Great Basin Ecological Site Development Project:

State and Transition Models for Major Land Resource Area 27 Nevada

Gabbs, Nevada, MLRA 27, Nevada. T.K. Stringham, May 2024

Nevada Agricultural Experiment Station Research Report NAES-TR-26-02

June 2026

Tamzen K. Stringham, William C. Richardson, Lucas Phipps, Wade Lieurance, Patti Novak-Echenique

EXPERIMENT STATION

College of Agriculture,
Biotechnology & Natural Resources

Recommended citation:

Stringham, T.K., W.C. Richardson, L. Phipps, W. Lieurance, P. Novak-Echenique. 2026. Great Basin Ecological Site Development Project: State-and-Transition Models for Major Land Resource Area 27, Nevada. University of Nevada Reno, Nevada Agricultural Experiment Station Research Report NAES-TR-26-02. 673 p.

Final Report submitted to USDOI Bureau of Land Management as fulfillment of Agreement # L21AC10513.

Executive Summary

This report was completed in June 2026 in fulfillment of Agreement L21AC10513 with the Bureau of Land Management. It contains state-and-transition models (STMs) for 67 ecological sites within Major Land Resource Area 27 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 27 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.

Authors

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 an Assistant Professor with the University of Nevada, Reno

Wade Lieurance is a Rangeland Ecologist with University of Nevada, Reno

Patti Novak-Echenique, formerly a Rangeland Management Specialist with the Bureau of Land Management, Sparks, Nevada (retired)

Table of Contents

Executive Summary **2**

Introduction **8**
Definitions and Standardized STM Concepts for this Report *11*
Major Land Resource Area 27 ..... *14*
References *15*

Major Land Resource Area 27 Disturbance Response Groups **16**
Ecological Sites and Associated Disturbance Response Groups *16*
Ecological Sites Omitted from This Report *18*

MLRA 27 Group 1: Calcareous soils with black sagebrush and needlegrasses **19**
Description of MLRA 27 Disturbance Response Group 1 ..... *19*
State and Transition Model Narrative for Group 1 ..... *28*
Potential Resilience Differences with other Ecological Sites in this Group *38*
Modal State and Transition Model for Group 1 MLRA 27 ..... *39*
Additional State and Transition Models for Group 1 MLRA 27 ..... *41*
References *43*

MLRA 27 Group 2: Lahontan sagebrush and needlegrasses **50**
Description of MRLA 27 Disturbance Response Group 2 ..... *50*
State and Transition Model Narrative for Group 2 ..... *59*
Potential Resilience Differences with other Ecological Sites in this Group *70*
Modal State and Transition Model for Group 2 in MRLA 27 ..... *73*
Additional State and Transition Models for Group 2 in MLRA 27 ..... *75*
References *83*

MLRA 27 Group 3: Wyoming big sagebrush and needlegrasses **90**
Description of MRLA 27 Disturbance Response Group 3 ..... *90*
State and Transition Model Narrative Group 3 ..... *100*
Potential Resilience Differences with other Ecological Sites *110*
Modal State and Transition Model for Group 3 in MLRA 27 ..... *114*
Additional State and Transition Models for Group 3 in MLRA 27 ..... *116*
References *128*

MLRA 27 Group 4: Big sagebrush and needlegrasses **135**
Description of MRLA 27 Disturbance Response Group 4 ..... *135*
State and Transition Model Narrative Group 4 ..... *145*
Potential Resilience Differences with other Ecological Sites *155*
Modal State and Transition Model for Group 4 in MLRA 27 ..... *156*
Additional State and Transition Models for Group 4 in MLRA 27 ..... *158*
References *162*

MLRA 27 Group 5: Sites associated with ephemeral streams **169**
Description of MLRA 27 Disturbance Response Group 5 ..... *169*
State and Transition Model Narrative Group 5 ..... *177*
Modal State and Transition Model for Group 5 MLRA 27 ..... *183*
References *185*

MLRA 27 Group 6: Low sagebrush and Idaho fescue **191**
Description of MRLA 27 Disturbance Response Group 6 ..... *191*
State and Transition Model Narrative for Group 6 ..... *199*
Modal State and Transition Model for Group 6 in MRLA 27 ..... *208*

References *210*

MLRA 27 Group 7: Loamy soils with mountain big sagebrush and needlegrasses **216**
Description of MLRA 27 Disturbance Response Group 7 ..... *216*
State and Transition Model Narrative for Group 7 ..... *222*
Modal State and Transition Model for Group 7 in MLRA 27 ..... *230*
References *232*

MLRA 27 Group 8: Eroded soils with spiny hopsage and cool-season grasses **237**
Description of MLRA 27 Disturbance Response Group 8 ..... *237*
State and Transition Model Narrative for Group 8 ..... *245*
Modal State and Transition Model for Group 8 in MLRA 27 ..... *250*
References *252*

MLRA 27 Group 9: Loamy soils with basin wildrye **258**
Description of MLRA 27 Disturbance Response Group 9 ..... *258*
State and Transition Model Narrative for Group 9 ..... *266*
Modal State and Transition Model for Group 9 in MLRA 27 ..... *273*
References *275*

MLRA 27 Group 10: Alkaline soils with Torrey's saltbush and basin wildrye **281**
Description of MLRA 27 Disturbance Response Group 10 ..... *281*
State and Transition Model Narrative for Group 10 ..... *291*
Potential Resilience Differences with Other Ecological Sites in this Group *299*
Modal State and Transition Model for Group 10 in MLRA 27 ..... *301*
Additional State and Transition Models for Group 10 in MLRA 27 ..... *303*
References *305*

MLRA 27 Group 11: Sandy sites dominated by saltbush and Indian ricegrass **312**
Description of MLRA 27 Disturbance Response Group 11 ..... *312*
State and Transition Model Narrative for Group 11 ..... *322*
Potential Resilience Differences with Other Ecological Sites in this Group *330*
Modal State and Transition Model for Group 11 in MLRA 27 ..... *332*
Additional State and Transition Models for Group 11 in MLRA 27 ..... *334*
References *338*

MLRA 27 Group 12: Alkaline soils with shadscale and black greasewood **345**
Description of MLRA 27 Disturbance Response Group 12 ..... *345*
State and Transition Model Narrative for Group 12 ..... *354*
Potential Resilience Differences with Other Ecological Sites in this Group *361*
Modal State and Transition Model for Group 12 in MLRA 27 ..... *363*
Additional State and Transition Models for Group 12 in MLRA 27 ..... *365*
References *369*

MLRA 27 Group 13: Seasonally flooded areas with black greasewood and basin wildrye **376**
Description of MLRA 27 Disturbance Response Group 13 ..... *376*
State and Transition Model Narrative for Group 13 ..... *384*
Modal State and Transition Model for Group 13 in MLRA 27 ..... *395*
References *397*

MLRA 27 Group 14: Loamy soils with Bailey's greasewood, shadscale and Indian ricegrass **403**
Description of MLRA 27 Disturbance Response Group 14 ..... *403*
State and Transition Model Narrative for Group 14 ..... *413*
Potential Resilience Differences with Other Ecological Sites in this Group *421*
Modal State and Transition Model for Group 14 in MLRA 27 ..... *426*

Additional State and Transition Models for Group 14 in MLRA 27 ..... *428*
References *448*

MLRA 27 Group 15: Silty soils with winterfat and Indian ricegrass **455**
Description of MLRA 27 Disturbance Response Group 15 ..... *455*
State and Transition Model Narrative for Group 15 ..... *463*
Modal State and Transition Model for Group 15 MLRA 27 ..... *470*
References *472*

MLRA 27 Group 16: Salt-affected soils with iodinebush and warm-season grasses **478**
Description of MLRA 27 Disturbance Response Group 16 ..... *478*
State and Transition Model Narrative for Group 16 ..... *484*
Modal State and Transition Model for Group 16 in MLRA 27 ..... *487*
References *489*

MLRA 27 Group 17: Sandy soils dominated by black greasewood and Indian ricegrass **494**
Description of MLRA 27 Disturbance Response Group 17 ..... *494*
State and Transition Model Narrative for Group 17 ..... *506*
Potential Resilience Differences with Other Ecological Sites in this Group *512*
Modal State and Transition Model for Group 17 in MLRA 27 ..... *515*
Additional State and Transition Models for Group 17 in MLRA 27 ..... *517*
References *519*

MLRA 27 Group 18: Salt-affected soils with black greasewood and warm-season grasses **528**
Description of MLRA 27 Disturbance Response Group 18 ..... *528*
State and Transition Model Narrative for Group 18 ..... *538*
Modal State and Transition Model for Group 18 in MLRA 27 ..... *549*
References *551*

MLRA 27 Group 19: Sandy soils dominated by fourwing saltbush **559**
Description of MLRA 27 Disturbance Response Group 19 ..... *559*
State and Transition Model Narrative for Group 19 ..... *567*
Potential Resilience Differences with Other Ecological Sites in this Group *572*
Modal State and Transition Model for Group 19 in MLRA 27 ..... *573*
Additional State and Transition Models for Group 19 in MLRA 27 ..... *575*
References *577*

MLRA 27 Group 20: Pinyon and/or juniper woodland with Wyoming big sagebrush understory **583**
Description of MLRA 27 Disturbance Response Group 20 ..... *583*
State and Transition Model Narrative for Group 20 ..... *596*
Potential Resilience Differences with other Ecological Sites in this Group *603*
Modal State and Transition Model for Group 20 MLRA 27 ..... *605*
Additional State and Transition Models for Group 20 MLRA 27 ..... *607*
References *609*

MLRA 27 Group 21: Pinyon and juniper woodland with mountain big sagebrush understory **617**
Description of MLRA 27 Disturbance Response Group 21 ..... *617*
State and Transition Model Narrative for Group 21 ..... *630*
Modal State and Transition Model for Group 21 in MLRA 27 ..... *639*
References *641*

MLRA 27 Group 22: Alluvial flats and axial stream floodplains dominated by saltgrass **650**
Description of MLRA 27 Disturbance Response Group 22 ..... *650*
State and Transition Model Narrative for Group 22 ..... *655*
Potential Resilience Differences with other Ecological Sites in this Group *663*

Modal State and Transition Model for Group 22 in MLRA 27 ..... *664*
Additional State and Transition Models for Group 22 in MLRA 27 ..... *666*
References *670*

Supplemental Information **673**

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 an Assistant Professor with the University of Nevada, Reno
- Wade Lieurance is a Rangeland Ecologist with University of Nevada, Reno
- Patti Novak-Echenique, formerly a Rangeland Management Specialist with the Bureau of Land Management, Sparks, Nevada (retired)

Additional support members of the team:

- Hondo Brisbin, formerly a PhD student at University of Nevada, Reno
- Kylie Hopkins, Student Technician with University of Nevada, Reno
- Zachary Wells, Student Technician with University of Nevada, Reno
- William Kneiblher, Student Technician with University of Nevada, Reno
- Kaden Schorovsky, Student Technician with University of Nevada, Reno
- Xavier Davila, Student Technician with University of Nevada, Reno

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 127 field notes over the course of three field seasons and 7 weeks of field work. The Final Report contains the Disturbance Response Group list for MLRA 27, 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, Phase 1.1 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 27

MLRA 27 (NRCS 2022).

Major Land Resource Area 27, known as Fallon-Lovelock Area, is 15,411 mi^2 (9.86 M ac) in size. Almost all of MLRA 27 is located in Nevada, with 1% occurring south of the Skedaddle Mountains, Lassen County, California. Elevation is 3,300–5,900 ft in most of the area, with mountains as high as 7,870 ft. This MLRA consists of isolated, north-south-trending, uplifted fault-block mountain ranges that are separated by broad, hydrologically closed basins. This area is strongly influenced by the rain shadow of the Sierra Nevada mountains and Pleistocene Lake Lahontan. Extensive playas, including the Smoke Creek Desert, Black Rock Desert, Carson Sink, and Humbolt Sink occur in this region due to the drying of this prehistoric Lake. Also occurring in this region are the remnants of Lake Lahontan (Pyramid, Walker, and Honey Lakes) as well as four major rivers, the Humbolt, Truckee, Carson, and Walker. The valleys consist mostly of alluvial fill influenced by lacustrine sediments. The mountains are dominated by andesite and basalt rocks, with Tertiary and Mesozoic intrusives along the western border 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 and commonly loamy-skeletal or sandy-skeletal. The majority of soils in this area have a mesic temperature regime with an aridic moisture regime (NRCS 2022).

Average annual precipitation is 4–11 in., increasing with elevation up to 21 in. This area experiences most of its rainfall from high-intensity, convective thunderstorms during the growing season with very low precipitation from summer to midautumn. The average annual temperature is 39–56°F, decreasing with elevation. The freeze-free period averages 155 days, but is 110–195 days along an elevation gradient (NRCS 2022).

References

Briske, D. D., B. T. Bestelmeyer, T. K. Stringham, and P. L. Shaver. 2008. Recommendations for development of resilience-based state-and-transition models. Rangeland Ecology & Management **61**:359-367.

Caudle, D., J. DiBenedetto, M. Karl, H. Sanchez, and C. Talbot. 2013. Interagency ecological site handbook for rangelands. U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.

Miller, R. F., R. J. Tausch, E. D. McArthur, D. D. Johnson, and S. C. Sanderson. 2008b. Age structure and expansion of piñon-juniper woodlands: A regional perspective in the Intermountain West. Research Paper Report RMRS-RP-69, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

NRCS. 2017. National ecological site handbook. U.S. Department of Agriculture, Natural Resources Conservation Service.

NRCS. 2022. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. Handbook 296, U.S. Department of Agriculture, Natural Resources Conservation Service.

Stringham, T. K., W. C. Krueger, and P. L. Shaver. 2003. State and transition modeling: An ecological process approach. Journal of Range Management **56**:106-113.

Stringham, T. K., P. Novak-Echenique, D. K. Snyder, S. Peterson, and K. A. Snyder. 2016. Disturbance response grouping of ecological sites increases utility of ecological sites and state-and-transition models for landscape scale planning in the Great Basin. Rangelands **38**:371-378.

Stringham, T. K., D. K. Snyder, P. Novak-Echenique, A. Wartgow, A. Badertscher, and K. O'Neill. 2019. Great Basin ecological site development project: State and transition models for Major Land Resource Area 23, Nevada and portions of California. Nevada Agricultural Experiment Station Research Report 2019-01, University of Nevada Reno, USA.

