable and fire can be used to remove the thatch layer, consume standing vegetation, and even reduce seed levels. Furbush (1953) reported that timing a burn while the seeds were in the milk stage effectively reduced medusahead the following year. He further reported that adjacent unburned areas became a seed source for reinvasion the following year (Furbush 1953).

Livestock/Wildlife Grazing Interpretations:

Although not a preferred forage species, Sonoran scrub oak is consumed by cattle year-round. However, caution is warranted, as oak poisoning from tannic acids can be fatal, and even nonfatal consumption may reduce cattle performance by reducing roughage digestibility and hindering energy and protein metabolism (Ruyle et al. 1986). Peak consumption typically occurs between December and April, potentially comprising 35% to nearly 40% of the diet, while the lowest intake is observed from July to September due to the availability of warm-season grasses (Ruyle et al. 1986). Sonoran scrub oak is considered an important browse species, providing the chief reserve supply of winter and drought emergency forage (USFS 1988). Furthermore, its foliage and acorns are consumed considerably by goats, deer, wild turkey, small mammals, and other wild game (USFS 1988).

Utah serviceberry is a very important plant because of the amount of food, cover, and habitat it provides to both livestock and wildlife. Its leaves, branches, and berries are used by many wildlife species, including big game, birds, and small animals (Noller 2008). It is considered highly palatable, good cattle forage, good to excellent sheep and goat browse, and preferred forage for elk (*Cervus canadensis*) (McCulloch 1955, Wasser et al. 1982). Additionally, its persistent dried fruit may be an emergency food source for birds and small mammals (Wasser et al. 1982). In order to maintain vigorous growth after seeding or live planting, controlled browsing to reduce component is necessary (Noller 2008). Once it is established, the plant can withstand moderate to heavy browsing during years with at least average precipitation, however browsing should not exceed 50% of current season growth (Noller 2008).

Gambel oak is considered an important species for wildlife forage, even though it is not highly palatable. This is due to how widespread and abundant it is, especially on winter ranges. Gambel oak leaves provide important forage for deer and elk year-round, and acorns are an extremely valuable mast crop, especially for black bears in the fall (Jester et al. 2008). Due to being a sprouter, Gambel oak can provide valuable forage and cover in post-fire communities (Premoli and Steinke 2008). Additionally, Gambel oak is the preferred habitat type for elk and deer during the winter months, and is utilized by black bears and turkeys in the spring (Kaufmann et al. 2016). However, because it produced tannic and gallic acids, poisoning of livestock can occur if too much is consumed (Larese-Casanova 2012a).

Despite low palatability, mountain big sagebrush is eaten by domestic sheep, cattle, goats, and horses (Welch 2005). Chemical analysis indicates that the leaves of big sagebrush equal alfalfa meal (*Medicago sativa*) in protein, have a higher carbohydrate content, and yield twelvefold more fat (Dayton 1931). There is evidence that wild ungulates utilize mountain big sagebrush as winter browse. Fecal samples from ungulates in Montana showed that bighorn sheep, mule deer, and elk all consumed mountain big sagebrush in small amounts in winter, while cattle had no sign of sagebrush use. In studies by Personius et al. (1987) and Sheehy and Winward (1981) mountain big sagebrush was one of the most preferred taxa by mule deer.

Muttongrass is very palatable for wildlife and livestock and is rated as excellent forage for cattle and horses, and good for domestic sheep. Muttongrass starts growth in late winter or early spring and provides excellent early feed. Muttongrass foliage cures well and is good fall forage, but not as good as spring or summer, and can withstand moderately heavy grazing (Humphrey et al. 1952, Marquiss and Lang 1959).

State and Transition Model Narrative for Group 29:

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 29 Disturbance Response Group 29.

Reference State 1.0:

The Reference State 1.0 is a representative of the natural range of variability under pristine conditions. The reference state has three general community phases; a shrub-grass dominant phase, a perennial grass dominant phase, and a shrub dominant phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire and/or periodic drought.

Community Phase 1.1:
Sonoran scrub oak and Utah serviceberry dominate the overstory shrub component. Mountain big sagebrush is sub-dominant. Muttongrass dominates understory grass component. Other perennial bunchgrasses present in trace amounts. Potential vegetative composition by air-dry weight is approximately 35% grasses, 10% forbs, 55% shrubs and up to 1% trees (singleleaf pinyon and Utah juniper). Approximate ground cover is 50 to 60% (basal and crown). Total annual air-dry production ranges from 800 to 1,400 lb/ac.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
Frequent fire reduces the shrub overstory and allows perennial bunchgrasses, particularly muttongrass, to dominate the site. Fires are typically low severity resulting in a mosaic pattern due to low fuel loads. Sonoran scrub oak, Utah serviceberry, and other sprouting shrubs are likely to sprout post-disturbance.

Community Phase 1.2:
Muttongrass and other perennial bunchgrasses dominate. Mountain big sagebrush decreased to trace. Sonoran scrub oak, Utah serviceberry, and other sprouting shrubs are sprouting in response to disturbance. Sonoran scrub oak is likely to sprout more aggressively and therefore recover quicker than other shrubs.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
Time and lack of disturbance allow shrubs to re-establish.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0:

Trigger: Introduction of non-native annual plants and livestock grazing.

Slow variables: Over time the annual non-native plants will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

This state is similar to the Reference State 1.0 but has three similar community phases because of the introduction of livestock grazing. Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of invasive weeds and grazing. Non-natives may increase in abundance but will not become dominant within this State. These non-natives can be highly flammable and can promote fire where historically fire had been infrequent. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These feedbacks include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal.

Community Phase 2.1:
Sonoran scrub oak and Utah Serviceberry dominate the overstory shrub component. Mountain big sagebrush is sub-dominant. Muttongrass dominates understory grass component. Other perennial bunchgrasses present in trace amounts. Annual non-native species are present. Singleleaf pinyon and Utah juniper may be present.

North Slope 12-14" P.Z. (R029XY172NV), Current Potential 2.1, T. Stringham, May 2022

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
Fire and/or drought reduces the shrub overstory and creates a mosaic of shrubs and perennial grasses. Fires are typically low severity resulting in a mosaic pattern due to low fuel loads. Sonoran scrub oak, Utah serviceberry, and other sprouting shrubs are likely to sprout post-disturbance. Annual non-native species respond well after disturbance.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.3:
Time and lack of disturbance allow mountain big sagebrush and other shrubs to increase and become dominant.

Community Phase 2.2:
Muttongrass and other perennial bunchgrasses increase in cover. Mountain big sagebrush decreased to trace. Sonoran scrub oak, Utah serviceberry, and other sprouting shrubs are sprouting in response to disturbance. Sonoran scrub oak is likely to sprout more aggressively and therefore recover quicker than other shrubs. Annual non-native species remain stable and may be increasing post-disturbance. Singleleaf pinyon and Utah juniper may be present.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Time and lack of disturbance allow shrubs to dominate.

Community Phase 2.3 (At Risk):
Sonoran scrub oak, Utah serviceberry, and mountain big sagebrush increase in the absence of disturbance and dominate. Muttongrass and other perennial bunchgrasses are reduced from competition with shrubs, drought, and/or herbivory. Annual non-native species are stable and may be increasing. Singleleaf pinyon pine and Utah juniper may be present.

Community Phase Pathway 2.3a, from Phase 2.3 to 2.1:
Low severity fire and/or herbivory that favors perennial bunchgrasses will reduce shrub overstory, allowing perennial bunchgrasses to increase and creating a shrub/grass mosaic.

Community Phase Pathway 2.3b, from Phase 2.3 to 2.2:
Fire eliminates/reduces the shrub overstory, allowing perennial bunchgrass understory to increase. Shrubs such as Sonoran scrub oak and Utah serviceberry are likely to sprout in response to disturbance. Annual non-natives will increase with disturbance.

T2A: Transition from Current Potential State 2.0 to Shrub State 3.0:

Trigger: To Community Phase 3.1: Inappropriate, chronic, grazing will decrease or eliminate deep-rooted perennial bunchgrasses, and favor shrub growth and establishment. To Community Phase 3.2: High severity fire removes shrub overstory and decreases perennial bunchgrasses, allowing annual non-native species to increase. Sonoran scrub oak, Utah serviceberry, and other sprouting shrubs will recover quicker in response to disturbance, dominating the site.

Slow variables: Long term decrease in deep-rooted perennial grass density.

Threshold: Loss of deep-rooted perennial bunchgrasses changes nutrient cycling, nutrient redistribution, and reduces soil organic matter.

Shrub State 3.0:

This state has two community phases: (3.1) a shrub-dominated overstory and annual non-native species-dominated understory phase and a (3.2) sprouting shrub and non-native annual species dominated phase. This site has crossed a biotic threshold and site processes are being controlled by shrubs. Singleleaf pinyon and Utah juniper may be present in either phase.

Community Phase 3.1:
Sonoran scrub oak, Utah serviceberry, mountain big sagebrush, and other shrubs dominate. Perennial bunchgrasses are reduced to trace and may be absent. Annual non-native species are increasing. Singleleaf pinyon and Utah Juniper may be present. Bare ground may be significant.

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:
Fire that reduces non-sprouting shrubs allows sprouting shrubs to dominate. Annual non-native species increase and dominate understory.

Community Phase 3.2 (At Risk):

Sonoran scrub oak, Utah serviceberry, and other sprouting shrubs dominate overstory. Mountain big sagebrush reduced to trace. Perennial bunchgrasses trace or missing. Annual non-native species are stable and/or increasing. Singleleaf pinyon and Utah Juniper may be present. Bare ground may be significant.

North Slope 12-14" P.Z. (R029XY172NV), Shrub State 3.2 (At Risk), T. Stringham, May 2022

Community Phase Pathway 3.2a, from Phase 3.2 to 3.1:
Time and lack of disturbance and/or grazing management that favors the establishment and growth of shrubs allows shrub component to recover and out compete annual non-native understory.

T3A: Transition from Shrub State 3.0 to Annual State 4.0:

Trigger: To Community Phase 4.1: Severe fire significantly reduces shrub cover allowing annual non-native species to dominate.

Slow variables: Reduction in perennial bunchgrasses and shrubs facilitating an increase in non-native annual species. Non-native annual species perpetuate through seed production.

Threshold: Annual non-native species dominate the site. Loss of perennial grasses changes spatial and temporal nutrient cycling and nutrient redistribution and reduces soil organic matter.

Annual State 4.0:

This state has two community phases: (4.1) an annual non-native species-dominated understory phase and a (4.2) sprouting shrub and non-native annual species dominated phase.

This site has crossed a biotic threshold and site processes are being controlled by annual species.

Community Phase 4.1:
Cheatgrass and other non-native annual species dominate the site. Sprouting shrubs may be increasing. Trace amounts of perennial bunchgrasses may be present. Burned sagebrush and tree skeletons may be present.

Community Phase Pathway 4.1a, from Phase 4.1 to 4.2:
Time and lack of disturbance allows sprouting shrubs to increase and dominate the site. Annual non-native species dominate the understory.

Community Phase 4.2:
Sprouting shrubs increase and dominate the site. Cheatgrass and other non-native annual species dominate the understory. Trace amounts of perennial bunchgrasses and non-sprouting shrubs present. Burned sagebrush and tree skeletons may be present.

Community Phase Pathway 4.2a, from Phase 4.2 to 4.1:
Frequent wildfires reduce the shrub overstory. The understory is dominated by annual non-native species.

States Not Observed in Group 29:

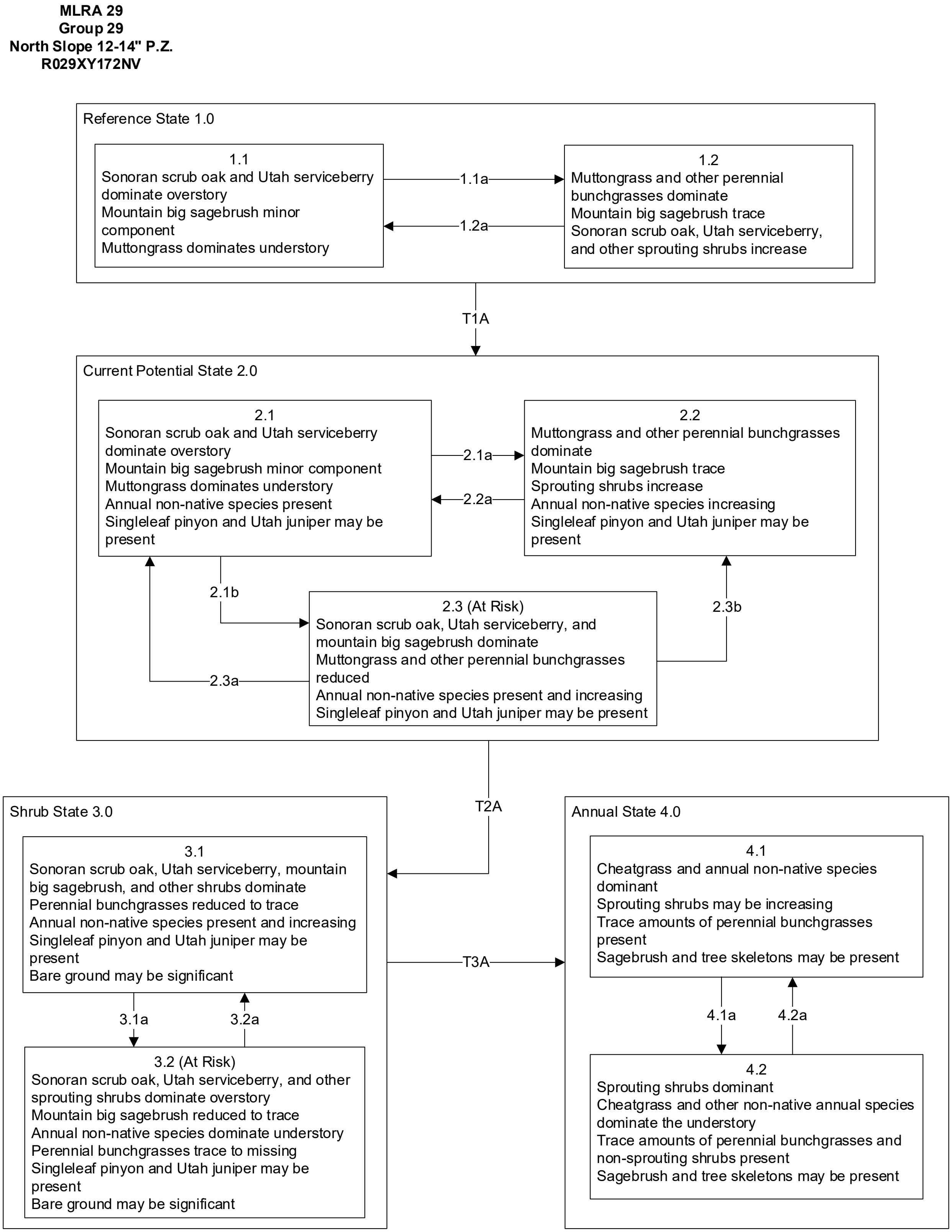
Tree State: A Tree State was not observed for the modal site, though such a state may be possible, particularly at higher elevation ranges. Singleleaf pinyon and Utah juniper will readily increase in the absence natural disturbance regimes potentially dominating site resources.

Potential Resilience Differences with Other Ecological Sites in this Group:

Oak Thicket (R029XY171NV):

The reference plant community is dominated by Gambel oak (*Quercus gambelii*) with Utah serviceberry comprising a minor component. This site is more productive, producing 5,000 lb/ac during normal years, due to deeper soils and 25% higher ground cover (75 to 85%). Potential vegetation composition by air-dry weight is approximately 5% grasses, 5% forbs and 85% shrubs and trees. Due to Gambel oak's physiological adaptations to drought, ability to sprout, and use of allelopathic toxins that suppress other plant species, the resilience of this site is expected to be higher than the modal and is less likely to transition to an Annual or Tree State. Large Gambel oak shrubfields can persist for many years because of its ability to resprout post-fire, competitive advantages over conifer species, and drought resilience (Guiterman et al. 2018). This site has higher resilience than the modal site. A Shrub State, an Annual State and a Tree State are not expected for this site.

Modal State and Transition Model for Group 29 in MLRA 29:



MLRA 29
Group 29
North Slope 12-14" P.Z.
R029XY172NV

Reference State 1.0 Community Phase Pathways
1.1a: Frequent fire reduces shrub overstory and allows perennial bunchgrasses to dominate the site.
1.2a: Time and lack of disturbance allow Sonoran scrub oak to regenerate.

Transition T1A: Introduction of non-native annual species.

Current Potential State 2.0 Community Phase Pathways
2.1a: Fire and/or drought reduces shrub overstory and creates a mosaic of shrubs and perennial grasses.
2.1b: Time and lack of disturbance allows mountain big sagebrush and other shrubs to increase and dominate the site.
2.2a: Time and lack of disturbance allows shrubs to increase and dominate.
2.3a: Low severity fire and/or herbivory favoring perennial bunchgrasses will reduce shrub overstory.
2.3b: Fire reduces or eliminates the shrub overstory, allowing perennial bunchgrasses to increase.

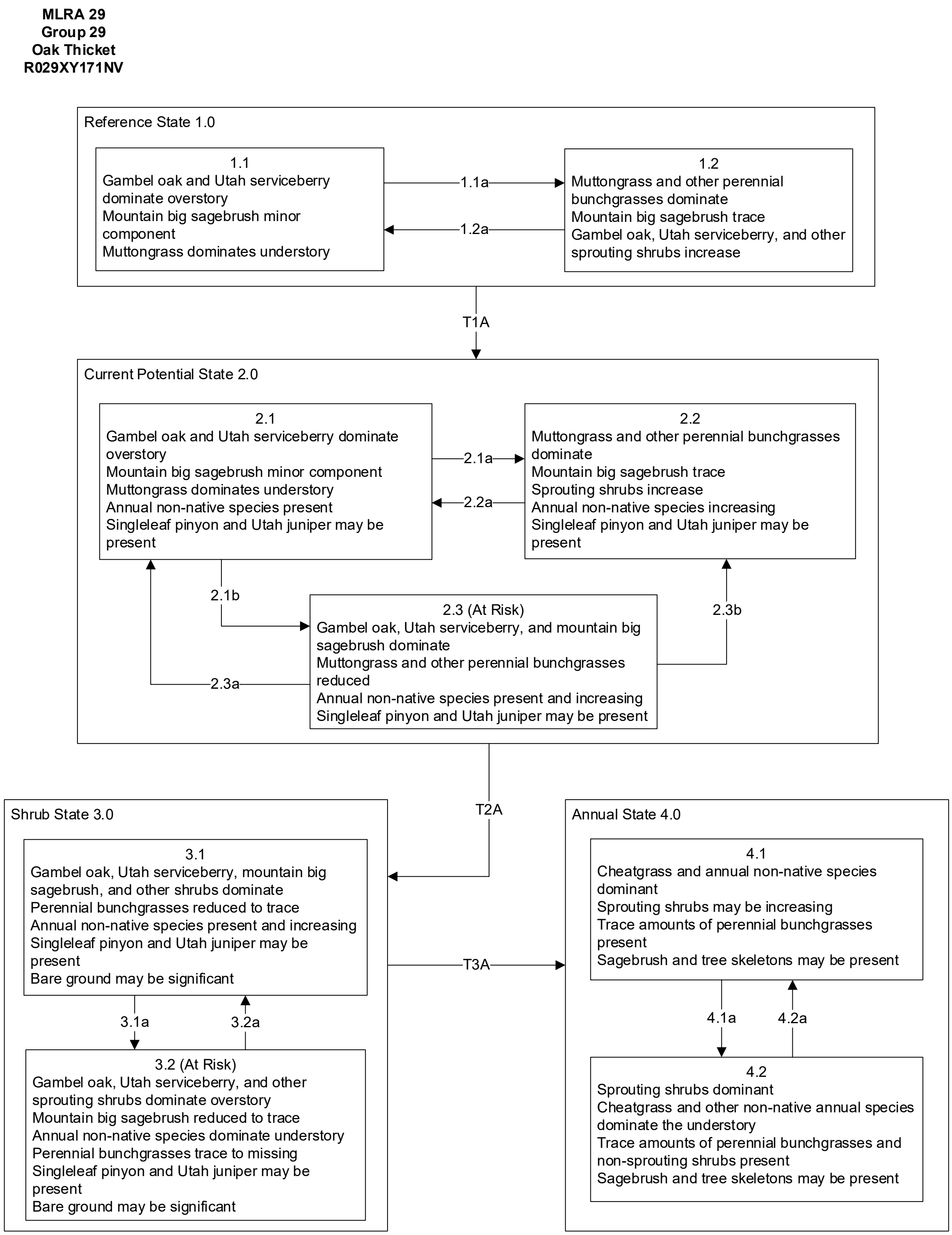
Transition T2A: Inappropriate, chronic grazing will decrease or eliminate deep-rooted perennial bunchgrasses and favor shrub growth and establishment (to 3.1). High severity fire removes shrub overstory and decreases perennial bunchgrasses, allowing annual non-native species and sprouting shrubs to increase (to 3.2).

Shrub State 3.0 Community Phase Pathways
3.1a: Fire that reduces non-sprouting shrubs allows sprouting shrubs to dominate.
3.2a: Time and lack of disturbance and/or grazing management that favors shrub growth allows shrub component to recover and out-compete non-native understory.

Transition T3A: Severe fire significantly reduces shrub cover, allowing annual non-native species to increase and dominate.

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of disturbance allows sprouting shrubs to increase and dominate the site. Annual non-native species dominate the understory.
4.2a: Frequent wildfire reduces the shrub overstory.

Additional State and Transition Models for Group 29 in MLRA 29:



MLRA 29
Group 29
Oak Thicket
R029XY171NV

Reference State 1.0 Community Phase Pathways
1.1a: Frequent fire reduces shrub overstory and allows perennial bunchgrasses to dominate the site.
1.2a: Time and lack of disturbance allow Gambel oak to regenerate.

Transition T1A: Introduction of non-native annual species.

Current Potential State 2.0 Community Phase Pathways
2.1a: Fire and/or drought reduces shrub overstory and creates a mosaic of shrubs and perennial grasses.
2.1b: Time and lack of disturbance allows mountain big sagebrush and other shrubs to increase and dominate the site.
2.2a: Time and lack of disturbance allows shrubs to increase and dominate.
2.3a: Low severity fire and/or herbivory favoring perennial bunchgrasses will reduce shrub overstory.
2.3b: Fire reduces or eliminates the shrub overstory, allowing perennial bunchgrasses to increase.

Transition T2A: Inappropriate, chronic grazing will decrease or eliminate deep-rooted perennial bunchgrasses and favor shrub growth and establishment (to 3.1). High severity fire removes shrub overstory and decreases perennial bunchgrasses, allowing annual non-native species and sprouting shrubs to increase (to 3.2).

Shrub State 3.0 Community Phase Pathways
3.1a: Fire that reduces non-sprouting shrubs allows sprouting shrubs to dominate.
3.2a: Time and lack of disturbance and/or grazing management that favors shrub growth allows shrub component to recover and out-compete non-native understory.

Transition T3A: Severe fire significantly reduces shrub cover, allowing annual non-native species to increase and dominate.

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of disturbance allows sprouting shrubs to increase and dominate the site. Annual non-native species dominate the understory.
4.2a: Frequent wildfire reduces the shrub overstory.

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MLRA 29 Group 30: Singleleaf pinyon pine with white fir

Description of MLRA 29 Disturbance Response Group 30

Disturbance Response Group (DRG) 30 consists of one ecological site PIMO-ABCOC/ AMUT/POFE (F029XY096NV). This site typically occurs on north-facing mountain sideslopes. The slopes range from 15 to 75%, but slope gradients of 30 to 50% are typical. The precipitation ranges from 16 to 18 in. (41–46 cm). Elevation ranges from 6,000 to 7,200 ft (1,829–2,195 m). This site typically occurs on north-facing mountain sideslopes. The soils on these sites are shallow to very shallow and well drained. Available water holding capacity is low on this site, but plants extend roots into rock crevices to capitalize on moisture held deeper in bedrock. Runoff is medium to rapid. Potential for sheet erosion is moderate to severe, depending on site slope. The soil temperature regime is frigid and the soil moisture regime is xeric. The reference plant community is dominated by Rocky Mountain white fir (*Abies concolor*) and singleleaf pinyon (*Pinus monophyla*). With an overstory cover of approximately 30%, tree canopy composition is approximately 40 to 60% singleleaf pinyon and 60 to 40% Rocky Mountain white fir. Utah serviceberry (*Amelanchier utahensis)* and mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*) are the most common shrubs found in the understory. Muttongrass (*Poa fendleriana)* is a dominant understory grass but can be found with Sandberg's bluegrass (*Poa secunda*), Thurber's needlegrass (*Achnatherum thurberianum),* Indian ricegrass *(Achnatherum hymenoides)*, and pine needlegrass (*Achnatherum pinetorum).* Understory production ranges from 50 to 700 lb/ac depending on overstory canopy cover and annual variability. This site is of low site quality for singleleaf pinyon and very low site quality for white fir.

Disturbance Response Group 30 Ecological Sites:

PIMO-ABCOC/AMUT/POFE (Shallow Bouldery Loam 16-18" P.Z.) – Modal F029XY096NV

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasives. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans a unique area in Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area. Flashy, summer storm events contribute significantly to annual precipitation as well. Air and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

Pinyon and juniper-dominated plant communities in the cold desert of the Great Basin and Colorado Plateau occupy over 18 million hectares (44.8 M ac) (Miller and Tausch 2001, Miller et al. 2019). Soils occupied by persistent woodlands are most commonly shallow to restrictive layers including claypans, calcareous horizons, and fractured bedrock (Miller et al. 2019). In addition, soil surfaces are typically very coarse-textured with gravelly to extremely cobbly material, often resulting in very low to low soil moisture storage (Miller et al. 2019). In the mid to late 1900s, the number of pinyon and juniper trees established per decade began to increase compared to the previous several hundred years. The substantial increase in conifer establishment is attributed to a number of factors the most important being (1) cessation of the aboriginal burning (Tausch 1999), (2) change in climate with rising temperatures (Heyerdahl et al. 2006), (3) the reduced frequency of fire likely driven by the introduction of domestic livestock, (4) a decrease in wildfire frequency along with improved wildfire suppression efforts and (5) potentially increased CO2 levels favoring woody plant establishment (Bunting 1994, Tausch 1999). Miller et al. (2008b) found pre-settlement tree densities averaged 2 to 11 per acre in six woodlands studied across the Intermountain West. Current stand densities range from 80 to 358 trees/ac. In Utah, Nevada, and Oregon, trees established prior to 1860 accounted for only 2% or less of the total population of pinyon and juniper (Miller et al. 2008b). The research strongly suggests that for over 200 years prior to settlement, woodlands in the Great Basin were relatively low density with limited rates of establishment (Miller and Tausch 2001, Miller et al. 2008b). This evidence strongly suggests that tree canopy cover of 10 to 20% may be more representative of these sites in pristine condition. Increases in pinyon and juniper densities post-settlement were the result of both infill in mixed-age tree communities and expansion into shrub-steppe communities. Pre-settlement trees accounted for less than 2% of the stands sampled in Nevada, Oregon, and Utah (Miller et al. 1999, Miller and Tausch 2001, Miller et al. 2008b). However, the proportion of old-growth can vary depending on disturbance regimes, soils, and climate. Some ecological sites are capable of supporting persistent woodlands, likely due to specific soils and climate resulting in infrequent stand replacement disturbance regimes. In the Great Basin, old-growth trees have been found to typically grow on rocky shallow or sandy soils that support little understory vegetation to carry a fire (Holmes et al. 1986, Miller and Rose 1995, West et al. 1998).

Infilling by younger trees increases canopy cover causing a decrease in understory perennial vegetation and an increase in bare ground. As pinyon trees increase in density so does the litter. Infilling shifts stand-level biomass from ground fuels to canopy fuels which has the potential to significantly impact fire behavior. The more tree-dominated pinyon woodlands become, the less likely they are to burn under moderate conditions, resulting in infrequent high-intensity fires (Gruell 1999, Miller et al. 2008b). Additionally, as the understory vegetation declines in vigor and density with increased canopy, the seed and propagules of the understory plant community also decrease significantly. The increase in bare ground allows for the invasion of non-native annual species such as cheatgrass and with intensive wildfire, the potential for conversion to annual exotics is a serious threat (Tausch 1999, Miller et al. 2008b).

Singleleaf pinyon is long-lived tree species with wide ecological amplitudes (Tausch et al. 1981, West et al. 1998, Weisberg and Ko 2012). The maximum ages of pinyon exceed 1,000 years and stands with maximum age classes are only found on steep rocky slopes with no evidence of fire (West et al. 1975). Pinyon is slow-growing and very intolerant to shade with the exception of young plants, usually first-year seedlings (Tueller and Clark 1975). Singleleaf pinyon seedling establishment is episodic. Population age structure is affected by drought, which reduces seedling and sapling recruitment more than other age classes. The ecotones between singleleaf pinyon woodlands and adjacent shrublands and grasslands provide favorable microhabitats for singleleaf pinyon seedling establishment since they are active zones for seed dispersal, nurse plants are available, and singleleaf pinyon seedlings are only affected by competition from grass and other herbaceous vegetation for a couple of years.

Specific successional pathways after disturbance in pinyon stands are dependent on a number of variables, such as plant species present at the time of disturbance and their individual responses to disturbance, past management, type and size of disturbance, available seed sources in the soil or adjacent areas, and site and climatic conditions throughout the successional process.

Phillips (1909) recognized that the pinyons are more resistant to disease than most of the conifers with which it associates. Hepting (1971) lists several diseases affecting pinyon including: foliage diseases, tarspot needle cast *(Davisomycella ampla)*, stem diseases such as blister rust *(Cronartium ribicola)* and dwarf mistletoe *(Arceuthobium spp.)*, root diseases and trunk rots, red heart rot, and butt rot (caused by *Polyporus schweinitzii)*. The pinyon ips beetle *(Ips confuses*) and pinyon needle scale (*Matsucoccus acalyptus*) are both native insects to Nevada that attack pinyon pines throughout their range. The pinyon needle scale weakens trees by killing needles older than 1 year. Sometimes small trees are killed by repeated feeding and large trees are weakened to the point that they are attacked by the pinyon ips beetle. The beetle typically kills weak and damaged trees (Phillips and Reboletti 2014). During periods of long-term drought, the impact of these two insects on singleleaf pinyon can be substantial.

The pinyon jay (*Gymnorhinus cyanocephalus)* and other members of the seed caching corvids play an important role in pinyon pine regeneration. These birds cache the seeds in the soil for future use. Those seeds that escape harvesting by the birds and rodents have the opportunity to germinate under favorable soil and climatic conditions (Lanner 1981). A mutualistic relationship exists between the trees that produce food and the animals that disperse the seeds, thereby ensuring the perpetuation of the trees. Large crops of seeds may stimulate reproduction in birds, especially the pinyon jay (Ligon 1974).

Pinyon growth is dependent mostly upon soil moisture stored from winter precipitation, mainly snow. Much of the summer precipitation is ineffective, being lost in runoff after summer convection storms or by evaporation and interception (Tueller and Clark 1975). Pinyon is highly resistant to drought which is common in the Great Basin. Tap roots of pinyon have a relatively rapid rate of root elongation and are thus able to persist until precipitation conditions are more favorable (Emerson 1932).

Rocky Mountain white fir occurs in 31 mountain ranges and in 10 counties in Nevada but it is relatively uncommon (Charlet 1996). It is considered fairly drought resistant and is a strong competitor with associated species (Maul 1958). It has good mast years at irregular intervals of 2 to 4 years. Seed bearing continues for many years but is more abundant during the period of rapid height growth (ages 50 to 100 years). Pole-size trees in dense stands usually bear seeds only when their leaders reach full sunlight (Maul 1958). Any tree-top damage caused by insects, diseases, and mechanical agents such as ice, snow or wind directly reduces mast production. Crown decadence can be caused by fir mistletoe (*Phoradendron pauciflorum*), western dwarf mistletoe (*Arceuthobium campylopodum*), and the fir engraver beetle (*Scolytus ventralis*). Trees that lose their tops may develop new terminals and resume cone-bearing (Maul 1958). Fir-cone moths *(Barbara* spp.) often seriously injure cones and seed chalcids (*Megastigumus* spp.) often damage Rocky Mountain white fir seeds (Maul 1958).