Major Land Resource Area 27 Disturbance Response Groups

Ecological Sites and Associated Disturbance Response Groups

Ecological Site Name	*Status*	*Dominant Vegetation*	*Site ID*
Group 1: Calcareous soils with black sagebrush and needlegrasses			
Shallow Calcareous Loam 10-12"	***Modal***	***ARNO4/ACTH7***	***R027XY032NV***
Shallow Calcareous Slope 8-10"		ARNO4/ACSP12-ACHY	R027XY061NV
Shallow Calcareous Loam 8-10"		ARNO4/ACHY	R027XY031NV
Group 2: Lahontan sagebrush and needlegrasses			
Gravelly Claypan 8-10"	***Modal***	***ARARL3/ACTH7***	***R027XY079NV***
Droughty Claypan 8-10"		ARARL3/ACHY-ACSP12	R027XY070NV
Shallow Claypan 8-10"		ARARL3/ACSP12	R027XY020NV
Cobbly Claypan 8-10"		ARAR8/ACTH7	R027XY049NV
Granitic Claypan 8-10"		ARARL3/ACSP12	R027XY068NV
Group 3: Wyoming big sagebrush and needlegrasses			
Droughty Loam 8-10"	***Modal***	***ARTRW8-GRSP/ACHY***	***R027XY008NV***
Loamy Slope 8-10" P.Z.		ARTRW8/ACTH7	R027XY007NV
South Slope 8-10"		ARTRW8/ACSP12	R027XY051NV
Sandy 8-10"		ARTRT/ACHY-ELLAL	R027XY045NV
Granitic Slope 8-10"		ARTRW8/ACSP12	R027XY065NV
Gravelly Fan 8-10"		ARTR2-GRSP/ACHY-LECI4	R027XY029NV
Granitic Loam 8-10"		ARTRW8/ACSP12	R027XY067NV
Group 4: Big sagebrush and needlegrasses			
Granitic Slope 10-12"	***Modal***	***ARTR2/ACTH7***	***R027XY072NV***
Loamy 10-12"		ARTR2/ACTH7-LECI4	R027XY058NV
Loamy Slope 10-12"		ARTR2/ACTH7	R027XY054NV
Granitic Loam 10-12"		ARTRW8/ACTH7-ACHY	R027XY088NV
Granitic Fan 10-12"		ARTR2/LECI4-ACTH7-ACHY	R027XY092NV
Group 5: Sites associated with ephemeral streams			
Valley Wash 4-8"	***Modal***	***HYSA/ACHY***	***R027XY022NV***
Group 6: Low sagebrush and Idaho fescue			
Cobbly Claypan 12-14"	***Modal***	***ARAR8/FEID***	***R027XY046NV***
Mountain Ridge		ARAR8/POA-ACPI2-FEID	R027XY083NV
Claypan 14+		ARAR8/FEID	R027XY087NV
Group 7: Loamy soils with mountain big sagebrush and needlegrasses			
Granitic Slope 12-14"	***Modal***	***ARTRV/ACTH7***	***R027XY073NV***
Loamy 16+"		ARTRV/BRMA4-ACNED	R027XY086NV
Loamy Slope 16+"		ARTRV/FEID-ACNED	R027XY085NV

Mountain Shoulder 16+"		ARTRV/FEKI-ACLE9	R027XY084NV

Group 8: Eroded soils with spiny hopsage and cool-season grasses

Eroded Granitic Slope	***Modal***	***GRSP-TEGL-EPNE/ACSP12***	***R027XY047NV***

Group 9: Loamy soils with basin wildrye

Loamy Bottom 8-12"	***Modal***	***ARTRT/LECI4***	***R027XY003NV***
Loamy Fan 10-12"		ARTRT/LECI4	R027XY091NV

Group 10: Alkaline soils with Torrey's saltbush and basin wildrye

Deep Sodic Fan	***Modal***	***ATTO/LECI4***	***R027XY041NV***
Saline Flat		ATTO/LECI4	R027XY044NV

Group 11: Sandy sites dominated by saltbush and Indian ricegrass

Sandy 5-8"	***Modal***	***ATCA2/ACHY***	***R027XY009NV***
Sandy 3-5"		ATCA2/ACHY	R027XY060NV
Outwash Plain		ATCA2/ACHY	R027XY078NV

Group 12: Salty soils with shadscale and black greasewood

Sodic Terrace	***Modal***	***ATCO-SAVE4/ACHY***	***R027XY024NV***
Dry Sodic Terrace		SAVE4/ACHY	R027XY036NV
Dry Sodic Flat		SUMO	R027XY094NV

Group 13: Seasonally flooded areas with black greasewood and basin wildrye

Saline Bottom	***Modal***	***SAVE4/LECI4***	***R027XY006NV***

Group 14: Loamy soils with Bailey's greasewood, shadscale and Indian ricegrass

Gravelly Loam 4-8"	***Modal***	***ATCO-SABA14/ACHY***	***R027XY018NV***
Loamy 4-8"		ATCO-PIDE4/ACHY	R027XY013NV
Barren Gravelly Slope		ATCO/ACHY	R027XY027NV
Stony Slope 4-8"		ATCO-SABA14/ACHY	R027XY019NV
Coarse Gravelly Loam 5-8"		SABA14-ATCO/ACHY	R027XY050NV
South Slope 4-8"		ATCO/ACSP12	R027XY017NV
Coarse Gravelly Loam 3-5"		ATCO-LYCO2-SABA14/ACHY	R027XY043NV
Stony Loam 4-8"		SABA14-ATCO/ACHY	R027XY015NV
Stony Sodic Terrace 4-6"		ATCO-SABA14	R027XY076NV
Stony Terrace 4-8"		EPNE/ACSP12	R027XY093NV
Loamy Slope 5-8"		ATCO-PIDE4/ACHY	R027XY037NV
Beach Terrace		ATCO	R027XY010NV
Granitic Loam 5-8"		ATCO/ACSP12	R027XY074NV

Group 15: Silty soils with winterfat and Indian ricegrass

Coarse Silty 4-8"	***Modal***	***KRLA2/ACHY***	***R027XY014NV***

Group 16: Salt-affected soils with iodinebush and warm-season grasses

Moist Saline Flat	***Modal***	***ALOC2/DISP***	***R027XY077NV***

Group 17: Sandy soils dominated by black greasewood and Indian ricegrass

Sodic Dunes	***Modal***	***SAVE4/ACHY***	***R027XY016NV***
Sodic Sands		SAVE4/ACHY	R027XY012NV

Group 18: Salt-affected soils with black greasewood and warm-season grasses			
Sodic Flat	***Modal***	***SAVE4/DISP***	***R027XY025NV***

Group 19: Sandy soils dominated by fourwing saltbush			
Dunes 4-8"	***Modal***	***TETE4-ATCA2/ACHY***	***R027XY023NV***
Dunes 8-10"		ATCA2-EPNE/ACHY	R027XY053NV

Group 20: Pinyon and/or juniper woodland with Wyoming big sagebrush understory			
Shallow Rocky Loam	***Modal***	***PIMO-JUOS/ARTRW8/ACTH7***	***F027XY081NV***
JUOS/ARTRW8/ACTH7		JUOS/ARTRW8/ACTH7	F027XY075NV

Group 21: Pinyon and juniper woodland with mountain big sagebrush understory			
Very Steep Shallow Loam	***Modal***	***PIMO-JUOS/ARTRV***	***F027XY082NV***
PIMO/ARTRV/FEID		PIMO/ARTRV/FEID	F027XY080NV

Group 22: Alluvial flats and axial stream floodplains dominated by saltgrass			
Saline Meadow	***Modal***	***SPAI-DISP-JUBA***	***R027XY005NV***
Dry Saline Meadow		DISP-PUCCI	R027XY090NV
Sodic Bottom		DISP	R027XY089NV

Ecological Sites Omitted from This Report

The following list of ecological sites were omitted from this final report due to being riparian sites, which were outside the scope of this project.

Site Name	Dominant Vegetation	Site ID
Moist Floodplain	SALIX/LETR5-LECI4-PASM	R027XY002NV
Wetland	TYPHA-ELPA3-SCPA4	R027XY001NV
Wet Meadow 8-12"	CAREX-PONE3	R027XY004NV
POFR2/LETR5	POFR2/LETR5	F027XY038NV
Wet Meadow 4-8"	POJU-JUNCU	R027XY069NV

MLRA 27 Group 1: Calcareous soils with black sagebrush and needlegrasses

Description of MLRA 27 Disturbance Response Group 1

Disturbance Response Group (DRG) 1 consists of two ecological sites. The sites occur on summits and sideslopes of fan piedmonts, hills and lower mountains. The precipitation ranges from 8 to 14 in. Slopes range from 2 to 75% with less than 30% being typical. Elevation ranges from 5,000 to about 6,800 ft. Soils are formed from a variety of sources, including limestone and dolomite, metavolcanic and volcanic rock, and welded tuffs. These soils are typically calcareous or carbonatic and are often modified with high amounts of gravels, cobbles, or stones. The available water holding capacity is very low to low. 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 bordering on xeric 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 other associated species including winterfat (*Krascheninnikovia lanata*), spiny hopsage (*Grayia spinosa*), Bailey's greasewood (*Sarcobatus baileyi*) and Nevada jointfir (*Ephedra nevadensis*). The perennial grass understory is dominated by Thurber's needlegrass (*Achnatherum thurberianum*), Indian ricegrass (*Achnatherum hymenoides*), or desert needlegrass (*Achnatherum speciosum*). Total annual air-dry production ranges from 100 to 500 lb/ac.

Disturbance Response Group 1 Ecological Sites:

Shallow Calcareous Loam 10-12" P.Z. – Modal	R027XY032NV
Shallow Calcareous Slope 8-10" P.Z.	R027XY061NV

Modal Site:

The Shallow Calcareous Loam 10-12" P.Z. ecological site (R027XY032NV) 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 4–30% are most typical. Elevations range from 5,700 to 6,800 ft. 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. The shrub component is dominated by black sagebrush. Spiny hopsage, winterfat, and Nevada ephedra are also common. The herbaceous component is dominated by Thurber's needlegrass, Indian ricegrass and Sandberg bluegrass (*Poa secunda*) are also present in minor amounts. Other grasses include needle-and-thread (*Hesperostipa*

comata), squirreltail (*Elymus elymoides*) and galleta (*Pleuraphis jamesii*). Total annual air-dry production ranges from 200 to 500 lb/ac and is about 350 lb/ac in a normal year.

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 27 (MLRA 27 Fallon-Lovelock Area) is almost entirely in Nevada with < 1% in California. The entire area occurs in the rain shadow of the Sierra Nevada mountains and is influenced by Pleistocene Lake Lahontan. Extensive playas occur throughout the area and are a result of the drying of ancient Lake Lahontan. To the west, MLRA 27 has a gradual boundary with MLRA 26 (Carson Basin and Mountains) and to the east has a very gradual boundary with MLRA 24 (Humboldt Basin and Range Area). From west to east the soil temperature increases and the soil moisture decreases, resulting in vast areas dominated by salt-desert shrub communities. Isolated mountain ranges trending north to south are separated by broad desert plains and valleys. Elevations range from 3,300 to 5,900 ft with some mountain peaks at over 7,800 ft. The average annual precipitation ranges from 4 to 11 in. and as much as 21 in. at the highest elevations. The majority of annual precipitation is received during late fall and winter occurring mainly as snow. High-intensity, convective thunderstorms also contribute significantly to annual precipitation (NRCS 2022). 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).

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 4–20 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 77–81 cm (30–32 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 2012). 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 cool-season deep-rooted, perennial bunchgrasses that are found on these sites include Thurber's needlegrass, desert needlegrass, and Indian ricegrass. 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 (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.

Thurber's needlegrass is a native, cool-season grass common to the semiarid regions of the Intermountain West and is an important component of many sagebrush communities (Johnson et al. 2017). It is a deep-rooted perennial bunchgrass, 1–2 ft tall with fine, narrow in rolled leaves about 6–10 in. long (Perryman and Skinner 2007). It is very drought and cold tolerant and prefers well drained, fine sandy loam to silt loam soils. It is not tolerant of shade and saline or sodic soil conditions (Ogle 2006).

Indian ricegrass is a long-lived, cool-season perennial bunchgrass that grows from 4–24 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).

Desert needlegrass is a cool-season, perennial bunchgrass that grows 12–24 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).

Sandberg bluegrass is a shallow-rooted, cool-season perennial bunchgrass that grows from 3–6.1 dm (12–24 in.) tall (Perryman and Skinner 2007). It is notable for its early growth and short season of vegetative activity (Tisdale and Hironaka 1981). It is one of the most drought resistant of the bluegrasses because of the mass of coarse fibrous roots, and its ability to make growth, produce flowers, and mature its seeds early in the season while soil moisture is still available (USFS 1988a). Sandberg bluegrass is widely distributed and an important species in most of the West growing from 1,000 ft to as high as 12,000 ft elevation (USFS 1988a).

Galleta is a mat-forming, rhizomatous, native grass that is 11–19 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 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 (*Bromus tectorum*), 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 < 2 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 1998).

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 4–5 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 1966b).

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. 2021).

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, targeted grazing, prescribed fire and rangeland seeding. 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 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 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). 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 (0.45 perennial grasses/ft^2)

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. 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:

Fire return intervals in black sagebrush ecosystems have been estimated at 100–200 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 (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 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 12–16 in. of annual precipitation has been found to have greater fire survival (Boltz 1994). In lower precipitation zones, broom snakeweed *(Gutierrezia* spp.) yellow rabbitbrush (*Chrysothamnus viscidiflorus*), and/or ephedra (*Ephedra* spp.) may become the dominant shrub species following fire often with an understory of galleta, 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).

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).

Conversely, 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. 1976a). 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, Davies and Bates 2008). However, Thurber's needlegrass often survives fire and will continue growth when conditions are favorable (Koniak 1985a, Davies and Bates 2008). 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.

Desert needlegrass has been shown to be a major increaser after disturbance including fire. In a systematic review of 43 studies, centered in the Mojave Desert, Abella (2009) highlighted a 7.4-fold increase in mean relative abundance on disturbed sites in comparison to undisturbed sites. This is supported by Thatcher and Hart (1974) who recorded an annual production of desert needlegrass of 1,271 lb/ac on communities with recent fire activity compared to 612 lb/ac on sites where fire was not a factor.

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) and may retard reestablishment of deeper-rooted bunchgrasses.

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). Galleta and Sandberg bluegrass 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.

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 1987b). 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 (*Chrysothamnus viscidiflorus*). Following wildfire, surviving black sagebrush plants may experience increased herbivory with potential negative impacts (Wambolt 1996).

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).

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.

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 2008a).

Reduced bunchgrass vigor or density provides an opportunity for Sandberg bluegrass expansion and/or cheatgrass and other invasive species to occupy interspaces. Sandberg bluegrass increases under grazing pressure (Tisdale and Hironaka 1981) and is capable of co-existing with cheatgrass or other weedy species. Excessive 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.

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). Once the plant cures and its palatability declines to poor domestic livestock will not utilize it unless more palatable species are unavailable (USDA 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 Thurber's needlegrass and Indian ricegrass. 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 1

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 27 Disturbance Response Group 1.

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 black sagebrush, Thurber's needlegrass and Indian ricegrass. Winterfat, spiny hopsage and Sandberg's bluegrass are other common species. Forbs are a minor component. Approximate vegetative composition by air-dry weight is 50% grasses, 5% forbs and 45% shrubs. Approximate ground cover (basal and crown) is 20–30%. Total annual air-dry production ranges from 200 to 500 lb/acre.

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 and forbs to increase. Shrubs such as shadscale (*Atriplex confertifolia*) and yellow rabbitbrush 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, Sandberg's bluegrass, needle-and-thread (*Hesperostipa comata*) and other perennial bunchgrasses dominate. Thurber's needlegrass may be eliminated or reduced. Sprouting shrubs such as yellow rabbitbrush, shadscale and Nevada jointfir 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. Bailey's greasewood may also increase. Sandberg bluegrass and/or galleta may increase in the understory and become the co-dominant with deep rooted bunchgrasses.

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 Thurber's needlegrass, Indian ricegrass, and Sandberg bluegrass dominant in the understory.

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. Brush treatments and inappropriate sheep grazing will 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. Black sagebrush is present in trace amounts; perennial bunchgrasses and sprouting shrubs dominate the site. Depending on fire severity patches of intact black sagebrush may remain. Shadscale and 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.