Rocky Mountain white fir reproduces solely by seed. Seeds are mostly disseminated by wind and to minor extent by rodents. Seed dissemination occurs from September through October or later depending on elevation. The greatest number of seeds fall close to the base of the tree with wind dissemination influenced by height of tree, surrounding forest canopy, terrain, updrafts, air turbulence and direction of prevailing winds (Maul 1958). Seed germination requires available surface soil moisture and suitable temperatures. White fir seedlings are shade tolerant but once established grow best in full sun. White fir is slow growing until about 30 years of age and then growth rapidly accelerates (Markstrom and McElderry 1984). This may be due to competition from other species; white fir can survive for long periods of time as a suppressed tree and still be able to respond to release by increasing growth rapidly (Laacke 1990). The record white fir is 107 in. (2.7 m) diameter and 192 ft (58.5 m) tall (Markstrom and McElderry 1984), but tree heights rarely exceed 100 ft (30.5 m). These trees grow on a variety of soils developed from diverse parent materials. White fir may be more dependent on moisture availability and temperature than soil series. Growth and development are best on moderately deep and well-drained sandy-loam to clay-loam soils regardless of parent material. White fir may invade meadows by growing near older lodgepole pines, it can take advantage of the drier soils near the pine roots (Laacke 1990).

A common insect pest of Rocky Mountain white fir is the fir engraver, a beetle that causes considerable damage and mortality (Markstrom and McElderry 1984). Defoliators including Douglas-fir tussock moth and wester spruce budworm, reduce growth and may kill some trees (Markstrom and McElderry 1984). White fir is subject to windthrow and is often intensified by root rot from *Fomes annosus* that becomes established through old fire wounds (Maul 1958). Windthrow may also be caused by partial cutting; which can leave this shallower-rooted species unprotected (Markstrom and McElderry 1984).

Utah serviceberry is a large shrub that grows from 2 to 4 m tall (6.5 to 13 ft) and typically grows in big sagebrush, pinyon-juniper, and aspen communities (Hammond 2012). Despite typically being found surrounded by other species, serviceberry seedlings can be out-competed by dense stands of grasses and forbs. Utah serviceberry is top-killed by fire but resprouts from an underground crown, and its branches, leaves, and berries all provide forage for wildlife and livestock (Noller 2008). *A. utahensis* is more drought tolerant than other serviceberry species, and its root system is very deep and spreading and well adapted to coarse-textured soils (Hammond 2012). However, Utah serviceberry has been found to be intolerant of high water tables and poorly drained soils. The only pest known to be a serious threat to Utah serviceberry is cedar-apple rust *(Gymnosporangium juniperi-virginianae)*, which *A. utahensis* can host in its leaves and berries when growing in proximity to Junipers *(Juniperus* spp.) (Wasser et al. 1982).

Mountain big sagebrush is generally long-lived; therefore, it is not necessary for new individuals to recruit every year for perpetuation of the stand. Infrequent large recruitment events and simultaneous low, continuous recruitment is the foundation of population maintenance (Noy-Meir 1973). Survival of the seedlings is dependent on adequate moisture conditions.

Muttongrass is a tufted, multi-flowered, perennial bunchgrass that can grow between 8 and 30 in. tall and has narrow leaves, which range from 1 to 3 mm wide. It is found in lower elevations in the northern extent of its native range, and higher elevations in the south. Muttongrass is one of the most drought-tolerant bluegrasses and is useful for restoring communities disturbed by fire, grazing, or mining, but is limited in its use due to low seed viability. Muttongrass plants are most frequently pistillate, but staminate plants do occasionally occur, which are able to hybridize and crossbreed with other bluegrasses. Muttongrass is found throughout the western United States as a primary component of the understory of pinyon-juniper communities and aspen and pine forests (Tilley et al. 2007).

The ecological site in this DRG have moderate resilience to disturbance and resistance to invasion. Resilience increases with elevation, aspect, precipitation, and nutrient availability.

Long-term disturbance responses may be influenced by slight differences in landscape topography. Concave areas receive run-in from adjacent landscapes and consequently retain more moisture to support the growth of deep-rooted perennial grasses, whereas convex areas are slightly less resilient and may have more shallow-rooted perennial grasses. North slopes are also more resilient than south slopes because lower soil surface temperatures operate to keep moisture content higher on northern exposures.

Fire Ecology:

Traits that allow coniferous species to persist in high fire frequency areas are 1) traits that allow species to survive fire such as thick bark, and high crowns, and 2) traits that allow species to repopulate an area rapidly after fire such as serotinous cones, persistent seed banks and increased flowering after fire (Russell 1994). Prolonged absence of fire in fire-type communities can allow for an increase in fine fuels (Russell 1994). The development of shrubs and young trees in the understory can act as ladder fuels increasing the probability of crown fires. The number of fires was shown to be higher where fire was not suppressed but the average size of fires was significantly higher where fire was suppressed (Russell 1994).

At higher elevations and fire safe zones where these sites occur, the understory is scarce and fire is infrequent and of low intensity due to low fuel loads. Fires in these zones are more likely related to El Nino events and higher production years (Sherriff et al. 2001).

Fire suppression has aided an increase in the population of the white fir. Where fires were more frequent young plants were killed in the understory, with fire suppression these shade tolerant species have been allowed to mature. They act as “fire ladders” which conduct flames into the canopies of other trees, chiefly pines. Pine trees are not tolerant of shade and do not become established under canopies of white fir, thus the transition of pine dominated forests to firs (Lanner 2002). Burning in areas where white fir is undesired may be the best management practice to control its populations (Laacke 1990).

Mountain big sagebrush is killed by fire (Neuenschwander 1980, Blaisdell et al. 1982), and does not resprout (Blaisdell 1953). Post-fire regeneration occurs from seed and will vary depending on site characteristics, seed source, and fire characteristics. Mountain big sagebrush seedlings can grow rapidly and may reach reproductive maturity within 3 to 5 years (Bunting et al. 1987). Mountain big sagebrush may return to pre-burn density and cover within 15 to 20 years following fire, but establishment after severe fires may proceed more slowly and can take up to 50 years (Bunting et al. 1987, Miller and Heyerdahl 2008, Ziegenhagen and Miller 2009).

Utah serviceberry is a large, fire-tolerant shrub that may occur on one or more the ecological sites contained within this DRG. It is top-killed by fire, but sprouts from the underground root crown after disturbance (Carmichael et al. 1978). However, this resprouting is reliant on the amount of moisture in the soil and Utah serviceberry is more adapted for drier soils, which will limit the potential for a sprout to successfully grow (Hammond 2012). *A. utahensis* can also re-colonize an area after fire via seeds, but this can require up to 8 to 10 years for plants to be fully matured and productive (Noller 2008).

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The initial condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species' response. For most forbs and grasses the growing points are located at or below the soil surface providing relative protection from disturbances that decrease above-ground biomass, such as grazing or fire. Thus, fire mortality is more correlated to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant, and abundance of old growth (Wright 1971, Young 1983). However, the season and severity of the fire will influence plant response. Plant response will vary depending on post-fire soil moisture availability.

Muttongrass is top killed by fire but will resprout after low to moderate severity fires. A study by Vose and White (1991) in an open sawtimber site, found minimal difference in overall effect of burning on muttongrass.

Livestock/Wildlife Grazing Interpretations:

Pinyon woodlands provide a diversity of habitat for wildlife. Although the foliage of pinyon varies in palatability among fauna, pinyon nuts and juniper berries are preferred by many species. The understory species provide fruits and browse for large ungulates, small mammals, birds, and beavers (Wildlife Action Plan Team 2012).

Ungulates will use pinyon trees for cover and graze the foliage. The understory species also provide critical browse for deer *(Odocoileus spp.)*. The trees provide important cover for mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis)* wild horses *(Equus ferus)*, mountain lion (*Puma concolor*), bobcat (*Lynx rufus*), and pronghorn antelope (*Antilocapra americana*) (Logan and Irwin 1985, Evans 1988, Coates and Schemnitz 1994, Gottfried and Severson 1994).

Mule deer is considered the dominant big game species in the pinyon woodland and depend heavily on these woodlands for cover, shelter, and emergency forage during severe winters (Frischknecht 1975). Mule deer will eat singleleaf pinyon foliage, using the foliage moderately in winter, spring, and summer (Kufeld et al. 1973). Deep snows in higher elevation forest zones force mule deer and elk down into pinyon habitats during winter. This change in habitat allows mule deer and elk to browse the dwarf trees and shrubs (Gottfried and Severson 1994).

The diet of pronghorn antelope *(Antilocapra americana)* varies considerably; however, singleleaf pinyon was shown to comprise 1 to 2% of the winter diet of pronghorn antelope that occur in pinyon-juniper habitat. Desert bighorn sheep (*Ovis nelson*) may utilize pinyon habitat, but only where the terrain is rocky and steep (Gottfried et al. 2000). Gray foxes (*Urocyon cinereoargenteus*), bobcats (*Lynx rufus*), coyotes (*Canis latran*s), weasels (*Mustela frenata*), skunks (*Mephitis* spp.), badgers (*Taxidea taxus*), and ringtail cats *(Bassariscus astutus*) search for prey in pinyon habitat woodlands (Short and McCulloch 1977).

The pinyon mouse *(Peromyscus truei*) is a pinyon-juniper obligate and uses the woodlands for cover and food (Hoffmeister 1981). Other small mammals include the porcupine (*Hystricomorph hystricidae*), desert cottontail (*Sylvilagus audubonii*), Nuttall's cottontail (*S. nuttallii*), deer mouse (*Peromyscus maniculatus*), Great Basin pocket mouse (*Perognathus parvus*), chisel-toothed kangaroo rat (*Dipodomys microps*) and desert woodrat (*Neotoma lepida*) (Turkowski and Watkins 1976).

Many bird species are associated with the pinyon habitat; some are permanent residents, some summer residents, and some winter residents, depending upon location. For birds and bats, the woodland provides structure for nesting and roosting, and locations for foraging. Singleleaf pinyon provides a number of cavities and the stringy, fibrous bark provides quality nesting material as well as the food provided by the tree's seeds and berries (Short and McCulloch 1977). Many bird species depend on juniper berry-cones and pine nuts for fall and winter food (Balda and Masters 1980). Several bird species are obligates, including gray flycatcher (*Epidonax wrightii)*, scrub jay (*Aphelocoma californica)*, plain titmouse (*Parus inornatus ridgwayi*), and gray vireo (*Vireo vicinior)*; several species are semi-obligates including black-chinned hummingbird (*Archilochus alexandri*), ash-throated flycatcher (*Myiarchus cinerascens*), pinion jay (*Gymnorhinus cyanocephalus*), American bushtit (*Psaltriparus minimus*), Bewick's wren (*Thryomanes bewickii*), Northern mockingbird (*Mimus polyglottos*), blue-gray gnatcatcher (*Polioptila caerulea*), black-throated gray warbler (*Dendroica nigrescens*), house finch (*Haemorhous mexicanus*), spotted towhee (*Pipilo maculatus*), lark sparrow (*Chondestes grammacus*) and black-chinned sparrow (*Zonotrichia atricapilla)* (Balda and Masters 1980). Ferruginous hawk (*Buteo regalis*), a conservation priority species due to recent population declines in Nevada, nests in older trees of sufficient size and structure to support their large nest platforms (Holechek 1981).

Mule deer are especially fond of succulent, new white fir growth in the spring (Laacke 1990). Porcupines prefer the bark of white fir, and have been known to forage so enthusiastically that they destroy saplings (Hayward 1945). Rocky Mountain white fir seeds are eaten by several species of small mammals. Indications of small rodents feeding on the cambial tissue of white fir were noticed in the study by Hayward (Hayward 1945). Rodents trapped in the study area where white fir trees occur include: deer mouse (*Peromyscus maniculatus*), meadow vole (*Microtus mordax mordax*), montane vole (*Microtus montanus nanus*), hidden- forest chipmunk (*Tamias umbrinus*) yellow-pine chipmunk (*Tamias amoenus*), jumping mouse (*Zapus pinceps*) and montane shrew, (*Sorex monticolus*). Pocket gophers (*Thomomys monticola*), flying squirrels

(*Glaucomys sabrinus*), and ground squirrels (*Otospermophilus beecheyi*) also occur in subalpine habitat and are known to utilize white fir habitat (Laacke 1990, Waters and Zabel 1995). Browsing by big game may retard the height of white fir for many years (Markstrom and McElderry 1984).

Several other mammals, although do not actively use the trees for food or shelter, inhabit the same ecosystems (subalpine, montane, timberline) in which white fir trees occur in Nevada. Yellow-bellied marmots (*Marmota flaviventris*) found in meadows, valleys, and foothills, where forests and meadows form a mosaic will also inhabit subalpine communities above 6,500 ft (2 km) (Linzey and Hammerson 2008).

Muttongrass is relatively grazing tolerant. It is palatable and nutritional forage for livestock and wildlife when it is in the early stages of growth. It rates as excellent forage for cattle and horses, and good for sheep, elk and deer (USFS 1937). Muttongrass persists well in open areas and under canopies of oak and other shrubs (Monsen et al. 2004b). Muttongrass may be more shade tolerant than other perennial bunchgrasses and may persist in the understory as the canopy closes (Erdman 1970).

State and Transition Model Narrative for Group 30:

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 29 disturbance response group 30.

Reference State 1.0:

The Reference State 1.0 is representative of the natural range of variability under pristine conditions. This reference state has four general community phases: a mature woodland phase (1.1), a shrub-herbaceous phase (1.2), an immature woodland phase (1.3), and over-mature woodland (1.4). State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire, periodic long-term drought and/or insect or disease attack.

Community Phase 1.1:

This community phase is characterized by mature Rocky Mountain white fir and singleleaf leaf pinyon trees. The visual aspect and vegetal structure are dominated by pinyon and white fir that have reached or are near maximal heights for the site. Tree canopy cover ranges from 20 to 35%. Mountain big sagebrush and Utah serviceberry are the dominant shrubs in the understory. Muttongrass is the dominant grass. Understory vegetation is strongly influenced by tree competition, overstory shading, and duff accumulation. Understory production is 150 to 300 lb/ac.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
High severity, stand replacing fire would reduce tree cover and allow for the herbaceous understory to increase.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.4:
A lightning strike, low severity fire and/or disease and insects would reduce the tree cover and shrubs in the understory and allow the perennial bunchgrasses to increase.

Community Phase 1.2
This community phase is characterized by a post-fire shrub and herbaceous community. Sprouting shrubs such as Utah serviceberry and ephedra (*Ephedra viridis*) may increase. Perennial grasses in the understory such as muttongrass, Indian ricegrass and pine needlegrass may increase due to reduced competition from the overstory and increased sunlight. Conifers may be present in patches and fire safe zones. Tree seedlings and saplings may reach a canopy cover of 5 to 10%. Understory production ranges from 400 to 700 lb/ac under a sparse canopy (<10%).

Community Phase Pathway 1.2a, from Phase 1.2 to 1.3:
Time without disturbance such as fire, long-term drought or disease will allow for the trees and shrubs to increase in height and density.

Community Phase 1.3:
This phase is characterized by an immature woodland. The visual aspect and vegetal structure are dominated by singleleaf pinyon and white fir trees greater than 4.5 ft (1.4 m) in height. Dominants are the tallest trees on the site; co-dominants are 65 to 85% of the highest trees. Pinyon and white fir seedlings and saplings increase in size and density. The herbaceous understory decreases due to competition from maturing conifer seedlings and saplings. Understory vegetation is moderately influenced by a tree overstory canopy of 10 to 20%. Understory production ranges from 200 to 500 lb/ac.

Community Phase Pathway 1.3a, from Phase 1.3 to 1.1:
Time without disturbance such as fire, long-term drought or disease will allow for the trees and shrubs to increase in height and density.

Community Phase Pathway 1.3b, from Phase 1.3 to 1.2:
Fire would reduce the maturing trees and shrubs and allow for the herbaceous understory to increase.

Community Phase 1.4:
This phase is dominated by singleleaf pinyon and white fire that have reached maximal heights for the site. Dominant and co-dominant pinyon trees average greater than 15 in. at one-foot stump height. Dominant white fir trees average greater than 10 in. (25 cm)

in diameter at breast height. Understory vegetation is sparse or absent due to tree competition, overstory shading, and duff accumulation. White fir seedlings are common in the understory. Tree canopy cover is often greater than 50%. Understory production under a dense canopy (36–50%) ranges from 50 to 200 lb/ac.

Community Phase Pathway 1.4a, from Phase 1.4 to 1.1:
Low intensity fire, insect infestation, or disease kills individual trees within the stand reducing canopy cover to less than 20%. Over time young trees mature to replace and maintain the mature woodland. The mountain big sagebrush and perennial bunchgrass community increases in density and vigor.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0

Trigger: This transition is caused by the introduction of non-native annual plants, such as cheatgrass and mustards.

Slow variables: Over time the annual non-native species will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

This state is similar to the Reference State 1.0, with four general community phases: a mature woodland phase (2.1), a shrub-herbaceous phase (2.2), an immature woodland phase (2.3), and an over-mature woodland phase (2.4). Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of non-native species. These non-natives, particularly cheatgrass, can be highly flammable and promote fire where historically fire had been infrequent. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal. Fires within this community with the small amount of non-native annual species present are likely still small and patchy due to low fuel loads. This fire type will create a plant community mosaic that will include all/most of the following community phases within this state.

Community Phase 2.1:

This phase is characterized by mature singleleaf pinyon and white fir trees with an understory of mountain big sagebrush, Utah serviceberry and perennial bunchgrasses. The visual aspect and vegetal structure are dominated by singleleaf pinyon and white fir trees that have reached or are near maximal heights for the site. Tree canopy cover ranges from 20 to 35%. Tree crowns may be flat- or round-topped. At fire-safe sites, dominant singleleaf pinyon trees average greater than 15 in. (38 cm) in diameter at one-foot stump height. Muttongrass is the most prevalent grass in the understory, found primarily under tree canopies. Mountain big sagebrush and Utah serviceberry are the primary understory shrubs. Understory production ranges from 150 to 300 lb/ac under a medium canopy cover (20–30%). Non-native, annual weeds are a minor component.

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
High severity, stand replacing fire would reduce tree cover and allow for the herbaceous understory to increase.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.4:
A lightning strike, low severity fire and/or disease and insects would reduce the trees in the overstory and shrubs in the understory allowing the perennial bunchgrasses to increase.

Community Phase 2.2
This community phase is characterized by a post-fire shrub and herbaceous community. Muttongrass and other perennial grasses dominate. Forbs may increase post-fire but will likely return to pre-burn levels within a few years. Pinyon and white fir seedlings up to 4 ft (1.2 m) in height may be present. Mountain big sagebrush may be present in unburned patches. Burned tree skeletons may be present; however, these have little or no effect on the understory vegetation. Annual non-native species generally respond well after fire and may be stable or increasing within the community. Canopy cover of trees is less than 10%. Understory production ranges from 200 to 500 lb/ac.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.3:
Time without disturbance such as fire, long-term drought or disease will allow for the trees and shrubs to increase in height and density.

Community Phase 2.3:
This phase is characterized by an immature woodland. The visual aspect and vegetal structure are dominated by singleleaf pinyon and white fir trees greater than 4.5 ft (1.4 m) in height. Dominants are the tallest trees on the site; co-dominants are 65 to 85% of the highest trees. Pinyon and white fir seedlings and saplings increase in size and density. The herbaceous understory decreases due to competition from maturing conifer seedlings and saplings. Understory vegetation is moderately influenced by a tree overstory canopy of 10 to 20%. Understory production ranges from 200 to 500 lb/ac.

Community Phase Pathway 2.3a, from Phase 2.3 to 2.1:
Time without disturbance such as fire, long-term drought or disease will allow for the trees and shrubs to increase in height and density.

Community Phase Pathway 2.3b, from Phase 2.3 to 2.2:
Fire would reduce the maturing trees and shrubs and allow for the herbaceous understory to increase.

Community Phase 2.4:
This phase is dominated by singleleaf pinyon and white fire that have reached maximal heights for the site. Dominant and co-dominant pinyon trees average greater than 15 in. (38 cm) at one-foot stump height. Dominant white fir trees average greater than 10 inches in diameter at breast height. Understory vegetation is sparse or absent due to tree competition, overstory shading, and duff accumulation. White fir seedlings are common in the understory. Tree canopy cover is often greater than 50%. Understory production under a dense canopy (36–50%) ranges from 50 to 200 lb/ac.

Community Phase Pathway 2.4a, from Phase 2.4 to 2.1:
Low intensity fire, insect infestation, or disease kills individual trees within the stand reducing canopy cover to less than 20%. Over time young trees mature to replace and maintain the mature woodland. The mountain big sagebrush and perennial bunchgrass community increases in density and vigor.

Infilled Tree State 3.0

This state has two community phases that are characterized by the dominance of singleleaf pinyon and white fir in the overstory. This state is identifiable by 35 to over 50% cover of singleleaf pinyon and white fir. This stand exhibits a mixed age class. Older trees are at maximal height and upper crowns of singleleaf pinyon may be flat-topped or rounded. Younger trees are typically cone- or pyramidal-shaped. Understory vegetation is sparse due to increasing shade and competition from trees.

Community Phase 3.1:
Singleleaf pinyon and white fir dominate the aspect. Understory vegetation is thinning. Perennial bunchgrasses are sparse and mountain big sagebrush skeletons are as common as live shrubs due to tree competition for soil water, overstory shading, and duff accumulation. Tree canopy cover is greater than 35%. Annual non-native species may be present. Bare ground areas are prevalent and soil redistribution is evident.

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:
Time without disturbance such as fire, long-term drought, or disease will allow for the gradual maturation of singleleaf pinyon and white fir trees. Infilling by younger trees continues.

Community Phase 3.2:
Singleleaf pinyon and white fir dominate the aspect. Tree canopy cover exceeds 35% and may be over 50%. Understory vegetation is sparse to absent. Perennial bunchgrasses, if present exist in the dripline or under the canopy of trees. Mountain big sagebrush skeletons are common or the sagebrush has been extinct long enough that only scattered limbs remain. Mat-forming forbs or Sandberg's bluegrass may dominate interspaces. Annual non-native species may be present and are typically found under the trees. Bare ground areas are large and interconnected. Soil redistribution may be extensive.

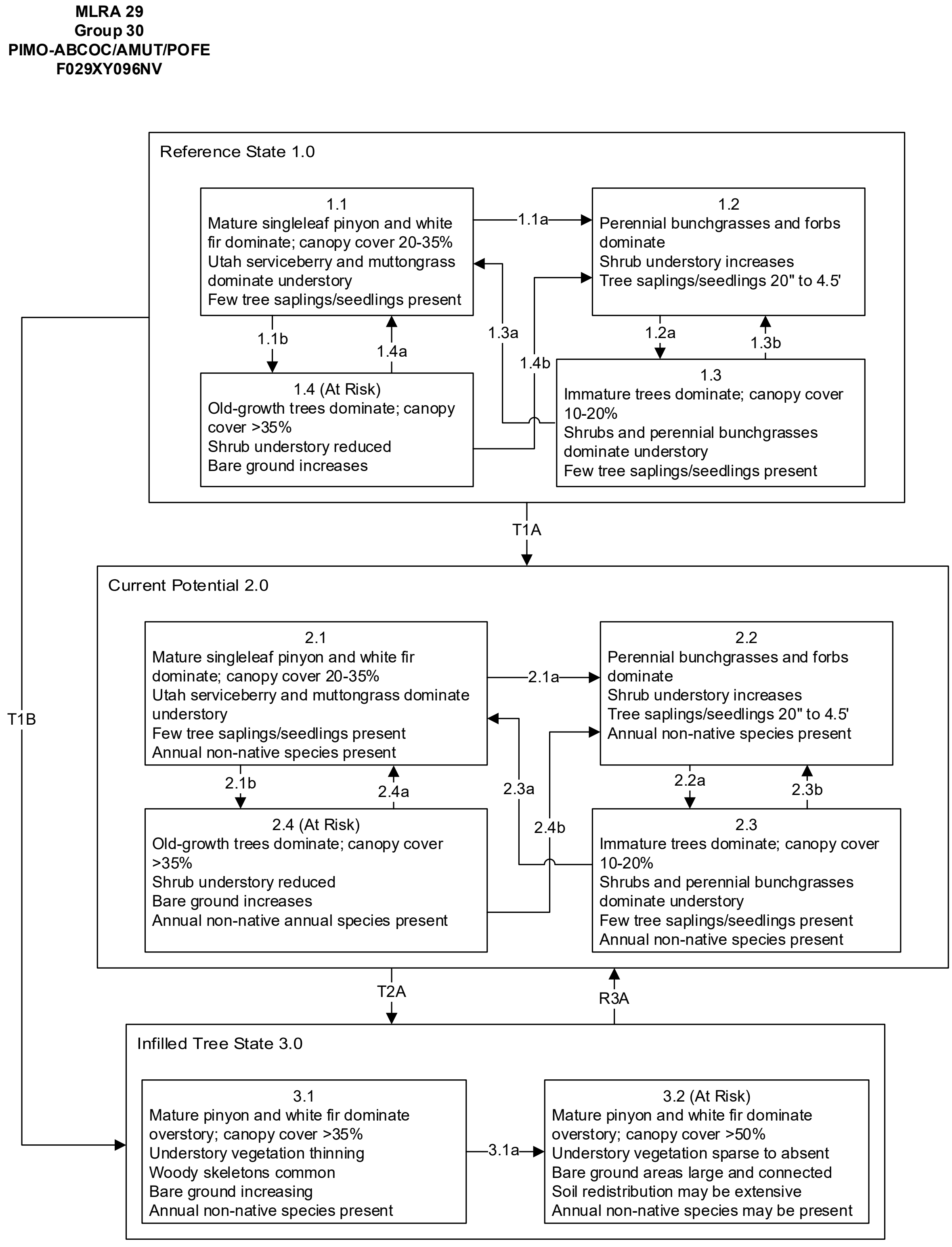
R3A Restoration from Infilled Tree State 3.0 to Current Potential State 2.0:

Manual or mechanical thinning of trees coupled with seeding of native species. Prescribed fire during fall or winter coupled with seeding. Probability of success is highest from community phase 3.1.

States Not Observed in Group 30:

An Annual State was not observed for this site and remote sensing did not indicate a high cover of annual forbs and grasses where this site is mapped. This site occurs on northerly-facing mountain sideslopes which have higher resilience than southerly-facing sideslopes.

Modal State and Transition Model for Group 30 in MLRA 29:



MLRA 29
Group 30
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Reference State 1.0 Community Phase Pathways
1.1a: High severity crown fire reduces or eliminates singleleaf pinyon and white fir overstory, allowing sprouting shrubs and perennial bunchgrasses to dominate.
1.1b: Time, lack of disturbance such as fire, insect attack, disease, or drought allows for infilling of young trees. Understory vegetation reduced due to tree competition.
1.2a: Time, lack of disturbance such as fire, insect attack, disease, or drought allows for maturation of overstory. Excessive herbivory by wildlife may reduce perennial grass understory.
1.3a: Time, lack of disturbance such as fire, insect attack, disease, or drought allows for infilling of young trees that reduces perennial grass understory.
1.3b: Fire reduces or eliminates tree cover.
1.4a: Low intensity fire, insect infestation, or disease kills individual trees, reducing the canopy cover to less than 35 percent.
1.4b: High severity crown fire will reduce or eliminate tree cover.

Transition T1A: Introduction of non-native annual species.

Transition T1B: Time and a lack of disturbance allows for trees to dominate site resources; may be coupled with inappropriate grazing management and/or fire suppression that favors shrub and tree dominance.

Current Potential 2.0 Community Phase Pathways
2.1a: High severity crown fire will eliminate/reduce singleleaf pinyon and white fir overstory, allowing sprouting shrubs and perennial bunchgrasses to dominate.
2.1b: Time, lack of disturbance such as fire, insect attack, disease, or drought allows for infilling of young trees. Understory vegetation reduced due to tree competition.
2.2a: Time, lack of disturbance such as fire, insect attack, disease, or drought allows for maturation of overstory. Excessive herbivory by wildlife may reduce perennial grass understory.
2.3a: Time, lack of disturbance such as fire, insect attack, disease, or drought allows for infilling of young trees that reduces perennial grass understory.
2.3b: Fire reduces or eliminates tree cover.
2.4a: Low intensity fire, insect infestation, or disease kills individual trees, reducing the canopy cover to less than 35 percent.
2.4b: High severity crown fire will reduce or eliminate tree cover.

Transition T2A: Time and a lack of disturbance allows for trees to dominate site resources; may be coupled with inappropriate grazing management and/or fire suppression that favors shrub and tree dominance.

Infilled Tree State 3.0 Community Pathways
3.1a: Time and lack of disturbance such as fire, insect attack, disease, or drought allows younger trees to infill.

Restoration R3A: Mechanical or hand thinning of trees coupled with seeding. Prescribed fire during fall or winter coupled with seeding. Success unlikely from phase 3.2.

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MLRA 29 Group 31: Ponderosa pine and mixed chaparral shrubs

Description of MLRA 29 Disturbance Response Group 31

Disturbance Response Group (DRG) 31 consists of one ecological site: Rocky Loamy Slope 16"+ P.Z. (PIPOS/ARPA6-AMUT-QUGA F029XY086NV). This forest site occurs on mountain sideslopes of mostly northerly aspects at the lower elevations of its range and on all aspects at higher elevations. Slopes range from 30 to 75% and elevations range from approximately 6,200 to 7,600 ft (1,890–2,317 m). Precipitation ranges from 16 to more than 19 in. (41–48 cm). The soils on this site are deep and well drained and strongly influenced by volcanic ash and glass. Soils are coarsely textured, ashy-skeletal and have an ochric epipedon which occurs from 0 to 8 in. (0–20 cm). The parent material for this DRG consists of residuum and colluvium derived from rhyolitic tuffs with a strong influence from volcanic ash. These soils have a neutral pH and can be grayish brown to pale brown in color. The soils are skeletal with 35 to 60% gravels and cobbles throughout the soil profile. Potential for sheet and rill erosion is moderate to severe on mountain slopes (depending on slope). The soil moisture regime is typic ustic and the soil temperature regime is frigid.

The reference plant community is dominated by Rocky Mountain ponderosa pine (*Pinus ponderosa* var. *scopulorum*). The dominant understory shrubs are greenleaf manzanita (*Arctostaphylos patula*), Gambel oak (*Quercus gambelii*), Utah serviceberry (*Amelanchier utahensis*), and mountain big sagebrush (*Artemisia tridentata ssp. vaseyana*). Understory grasses and grasslike plants include muttongrass (*Poa fendleriana*), Sandberg bluegrass (*Poa secunda*), bottlebrush squirreltail (*Elymus elymoides*) and Ross' sedge (*Carex rossii*). Under a medium canopy cover of 21 to 35%, the annual production ranges from 300 to 700 lb/ac, with 500 lb/ac in normal years. This forest community is of low site quality for tree production with a site index of 65 to 77 (Meyer 1938).

Disturbance Response Group 31 Ecological Sites:

PIPOS/ARPA6-AMUT-QUGA (Rocky Loamy Slope 16+" P.Z.) – Modal	F029XY086NV

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasive species. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans a unique area in Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area. Flashy, summer storm events contribute significantly to annual precipitation as well. Air and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

Ponderosa pine is a deep-rooted tree when compared to other western conifer species (Fitzgerald 2005) and is highly drought resistant throughout its range (Bates 1923, Conkle and Critchfield 1988). Individuals are fairly shade intolerant and require canopy disturbance for establishment (Stein 1988, Bond et al. 1999). Stands can be of varying age structure but historically have generally been open with a variety of age classes (Mast et al. 1998, Mast et al. 1999). Pockets of Rocky Mountain ponderosa pine forest exist at high elevations within western and southwestern Nevada as relict populations from the last glacial maximum. Westward expansion of eastern populations of Rocky Mountain ponderosa pine occurred during that time, resulting in more ubiquitous cover at lower elevations (Martin and Mehringer 1965, Wells 1983). Rocky Mountain ponderosa pine then retreated upslope to higher elevations and more northerly aspects as the climate became warmer and drier in these regions.