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. 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 Slope 8-10" P.Z. (R027XY031NV), Current Potential State 2.3, T. Stringham, September 2025

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 black sagebrush, or spring grazing by sheep of black sagebrush promotes the perennial bunchgrass understory. Brush treatments with minimal soil disturbance will also decrease black 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 black 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 squirreltail (*Elymus elymoides*), Sandberg bluegrass and/ or galleta and favor shrub growth and establishment. To Community Phase 3.2: Severe fire will remove the black sagebrush overstory, decrease perennial bunchgrasses and

enhance squirreltail, galleta and/or Sandberg bluegrass. Soil-disturbing brush treatments and/or inappropriate sheep grazing will reduce black sagebrush and potentially increase sprouting shrubs and 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 Annual State 4.0:

Trigger: High-intensity 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.

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 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.

Shrub State 3.0:

This state has two community phases in which the overstory is dominated by either black sagebrush (3.1) or shrubs (3.2) such as yellow rabbitbrush, shadscale (*Atriplex confertifolia*) and/or Nevada jointfir. 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 the overstory while 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.

Shallow Calcareous Loam 10-12" P.Z. (R027XY032NV), Shrub State 3.1, T. Stringham, May 2024

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 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 and/or ephedra dominate the overstory while squirreltail, galleta, and Sandberg bluegrass dominate the understory. Shadscale may also be common. Annual non-native species may be increasing and bare ground is significant. This site is at risk for an increase in invasive non-native annuals. This community phase is at risk of transitioning to an Annual State 4.0.

Shallow Calcareous Loam 10-12" P.Z. (R027XY032NV), Shrub State 3.2, T. Stringham, May 2024

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 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.

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 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.

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 shrubs. In this state, a biotic threshold has been crossed and state dynamics are driven by the dominance and persistence of the invasive annual plant 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. The fire-return interval has shortened due to the dominance of non-native annuals 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 and shadscale 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 10-12" P.Z. (R027XY032NV), Annual State 4.1, T. Stringham, September 2025

Community Phase Pathway 4.1a, from Phase 4.1 to 4.2:
Time and lack of fire allows for 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 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.

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.

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.

Community Phase Pathway 5.2a, from Phase 5.2 to 5.1:
Tree thinning, typically for fuels management.

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.

States Not Observed in Group 1:

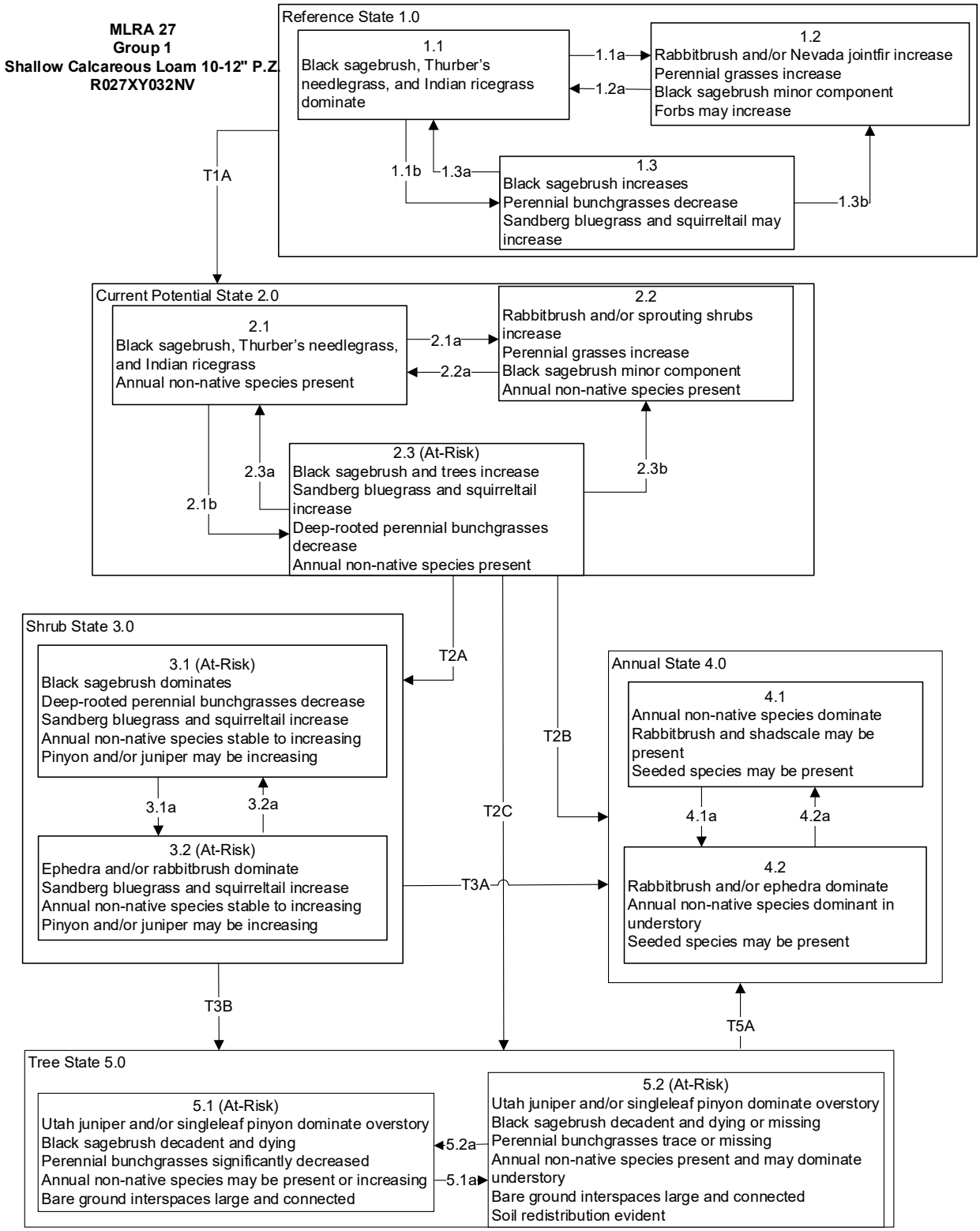
Seeded State: A Seeded State for this DRG was not observed however this state occurs in a similar DRG (11) in MLRA 29. A restoration pathway can occur with the removal of trees in community phase 5.1 and seeding of introduced species. If restoration efforts fail, this site could transition to an Annual State 4.0. A restoration pathway to a Seeded State can also occur from the Shrub State.

Potential Resilience Differences with other Ecological Sites in this Group

Shallow Calcareous Slope 8-10" P.Z. (R027XY061NV):

This site occurs on sideslopes of hills and mountains on slopes ranging from 30 to 75%. The reference plant community is dominated by black sagebrush, desert needlegrass and Indian ricegrass. This site occurs on slope gradients typically steeper than the modal and therefore are more susceptible to soil erosion. Elevations range from approximately 5,000 to 6,500 ft. This site is most commonly found on southerly aspects making this site less resilient than the modal. Shadscale and spiny hopsage dominate 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. A Tree State is unlikely on this site because of lower precipitation and its occurrence on southerly aspects.

Modal State and Transition Model for Group 1 MLRA 27



MLRA 27
Group 1
Shallow Calcareous Loam 10-12" P.Z.
R027XY032NV

Reference State 1.0 Community Pathways:
1.1a: Low severity fire resulting in a grass/shrub mosaic pattern.
1.1b: Time and lack of disturbance such as fire. Drought, herbivory, or combinations of these would reduce perennial grasses in the understory.
1.2a: Time and lack of disturbance such as fire allows for shrub reestablishment.
1.3a: Low severity fire or herbivory resulting in a grass/shrub mosaic pattern.
1.3b: High severity fire significantly reduces sagebrush cover leading to early/mid-seral community dominated by sprouting shrubs, perennial grasses and forbs.

Transition T1A: Introduction of non-native plants.

Current Potential State 2.0 Community Pathways:
2.1a: Fire, inappropriate grazing or brush treatments (i.e. mowing) with minimal soil disturbance creates a grass/shrub mosaic.
2.1b: Time and lack of disturbance such as fire. Drought, inappropriate grazing management, or combinations of these would reduce perennial grasses in the understory.
2.2a: Time and lack of disturbance such as fire, drought, inappropriate grazing management, or combinations of these.
2.3a: Low severity fire creates sagebrush/grass mosaic. Brush treatments with minimal soil disturbance and/or grazing management that reduces shrubs would allow for an increase in perennial bunchgrasses.
2.3b: High severity fire significantly reduces sagebrush and leads to early/mid-seral community dominated by sprouting shrubs, perennial grasses and forbs.

Transition T2A: Time and lack of disturbance and/or inappropriate grazing management (to 3.1) or fire, soil disturbing brush treatments and/or inappropriate sheep grazing (3.2).

Transition T2B: Fire in at-risk community phase (from 2.3) may transition to annual state (4.0), soil disturbing treatments may also transition to an annual state.

Transition T2C: Time and lack of disturbance allows for the maturation of the tree community.

Shrub State 3.0 Community Pathways:
3.1a: Fire and/or sheep grazing management which reduces black sagebrush. Brush treatments (i.e. mowing) with minimal soil disturbance.
3.2a: Time and lack of disturbance and/or grazing management that favors the establishment and growth of sagebrush allows for the shrub component to recover.

Transition T3A: Fire and/or soil disturbing treatments (i.e. failed restoration attempts) (to 4.0).

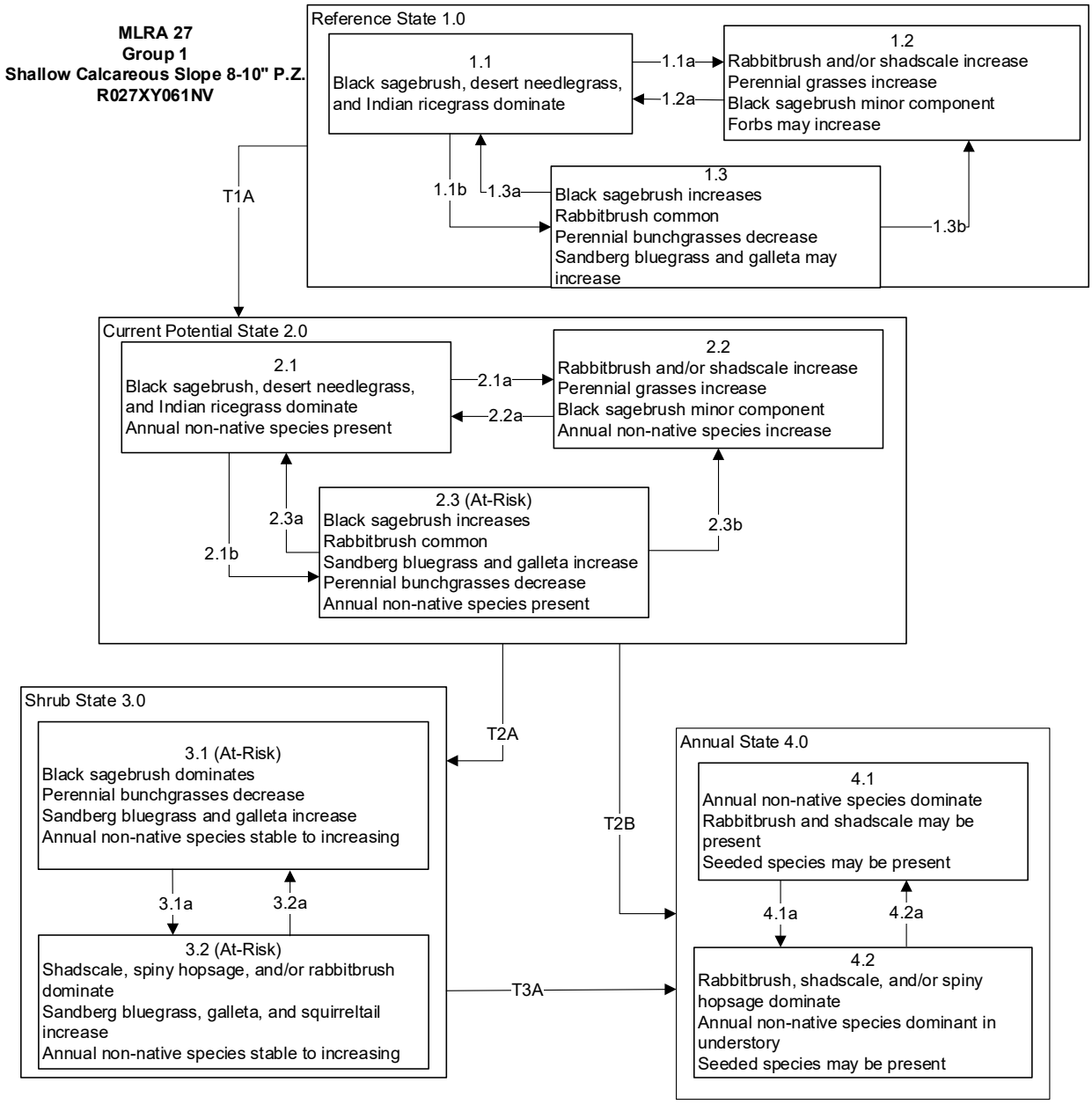
Transition T3B: Time and lack of disturbance allows for the maturation of the tree community.

Annual State 4.0 Community Pathways:
4.1a: Time and lack of disturbance (unlikely to occur).
4.2a: Fire.

Tree State 5.0 Community Pathways:
5.1a: Time and lack of disturbance allows for the maturation of the tree community.
5.2a: Tree thinning (typically for fuels management).

Transition T5A: Catastrophic fire that significantly reduces or eliminates the trees and any remaining shrubs or inappropriate tree removal practices with soil disturbance.

Additional State and Transition Models for Group 1 MLRA 27



MLRA 27
Group 1
Shallow Calcareous Slope 8-10" P.Z.
R027XY061NV

Reference State 1.0 Community Pathways:
1.1a: Low severity fire resulting in a shrub/grass mosaic pattern.
1.1b: Time and lack of disturbance such as fire. Drought, herbivory, or combinations of these would reduce perennial grasses in the understory.
1.2a: Time and lack of disturbance such as fire.
1.3a: Low severity fire or herbivory resulting in a grass/shrub mosaic pattern.
1.3b: High severity fire significantly reduces sagebrush cover leading to early/mid-seral community dominated by sprouting shrubs, perennial grasses and forbs.

Transition T1A: Introduction of non-native plants.

Current Potential State 2.0 Community Pathways:
2.1a: Fire, inappropriate grazing, or brush treatments (i.e. mowing) with minimal soil disturbance will reduce the shrub component and increase the perennial grasses and forbs.
2.1b: Time and lack of disturbance such as fire. Drought, inappropriate grazing management, or combinations of these would reduce perennial grasses in the understory.
2.2a: Time and lack of disturbance such as fire, drought, inappropriate grazing management, or combinations of these.
2.3a: Low severity fire creates sagebrush/grass mosaic. Brush treatment with minimal soil disturbance and/or grazing management that reduces shrubs would allow for an increase in perennial bunchgrasses.
2.3b: High severity fire significantly reduces sagebrush and leads to early/mid-seral community dominated by sprouting shrubs, perennial grasses and forbs.

Transition T2A: Time and lack of disturbance and/or inappropriate grazing management (to 3.1) or fire, soil disturbing brush treatments and/or inappropriate sheep grazing (3.2).