Mountain big sagebrush is generally long-lived; therefore, it is not necessary for new individuals to recruit every year for perpetuation of the stand. Infrequent large recruitment events and simultaneous low, continuous recruitment is the foundation of population maintenance (Noy-Meir 1973). The survival of the seedlings is dependent on adequate moisture conditions.

Utah serviceberry is a large shrub that grows from 2 to 4 m (6.5 to 13 ft) tall and typically grows in big sagebrush, pinyon-juniper, and aspen communities (Hammond 2012). Despite typically being found surrounded by other species, serviceberry seedlings can be outcompeted by dense stands of grasses and forbs. Utah serviceberry is top-killed by fire but resprouts from an underground crown, and its branches, leaves, and berries all provide forage for wildlife and livestock (Noller 2008). *A. utahensis* is more drought tolerant than other serviceberry species, and its root system is very deep and spreading and well adapted to coarse-textured soils

(Hammond 2012). The only pest known to be a serious threat to Utah serviceberry is cedar-apple rust *(Gymnosporangium juniperi-virginianae)*, which *A. utahensis* can host in its leaves and berries when growing in proximity to junipers *(Juniperus* spp.) (Wasser 1982).

Gambel oak is a deciduous small tree or shrub that is found in the foothills and lower mountains of western North America. It can occasionally grow as tall as 50 ft (15 m) but typically grows less than 30 ft (9 m) tall. Gambel oak has been known as a valuable resource for a long time, providing cover, habitat, and food for many different wildlife species. With the help of a healthy, productive understory, Gambel oak provides erosion protection over large areas (Kaufmann et al. 2016). Gambel oak is a sprouter, meaning that a Gambel oak plant can re-sprout from tissue underground, even when any of the plant above ground is killed from fire, grazing, or other forms of disturbance, as opposed to non-sprouters, which are killed by fire and rely on seed dispersal for post-dispersal colonization (Premoli and Steinke 2008). This makes Gambel oak a key component in restoring disturbed communities, because fresh, young plants will sprout, spread, and compete against invasive species.

Greenleaf manzanita is an evergreen shrub and is the most widespread of the manzanitas, occurring in Washington, Oregon, Montana, California, Nevada, Utah, Colorado, Arizona and New Mexico. It occurs on well-drained rocky slopes in association with coniferous forests and high elevation chaparral (Wilken and Burgher 2006). Greenleaf manzanita has a high tolerance for cold, below-freezing winters, but depends partly on snow cover to protect dormant buds and below normal temperatures (Nelson and Tiernan 1983).

Muttongrass is a tufted, multi-flowered, perennial bunchgrass that can grow between 8 and 30 in. (20–76 cm) tall and has narrow leaves, which range from 1 to 3 mm (<1 in.) wide. It is found in lower elevations in the northern extent of its native range, and higher elevations in the south. Muttongrass is one of the most drought-tolerant bluegrasses and is useful for restoring communities disturbed by fire, grazing, or mining, but is limited in its use due to low seed viability. Muttongrass plants are most frequently pistillate, but staminate plants do occasionally occur, which are able to hybridize and crossbreed with other bluegrasses. Muttongrass is found throughout the western United States as a primary component of the understory of pinyon-juniper communities and aspen and pine forests (Tilley et al. 2007).

Squirreltail (aka bottlebrush squirreltail) is a short, cool-season bunchgrass that grows between 10 to 45 cm tall (4–8 in.). It is found in plant communities ranging from salt-desert scrub to alpine meadows, from 2,000 ft to 11,500 ft (610–3,505 m) in elevation, from Mexico to British Columbia (Medin 1990, Monsen et al. 2004a). Squirreltail can be found above 2,000 ft (610 m) in elevation, and in areas that receive at least 5 in. of precipitation per year (Welsh et al. 1987). Squirreltail reproduces primarily through seed. The long awns of the fruit allow for wind dispersal up to 130 ft (40 m) away from the parent plant (Hironaka and Tisdale 1963, Marlette and Anderson 1986). It is an allotetraploid that can self-pollinate and is able to hybridize with other grasses, including other species of *Elymus* and some species of *Hordeum* (barley) (Welsh et al. 1987). Squirreltail is capable of facultative fall or spring germination, develops extensive roots at low temperatures, and produces seeds early in the season (Reynolds and Fraley 1989, Hironaka 1994, Monsen et al. 2004a).

The ecological site in this DRG has moderate resilience to disturbance and resistance to invasion. Two stable states were identified for this site.

Fire Ecology:

Historical fires in the Clover Mountains were typically frequent (mean fire return intervals of less than 10 years) and ranged from small fires to widespread fires (Kilpatrick 2009). Studies indicate that the longest fire-free period was 33 years, dating from 1675 to 1946, when a large stand-replacing fire in 1946 occurred under drier than average conditions. Since the 1946 fire, the Clover Mountains have experienced a drop in fire occurrence, with a fire-free period from 1946 to 2009 (Kilpatrick 2009).

Ponderosa pine has multiple adaptations that allows cone-bearing adults to survive both low- and high-intensity fires. At a young age, it develops a thick, corky bark that protects the cambium from fire (Hall 1980, Miller 2000, Fitzgerald 2005). The pine's terminal buds are protected by thick bud scales and long needles with high moisture content fire (Miller 2000). A study in the Sierra Nevada mountains showed that even if the crown of ponderosa pine is scorched, the tree often survives and "flushes" with new needles in the following growing season after fire (Hanson and North 2009). When estimating fire severity and post-fire mortality of ponderosa pines, this survival should be taken into account. Post-fire conditions of bare mineral soil, increased soil moisture, and low canopy cover are favorable to seedling survival (Bradley et al. 1992, Flathers et al. 2016). This community is not immune to negative effects of fire, however. In the seedling stage, ponderosa pine is readily killed by fire, and dense stands of this tree typically succumb to fire (Agee 1996). The cones are not serotinous and seeds are not long-lived in the soil, thus ponderosa pine will not return to dominance in large patches of high-severity fire (Korb et al. 2019).

Mountain big sagebrush is killed by fire (Neuenschwander 1980, Blaisdell et al. 1982) and does not resprout (Blaisdell 1953). Post-fire regeneration occurs from seed and will vary depending on site characteristics, seed source, and fire characteristics. Mountain big sagebrush seedlings can grow rapidly and may reach reproductive maturity within 3 to 5 years (Bunting et al. 1987). Mountain big sagebrush may return to pre-burn density and cover within 15 to 20 years following fire, but establishment after severe fires may proceed more slowly (Bunting et al. 1987).

Utah serviceberry is a large, fire-tolerant shrub, is a dominant understory species of this site. It is top-killed by fire but sprouts from the underground root crown after disturbance. However, resprouting is reliant on the amount of moisture in the soil and Utah serviceberry is more adapted for drier soils, which will limit the potential for a sprout to successfully grow

(Hammond 2012). *A. utahensis* can also re-colonize an area after fire via seeds, but this may require up to 8 to 10 years for plants to be fully mature and productive (Noller 2008).

Gambel oak is extremely fire tolerant due to its lignotubers/rhizomes (Kaufmann et al. 2016). When Gambel oak is killed by fire, most of the vegetative tissue underground is still alive, and the plant can sprout and grow from what is left. This gives Gambel oak and other sprouters an advantage over non-sprouters, or “obligate seeders” because they rely on seed dispersal in order to colonize an area after a fire or other disturbance (Premoli and Steinke 2008).

Greenleaf manzanita is a crown-sprouting shrub and also produces a prolific seed crop which may be stored in the soil for decades, germinating readily only after fire (Pase and Brown 1982). Seeds are dispersed by scatter-hoarding small mammals and carnivorans through mutualism (Moore and Vander Wall 2015).

Grasses on the site include muttongrass, Sandberg bluegrass and bottlebrush squirreltail. The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The initial condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species response. For most forbs and grasses, the growing points are located at or below the soil surface providing relative protection from disturbances which decrease above ground biomass, such as grazing or fire. Thus, fire mortality is more correlated to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant and abundance of old growth (Wright 1971, Young 1983).

Muttongrass, a dominant understory grass in this group, is top-killed by fire but will sprout after low to moderate severity fires. A study by Vose and White (1991), in an open saw timber site found minimal difference in the overall effect of burning on muttongrass.

Bottlebrush squirreltail is considered one of the most fire-resistant bunchgrasses due to its small size, coarse stems, and sparse leafy material (Wright and Klemmedson 1965, Wright 1971, Britton et al. 1990). Post-fire regeneration occurs from surviving root crowns and from on- and off-site seed sources (Bradley et al. 1992). Bottlebrush squirreltail can produce large numbers of highly germinable seeds, with relatively rapid germination (Young and Evans 1977) when exposed to the correct environmental cues. Early spring growth and ability to grow at low temperatures contribute to the persistence of squirreltail among cheatgrass-dominated ranges (Hironaka and Tisdale 1973). Research from Kulpa and Leger (2013) indicates that squirreltail is capable of relatively rapid natural selection to improve survival in low-water, competitive environments. These traits and others make squirreltail competitive with cheatgrass and medusahead (*Taeniatherum caput-medusae*) (Hironaka and Sindelar 1975, Hironaka 1994).

Livestock/Wildlife Grazing Interpretations:

This site is limited in extent, has low productivity, and occurs on steep sideslopes of hills and mountains, making this site limited for forage resources. Ponderosa pine habitat, however, supports a variety of wildlife and provides shelter for deer (Fryer 2018). Numerous rodents and birds also use ponderosa pine for shelter, and rely on the pinenuts for a food source (Hatz 2007). Clark's nutcracker (*Nucifraga columbiana*) is an important disperser of seed for ponderosa pine, as it caches seeds in locations appropriate for growth (Lorenz et al. 2011). Ponderosa pine provides critical habitat for white-headed woodpeckers (*Leuconotopicus albolarvatus*) (Ligon 1973, Kozma 2010), but it is unclear how this ecological site is used considering its limited extent. Cavity-nesting birds likely rely on the vertical structure of these unique forest sites.

Gambel oak is considered an important species for wildlife forage, even though it is not highly palatable. This is due to how widespread and abundant it is, especially on winter ranges. Gambel oak leaves provide important forage for deer and elk year-round, and acorns are an extremely valuable mast crop, especially for black bears in the fall (Jester et al. 2008). Due to being a sprouter, Gambel oak can provide valuable forage and cover in post-fire communities (Premoli and Steinke 2008).

Utah serviceberry is a very important plant because of the amount of food, cover, and habitat it provides to both livestock and wildlife. Its leaves, branches, and berries are used by many wildlife species, including big game, birds, and small animals (Noller 2008). *A. utahensis* is highly palatable to wildlife and livestock and is a preferred forage for elk (McCulloch 1955).

Despite low palatability, mountain big sagebrush is eaten by sheep, cattle, goats, and horses. Chemical analysis indicates that the leaves of big sagebrush equal alfalfa meal *(Medicago sativa)* in protein, have a higher carbohydrate content, and yield twelvefold more fat (USFS 1937).

Muttongrass is very palatable for wildlife and livestock and is rated as excellent forage for cattle and horses, and good for sheep. Muttongrass starts growth in late winter or early spring and provides excellent early feed. Muttongrass foliage cures well and is good fall forage, but not as good as spring or summer (Humphrey et al. 1952), and can withstand moderately heavy grazing (Marquiss and Lang 1959).

Squirreltail has low palatability as spring, summer, or fall forage, but is considered very palatable winter forage and generally increases in abundance when moderately grazed or protected (Hutchings and Stewart 1953, Currie 1975). In addition, moderate trampling by livestock in big sagebrush rangelands of central Nevada enhanced bottlebrush squirreltail seedling emergence compared to untrampled conditions. Heavy trampling, however, was found to significantly reduce germination sites (Eckert and Spencer 1987).

State and Transition Model Narrative for Group 31:

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for MLRA 29 Disturbance Response Group 31.

Reference State 1.0:

The Reference State 1.0 is representative of the natural range of variability under pristine conditions. This reference state has four general community phases: a mature woodland phase (1.1), a shrub-herbaceous phase (1.2), an immature woodland phase (1.3), and an over-mature woodland phase (1.4). State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire, periodic drought, and/or insect or disease attack. Fuels loads and climate were the driving force for pre-settlement fires. Fires occurred primarily in dry years following wet years during the growing season (Battaglia and Shepperd 2007). Frequent, low intensity surface fires created irregularly spaced, uneven-aged stands with trees growing together in small even-aged groups and shrubs and grasses between the groups. Mean fire return intervals were less than 10 years (Kilpatrick 2009). This fire type will create a plant community mosaic that will include all/most of the following community phases within this state.

Community Phase 1.1:
This phase is characterized by widely dispersed mature ponderosa pine trees with an understory of non-sprouting and sprouting shrubs (mountain big sagebrush, oak, manzanita, serviceberry), and perennial bunchgrasses. The visual aspect is dominated by ponderosa pine with about a 20 to 35% canopy cover. Trees have reached maximal or near maximal heights for the site. Muttongrass is the dominant perennial grass and perennial forbs such as phlox, buckwheat (*Eriogonum* spp.), linanthus (*Linanthus* spp.) and lupine (*Lupinus* spp.) are minor components. Understory production ranges between 300 to 700 lb/ac.

Rocky Loamy Slope 16+" (F029XY086NV) Reference State 1.1, T. Stringham, May 2022

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
A fire will eliminate or reduce the ponderosa pine overstory and the fire-intolerant shrub component. This allows for the perennial bunchgrasses and fire-adapted shrubs to dominate the site.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.4:
Time without disturbances such as fire, drought, insect infestation or disease will allow for the gradual infilling of ponderosa pine.

Community Phase 1.2:
This community phase is characterized by a fire-adapted shrub (manzanita, Gambel oak, Utah serviceberry) and an herbaceous community. Muttongrass and other perennial grasses dominate. Biodiversity of herbaceous plants increases for the first few years post-fire. Tree seedlings up to 20 in. (51 cm) in height and saplings up to 4 ft (1.2 m) in height may be present. Big sagebrush may be present in unburned patches. Burned tree skeletons may be present; however, these have little or no effect on the understory vegetation.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.3:
Time without disturbances such as fire, drought, insect infestation or disease will allow for the gradual infilling and maturation of the ponderosa pine component. Excessive herbivory by wildlife may also reduce perennial grass understory.

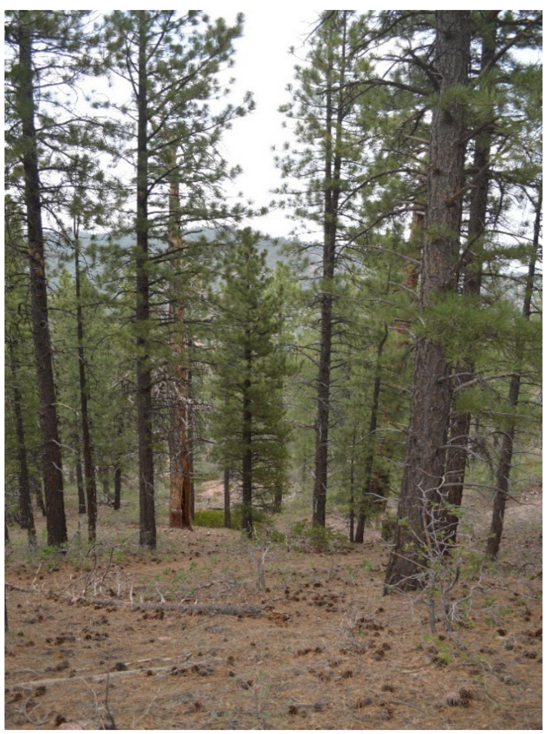
Community Phase 1.3:
This community phase is characterized by an immature woodland, with ponderosa pine trees averaging over 4.5 ft (1.4 m) in height. Tree canopy cover is between 10 to 20%. At this stage of woodland development, the tree canopy has broken through the suppression of the fire-adapted shrub community. The young ponderosa pines are still

very susceptible to fire at this state. Seedlings and saplings of ponderosa pine are common in the understory. Dominants are the tallest trees on the site; co-dominants are 65 to 85% of the highest of dominant trees. Understory vegetation is moderately influenced by the tree canopy and is dominated by mountain big sagebrush, Utah serviceberry, Gambel oak and greenleaf manzanita.