Transition T2B: Fire in at-risk community phase (from 2.3) may transition to an annual state (4.0), soil disturbing treatments may also transition to an annual state.

Shrub State 3.0 Community Pathways:
3.1a: Fire and/or sheep grazing management which reduces black sagebrush. Brush treatments (i.e. mowing) with minimal soil disturbance.
3.2a: Time and lack of disturbance and/or grazing management that favors the establishment and growth of sagebrush allows for the shrub component to recover.

Transition T3A: Fire and/or soil disturbing treatments (i.e. failed restoration attempts) (to 4.0).

Annual State 4.0 Community Pathways:
4.1a: Time and lack of disturbance (unlikely to occur).
4.2a: Fire.

References

Abella, S. R. 2009. Post-fire plant recovery in the Mojave and Sonoran Deserts of western North America. Journal of Arid Environments **73**:699-707.

Allen, E. B., and M. F. Allen. 1988. Facilitation of succession by the nonmycotrophic colonizer *Salsola kali* (Chenopodiaceae) on a harsh site: effects of mycorrhizal fungi. American Journal of Botany **75**:257-266.

Banner, R., M. S. Pratt, and J. Bowns. 2011. Grasses and Grasslike Plants of Utah: A Field Guide. Utah State University Extension, Logan, UT.

Bates, J. D., T. Svejcar, R. F. Miller, and R. A. Angell. 2006. The effects of precipitation timing on sagebrush steppe vegetation. Journal of Arid Environments **64**:670-697.

Baughman, O. W., R. Burton, M. Williams, P. J. Weisberg, T. E. Dilts, and E. A. Leger. 2017. Cheatgrass die-offs: a unique restoration opportunity in northern Nevada. Rangelands **39**:165-173.

Baughman, O. W., S. E. Meyer, Z. T. Aanderud, and E. A. Leger. 2016. Cheatgrass die-offs as an opportunity for restoration in the Great Basin, USA: will local or commercial native plants succeed where exotic invaders fail? Journal of Arid Environments **124**:193-204.

Beale, D. M., and A. D. Smith. 1970. Forage use, water consumption, and productivity of pronghorn antelope in western Utah. The Journal of Wildlife Management **34**:570-582.

Beatley, J. C. 1975. Climates and vegetation pattern across the Mojave/Great Basin Desert transition of southern Nevada. The American Midland Naturalist **93**:53-70.

Beetle, A. A. 1960. A study of sagebrush: the section *Tridentatae* of *Artemisia*. Bulletin 368, University of Wyoming, Agricultural Experimental Station, Laramie, WY.

Bentz, B., D. Alston, and T. Evans. 2008. Great Basin insect outbreaks. Pages 45-48 *in* Collaborative management and research in the Great Basin - Examining the issues and developing a framework for action. General Technical Report RMRS-GTR-204. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Bertiller, M. B., A. M. Beeskow, and F. Coronato. 1991. Seasonal environmental variation and plant phenology in arid Patagonia (Argentina). Journal of Arid Environments **21**:1-11.

Bich, B. S., J. L. Butler, and C. A. Schmidt. 1995. Effects of differential livestock use on key plant species and rodent populations within selected *Oryzopsis hymenoides*/*Hilaria jamesii* communities of Glen Canyon National Recreation Area. The Southwestern Naturalist **40**:281-287.

Blaisdell, J. P., and R. C. Holmgren. 1984. Managing intermountain rangelands - salt-desert shrub ranges. General Technical Report INT-163, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Blank, R. R., C. Clements, T. Morgan, D. Harmon, and F. Allen. 2020. Suppression of cheatgrass by perennial bunchgrasses. Rangeland Ecology & Management **73**:766-771.

Boerboom, C. 1993. Russian thistle (*Salsola iberica* Sennen & Pau).

Boltz, M. 1994. Factors influencing postfire sagebrush regeneration in south-central Idaho. Pages 281-290 *in* Proceedings—Ecology and management of annual rangelands;

September 1994; Boise, ID. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Booth, D. T., C. G. Howard, and C. E. Mowry. 1980. 'Nezpar' Indian ricegrass: description, justification for release, and recommendations for use. Rangelands **2**:53-54.

Boyd, C. S., K. W. Davies, and A. Hulet. 2015. Predicting fire-based perennial bunchgrass mortality in big sagebrush plant communities. International Journal of Wildland Fire **24**:527-533.

Bradford, J. B., and W. K. Lauenroth. 2006. Controls over invasion of *Bromus tectorum*: the importance of climate, soil, disturbance and seed availability. Journal of Vegetation Science **17**:693-704.

Bradley, B. A., C. A. Curtis, E. J. Fusco, J. T. Abatzoglou, J. K. Balch, S. Dadashi, and M.-N. Tuanmu. 2018. Cheatgrass (*Bromus tectorum*) distribution in the intermountain Western United States and its relationship to fire frequency, seasonality, and ignitions. Biological Invasions **20**:1493-1506.

Brehm, J. R. 2019. Cheatgrass die-off in the Great Basin: a comparison of remote sensing detecting methods and identification of environments favorable to die-off. M.S. Thesis. University of Nevada, Reno, NV.

Britton, C. M., G. R. McPherson, and F. A. Sneva. 1990. Effects of burning and clipping on five bunchgrasses in eastern Oregon. The Great Basin Naturalist **50**:115-120.

Butler, M., F. Brummer, J. Weber, and R. Simmons. 2011. Restoring Central Oregon rangeland from ventenata and medusahead to a sustainable bunchgrass environment – Warm Springs and Ashwood. COARC 2011, Oregon State University, Central Oregon Agricultural Research and Extension Center, Corvallis, OR.

Caudle, D., J. DiBenedetto, M. Karl, H. Sanchez, and C. Talbot. 2013. Interagency ecological site handbook for rangelands. U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.

Chambers, J. C., B. A. Bradley, C. S. Brown, C. D'Antonio, M. J. Germino, J. B. Grace, S. P. Hardegree, R. F. Miller, and D. A. Pyke. 2013. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of western North America. Ecosystems **17**:360-375.

Chambers, J. C., B. A. Roundy, R. R. Blank, S. E. Meyer, and A. Whittaker. 2007. What makes Great Basin sagebrush ecosystems invasible by *Bromus tectorum*? Ecological Monographs **77**:117-145.

Clark, S. L., D. J. Sebastian, S. J. Nissen, and J. R. Sebastian. 2019. Effect of indaziflam on native species in natural areas and rangeland. Invasive Plant Science and Management **12**:60-67.

Clements, C. D., D. N. Harmon, and R. R. Blank. 2022. Seed mix performance and cheatgrass suppression on arid rangelands. Rangelands **44**:129-135.

Comstock, J. P., and J. R. Ehleringer. 1992. Plant adaptation in the Great Basin and Colorado Plateau. The Great Basin Naturalist **52**:195-215.

Cook, C. W., and R. D. Child. 1971. Recovery of desert plants in various states of vigor. Rangeland Ecology & Management/Journal of Range Management Archives **24**:339-343.

Cook, C. W., K. Taylor, and L. E. Harris. 1962. The effect of range condition and intensity of grazing upon daily intake and nutritive value of the diet on desert ranges. Journal of Range Management **15**:1-6.

Courkamp, J. S., P. J. Meiman, and M. W. Paschke. 2022. Indaziflam reduces seed bank richness and density but not sagebrush-grassland plant diversity. Rangeland Ecology & Management **84**:31-44.

Cronin, E. H., and M. C. X. Williams. 1966b. Principles for managing ranges infested with halogeton.

Daubenmire, R. 1970. Steppe vegetation of Washington. Technical Report 62, Washington State University, Washington Agricultural Experiment Station, Pullman, WA.

Daubenmire, R. 1975. Plant succession on abandoned fields, and fire influences in a steppe area in southeastern Washington. Northwest Science **49**:36-48.

Davies, K. W., and J. D. Bates. 2008. The response of Thurber's needlegrass to fall prescribed burning. Rangeland Ecology & Management **61**:188-193.

Davies, K. W., C. S. Boyd, J. D. Bates, and A. Hulet. 2015a. Dormant season grazing may decrease wildfire probability by increasing fuel moisture and reducing fuel amount and continuity. International Journal of Wildland Fire **24**:849-856.

Davies, K. W., A. M. Nafus, C. S. Boyd, A. Hulet, and J. D. Bates. 2016. Effects of using winter grazing as a fuel treatment on Wyoming big sagebrush plant communities. Rangeland Ecology & Management **69**:179-184.

Eckert, R. E., Jr., A. D. Bruner, and G. J. Klomp. 1972. Response of understory species following herbicidal control of low sagebrush. Journal of Range Management **25**:280-285.

Eckert, R. E., Jr., and J. S. Spencer. 1987. Growth and reproduction of grasses heavily grazed under rest-rotation management. Journal of Range Management **40**:156-159.

Everett, R. L., P. T. Tueller, J. B. Davis, and A. D. Brunner. 1980. Plant phenology in galleta-shadscale and galleta-sagebrush associations. Rangeland Ecology & Management/Journal of Range Management Archives **33**:446-450.

Evert, R. F. 2006. Esau's plant anatomy: Meristems, cells, and tissues of the plant body - Their structure, function, and development. Third Edition edition. John Wiley & Sons, Inc., Hoboken, New Jersey.

Furbush, P. 1953. Control of medusa-head on California ranges. Journal of Forestry **51**:118-121.

Furniss, M. M., and W. F. Barr. 1975. Insects affecting important native shrubs of the Northwestern United States. General Technical Report INT-19, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Ganskopp, D. L. 1988. Defoliation of Thurber needlegrass: herbage and root responses. Journal of Range Management **41**:472-476.

Harrington, H. D. 1954. Manual of the plants of Colorado: For the identification of the ferns and flowering plants of the state. Sage Books, Denver, CO.

Hironaka, M. 1963. Plant environment relations of major species in sagebrush-grass vegetation of southern Idaho. Dissertation. University of Wisconsin, Madison, Madison, WI.

Horton, H. 1989. Interagency forage and conservation: planting guide for Utah. AG-433, Utah State University, Utah Cooperative Extension Service, Logan, UT.

Jameson, D. A. 1962. Effects of burning on a galleta-black grama range invaded by juniper. Ecology **43**:760-763.

Jensen, M. E. 1990. Interpretation of environmental gradients which influence sagebrush community distribution in northeastern Nevada. Journal of Range Management **43**:161-167.

Johnson, N. C. 1998. Responses of *Salsola kali* and *Panicum virgatum* to mycorrhizal fungi, phosphorus and soil organic matter: implications for reclamation. Journal of Applied Ecology **35**:86-94.

Johnson, R., E. Leger, and K. Vance-Borland. 2017. Genecology of Thurber's Needlegrass (Achnatherum thurberianum [Piper] Barkworth) in the Western United States. Rangeland Ecology & Management **70**:509-517.

Jones, T. A. 1990. A viewpoint on Indian ricegrass research: its present status and future prospects. Journal of Range Management **43**:416-420.

Kaapro, J., and J. Hall. 2012. Indaziflam - a new herbicide for pre-emergent control of weeds in turf, forestry, industrial vegetation and ornamentals. Pages 224-227 *in* 23rd Asian-Pacific Weed Science Society Conference: Conference Proceedings Volume 1; Queensland, Australia; September 26-29 2011. Asian-Pacific Weed Science Society.

Kearney, T. H., R. H. Peebles, J. T. Howell, and E. McClintock. 1960. Arizona flora. Second edition. University of California Press, Berkeley, CA.

Kitchen, S. G., and E. D. McArthur. 2007. Big and black sagebrush landscapes. Pages 73-94 *in* Fire ecology and management of the major ecosystems of southern Utah. General Technical Report RMRS-GTR-202. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Klemmedson, J. O., and J. G. Smith. 1964. Cheatgrass (*Bromus tectorum* L.). The Botanical Review **30**:226-262.

Koniak, S. 1985a. Succesion in pinyon-juniper woodlands following wildfire in the Great Basin. The Great Basin Naturalist **45**:556-566.

Mack, R. N., and D. A. Pyke. 1983. The demography of *Bromus tectorum*: Variation in time and space. Journal of Ecology **71**:69-93.

Mahalovich, M. F., and E. D. McArthur. 2004. Sagebrush (*Artemisia* spp.) seed and plant transfer guidelines. Native Plants Journal **5**:141-148.

McArthur, E. D., A. C. Blauer, A. P. Plummer, and R. Stevens. 1979. Characteristics and hybridization of important intermountain shrubs III. Sunflower family. Research Paper INT-220, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Meyer, S. E. 2008a. *Artemisia* L. sagebrush. Pages 274-280 *in* The woody plant seed manual; Agricultural Handbook No. 727. U.S. Department of Agriculture, Forest Service, Washington, D.C.

Miller, H., D. Clausnitzer, and M. Borman. 1994. Medusahead. Pages 253-279 *in* The identification, distribution, impacts, biology and management of noxious rangeland weeds. Scientific Contract Report. Interior Columbia Basin, Ecosystem Management Project, Science Integration Team, Terrestrial Staff, Range Task Group, Walla Walla, WA.

Miller, R. F., S. T. Knick, D. A. Pyke, C. W. Meinke, S. E. Hanser, M. J. Wisdom, and A. L. Hild. 2008a. Characteristics of sagebrush habitats and limitations to long-term conservation. Administrative Report, U.S. Department of the Interior; U.S. Geological Survey, Reston, VA.

Mozingo, H. N. 1987b. Shrubs of the Great Basin: A natural history. University of Nevada Press, Reno, NV.

Noy-Meir, I. 1973. Desert ecosystems: Environment and producers. Annual Review of Ecology and Systematics **4**:25-51.

NRCS. 2022. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. Handbook 296, U.S. Department of Agriculture, Natural Resources Conservation Service.

Ogle, D., St. John, L, Tilley, D, Jones, T. 2006. Plant Guide for Thurber's Needlegrass. USDA NRCS, USDA NRCS Idaho State Office.

Pearson, L. C. 1964. Effect of harvest date on recovery of range grasses and shrubs. Agronomy Journal **56**:80-82.

Pearson, L. C. 1965. Primary production in grazed and ungrazed desert communities of eastern Idaho. Ecology **46**:278-285.

Perkins, S. 2008a. Plant fact sheet for desert needlegrass (*Achnatherum speciosum*). USDA NRCS Great Basin Plant Materials Center, Fallon, Nevada.

Perryman, B. L., B. W. Schultz, M. Burrows, T. Shenkoru, and J. Wilker. 2020. Fall-grazing and grazing-exclusion effects on cheatgrass (*Bromus tectorum*) seed bank assays in Nevada, United States. Rangeland Ecology & Management **73**:343-347.

Perryman, B. L., and Q. D. Skinner. 2007. A Field Guide to Nevada Grasses. Indigenous Rangeland Management Press, Lander, WY.

Peters, E. F., and S. C. Bunting. 1994. Fire conditions pre-and post-occurrence of annual grasses on the Snake River Plain. Pages 31-36 *in* Proceedings—Ecology and management of annual rangelands; September, 1994; Boise, ID. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Pratt, M. S., G. A. Rasmussen, and R. E. Banner. 2002. Range judging in Utah. NR 505, Utah State University Extension, Logan, UT.

Quinones, F. A. 1981. Indian ricegrass evaluation and breeding. Bulletin 681, New Mexico State University, Agricultural Experiment Station, Las Cruces, NM.

Sampson, A. W., A. Chase, and D. W. Hedrick. 1951. California grasslands and range forage grasses. Bulletin 724, University of California, the College of Agriculture, California Agricultural Experiment Station, Berkeley, CA.

Schultz, B., and K. McAdoo. 2002. Common sagebrush in Nevada. Special Publication SP-02-02, University of Nevada, Cooperative Extension, Reno, NV.

Sebastian, D. J., S. J. Nissen, J. R. Sebastian, P. J. Meiman, and K. G. Beck. 2017b. Preemergence control of nine invasive weeds with aminocyclopyrachlor, aminopyralid, and indaziflam. Invasive Plant Science and Management **10**:99-109.

Sheley, R. L., E. A. Vasquez, A.-M. Chamberlain, and B. S. Smith. 2012. Landscape-scale rehabilitation of medusahead (*Taeniatherum caput-medusae*)-dominated sagebrush steppe. Invasive Plant Science and Management **5**:436-442.

Smith, J. T., B. W. Allred, C. S. Boyd, K. W. Davies, M. O. Jones, A. R. Kleinhesselink, J. D. Maestas, S. L. Morford, and D. E. Naugle. 2021. The elevational ascent and spread of invasive annual grass dominance in the Great Basin, USA. Diversity and Distributions **28**:83-96.

Stevens, R., K. R. Jorgensen, and J. N. Davis. 1981. Viability of seed from thirty-two shrub and forb species through fifteen years of warehouse storage. Western North American Naturalist **41**:274-277.

Stubbendieck, J. L., S. L. Hatch, N. M. Bryan, and C. D. Dunn. 2017. North American wildland plants. Third edition. University of Nebraska Press, Lincoln, NE.

Stubbendieck, J. L., S. L. Hatch, and L. M. Landholt. 2003. North American wildland plants. University of Nebraska Press, Lincoln, NE.

Thatcher, A. P. 1959. Distribution of sagebrush as related to site differences in Albany County, Wyoming. Journal of Range Management **12**:55-61.

Thatcher, P. A., and L. V. Hart. 1974. Spy Mesa yields better understanding of pinyon-juniper in range ecosystem. Journal of Range Management **27**:354.

Tilley, D., and L. St. John. 2012. Plant guide for black sagebrush (*Artemisia nova*). USDA Natural Resources Conservation Service, Plant Materials Center, Aberdeen, ID.

Tisdale, E. W., and M. Hironaka. 1981. The sagebrush - grass region: A review of the ecological literature. Forest, Wildlife and Range Experiment Station, University of Idaho **209**.

Tisdale, E. W., and G. Zappetini. 1953. Halogeton studies on Idaho ranges. Journal of Range Management **6**:225-236.

Uresk, D., J. Cline, and W. Rickard. 1976a. Impact of wildfire on three perennial grasses in south-central Washington. Rangeland Ecology & Management/Journal of Range Management Archives **29**:309-310.

USDA USFS. 1937. Range Plant Handbook. United States Department of Agriculture, Forest Service, Washington DC.

USFS. 1988a. Range plant handbook. Reprint of 1937 edition. Dover Publications, New York, NY.

Vallentine, J. F. 1989. Range development and improvements. Academic Press, Inc., San Diego, CA.

Van Vuren, D. 1984. Summer diets of bison and cattle in southern Utah. Journal of Range Management **37**:260-261.

Wallace, A., W. Rhods, and E. Frolich. 1968. Germination behavior of *Salsola* as influenced by temperature, moisture, depth of planting, and gamma irradiation. Agronomy Journal **60**:76-78.

Wambolt, C. L. 1996. Mule deer and elk foraging preference for 4 sagebrush taxa. Journal of Range Management **49**:499-503.

Weisberg, P. J., T. E. Dilts, O. W. Baughman, S. E. Meyer, E. A. Leger, K. J. V. Gunst, and L. Cleeves. 2017. Development of remote sensing indicators for mapping episodic die-off of an invasive annual grass (*Bromus tectorum*) from the Landsat archive. Ecological Indicators **79**:173-181.

West, N. E. 1994. Effects of fire on salt-desert shrub rangelands. Pages 71-74 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, ID.

Wright, H. A. 1971. Why squirreltail is more tolerant to burning than needle-and-thread. Journal of Range Management **24**:277-284.

Wright, H. A. 1985. Effects of fire on grasses and forbs in sagebrush-grass communities. Pages 12-21 *in* Rangeland fire effects: A symposium; Boise, ID; November 27-29, 1984. U.S. Department of the Interior, Bureau of Land Management, Boise, ID.

Wright, H. A., and J. O. Klemmedson. 1965. Effect of fire on bunchgrasses of the sagebrush-grass region in Southern Idaho. Ecology **46**:680-688.

Wright, H. A., L. F. Neuenschwander, and C. M. Dritton. 1979. The role and use of fire in sagebrush-grass and pinyon-juniper plant communities: A state-of-the-art review. General Technical Report INT-58, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Young, F., R. Veseth, D. Thill, W. Schillinger, and D. Ball. 1995. Managing Russian thistle under conservation tillage in crop-fallow rotations.

Young, R. P. 1983. Fire as a vegetation management tool in rangelands of the intermountain region. Pages 18-31 *in* Managing Intermountain rangelands—Improvement of range and wildlife habitats. Proceedings of Symposia: September 15-17, 1981, Twin Falls, Idaho June 22·24, 1982, Elko, Nevada. General Technical Report INT-GTR-157. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Zamora, B., and P. T. Tueller. 1973. *Artemisia arbuscula*, *A. longiloba*, and *A. nova* habitat types in northern Nevada. Great Basin Naturalist **33**:225-242.

MLRA 27 Group 2: Lahontan sagebrush and needlegrasses

Description of MRLA 27 Disturbance Response Group 2

Disturbance Response Group (DRG) 2 consists of five ecological sites. These sites occur on upper fan piedmonts and summits and sideslopes of hills and mountains. The elevation range of this group is 4,500 to 7,500 ft. Slopes range from 2 to 75%. The precipitation zone for these sites ranges from 8 to 10 in. Soils on these sites are typically shallow to very shallow and well drained. Soils exhibit root restrictive layers such as dense clays within the subsoil which limit plant growth and rooting on these sites. Available water capacity is low to very low. The soil moisture regime is typically aridic bordering on xeric and the soil temperature regime is mesic. The reference plant communities for these sites are dominated by Lahontan sagebrush (*A. arbuscula ssp. longicaulis*). Spiny hopsage (*Grayia spinosa*)**,** winterfat (*Krascheninnikovia lanata*) and Bailey's greasewood (*Sarcobatus baileyi*) are also common shrub species. The understory is dominated by deep-rooted perennial bunchgrasses such as Thurber's needlegrass (*Achnatherum thurberianum*), desert needlegrass (*Achnatherum speciosum*) and Indian ricegrass (*Achnatherum hymenoides*). Sandberg bluegrass (*Poa secunda*) and squirreltail (*Elymus elymoides*) are also common. Total annual air-dry production in a normal year ranges from 250 to 600 lb/acre for the group.

Disturbance Response Group 2 Ecological Sites:

Gravelly Claypan 8-10" P.Z. – Modal	R027XY079NV
Droughty Claypan 8-10" P.Z.	R027XY070NV
Shallow Claypan 8-10" P.Z.	R027XY020NV
Granitic Claypan 8-10" P.Z.	R027XY068NV
Cobbly Claypan 8-10" P.Z.	R027XY049NV

Modal Site:

The Gravelly Claypan 8-10" P.Z. (R027XY079NV) ecological site is the modal for this group as it has the most acres mapped. This site occurs on summits and sideslopes of hills and mountains. Slopes generally range from 15 to 50%. Elevations range from 6,000 to 7,500 ft. At lower elevations this site is restricted to northerly aspects. Average annual precipitation is approximately 8–10 in. The soils of this site are typically shallow to bedrock, well drained and moderately permeable. Parent material is residuum and colluvium derived from metamorphic or igneous rocks. The soils have a thick (5–15 in.) argillic horizon with clay content ranging from 23 to 60%. The available water capacity is low. Infiltration is restricted once soils are wetted and water is lost by runoff or evaporation. The reference plant community is dominated by Lahontan sagebrush and Thurber's needlegrass. Spiny hopsage, Sandberg bluegrass and desert

needlegrass are also common on this site. Total annual air-dry 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 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 27 (MLRA 27 Fallon-Lovelock Area) is almost entirely in Nevada with < 1% in California. The entire area occurs in the rain shadow of the Sierra Nevada mountains and is influenced by Pleistocene Lake Lahontan. Extensive playas occur throughout the area and are a result of the drying of ancient Lake Lahontan. To the west, MLRA 27 has a gradual boundary with MLRA 26 (Carson Basin and Mountains) and to the east has a very gradual boundary with MLRA 24 (Humboldt Basin and Range Area). From west to east the soil temperature increases and the soil moisture decreases, resulting in vast areas dominated by salt-desert shrub communities. Isolated mountain ranges trending north to south are separated by broad desert plains and valleys. Elevations range from 3,300 to 5,900 ft with some mountain peaks over 7,800 ft. The average annual precipitation ranges from 4 to 11 in. and as much as 20 in. at the highest elevations. The majority of annual precipitation is received during late fall and winter occurring mainly as snow. High-intensity, convective thunderstorms also contribute significantly to annual precipitation (NRCS 2022). 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 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) and less than a 1.0 m (3.2 ft) for low sagebrush community types (Jensen 1990). These shrubs have a flexible generalized root system with development of both taproots and laterals near the surface (Comstock and Ehleringer 1992).

The dominant perennial bunchgrasses include Thurber's needlegrass, Indian ricegrass and desert needlegrass. These grasses are deep-rooted perennial grasses and 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 (19 in.) of the soil profile. General differences in root depth distributions between grasses and shrubs results in resource partitioning in these shrub/grass systems.

Thurber's needlegrass is a native, cool-season grass common to the semiarid regions of the Intermountain West and is an important component of many sagebrush communities (Johnson et al. 2017). It is a deep-rooted perennial bunchgrass, 1–2 ft tall with fine, narrow in rolled leaves about 6–10 in. long (Perryman and Skinner 2007). It is very drought and cold tolerant and prefers well drained, fine sandy loam to silt loam soils. It is not tolerant of shade and saline or sodic soil conditions (Ogle 2006).

Indian ricegrass, the dominant understory species of this group, is a long-lived, cool-season perennial bunchgrass that grows from 4–24 in. tall (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, perennial bunchgrass that grows 12–24 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).

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).

Lahontan sagebrush was only recently identified as a unique species of sagebrush (Winward and McArthur 1995). Lahontan sagebrush is a cross between low sagebrush (*Artemisia*

arbuscula) and Wyoming big sagebrush (*Artemisia tridentata ssp. wyomingensis)* and is typically found near the old shorelines of Lake Lahontan from the Pleistocene epoch. This subspecies grows on soils similar to low sagebrush with shallow depths and low water holding capacity (Winward and McArthur 1995).

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). It grows on soils that have a strongly-structured B2t (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 Lahontan sagebrush populations.

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 changes resource uptake and increases nutrient availability, often to the benefit of non-native species. Native species are often damaged by disturbance and their ability to use resources is depressed for a time, even though resource pools may increase following disturbance from depressed used by plants and/or the decomposition of dead plant material (Whisenant 1999, Miller et al. 2013).

The introduction of non-native annual species, like cheatgrass (*Bromus tectorum*), may cause an increase in fire frequency and eventually lead to an annual state. Conversely, as fire frequency decreases, sagebrush will increase and with inappropriate grazing management the perennial bunchgrasses and forbs may be reduced. 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 will dominate the site and sagebrush will be severely reduced along with the herbaceous understory. Bluegrasses (*Poa* spp.) 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. Thurber's or desert needlegrass) whereas convex areas where runoff occurs are slightly less resilient and may have more shallow-rooted perennial grasses (i.e. 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 (*Bromus tectorum*) and medusahead (*Taeniatherum caput-medusae*). Both species are non-native, 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 et al. 1999a). Medusahead and 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 medusahead. By 2003, medusahead occupied approximately 2.3 million acres in 17 western states (Rice 2005). In the Intermountain West, the exponential increase in dominance by medusahead has largely been at the expense of cheatgrass (Harris 1967, Hironaka 1994).

Medusahead matures 2–3 weeks later than cheatgrass (Harris 1967) and recently, James et al. (2008) measured leaf biomass over the growing season and found that medusahead maintained vegetative growth later in the growing season than cheatgrass. Mangla et al. (2011) also found medusahead had a longer period of growth and more total biomass than cheatgrass and hypothesized this difference in relative growth rate may be due to the ability of medusahead to maintain water uptake as upper soils dry compared to co-occurring species, especially cheatgrass. Medusahead litter has a slow decomposition rate, because of high silica content, allowing it to accumulate over time and suppress competing vegetation (Bovey et al. 1961, Davies and Johnson 2008). Harris (1967) reported medusahead roots have thicker cell walls compared to those of cheatgrass, allowing it to more effectively conduct water, even in very dry conditions. 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. Collectively, the body of research suggests that the continued invasion and dominance of medusahead onto native grasslands and cheatgrass infested grasslands will continue to increase in severity because conditions that favor native bunchgrasses or cheatgrass over medusahead are rare (Mangla et al. 2011). Medusahead replaces native vegetation and cheatgrass directly by competition and suppression and native vegetation indirectly by increasing fire frequency.

Methods to control medusahead and cheatgrass include herbicide application, prescribed fire, targeted grazing, and rangeland seeding of primarily non-native wheatgrasses (*Agropyron* spp.).

Mapping potential or current invasion vectors is a management method designed to increase the cost effectiveness of control methods. A study by Davies et al. (2013), found an increase in medusahead cover near roads. Cover was higher near animal trails than random transects but the difference was less evident. This implies that vehicles and animals aid the spread of the weed; however, vehicles are the major vector of movement. 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 medusahead and cheatgrass than spraying alone (Sheley et al. 2012). Where native bunchgrasses are missing from the site, revegetation of medusahead or cheatgrass invaded rangelands has been shown to have a higher likelihood of success when using introduced perennial bunchgrasses such as crested wheatgrass (*Agropyron cristatum*) (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 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), however caution in using these results is advised, as only one 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.

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 (*Purshia tridentata*), and multiple sagebrush species to three rates of imazapic and the same rates with methylated seed oil as a surfactant. They found 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 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). 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 100–400 lb/ac (110- 450 kg/ha) but are occasionally as high as 600 lb/ac (680 kg/ha) in low sagebrush habitat types (Bradley et al. 1992).

Low sagebrush is killed by fire and does not sprout (Tisdale and Hironaka 1981). Reestablishment occurs from off-site wind-dispersed seed (Bradley et al. 1992). 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 et al. 1982). We were unable to find any substantial research on success of seeding low sagebrush after fire. To date, we have not been able to find specific research on the fire response of Lahontan sagebrush but field observations indicate this species is killed by fire and does not resprout.

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. 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. 1976b). 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 1985b). 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. Sandberg bluegrass has been found to increase following fire, likely due to its low stature and productivity (Daubenmire 1975) and may retard reestablishment of deeper-rooted bunchgrasses.

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).