Community Phase Pathway 1.3a, from 1.3 to 1.4:
Time without disturbances such as fire, drought, insect infestation or disease will allow for the gradual maturation of ponderosa pine. Infilling by younger trees continues. Excessive herbivory by wildlife may reduce the perennial grass understory.

Community Phase Pathway 1.3b, from Phase 1.3 to 1.2:
Fire reduces or eliminates tree canopy, allowing perennial grasses and fire-adapted shrubs to dominate the site.

Community Phase 1.4 (at-risk):
This phase is dominated by ponderosa pine that have reached maximal heights for the site. The crown is typically broadly conical to round-shaped. Lower branches may be self-pruned. The stand exhibits mixed age classes and canopy cover may be 45% or greater. The density and vigor of the shrub and perennial bunchgrass understory is decreased. This community is at risk of crossing a threshold; after a stand-replacing crown fire this phase may transition to the Sprouting Shrub State 3.0.



Rocky Loamy Slope 16+" P.Z. (F029XY086NV), Reference State 1.4, T. Stringham, August 2021

Community Phase Pathway 1.4a, from Phase 1.4 to 1.1:

Low intensity fire, insect infestation, or disease kills individual trees and may thin seedlings, saplings and young trees and create gaps in the canopy. Gaps in the canopy enables light-intolerant pine germination and reduces the invasion of shade tolerant species. Over time, young trees mature to replace and maintain the old-growth woodland.

Community Phase Pathway 1.4b, from Phase 1.4 to 1.2:
A fire will eliminate or reduce the ponderosa pine overstory and the shrub component which will allow for the fire-adapted shrubs and perennial bunchgrasses to dominate the site.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0:

Trigger: Introduction of non-native annual species.

Slow variables: Over time the annual non-native plants will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

T1B: Transition from Reference State 1.0 to Sprouting Shrub State 3.0

Trigger: Landscape wide, high-severity, stand-replacing fire reduces the ponderosa pine overstory and facilitates the fire-adapted shrubs in the understory to dominate the site.

Slow variables: Long fire-return intervals (50 to 100+ years) allow for the re-establishment of fire-adapted shrub seed banks and the development of the fuel loads and spatial continuity necessary for fire to occur.

Threshold: Increased canopy cover of trees increases the risk for severe stand-replacing crown fire. Loss of deep-rooted perennial bunchgrasses and shrubs changes temporal and spatial nutrient capture and cycling within the community.

Current Potential State 2.0:

This state is similar to the Reference State 1.0, with four general community phases: a mature woodland phase (2.1), a shrub-herbaceous phase (2.2), an immature woodland phase (2.3), and an over-mature woodland phase (2.4). Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of non-native species. These non-natives, particularly cheatgrass, can be highly flammable and promote fire where historically fire had been infrequent. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal. Fires within this community with the small amount of non-native annual species present are likely still small and patchy due to low fuel loads. This fire type will create a plant community mosaic that will include all/most of the following community phases within this state.

Community Phase 2.1:
This phase is characterized by widely dispersed mature ponderosa pine trees with an understory of non-sprouting and sprouting shrubs (big sagebrush, oak, manzanita, serviceberry), and perennial bunchgrasses. The visual aspect is dominated by ponderosa pine with about a 20 to 35% canopy cover. Trees have reached maximal or near maximal heights for the site and many tree crowns may be flat- or round-topped. Muttongrass is the dominant perennial grass and perennial forbs such as phlox, buckwheat (*Eriogonum* spp.), linanthus (*Linanthus* spp.) and lupine (*Lupinus* spp.) are minor components. Understory production ranges between 300 to 700 lb/ac. Annual non-native species are present.

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
A fire will eliminate or reduce the ponderosa pine overstory and the fire-intolerant shrub component. This allows for the perennial bunchgrasses and fire-adapted shrubs to dominate the site.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.4:
Time without disturbances such as fire, drought, insect infestation or disease will allow for the gradual infilling of ponderosa pine.

Community Phase 2.2:

This community phase is characterized by a fire-adapted shrub (manzanita, Gambel oak, Utah serviceberry) and perennial grass community. Muttongrass is the dominant grass. Forbs may increase after a fire but will likely return to pre-burn levels within a few years. Tree seedlings up to 20 in. (51 cm) in height and saplings up to 4 ft (1.2 m) in height may be present. Big sagebrush may be present in unburned patches. Burned tree skeletons may be present; however, these have little or no effect on the understory vegetation. Annual non-native species are present in areas with little canopy cover.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.3:

Time without disturbances such as fire, drought, insect infestation or disease will allow for the gradual infilling and maturation of the ponderosa pine component. Big sagebrush reestablishes. Excessive herbivory may reduce perennial grass understory.

Community Phase 2.3:

This community phase is characterized by an immature woodland, with ponderosa pine trees averaging over 4.5 ft (1.4 m) in height. Tree canopy cover is between 10 to 20%. At this stage of woodland development, the tree canopy has broken through the suppression of the fire-adapted shrub community. The young ponderosa pines are still very susceptible to fire at this state. Seedlings and saplings of ponderosa pine are common in the understory. Dominants are the tallest trees on the site; co-dominants are 65 to 85% of the highest of dominant trees. Understory vegetation is moderately influenced by the tree canopy and is dominated by mountain big sagebrush, Utah serviceberry, Gambel oak and greenleaf manzanita. Annual non-native species are present.

Community Phase Pathway 2.3a, from Phase 2.3 to 2.4:
Time without disturbances such as fire, drought, insect infestation or disease will allow for the gradual maturation of ponderosa pine. Infilling by younger trees continues. Excessive herbivory may also reduce the perennial grass understory.

Community Phase Pathway 2.3b, from Phase 2.3 to 2.2:

Fire reduces or eliminates tree canopy, allowing fire-adapted shrubs and perennial grasses to dominate the site.

Community Phase Pathway 2.4a, from Phase 2.4 to 2.1:

Low intensity fire, insect infestation, or disease kills individual trees and may thin seedlings and saplings create gaps in the canopy. Gaps in the canopy enables light-intolerant pine germination and reduces the invasion of shade tolerant species. Over time, young trees mature to replace and maintain the old-growth woodland. Annual non-natives present in trace amounts.

Community Phase Pathway 2.4b, from Phase 2.4 to 2.2:
A fire will eliminate or reduce the ponderosa pine overstory and the shrub component which will allow for the fire-adapted shrubs and perennial bunchgrasses to dominate the site. Annual non-natives will likely increase.

Community Phase 2.4 (at-risk):

This phase is dominated by ponderosa pine that have reached maximal heights for the site. The crown is typically broadly conical to round-shaped. Lower branches may be self-pruned. The stand exhibits mixed age classes and canopy cover may be 45% or greater. The density and vigor of the shrub and perennial bunchgrass understory is decreased. This community is at risk of crossing a threshold; without proper management this phase will transition to the Sprouting Shrub State 3.0.

T2A: Transition from Current Potential State 2.0 to Sprouting Shrub State 3.0:

Trigger: Landscape wide, high-severity, stand-replacing crown fire reduces the ponderosa pine overstory and facilitates the fire-adapted shrubs in the understory to dominate the site.

Slow variables: Long fire-return intervals (50 to 100+ years) allow for the re-establishment of fire-adapted shrub seed banks and the development of the fuel loads and spatial continuity necessary for fire to occur.

Threshold: Increased canopy cover of trees increases the risk for severe stand-replacing crown fire. Loss of deep-rooted perennial bunchgrasses and shrubs changes temporal and spatial nutrient capture and cycling within the community.

Sprouting Shrub State 3.0:

This state has two community phases – an early seral phase dominated by fire-adapted shrubs, perennial grasses and a mature fire-adapted shrub phase with a sparse understory of perennial grasses. Annual non-native species may be present. Time since fire may facilitate the maturation of the fire-adapted shrubs. The establishment of pure shrubfields of manzanita and other fire-adapted shrubs may limit future tree establishment because of the potential for intense fires that make tree establishment difficult (Savage and Mast 2005). This State can be extremely resilient and long-lasting (Guiterman et al. 2018).

Community Phase 3.1:
Fire-adapted shrubs such as oak, manzanita, Utah serviceberry, and silktassel dominate the overstory. Perennial bunchgrasses and forbs are common. Annual non-native species may be present.

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:
Time without disturbances such as fire, drought, insect infestation or disease will allow for the maturation of the fire-adapted shrubs. Fire return intervals may exceed 100 years.

Community Phase 3.2:
Fire-adapted shrubs such as oak, manzanita and silktassel dominate the overstory. Perennial grasses and forbs are sparse. Annual non-native species may dominate gaps in the shrub canopy. Ponderosa pine seedlings, saplings and/or young trees are present.

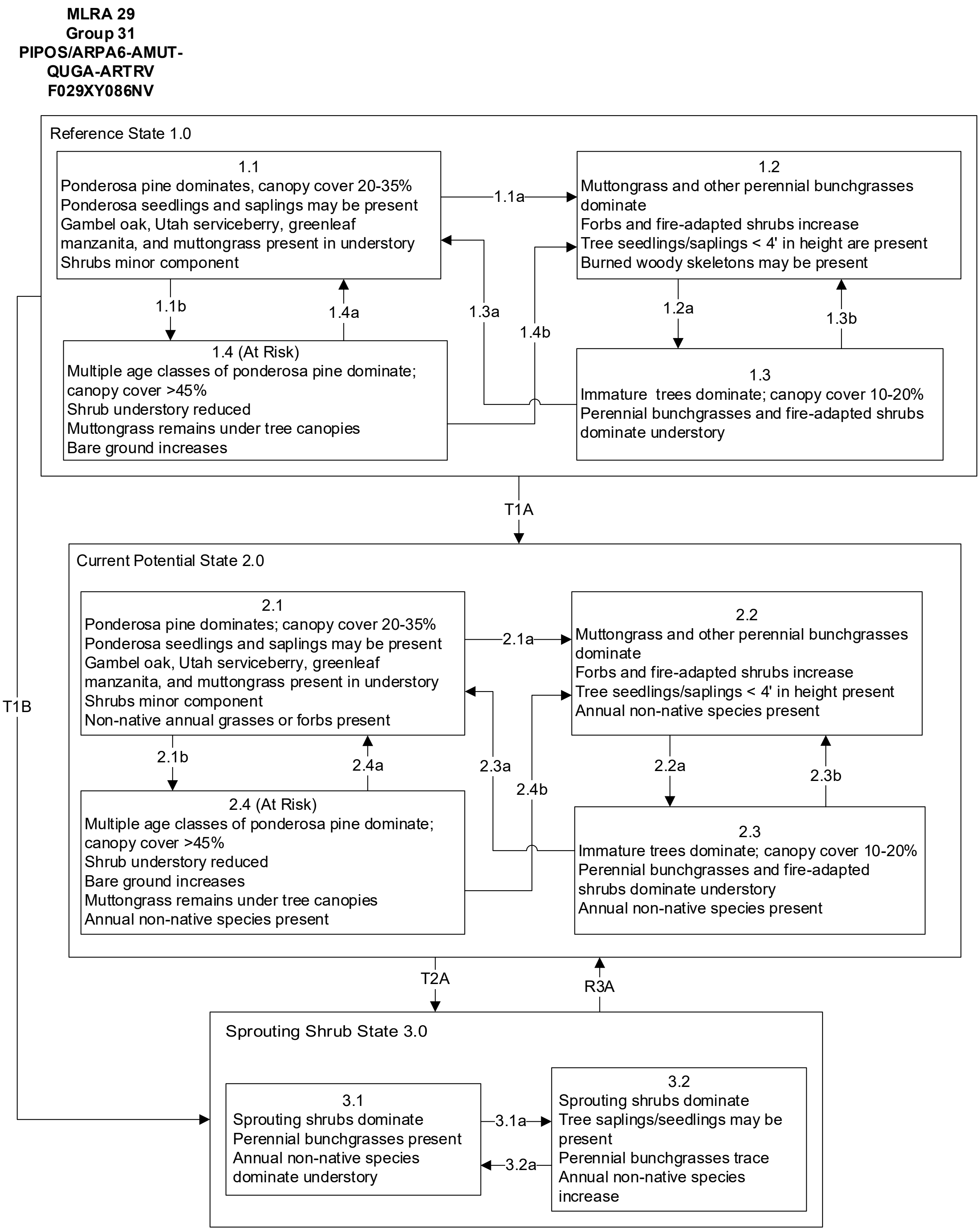
Rocky Loamy Slope 16+" P.Z. (F029XY086NV), Sprouting Shrub State 3.1, T. Stringham, June 2022

Community Phase Pathway 3.2a, from Phase 3.2 to 3.1:
Wildfires, with a fire-return interval less than 100 years, or other disturbances create a mosaic of late seral unburned patches and early seral burned patches dominated by fire-adapted shrubs.

R3A: Restoration from Sprouting Shrub State 3.0 to Current Potential State 2.0:

Periodic small prescribed burns or manual or mechanical thinning of shrubs coupled with seeding and planting of ponderosa trees. Herbicide treatment of non-native annual species may also be needed. Probability of success is highest on north-facing slopes at higher elevations of this site.

Modal State and Transition Model for Group 31 in MLRA 29:



MLRA 29
Group 31
PIPOS/ARPA6-AMUT-
QUGA-ARTRV
F029XY086NV

Reference State 1.0 Community Pathways
1.1a: High severity crown fire reduces or eliminates tree cover, allowing fire-adapted shrubs and perennial bunchgrasses to dominate.
1.1b: Time and lack of disturbance such as fire, insect attack, disease, or drought allows younger trees to infill.
1.2a: Time and lack of disturbance such as fire or drought facilitates establishment of ponderosa pine and greenleaf manzanita. Excessive herbivory by wildlife may also reduce perennial grass understory.
1.3a: Time and lack of disturbance such as fire, insect attack, or drought allows maturation of the woodland.
1.3b: Fire.
1.4a: Low severity fire, insect infestation, or disease removes individual trees and reduces total tree cover.
1.4b: High severity crown fire reduces or eliminates tree cover.

Transition T1A: Introduction of non-native annual species.

Transition T1B: Time and a lack of disturbance allows for trees to dominate site resources; may be coupled with inappropriate grazing management and/or fire suppression that favors shrub and tree dominance.

Current Potential State 1.0 Community Pathways
2.1a: High severity crown fire reduces or eliminates tree cover, allowing fire-adapted shrubs and perennial bunchgrasses to dominate.
2.1b: Time and lack of disturbance such as fire, insect attack, disease, or drought allows younger trees to infill.
2.2a: Time and lack of disturbance such as fire or drought facilitates establishment of ponderosa pine and greenleaf manzanita. Excessive herbivory by wildlife may also reduce perennial grass understory.
2.3a: Time and lack of disturbance such as fire, insect attack, disease or drought allows maturation of the woodland. Excessive herbivory may also reduce perennial grass understory.
2.3b: Fire.
2.4a: Low severity fire, insect infestation, or disease removes individual trees and reduces total tree cover.
2.4b: High severity crown fire reduces or eliminates tree cover.

Transition T2A: Time and a lack of disturbance allows for trees to dominate site resources; may be coupled with inappropriate grazing management and/or fire suppression that favors shrub and tree dominance.

Sprouting Shrub State 3.0 Community Phase Pathways
3.1a: Time and lack of disturbance such as fire, disease, insect attack, or drought allows for shrubs to recover.
3.2a: Low severity fire, disease, or drought reduces removes individual plants and reduces woody species cover.

Restoration R3A: Manual or mechanical thinning of shrubs coupled with herbicide treatment and seeding or planting of trees. Prescribed fire during fall or winter coupled with seeding. Success unlikely from phase 3.2.