Desert needlegrass has been shown to be a major increaser after disturbance including fire. In a systematic review of 43 studies, centered in the Mojave Desert, Abella (2009) highlighted a 7.4-fold increase in mean relative abundance on disturbed sites in comparison to undisturbed sites. This is supported by Thatcher and Hart (1974) who recorded an annual production of desert needlegrass of 1,271 lb/ac on communities with recent fire activity compared to 612 lb/ac on sites where fire was not a factor.

Sandberg bluegrass, a minor component of these ecological sites, has been found to increase following fire likely due to its low stature and productivity (Daubenmire 1975) and may retard reestablishment of deeper-rooted bunchgrasses.

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.

Throughout 2 years of site visits for this report, Lahontan sagebrush was observed in a heavily browsed state on ecological sites within this DRG. This recently differentiated subspecies of low sagebrush (Winward and McArthur 1995) is moderately to highly palatable to browse species (McArthur 2005, Rosentreter 2005). Dwarf sagebrush species such as Lahontan sagebrush, low sagebrush (*Artemisia arbuscula*), and black sagebrush (*Artemisia nova*) are preferred by mule deer for browse among the sagebrush species. Due to its palatability, it can often be hedged from grazing pressure (McArthur 2005).

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. "Heavy" was not defined in this study. 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). Thurber's needlegrass may increase in crude protein content after grazing (Ganskopp et al. 2007).

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.

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 2008a).

Squirreltail (*Elymus elymoides*) generally increases in abundance when moderately grazed or protected (Hutchings and Stewart 1953). It is considered to be fair to good forage for cattle, horses and sheep in the spring prior to seed development, and in the late fall after seed shatter. In addition, moderate trampling by livestock in 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 over utilization within the growing season.

Reduced bunchgrass vigor or density may provide an opportunity for squirreltail or Sandberg bluegrass expansion. With further degradation, cheatgrass and other invasive species may occupy interspaces. Sandberg bluegrass increases under grazing pressure (Tisdale and Hironaka 1981) and is capable of co-existing with cheatgrass or other weedy species. Excessive 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, squirreltail, Sandberg bluegrass, or cheatgrass may become the dominant understory with inappropriate grazing management. In most instances of this DRG, bare ground increased significantly with loss of perennial bunchgrasses.

Low and Lahontan 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).

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 27 Disturbance Response Group 2.

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 Lahontan sagebrush, Thurber's needlegrass and Sandberg bluegrass. Forbs and other perennial bunchgrasses make up smaller components. Potential vegetative composition is approximately 45% grasses, 5% forbs and 50% shrubs. Approximate ground cover (basal and crown) is 15–25%. 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 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. An insect infestation can also result in a loss of sagebrush allowing the perennial bunchgrasses to increase. 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. Squirreltail and Sandberg bluegrass dominate. Depending on fire severity patches of intact sagebrush may remain. Yellow rabbitbrush (*Chrysothamnus viscidiflorus*) and other sprouting shrubs may be sprouting. 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 reestablish and 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, insect 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:
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.

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 four 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 in trace amounts. Lahontan sagebrush, Thurber's needlegrass and Sandberg bluegrass dominate the site. Forbs and other shrubs and grasses make up smaller components of this site.

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. An insect infestation on the sagebrush may also result in a mosaic pattern. 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 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 Sandberg bluegrass 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 and/or shadscale are present in trace amounts; perennial bunchgrasses, such as squirreltail and Sandberg bluegrass, and perennial forbs dominate the site. Depending on fire severity patches of intact sagebrush may remain. Yellow rabbitbrush may be sprouting or dominant in the community. Perennial forbs may be a significant component for a number of years following fire. Annual non-native species are stable or increasing within the community.

Gravelly Claypan 8-10" P.Z. (R027XY079NV), Current Potential 2.2, T. Stringham, May 2025

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 Pathway 2.2b, from Phase 2.2 to 2.4:
Higher than normal spring precipitation favors annual non-native species such as cheatgrass. Non-native annual species will increase in production and density throughout the site. Perennial bunchgrasses may also increase in production.

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. Yellow rabbitbrush may be a significant component. Squirreltail or Sandberg bluegrass 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.

Gravelly Claypan 8-10" P.Z. (R027XY079NV), Shrub State 2.3 At-Risk of Tree, T. Stringham, May 2025

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. Annual non-native species respond well to fire and may increase post burn.

Community Phase Pathway 2.3c, from Phase 2.3 to 2.4:
Fall, winter, and spring precipitation and temperatures mediate the ability for annual grasses and perennial grasses to germinate and/or survive. Higher than normal spring precipitation creates high annual production of annual grass (Bradley et al. 2018). Higher than normal spring precipitation favors annual non-native species such as cheatgrass. Non-native annual species increase in production and density throughout the site. Perennial bunchgrasses may also increase in production.

Community Phase 2.4 (At-Risk):
This community is at risk of crossing into an annual state. Native bunchgrasses dominate; however, annual non-native species such as cheatgrass may be sub- or co-dominant in the understory. Annual production and abundance of these annuals may

increase drastically in years with heavy spring precipitation. Seeded species may be present. Sagebrush is a minor component. This site is susceptible to further degradation from grazing, drought, and fire.

Community Phase Pathway 2.4a, from Phase 2.4 to 2.2:
Fall, winter, and spring precipitation and temperatures mediate the ability for annual grasses and perennial grasses to germinate and/or survive. Depending on temperatures and precipitation in winter and spring, annual grass production may be reduced in favor of perennial bunchgrasses.

Community Phase Pathway 2.4b, from Phase 2.4 to 2.3:
Rainfall patterns favoring perennial bunchgrasses. Less than normal spring precipitation followed by higher-than-normal summer precipitation will increase perennial bunchgrass production.

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 shallow-rooted 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 annual and perennial forb growth. Squirreltail and/or Sandberg bluegrass 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 Annual State 4.0:

Trigger: Fire or soil disturbing 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. Squirreltail and/or Sandberg bluegrass increase with a reduction in deep-rooted

perennial bunchgrass competition and become the dominant grasses. 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. 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. Rabbitbrush may be a significant component. Deep-rooted perennial bunchgrasses are present in trace amounts and may be absent from the community. Squirreltail, Sandberg bluegrass, and/or forbs dominate the understory. Bare ground may be significant.

Droughty Claypan 8-10" P.Z. (R027XY070NV), Shrub State 3.1, T. Stringham, May 2025

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 Squirreltail and/or Sandberg bluegrass to dominate the site.

Community Phase 3.2:
Annual and perennial forbs dominate the site (i.e. Hooker's balsamroot (*Balsamorhiza hookeri*) and tapertip hawksbeard (*Crepis acuminata*). Squirreltail and/or Sandberg bluegrass may increase and be co-dominant with forbs. Deep-rooted perennial bunchgrasses are a minor component or missing. Annual non-native species may be present but are not dominant. Trace amounts of sagebrush or rabbitbrush may be present.

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 Lahontan 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.

R3A: Transition from Shrub State 3.0 to Seeded State 6.0:

Wildfire restoration - seeding of crested wheatgrass (*Agropyron cristatum*), forage kochia (*Bassia prostrata*) and/or other desired species.

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 nonnative 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.

Shallow Claypan 8-10" P.Z. (R027XY020NV), Annual State 4.1, P. Novak-Echenique, March 2026

Community Phase Pathway 4.1a, from Phase 4.1 to 4.2:
Time and lack of disturbance allows rabbitbrush and/or other sprouting shrubs to recover after fire. Probability of sagebrush establishment is extremely low.

Community Phase 4.2:
Rabbitbrush is typically the dominant overstory shrub. Sagebrush is a minor component or missing. Annual non-native species dominate the understory.

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. Lahontan 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 (At-Risk):
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 forbs in the interspaces. Sagebrush is stressed and dying. Annual non-native species are present under tree canopies. Bare ground interspaces are large and connected.

Gravelly Claypan 8-10" P.Z. (R027XY079NV), Tree State 5.1, T. Stringham, June 2025

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 (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. Bunchgrass may or may not be present. Sandberg bluegrass and/or squirreltail or 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 transition to the Annual State 4.0. Inappropriate tree removal practices with soil disturbance will cause a transition to the Annual State 4.

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.

R5A: Restoration Pathway from Tree State 5.0 to Seeded State 6.0:

Removal of trees and seeding of introduced and/or native species. If restoration efforts fail, this site could transition to an Annual State 4.0.

Seeded State 6.0:

This state has two community phases: a grass-dominated phase, and a shrub/grass-dominated phase. This state is characterized by the dominance of seeded introduced wheatgrass species and forage kochia in the understory. Yellow rabbitbrush, Sandberg bluegrass, and squirreltail are common. A Seeded State was observed for the Gravelly Claypan 8-10" P.Z. (R027XY079NV) site but was not observed for the other sites in this DRG. Successful seedings are possible at the upper elevations of these sites and may be possible in the Shrub State and the Annual State.

Community Phase 6.1:
Seeded wheatgrass, forage kochia and/or other seeded species dominate the community. Non-native annual species are present. Trace amounts of Lahontan sagebrush may be present, especially if seeded.

Gravelly Claypan 8-10" P.Z. (R027XY079NV), Seeded State 6.1, T. Stringham, May 2025

Community Phase Pathway 6.1a, from Phase 6.1 to 6.2:
Time and lack of disturbance allow shrubs to increase. Pathway may be coupled with inappropriate grazing management.

Community Phase 6.2:
Lahontan sagebrush and yellow rabbitbrush increase and becomes dominant in the overstory. Seeded species dominate understory. Annual non-native species may be present in trace amounts.

Community Phase Pathway 6.2a, from Phase 6.2 to 6.1:
Fire and/or brush management coupled with proper grazing management.

Potential Resilience Differences with other Ecological Sites in this Group

Droughty Claypan 8-10" P.Z. (R027XY070NV):

The reference plant community is Lahontan sagebrush, Indian ricegrass and desert needlegrass. Bailey's greasewood, Nevada jointfir and Sandberg bluegrass are common species on this site. This site occurs on upper fan piedmont slopes and sideslopes of hills and lower mountains, occurs from approximately 4,500–6,500 ft and is slightly less productive with 250 lb/acre in a normal year. The soils are shallow to very shallow and well drained. The water capacity is very low. Subsurface layers have an increase in clay content in relation to the surface soil. This site is similar to the modal site but at higher elevations this site is usually restricted to southerly exposures, thus it is unlikely that a Tree State would occur on these dry exposures.

Droughty Claypan 8-10" P.Z. (R027XY070NV), Shrub State 3.1, T. Stringham (May 2025)

Shallow Claypan 8-10" P.Z. (R027XY020NV):

The reference plant community is dominated by Lahontan sagebrush and desert needlegrass. This site occurs on upper fan piedmonts and summits and sideslopes of hills and lower mountains at elevations from 4,500 to 6,000 ft. This site is restricted to northerly aspects at lower elevations of this site. This site is less productive than the modal site with only 200 lb/ac in a normal year. This site is similar to the modal site and may have a Tree State at the upper elevations if it’s associated with a nearby forest ecological site.

Shallow Claypan 8-10" P.Z. (R027XY020NV), Shrub State 3.1, T. Stringham, May 2025

Granitic Claypan 8-10" P.Z. (R027XY068NV):

The reference plant community is dominated by Lahontan sagebrush and desert needlegrass. This site occurs on fan piedmont slopes on slopes ranging from 2 to 15%. Elevations range from 5,000 to 7,000 ft. This site is more productive than the modal site with an average of 600 lb/ac in normal years. This site is similar to the modal site and may have a Tree State at the upper elevations if it’s associated with a nearby forest ecological site.

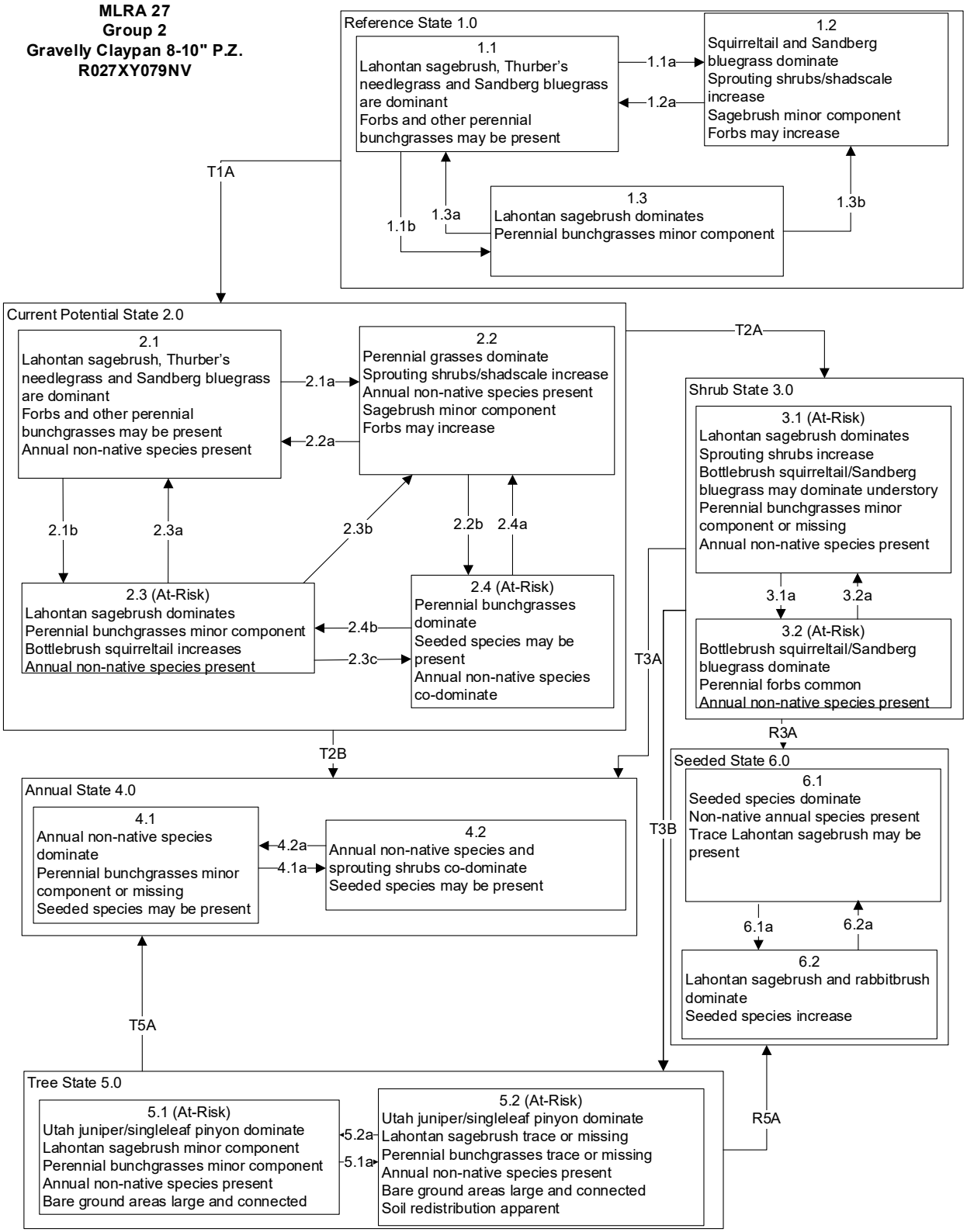
Granitic Claypan 8-10" P.Z. (R027XY068NV), Shrub State 2.2, T. Stringham, June 2025

Cobbly Claypan 8-10" P.Z. (R027XY049NV):

The reference plant community is dominated by Lahontan sagebrush and Thurber's needlegrass. This site occurs on mountain summits and sideslopes from 6,000 to 7,500 ft on slopes ranging from 8 to 50%. This site is restricted to northerly aspects at lower elevations of this site. Total annual production is 400 lb/ac in a normal year. A Tree State is likely to occur at the higher elevations of this site evidenced by remote sensing and aerial imagery.