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MLRA 29 Group 32: Riparian ponderosa pine forest

Description of MLRA 29 Disturbance Response Group 32

Disturbance Response Group (DRG) 32 consists of one ecological site: PIPOS/ARTRV/POFE (F029XY097NV). This forest site occurs on floodplains and stream terraces. Slopes range from 0 to 8% and elevations range from approximately 5,700 to 6,600 ft (1,737–2,012 m). Precipitation ranges from 16 to over 20 in. (41–51 cm). The soils on this site are very deep and well drained and are formed in alluvium derived from welded tuff and other volcanic rocks. Soils are sandy-skeletal and have a mollic epipedon which occurs from the soil surface to 10 in. (25 cm). These soils are slightly alkaline and are dark brown to grayish brown in color. The soils are skeletal with 15 to 80% gravels and cobbles throughout the soil profile. The soils are subject to flooding during periods of high runoff and streamflow. The soil moisture regime is aridic bordering on ustic and the soil temperature regime is mesic.

The plant community is dominated by Rocky Mountain ponderosa pine (*Pinus ponderosa* var. *scopulorum*). The dominant understory shrubs are mountain big sagebrush (*Artemisia tridentata ssp. vaseyana*), Gambel oak (*Quercus gambelii*), Utah serviceberry (*Amelanchier utahensis*), and antelope bitterbrush (*Purshia tridentata*). Understory grasses and grasslike plants include muttongrass (*Poa fendleriana*), Sandberg bluegrass (*Poa secunda*), needle-and-thread (*Hesperostipa comata*), Indian ricegrass (*Achnatherum hymenoides*) and Ross' sedge (*Carex rossii*). Under a medium canopy cover of 11 to 20%, the annual production ranges from 500 to 800 lb/ac, with 600 lb/ac in normal years. Overstory tree canopy composition is 100% ponderosa pine. Where this site associated with singleleaf pinyon and Utah juniper communities, these trees may comprise up to 5% of the understory. This site is of low site quality for tree production (Meyer 1938).

Disturbance Response Group 32 Ecological Sites:

PIPOS/ARTRV/POFE (PIPOS WSG: 4X1201) – Modal F029XY097NV

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasive species. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Major Land Resource Area 29 (MLRA 29) spans a unique area in Nevada where the Great Basin and Mojave deserts converge. As the transition zone between the two deserts, this area hosts an interesting climate pattern and suite of vegetation. The majority of annual precipitation is received during late fall and winter. However, monsoonal weather patterns also affect this area. Flashy, summer storm events contribute significantly to annual precipitation as well. Air and soil temperature regime differences, along with precipitation timing and amount, result in a mix of warm-season and cool-season species (Beatley 1975, Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow at higher elevations combined with lower temperatures results in deep percolation of moisture into the soil profile. Cool-season species take advantage of this soil moisture in early spring and initiate growth before warm-season species. Conversely, summer precipitation combined with higher temperatures results in much less soil moisture recharge due to evapotranspiration (Comstock and Ehleringer 1992). Warm-season species are uniquely adapted to these summer precipitation events and are able to respond with renewed growth when many cool-season species are dormant (Everett et al. 1980).

Ponderosa pine is a deep-rooted tree when compared to other western conifer species (Fitzgerald 2005) and is highly drought resistant throughout its range (Bates 1923, Conkle and Critchfield 1988). Individuals are fairly shade intolerant and require canopy disturbance for establishment (Stein 1988, Bond et al. 1999). Ponderosa pine is also flood resistant and grows on alluvial sites that flood in spring (Fryer 2018). Stands can be of varying age structure but historically have generally been open with a variety of age classes (Mast et al. 1998, Mast et al. 1999). Pockets of Rocky Mountain ponderosa pine forest exist at high elevations within western and southwestern Nevada as relict populations from the last glacial maximum (LGM). Westward expansion of eastern populations of Rocky Mountain ponderosa pine occurred during that time, resulting in more ubiquitous cover a lower elevations (Martin and Mehringer 1965, Wells 1983). Rocky Mountain ponderosa pine then retreated upslope to higher elevations and more northerly aspects as the climate became warmer and drier in these regions.

Mountain big sagebrush is generally long-lived; therefore, it is not necessary for new individuals to recruit every year for perpetuation of the stand. Infrequent large recruitment events and simultaneous low, continuous recruitment is the foundation of population maintenance (Noy-Meir 1973). The survival of the seedlings is dependent on adequate moisture conditions.

Utah serviceberry is a large shrub that grows from 2 to 4 m (6.5 to 13 ft) tall and typically grows in big sagebrush, pinyon-juniper, and aspen communities (Hammond 2012). Despite typically being found surrounded by other species, serviceberry seedlings can be outcompeted by dense stands of grasses and forbs. Utah serviceberry is top-killed by fire but resprouts from an underground crown, and its branches, leaves, and berries all provide forage for wildlife and livestock (Noller 2008). *A. utahensis* is more drought tolerant than other serviceberry species, and its root system is very deep and spreading and well adapted to coarse-textured soils (Hammond 2012). The only pest known to be a serious threat to Utah serviceberry is cedar-apple rust *(Gymnosporangium juniperi-virginianae)*, which *A. utahensis* can host in its leaves and berries when growing in proximity to junipers *(Juniperus* spp.) (Wasser 1982).

Gambel oak is a deciduous small tree or shrub that is found in the foothills and lower mountains of western North America. It can occasionally grow as tall as 50 ft (15 m) but typically grows less than 30 ft (9 m) tall. Gambel oak has been known as a valuable resource for a long time, providing cover, habitat, and food for many different wildlife species. With the help of a healthy, productive understory, Gambel oak provides erosion protection over large areas (Kaufmann et al. 2016). Gambel oak is a sprouter, meaning that a Gambel oak plant can re-sprout from tissue underground, even when any of the plant above ground is killed from fire, grazing, or other forms of disturbance, as opposed to non-sprouters, which are killed by fire and rely on seed dispersal for post-dispersal colonization (Premoli and Steinke 2008). This makes Gambel oak a key component in restoring disturbed communities, because fresh, young plants will sprout, spread, and compete against invasive species.

Muttongrass is a tufted, multi-flowered, perennial bunchgrass that can grow between 8 and 30 in. (20–76 cm) tall and has narrow leaves, which range from 1 to 3 mm (<1 in.) wide. It is found in lower elevations in the northern extent of its native range, and higher elevations in the south. Muttongrass is one of the most drought-tolerant bluegrasses and is useful for restoring communities disturbed by fire, grazing, or mining, but is limited in its use due to low seed viability. Muttongrass plants are most frequently pistillate, but staminate plants do occasionally occur, which are able to hybridize and crossbreed with other bluegrasses. Muttongrass is found throughout the western United States as a primary component of the understory of pinyon-juniper communities and aspen and pine forests (Tilley et al. 2007).

Indian ricegrass, the dominant understory species of the ecological sites within the 8 to 12 in. (20–30 cm) precipitation zone, is a long-lived, cool-season perennial bunchgrass that grows from 4 to 24 in. (10–61 cm) in height (Blaisdell and Holmgren 1984). Primarily adapted to coarse textured soils, its deep, fibrous root system makes Indian ricegrass one of the most drought-tolerant native species (Booth et al. 1980). Unlike other cool-season species, Indian ricegrass does not require vernalization (exposure to cold) in order to produce flowers and flowering can continue into late fall with favorable environmental conditions. This allows the seeds in each panicle to ripen over a longer period of time than most other species thus providing a greater opportunity for successful seed production (Jones 1990).

Needle-and-thread is a cool-season, perennial bunchgrass most commonly found on well-drained soils (Miller et al. 2013). It ranges in height from 12 to 36 in. (30–91 cm) tall

(Stubbendieck et al. 2003) and produces a widely-spreading, deep, and fibrous root system that allows it to capture moisture and nutrients effectively (Weaver 1958).

The ecological site in this DRG has moderate resilience to disturbance and resistance to invasion. Two stable states were identified for this site.

Fire Ecology:

Historical fires in the Clover Mountains were typically frequent (mean fire return intervals of less than 10 years) and ranged from small fires to widespread fires (Kilpatrick 2009). Studies indicate that the longest fire-free period was 33 years, dating from 1675 to 1946, when are large stand-replacing fire occurred under drier than average conditions. Since the 1946 fire, the Clover Mountains have experienced a drop in fire occurrence, with a fire-free period from 1946 to 2009 (Kilpatrick 2009).

Ponderosa pine has multiple adaptations that allows cone-bearing adults to survive both low- and high-intensity fires. At a young age, it develops a thick, corky bark that protects the cambium from fire (Hall 1980, Miller 2000, Fitzgerald 2005). The pine's terminal buds are protected by thick bud scales and long needles with high moisture content fire (Miller 2000). A study in the Sierra Nevada mountains showed that even if the crown of ponderosa pine is scorched, the tree often survives and "flushes" with new needles in the following growing season after (Hanson and North 2009). When estimating fire severity and post-fire mortality of ponderosa pines, this survival should be taken into account. Post-fire conditions of bare mineral soil, increased soil moisture, and low canopy cover are favorable to seedling survival (Bradley et al. 1992, Flathers et al. 2016). This community is not immune to negative effects of fire, however. In the seedling stage, ponderosa pine is readily killed by fire, and dense stands of this tree typically succumb to fire (Agee 1996). The cones are not serotinous and seeds are not long-lived in the soil, thus ponderosa pine will not return to dominance in large patches of high-severity fire (Korb et al. 2019).

Mountain big sagebrush is killed by fire (Neuenschwander 1980, Blaisdell et al. 1982) and does not resprout (Blaisdell 1953). Post-fire regeneration occurs from seed and will vary depending on site characteristics, seed source, and fire characteristics. Mountain big sagebrush seedlings can grow rapidly and may reach reproductive maturity within 3 to 5 years (Bunting et al. 1987). Mountain big sagebrush may return to pre-burn density and cover within 15 to 20 years following fire, but establishment after severe fires may proceed more slowly (Bunting et al. 1987).

Utah serviceberry is a large, fire-tolerant shrub. It is top-killed by fire but sprouts from the underground root crown after disturbance. However, resprouting is reliant on the amount of moisture in the soil and Utah serviceberry is more adapted for drier soils, which will limit the potential for a sprout to successfully grow (Hammond 2012). *A. utahensis* can also re-colonize an area after fire via seeds, but this may require up to 8 to 10 years for plants to be fully mature and productive (Noller 2008).

Gambel oak is extremely fire tolerant due to it being a sprouting shrub (Kaufmann et al. 2016). When Gambel oak is killed by fire, most of the vegetative tissue underground is still alive, and the plant can sprout and grow from what is left. This gives Gambel oak and other sprouters an advantage over non-sprouters, or “obligate seeders” because they rely on seed dispersal in order to colonize an area after a fire or other disturbance (Premoli and Steinke 2008).

The dominant grasses on the site include muttongrass, needle-and-thread, and Indian ricegrass. The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The initial condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species response. For most forbs and grasses, the growing points are located at or below the soil surface providing relative protection from disturbances which decrease above ground biomass, such as grazing or fire. Thus, fire mortality is more correlated to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant and abundance of old growth (Wright 1971, Young 1983).

Muttongrass, a dominant understory grass in this group, is top-killed by fire but will sprout after low to moderate severity fires. A study by Vose and White (1991), in an open saw timber site found minimal difference in the overall effect of burning on muttongrass.

Indian ricegrass is fairly fire tolerant (Wright 1985), which is likely due to its low culm density and below-ground plant crowns. Vallentine (1989) cites several studies in the sagebrush zone that classified Indian ricegrass as being slightly damaged from late summer burning. Indian ricegrass has also been found to reestablish on burned sites through seeds dispersed from adjacent unburned areas (Young 1983, West 1994). Thus, the presence of surviving, seed-producing plants facilitates the reestablishment of Indian ricegrass. Grazing management following fire to promote seed production and establishment of seedlings is important. When properly managed, Indian ricegrass can be a key factor in a community recovering from disturbance because it can grow in rough, rocky, coarse, and otherwise unproductive soils (Booth et al. 1980).

Needle-and-thread, contrary to Indian ricegrass, is a fine-leaf grass and is considered sensitive to fire (Akinsoji 1988, Bradley et al. 1992, Miller et al. 2013). Needle-and-thread is top-killed by fire but is likely to resprout if fire does not consume above-ground stems (Akinsoji 1988, Bradley et al. 1992). In a study by Wright and Klemmedson (1965), season of burn rather than fire intensity seemed to be the crucial factor in mortality for needle-and-thread grass. Early spring season burning was seen to kill the plants while August burning had no effect. Thus, under wildfire scenarios, needle-and-thread is often present in the post-burn community.

Livestock/Wildlife Grazing Interpretations:

This site is of limited extent but has a productive understory and provide forage and shelter for livestock. Ponderosa pine habitat also supports a variety of wildlife and provides cover for deer (Fryer 2018). Numerous rodents and birds use ponderosa pine for shelter, and rely on the pinenuts for a food source (Hatz 2007). Clark's nutcracker (*Nucifraga columbiana*) is an important disperser of seed for Ponderosa pine, as it caches seeds in locations appropriate for growth (Lorenz et al. 2011). Ponderosa pine provides critical habitat for white-headed woodpeckers (*Leuconotopicus albolarvatus*) (Ligon 1973, Kozma 2010), but it is unclear how this ecological site is used considering its limited extent. Cavity nesting birds likely rely on the vertical structure of these unique forest sites.

Gambel oak is considered an important species for wildlife forage, even though it is not highly palatable. This is due to how widespread and abundant it is, especially on winter ranges. Gambel oak leaves provide important forage for deer and elk year-round, and acorns are an extremely valuable mast crop, especially for black bears in the fall (Jester et al. 2008). Due to being a sprouter, Gambel oak can provide valuable forage and cover in post-fire communities (Premoli and Steinke 2008).

Utah serviceberry is a very important plant because of the amount of food, cover, and habitat it provides to both livestock and wildlife. Its leaves, branches, and berries are used by many wildlife species, including big game, birds, and small animals (Noller 2008). *A. utahensis* is highly palatable to wildlife and livestock and is a preferred forage for elk (McCulloch 1955).

Despite low palatability, mountain big sagebrush is eaten by sheep *(Ovis aries)*, cattle *(Bos taurus)*, goats *(Capra hircus)*, and horses *(Equus ferus)*. Chemical analysis indicates that the leaves of big sagebrush equal alfalfa *(Medicago sativa)* meal in protein, have a higher carbohydrate content, and yield twelvefold more fat (USFS 1937). Many wildlife species are dependent on the sagebrush ecosystem including the greater sage grouse *(Centrocercus urophasianus)*, sage sparrow *(Artemisiospiza nevadensis*), pygmy rabbit (*Brachylagus idahoensis*), and the sagebrush vole *(Lemmiscus curtatus)*. Dobkin and Sauder (2004) identified 61 species, including 24 mammals and 37 birds, associated with the shrub-steppe habitats of the Intermountain West.

Muttongrass is very palatable for wildlife and livestock and is rated as excellent forage for cattle and horses, and good for sheep. Muttongrass starts growth in late winter or early spring and provides excellent early feed. Muttongrass foliage cures well and is good fall forage, but not as good as spring or summer (Humphrey et al. 1952), and can withstand moderately heavy grazing (Marquiss and Lang 1959).

Indian ricegrass is a preferred forage species for livestock and wildlife and cures well, providing nutritious winter feed (Cook 1962, Booth et al. 1980). It is also readily utilized in early spring, being a source of green feed before most other perennial grasses have produced new growth (Quinones 1981). Booth et al. (1980) note that the plant does well when utilized in winter and spring. In eastern Idaho, productivity of Indian ricegrass was at least 10 times greater in undisturbed plots than in heavily (60% utilization) grazed ones (Pearson 1965). (Cook and Child 1971) found significant reduction in crown cover, plant vigor and herbage yield of Indian ricegrass when the species was utilized at 90% during any season. However, they found no reductions at 30% utilization during any season and no reductions at 60% utilization during winter and early spring grazing (Cook and Child 1971). The seed crop may be reduced where grazing is heavy (Bich et al. 1995). Tolerance to grazing increases after May, thus spring deferment may be necessary for stand enhancement (Pearson 1964, Cook and Child 1971); however, utilization of less than 60% is recommended. In summary, adaptive management is required to manage this bunchgrass well.