Cobbly Claypan 8-10" P.Z. (R027XY049NV), Shrub State 3.1, T. Stringham, June 2025

Modal State and Transition Model for Group 2 in MRLA 27



MLRA 27
Group 2
Gravelly Claypan 8-10" P.Z.
R027XY079NV

Reference State 1.0 Community Pathways
1.1a: Fire decreases or eliminates the sagebrush overstory and allows perennial bunchgrasses to dominate. Low severity fire typically creates a mosaic pattern; insect infestation can also reduce sagebrush. High severity fire following an unusually wet spring may reduce sagebrush cover to trace amounts.
1.1b: Time and lack of disturbance such as fire allows sagebrush to increase and become decadent. Long-term drought, herbivory, or combinations of these reduce perennial bunchgrasses and fine fuels, reducing fire frequency and allowing sagebrush to dominate the site.
1.2a: Time and lack of disturbance allows sagebrush to increase and reestablish.
1.3a: Low severity fire, herbivory, insect infestation, or combinations will reduce the sagebrush overstory and create a sagebrush/grass mosaic.
1.3b: Fire decreases or eliminates the sagebrush overstory and allows perennial bunchgrasses to dominate. Fires may be high severity due to sagebrush dominance, resulting in removal of the overstory shrub community.

Transition T1A: Introduction of non-native annual plants.

Current Potential State 2.0 Community Pathways:
2.1a: Fire reduces the shrub overstory and allows perennial bunchgrasses to dominate. Low severity fire typically creates a mosaic pattern; insect infestation may also create a mosaic. High severity fire following an unusually wet spring or management that increases fine fuels may reduce sagebrush to trace amounts. Annual non-native species are likely to increase after fire.
2.1b: Time and lack of disturbance allows sagebrush to increase and become decadent. Long-term drought reduces fine fuels and fire frequency, allowing sagebrush to dominate. Inappropriate grazing management reduces the perennial bunchgrass understory.
2.2a: Time and lack of disturbance and/or grazing management that favors shrub establishment and growth allows the shrub component to recover.
2.2b: Higher than normal spring precipitation favors annual non-native species such as cheatgrass, increasing annual production and density throughout the site. Perennial bunchgrasses may also increase in production.
2.3a: Grazing management that reduces shrubs, heavy late-fall or winter grazing that mechanically damages sagebrush, brush treatments with minimal soil disturbance, or low severity fire decreases sagebrush and releases perennial bunchgrasses, creating a sagebrush/grass mosaic. Annual non-native species may increase.
2.3b: Fire eliminates or reduces the sagebrush overstory and allows understory perennial grasses to increase. Fire may be high severity due to sagebrush dominance, and annual non-native species may increase after burning.
2.3c: Fall, winter, and spring precipitation and temperatures mediate annual and perennial grass germination and survival. Higher than normal spring precipitation favors cheatgrass and other annual non-native species, increasing annual production and density throughout the site. Perennial bunchgrasses may also increase in production.
2.4a: Fall, winter, and spring precipitation and temperatures mediate annual and perennial grass germination and survival. Winter and spring conditions that reduce annual grass production may favor perennial bunchgrasses.
2.4b: Rainfall patterns favoring perennial bunchgrasses, especially less than normal spring precipitation followed by higher than normal summer precipitation, increase perennial bunchgrass production.

Transition T2A: Inappropriate grazing decreases or eliminates deep-rooted perennial bunchgrasses, increases bare ground and shallow-rooted grazing-tolerant grasses, and favors shrub growth and establishment. Severe fire in Phase 2.3 may remove sagebrush overstory, decrease perennial bunchgrasses, and enhance annual and perennial forb growth.
Transition T2B: Fire or soil-disturbing treatment transitions the site to the Annual State.

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 greatly reduce overstory shrubs.
3.2a: Time and lack of disturbance and/or grazing management that favors sagebrush establishment and growth allows the shrub component to recover.

Transition T3A: Fire and/or treatments that disturb soil and the existing plant community transition the site to the Annual State.
Transition T3B: Absence of disturbance over time allows Utah juniper and/or singleleaf pinyon dominance.
Restoration Pathway R3A: Wildfire restoration seeding of crested wheatgrass, forage kochia, and/or other desired species.

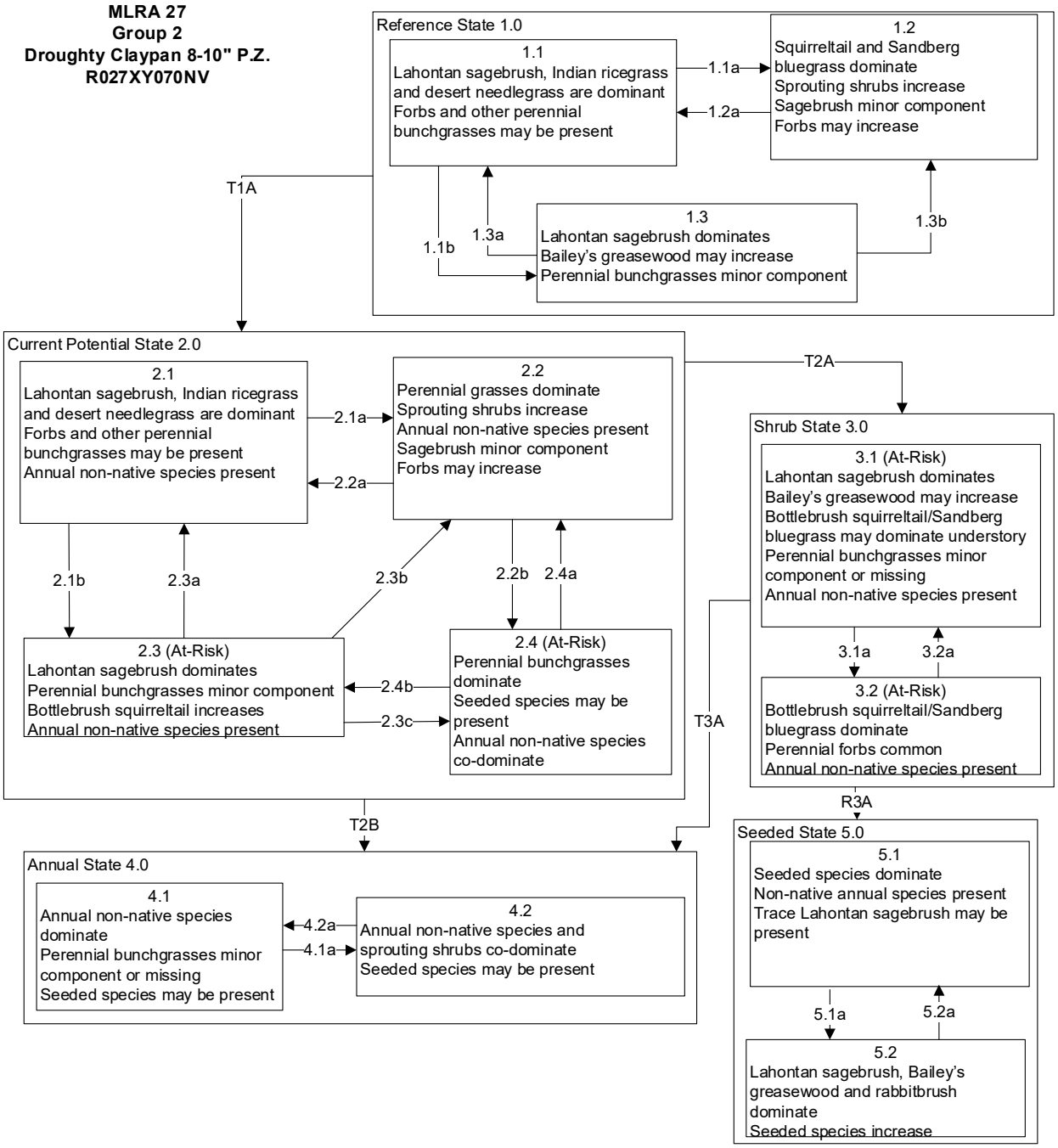
Annual State 4.0 Community Pathways
4.1a: Time and lack of disturbance allows rabbitbrush and/or other sprouting shrubs to recover after fire. Probability of sagebrush establishment is extremely low.
4.2a: Fire reduces or eliminates the overstory shrub component and allows annual non-native species to dominate the site.

Tree State 5.0 Community Pathways
5.1a: Time and lack of disturbance or management action allows Utah juniper and/or singleleaf pinyon to further mature and dominate site resources.
5.2a: Tree thinning treatment, typically for fuels management, reduces tree dominance and shifts the community toward the younger tree-dominated phase.

Transition T5A: Catastrophic stand-replacing fire or inappropriate tree removal practices with soil disturbance transitions the site to the Annual State.
Restoration Pathway R5A: Removal of trees and seeding of introduced or native species.

Seeded State 6.0 Community Pathways
6.1a: Time and lack of disturbance allows shrubs to increase. This pathway may be coupled with inappropriate grazing management, shifting the site toward a shrub/subshrub-dominated seeded phase.
6.2a: Fire or brush management coupled with proper grazing management.

Additional State and Transition Models for Group 2 in MLRA 27



MLRA 27
Group 2
Droughty Claypan 8-10" P.Z.
R027XY070NV

Reference State 1.0 Community Pathways
1.1a: Fire decreases or eliminates the sagebrush overstory and allows perennial bunchgrasses to dominate. Low severity fire typically creates a mosaic pattern; insect infestation can also reduce sagebrush. High severity fire following an unusually wet spring may reduce sagebrush cover to trace amounts.
1.1b: Time and lack of disturbance such as fire allows sagebrush to increase and become decadent. Long-term drought, herbivory, or combinations of these reduce perennial bunchgrasses and fine fuels, reducing fire frequency and allowing sagebrush to dominate the site.
1.2a: Time and lack of disturbance allows sagebrush to increase and reestablish.
1.3a: Low severity fire, herbivory, insect infestation, or combinations will reduce the sagebrush overstory and create a sagebrush/grass mosaic.
1.3b: Fire decreases or eliminates the sagebrush overstory and allows perennial bunchgrasses to dominate. Fires may be high severity due to sagebrush dominance, resulting in removal of the overstory shrub community.

Transition T1A: Introduction of non-native annual plants.

Current Potential State 2.0 Community Pathways:
2.1a: Fire reduces the shrub overstory and allows perennial bunchgrasses to dominate. Low severity fire typically creates a mosaic pattern; insect infestation may also create a mosaic. High severity fire following an unusually wet spring or management that increases fine fuels may reduce sagebrush to trace amounts. Annual non-native species are likely to increase after fire.
2.1b: Time and lack of disturbance allows sagebrush to increase and become decadent. Long-term drought reduces fine fuels and fire frequency, allowing sagebrush to dominate. Inappropriate grazing management reduces the perennial bunchgrass understory, although Sandberg bluegrass may increase depending on grazing management.
2.2a: Time and lack of disturbance and/or grazing management that favors shrub establishment and growth allows the shrub component to recover.
2.2b: Higher than normal spring precipitation favors annual non-native species such as cheatgrass, increasing annual production and density throughout the site. Perennial bunchgrasses may also increase in production.
2.3a: Grazing management that reduces shrubs, heavy late-fall or winter grazing that mechanically damages sagebrush, brush treatments with minimal soil disturbance, or low severity fire decreases sagebrush and releases perennial bunchgrasses, creating a sagebrush/grass mosaic. Annual non-native species may increase.
2.3b: Fire eliminates or reduces the sagebrush overstory and allows understory perennial grasses to increase. Fire may be high severity due to sagebrush dominance, and annual non-native species may increase after burning.
2.3c: Fall, winter, and spring precipitation and temperatures mediate annual and perennial grass germination and survival. Higher than normal spring precipitation favors cheatgrass and other annual non-native species, increasing annual production and density throughout the site. Perennial bunchgrasses may also increase in production.
2.4a: Fall, winter, and spring precipitation and temperatures mediate annual and perennial grass germination and survival. Winter and spring conditions that reduce annual grass production may favor perennial bunchgrasses.
2.4b: Rainfall patterns favoring perennial bunchgrasses, especially less than normal spring precipitation followed by higher than normal summer precipitation, increase perennial bunchgrass production.

Transition T2A: Inappropriate grazing decreases or eliminates deep-rooted perennial bunchgrasses, increases bare ground and shallow-rooted grazing-tolerant grasses, and favors shrub growth and establishment. Severe fire in Phase 2.3 may remove sagebrush overstory, decrease perennial bunchgrasses, and enhance annual and perennial forb growth.
Transition T2B: Fire or soil-disturbing treatment transitions the site to the Annual State.

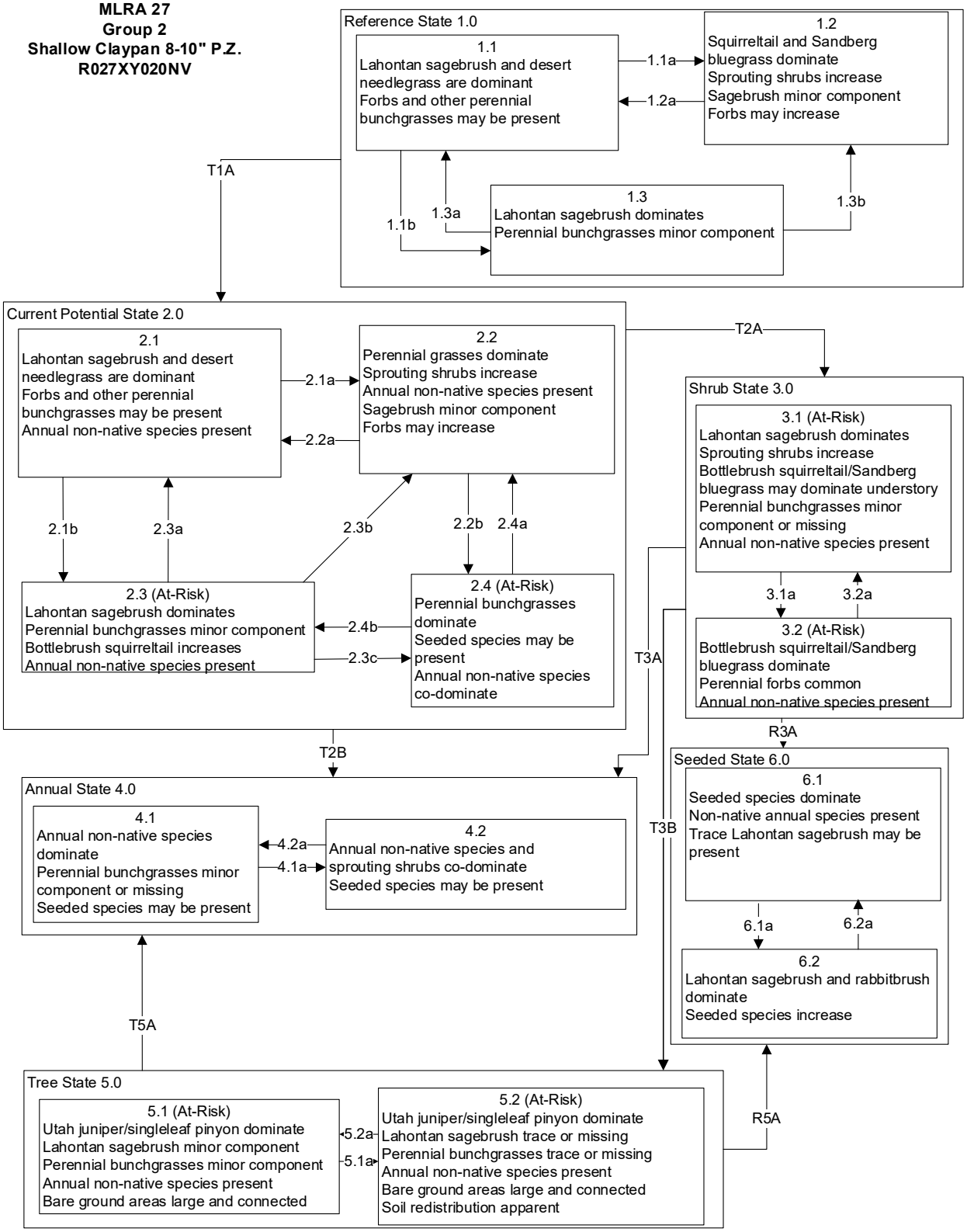
Shrub State 3.0 Community Pathways
3.1a: Fire, heavy fall grazing causing mechanical damage to shrubs, and/or brush treatments with minimal soil disturbance greatly reduce overstory shrubs.
3.2a: Time and lack of disturbance and/or grazing management that favors sagebrush establishment and growth allows the shrub component to recover.