Needle-and-thread is not grazing tolerant and will be one of the first grasses to decrease under heavy grazing pressure during the growing season (Smoliak et al. 1972, Tueller and Blackburn 1974). Heavy grazing (greater than 60% utilization) is likely to reduce basal area of these plants (Smoliak et al. 1972). With the reduction in competition from deep-rooted perennial bunchgrasses, the rhizomatous galleta grass and short-statured Sandberg bluegrass will likely increase (Jameson 1962, Smoliak et al. 1972). However, needle-and-thread cures well and provides good forage to livestock during fall and winter months if overgrazing does not occur (Stubbendieck et al. 2003).

State and Transition Model Narrative for Group 32:

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for MLRA 29 Disturbance Response Group 32.

Reference State 1.0:

The Reference State 1.0 is representative of the natural range of variability under pristine conditions. This reference state has four general community phases: a mature woodland phase (1.1), a shrub-herbaceous phase (1.2), an immature woodland phase (1.3), and an over-mature woodland phase (1.4). State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire, periodic drought, and/or insect or disease attack. Fuels loads and climate were the driving force for pre-settlement fires. Fires occurred primarily in dry years following wet years during the growing season (Battaglia and Shepperd 2007). Frequent, low intensity surface fires created irregularly spaced, uneven-aged stands with trees growing together in small even-aged groups and shrubs and grasses between the groups. Mean fire return intervals were less than 10 years (Kilpatrick 2009). This fire type will create a plant community mosaic that will include all/most of the following community phases within this state.

Community Phase 1.1:
This phase is characterized by widely dispersed mature ponderosa pine trees with an understory of non-sprouting and sprouting shrubs (mountain big sagebrush, Gambel oak, manzanita, Utah serviceberry), and perennial bunchgrasses. The visual aspect is dominated by ponderosa pine with about a 15 to 25% canopy cover. Trees have reached maximal or near maximal heights for the site. Muttongrass is the dominant perennial grass and perennial forbs such as phlox *(Phlox* spp.), beardtongue (*Penstemon* spp.), buckwheat (*Eriogonum* spp.), milkvetch (*Astragalus* spp.), and white sagebrush (*Artemisia ludoviciana*) are minor components. Understory production ranges between 500 to 800 lb/ac.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
A fire will eliminate or reduce the ponderosa pine overstory and the fire-intolerant shrub component. This allows for the perennial bunchgrasses and fire-adapted shrubs to dominate the site.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.4:
Time without disturbances such as fire, drought, insect infestation or disease will allow for the gradual infilling of ponderosa pine.

Community Phase 1.2:
This community phase is characterized by a fire-adapted shrub (manzanita, Gambel oak, Utah serviceberry) and herbaceous community. Muttongrass and other perennial grasses dominate. Biodiversity of herbaceous plants increases for the first few years post-fire. Tree seedlings up to 20 in. (51 cm) in height and saplings up to 4 ft (1.2 m) in height may be present. Tree canopy cover is less than 10%. Big sagebrush may be present in unburned patches. Burned tree skeletons may be present; however, these have little or no effect on the understory vegetation.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.3:
Time without disturbances such as fire, drought, insect infestation or disease will allow for the gradual infilling and maturation of the ponderosa pine component. Excessive herbivory by wildlife may also reduce perennial grass understory.

Community Phase 1.3:
This community phase is characterized by an immature woodland, with ponderosa pine trees averaging over 4.5 ft (1.4 m) in height. Tree canopy cover is between 15 to 20%. At this stage of woodland development, the tree canopy has broken through the suppression of the fire-adapted shrub community. The young ponderosa pines are still very susceptible to fire at this state. Seedlings and saplings of ponderosa pine are common in the understory. Dominants are the tallest trees on the site, co-dominants are 65 to 85% of the highest of dominant trees. Understory vegetation is moderately

influenced by the tree canopy and is dominated by mountain big sagebrush, Utah serviceberry, Gambel oak and antelope bitterbrush.

Community Phase Pathway 1.3a, from 1.3 to 1.4:
Time without disturbances such as fire, drought, insect infestation or disease will allow for the gradual maturation of ponderosa pine. Infilling by younger trees continues. Excessive herbivory by wildlife may reduce the perennial grass understory.

Community Phase Pathway 1.3b, from Phase 1.3 to 1.2:
Fire reduces or eliminates tree canopy, allowing perennial grasses and fire-adapted shrubs to dominate the site.

Community Phase 1.4:
This phase is an over-mature woodland dominated by ponderosa pine that have reached maximal heights for the site. The crown is typically broadly conical to round-shaped. Lower branches may be self-pruned. The stand exhibits mixed age classes and canopy cover may be 35% or greater. The density and vigor of the shrub and perennial bunchgrass understory is decreased.

Community Phase Pathway 1.4a, from Phase 1.4 to 1.1:

Low intensity fire, insect infestation, or disease kills individual trees and may thin seedlings, saplings and young trees and create gaps in the canopy. Gaps in the canopy enables light-intolerant pine germination and reduces the invasion of shade tolerant species. Over time young trees mature to replace and maintain the mature woodland. Annual non-natives present in trace amounts.

Community Phase Pathway 1.4b, from Phase 1.4 to 1.2:
A fire will eliminate or reduce the ponderosa pine overstory and the shrub component which will allow for the fire-adapted shrubs and perennial bunchgrasses to dominate the site.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0:

Trigger: Introduction of non-native annual species.

Slow variables: Over time the annual non-native plants will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

This state is similar to the Reference State 1.0, with four general community phases: a mature woodland phase (2.1), a shrub-herbaceous phase (2.2), an immature woodland phase (2.3), and an over-mature woodland phase (2.4). Ecological function has not changed; however, the resiliency of the state has been reduced by the presence of non-native species. These non-natives, particularly cheatgrass, can be highly flammable and promote fire where historically fire had been infrequent. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal. Fires within this community with the small amount of non-native annual species present are likely still small and patchy due to low fuel loads. This fire type will create a plant community mosaic that will include all/most of the following community phases within this state.

Community Phase 2.1:
This phase is characterized by widely dispersed mature ponderosa pine trees with an understory of non-sprouting and sprouting shrubs (mountain big sagebrush, Gambel oak, manzanita, Utah serviceberry), and perennial bunchgrasses. The visual aspect is dominated by ponderosa pine with about a 15 to 20% canopy cover. Trees have reached maximal or near maximal heights for the site. Muttongrass is the dominant perennial grass and perennial forbs such as phlox *(Phlox* spp.), beardtongue (*Penstemon* spp.), buckwheat (*Eriogonum* spp.), milkvetch (*Astragalus* spp.), and white sagebrush (*Artemisia ludoviciana*) are minor components. Understory production ranges between 500 to 800 lb/ac. Non-native annual grasses such as cheatgrass (*Bromus tectorum*) are scattered in the understory.

PIPOS/ARTRV/POFE (F029XY097NV) Community Phase 2.1, T. Stringham, August 2021

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
A fire will eliminate or reduce the ponderosa pine overstory and the fire-intolerant shrub component. This allows for the perennial bunchgrasses and fire-adapted shrubs to dominate the site.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.4:
Time without disturbances such as fire, drought, insect infestation or disease will allow for the gradual infilling of ponderosa pine.

Community Phase 2.2:

This community phase is characterized by a fire-adapted shrub (manzanita, Gambel oak, Utah serviceberry) and perennial grass community. Muttongrass is the dominant grass. Forbs may increase after a fire but will likely return to pre-burn levels within a few years. Tree seedlings up to 20 in. (50 cm) in height and saplings up to 4 ft (1.2 m) in height may be present. Big sagebrush may be present in unburned patches. Burned tree skeletons may be present; however, these have little or no effect on the understory vegetation.

PIPOS/ARTRV/POFE (F029XY097NV) Sprouting Shrub Phase, T. Stringham, June 2022

Community Phase Pathway 2.2a, from Phase 2.2 to 2.3:

Time without disturbances such as fire, drought, insect infestation or disease will allow for the gradual infilling and maturation of the ponderosa pine component. Big sagebrush reestablishes. Excessive herbivory may reduce perennial grass understory.

Community Phase 2.3:

This community phase is characterized by an immature woodland, with ponderosa pine trees averaging over 4.5 ft (1.4 m) in height. Tree canopy cover is between 10 to 20%. At this stage of woodland development, the tree canopy has broken through the suppression of the fire-adapted shrub community. The young ponderosa pines are still very susceptible to fire at this state. Seedlings and saplings of ponderosa pine are common in the understory. Dominants are the tallest trees on the site, co-dominants are 65 to 85% of the highest of dominant trees. Understory vegetation is moderately influenced by the tree canopy and is dominated by mountain big sagebrush, Utah serviceberry, Gambel oak and greenleaf manzanita. Annual non-native species are present.

Community Phase Pathway 2.3a, from Phase 2.3 to 2.4:
Time without disturbances such as fire, drought, insect infestation or disease will allow for the gradual maturation of ponderosa pine. Infilling by younger trees continues. Excessive herbivory may also reduce the perennial grass understory.

Community Phase Pathway 2.3b, from Phase 2.3 to 2.2:

Fire reduces or eliminates tree canopy, allowing fire-adapted shrubs and perennial grasses to dominate the site.

Community Phase Pathway 2.4a, from Phase 2.4 to 2.1:

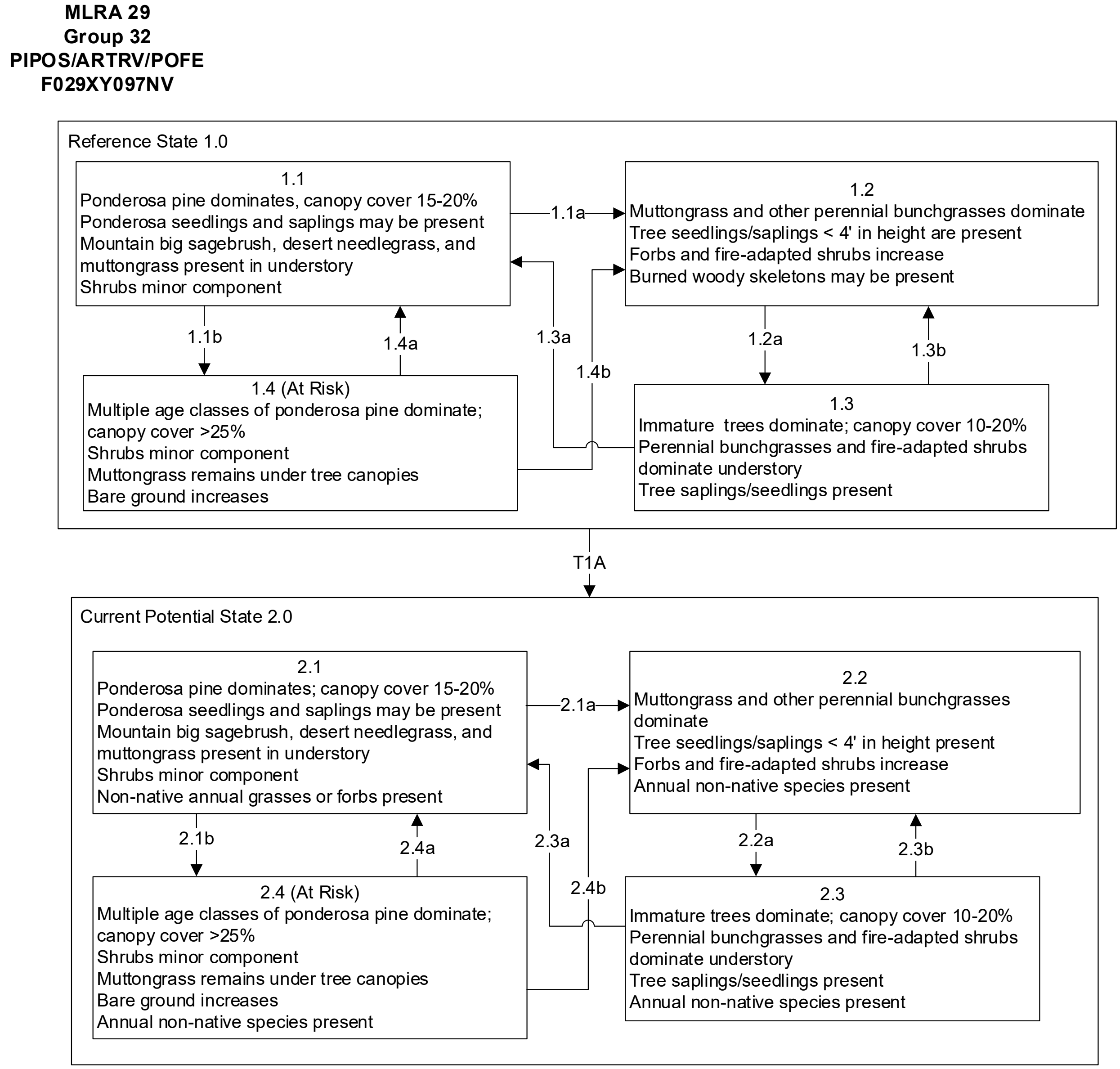
Low intensity fire, insect infestation, or disease kills individual trees and may thin seedlings and saplings create gaps in the canopy. Gaps in the canopy enables light-intolerant pine germination and reduces the invasion of shade tolerant species. Over time young trees mature to replace and maintain the old-growth woodland. Annual non-natives present in trace amounts.

Community Phase Pathway 2.4b, from Phase 2.4 to 2.2:
A fire will eliminate or reduce the ponderosa pine overstory and the shrub component which will allow for the fire-adapted shrubs and perennial bunchgrasses to dominate the site.

Community Phase 2.4:

This phase is an over-mature woodland dominated by ponderosa pine that have reached maximal heights for the site. The crown is typically broadly conical to round-shaped. Lower branches may be self-pruned. The stand exhibits mixed age classes and canopy cover may be 35% or greater. The density and vigor of the shrub and perennial bunchgrass understory is decreased.

Modal State and Transition Model for Group 32 in MLRA 29:



MLRA 29
Group 32
PIPOS/ARTRV/POFE
F029XY097NV

Reference State 1.0 Community Pathways
1.1a: High severity crown fire reduces or eliminates tree cover, allowing fire-adapted shrubs and perennial bunchgrasses to dominate.
1.1b: Time and lack of disturbance such as fire, insect attack, disease, or drought allows younger trees to infill.
1.2a: Time and lack of disturbance such as fire or drought facilitates establishment of ponderosa pine and mountain big sagebrush. Excessive herbivory by wildlife may also reduce perennial grass understory.
1.3a: Time and lack of disturbance such as fire, insect attack, or drought allows maturation of the woodland.
1.3b: Fire.
1.4a: Low severity fire, insect infestation, or disease removes individual trees and reduces total tree cover.
1.4b: High severity crown fire reduces or eliminates tree cover.

Transition T1A: Introduction of non-native annual species.

Current Potential State 1.0 Community Pathways
2.1a: High severity crown fire reduces or eliminates tree cover, allowing fire-adapted shrubs and perennial bunchgrasses to dominate.
2.1b: Time and lack of disturbance such as fire, insect attack, disease, or drought allows younger trees to infill.
2.2a: Time and lack of disturbance such as fire or drought facilitates establishment of ponderosa pine and mountain big sagebrush. Excessive herbivory by wildlife may also reduce perennial grass understory.
2.3a: Time and lack of disturbance such as fire, insect attack, disease or drought allows maturation of the woodland. Excessive herbivory may also reduce perennial grass understory.
2.3b: Fire.
2.4a: Low severity fire, insect infestation, or disease removes individual trees and reduces total tree cover.
2.4b: High severity crown fire reduces or eliminates tree cover.

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Supplemental Information

Supplemental information will be available in separate documents and will be posted on the Nevada Agricultural Experiment Station site or on the UNR Rangeland Ecology Lab page. These documents will also be available by request from Tamzen Stringham.

1. **Disturbance Response Group List**

   Provided as a separate file for convenient use.

2. **Field notes completed for the MLRA 29 STM Project**

   Field notes and landscape photographs collected between 2019 and 2023.

3. **List of all site visits for the MLRA 29 STM project – chronological**

   This is an abbreviated version of the site visit list. The full spreadsheet of site visit data is available electronically by request.

4. **Site visit counts by Disturbance Response Group and by STM State**

   Summarized site visit data.

5. **Geospatial data**

   These data will include DRG maps and site visit locations.