Transition T3A: Fire and/or treatments that disturb soil and the existing plant community transition the site to the Annual State.
Transition T3B: Absence of disturbance over time allows Utah juniper and/or singleleaf pinyon dominance.
Restoration Pathway R3A: Wildfire restoration seeding of crested wheatgrass, forage kochia, and/or other desired species.

Annual State 4.0 Community Pathways
4.1a: Time and lack of disturbance allows rabbitbrush and/or other sprouting shrubs to recover after fire. Probability of sagebrush establishment is extremely low.
4.2a: Fire reduces or eliminates the overstory shrub component and allows annual non-native species to dominate the site.

Seeded State 5.0 Community Pathways
5.1a: Time and lack of disturbance allows shrubs to increase. This pathway may be coupled with inappropriate grazing management, shifting the site toward a shrub/subshrub-dominated seeded phase.
5.2a: Fire or brush management coupled with proper grazing management.

MLRA 27
Group 2
Shallow Claypan 8-10" P.Z.
R027XY020NV



MLRA 27
Group 2
Shallow Claypan 8-10" P.Z.
R027XY020NV

Reference State 1.0 Community Pathways
1.1a: Fire decreases or eliminates the sagebrush overstory and allows perennial bunchgrasses to dominate. Low severity fire typically creates a mosaic pattern; insect infestation can also reduce sagebrush. High severity fire following an unusually wet spring may reduce sagebrush cover to trace amounts.
1.1b: Time and lack of disturbance such as fire allows sagebrush to increase and become decadent. Long-term drought, herbivory, or combinations of these reduce perennial bunchgrasses and fine fuels, reducing fire frequency and allowing sagebrush to dominate the site.
1.2a: Time and lack of disturbance allows sagebrush to increase and reestablish.
1.3a: Low severity fire, herbivory, insect infestation, or combinations will reduce the sagebrush overstory and create a sagebrush/grass mosaic.
1.3b: Fire decreases or eliminates the sagebrush overstory and allows perennial bunchgrasses to dominate. Fires may be high severity due to sagebrush dominance, resulting in removal of the overstory shrub community.

Transition T1A: Introduction of non-native annual plants.

Current Potential State 2.0 Community Pathways:
2.1a: Fire reduces the shrub overstory and allows perennial bunchgrasses to dominate. Low severity fire typically creates a mosaic pattern; insect infestation may also create a mosaic. High severity fire following an unusually wet spring or management that increases fine fuels may reduce sagebrush to trace amounts. Annual non-native species are likely to increase after fire.
2.1b: Time and lack of disturbance allows sagebrush to increase and become decadent. Long-term drought reduces fine fuels and fire frequency, allowing sagebrush to dominate. Inappropriate grazing management reduces the perennial bunchgrass understory.
2.2a: Time and lack of disturbance and/or grazing management that favors shrub establishment and growth allows the shrub component to recover.
2.2b: Higher than normal spring precipitation favors annual non-native species such as cheatgrass, increasing annual production and density throughout the site. Perennial bunchgrasses may also increase in production.
2.3a: Grazing management that reduces shrubs, heavy late-fall or winter grazing that mechanically damages sagebrush, brush treatments with minimal soil disturbance, or low severity fire decreases sagebrush and releases perennial bunchgrasses, creating a sagebrush/grass mosaic. Annual non-native species may increase.
2.3b: Fire eliminates or reduces the sagebrush overstory and allows understory perennial grasses to increase. Fire may be high severity due to sagebrush dominance, and annual non-native species may increase after burning.
2.3c: Fall, winter, and spring precipitation and temperatures mediate annual and perennial grass germination and survival. Higher than normal spring precipitation favors cheatgrass and other annual non-native species, increasing annual production and density throughout the site. Perennial bunchgrasses may also increase in production.
2.4a: Fall, winter, and spring precipitation and temperatures mediate annual and perennial grass germination and survival. Winter and spring conditions that reduce annual grass production may favor perennial bunchgrasses.
2.4b: Rainfall patterns favoring perennial bunchgrasses, especially less than normal spring precipitation followed by higher than normal summer precipitation, increase perennial bunchgrass production.

Transition T2A: Inappropriate grazing decreases or eliminates deep-rooted perennial bunchgrasses, increases bare ground and shallow-rooted grazing-tolerant grasses, and favors shrub growth and establishment. Severe fire in Phase 2.3 may remove sagebrush overstory, decrease perennial bunchgrasses, and enhance annual and perennial forb growth.
Transition T2B: Fire or soil-disturbing treatment transitions the site to the Annual State.

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 greatly reduce overstory shrubs.
3.2a: Time and lack of disturbance and/or grazing management that favors sagebrush establishment and growth allows the shrub component to recover.

Transition T3A: Fire and/or treatments that disturb soil and the existing plant community transition the site to the Annual State.
Transition T3B: Absence of disturbance over time allows Utah juniper and/or singleleaf pinyon dominance.
Restoration Pathway R3A: Wildfire restoration seeding of crested wheatgrass, forage kochia, and/or other desired species.

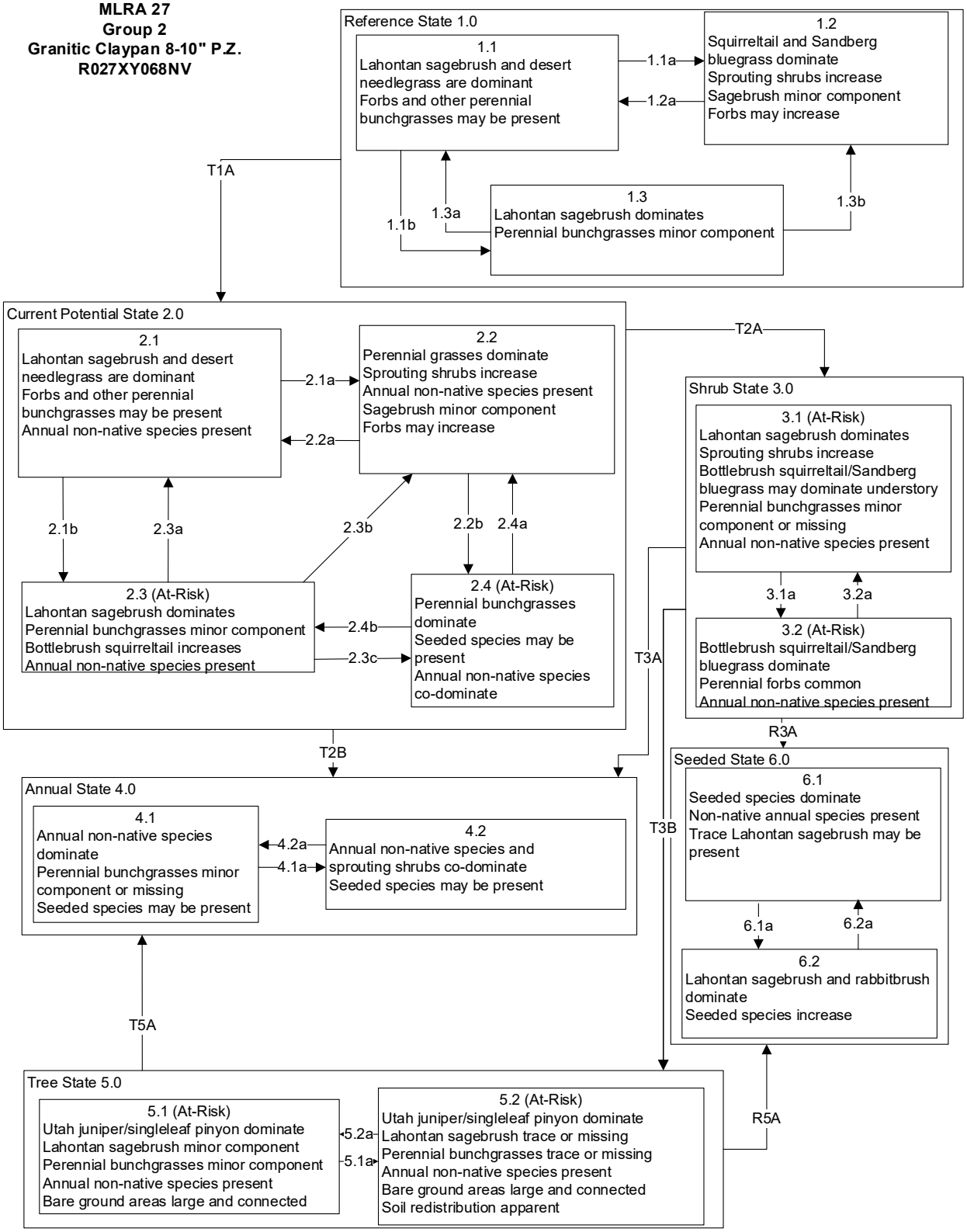
Annual State 4.0 Community Pathways
4.1a: Time and lack of disturbance allows rabbitbrush and/or other sprouting shrubs to recover after fire. Probability of sagebrush establishment is extremely low.
4.2a: Fire reduces or eliminates the overstory shrub component and allows annual non-native species to dominate the site.

Tree State 5.0 Community Pathways
5.1a: Time and lack of disturbance or management action allows Utah juniper and/or singleleaf pinyon to further mature and dominate site resources.
5.2a: Tree thinning treatment, typically for fuels management, reduces tree dominance and shifts the community toward the younger tree-dominated phase.

Transition T5A: Catastrophic stand-replacing fire or inappropriate tree removal practices with soil disturbance transitions the site to the Annual State.
Restoration Pathway R5A: Removal of trees and seeding of introduced or native species.

Seeded State 6.0 Community Pathways
6.1a: Time and lack of disturbance allows shrubs to increase. This pathway may be coupled with inappropriate grazing management, shifting the site toward a shrub/subshrub-dominated seeded phase.
6.2a: Fire or brush management coupled with proper grazing management.

MLRA 27
Group 2
Granitic Claypan 8-10" P.Z.
R027XY068NV



MLRA 27
Group 2
Granitic Claypan 8-10" P.Z.
R027XY068NV

Reference State 1.0 Community Pathways
1.1a: Fire decreases or eliminates the sagebrush overstory and allows perennial bunchgrasses to dominate. Low severity fire typically creates a mosaic pattern; insect infestation can also reduce sagebrush. High severity fire following an unusually wet spring may reduce sagebrush cover to trace amounts.
1.1b: Time and lack of disturbance such as fire allows sagebrush to increase and become decadent. Long-term drought, herbivory, or combinations of these reduce perennial bunchgrasses and fine fuels, reducing fire frequency and allowing sagebrush to dominate the site.
1.2a: Time and lack of disturbance allows sagebrush to increase and reestablish.
1.3a: Low severity fire, herbivory, insect infestation, or combinations will reduce the sagebrush overstory and create a sagebrush/grass mosaic.
1.3b: Fire decreases or eliminates the sagebrush overstory and allows perennial bunchgrasses to dominate. Fires may be high severity due to sagebrush dominance, resulting in removal of the overstory shrub community.

Transition T1A: Introduction of non-native annual plants.

Current Potential State 2.0 Community Pathways:
2.1a: Fire reduces the shrub overstory and allows perennial bunchgrasses to dominate. Low severity fire typically creates a mosaic pattern; insect infestation may also create a mosaic. High severity fire following an unusually wet spring or management that increases fine fuels may reduce sagebrush to trace amounts. Annual non-native species are likely to increase after fire.
2.1b: Time and lack of disturbance allows sagebrush to increase and become decadent. Long-term drought reduces fine fuels and fire frequency, allowing sagebrush to dominate. Inappropriate grazing management reduces the perennial bunchgrass understory.
2.2a: Time and lack of disturbance and/or grazing management that favors shrub establishment and growth allows the shrub component to recover.
2.2b: Higher than normal spring precipitation favors annual non-native species such as cheatgrass, increasing annual production and density throughout the site. Perennial bunchgrasses may also increase in production.
2.3a: Grazing management that reduces shrubs, heavy late-fall or winter grazing that mechanically damages sagebrush, brush treatments with minimal soil disturbance, or low severity fire decreases sagebrush and releases perennial bunchgrasses, creating a sagebrush/grass mosaic. Annual non-native species may increase.
2.3b: Fire eliminates or reduces the sagebrush overstory and allows understory perennial grasses to increase. Fire may be high severity due to sagebrush dominance, and annual non-native species may increase after burning.
2.3c: Fall, winter, and spring precipitation and temperatures mediate annual and perennial grass germination and survival. Higher than normal spring precipitation favors cheatgrass and other annual non-native species, increasing annual production and density throughout the site. Perennial bunchgrasses may also increase in production.
2.4a: Fall, winter, and spring precipitation and temperatures mediate annual and perennial grass germination and survival. Winter and spring conditions that reduce annual grass production may favor perennial bunchgrasses.
2.4b: Rainfall patterns favoring perennial bunchgrasses, especially less than normal spring precipitation followed by higher than normal summer precipitation, increase perennial bunchgrass production.

Transition T2A: Inappropriate grazing decreases or eliminates deep-rooted perennial bunchgrasses, increases bare ground and shallow-rooted grazing-tolerant grasses, and favors shrub growth and establishment. Severe fire in Phase 2.3 may remove sagebrush overstory, decrease perennial bunchgrasses, and enhance annual and perennial forb growth.
Transition T2B: Fire or soil-disturbing treatment transitions the site to the Annual State.

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 greatly reduce overstory shrubs.
3.2a: Time and lack of disturbance and/or grazing management that favors sagebrush establishment and growth allows the shrub component to recover.

Transition T3A: Fire and/or treatments that disturb soil and the existing plant community transition the site to the Annual State.
Transition T3B: Absence of disturbance over time allows Utah juniper and/or singleleaf pinyon dominance.
Restoration Pathway R3A: Wildfire restoration seeding of crested wheatgrass, forage kochia, and/or other desired species.

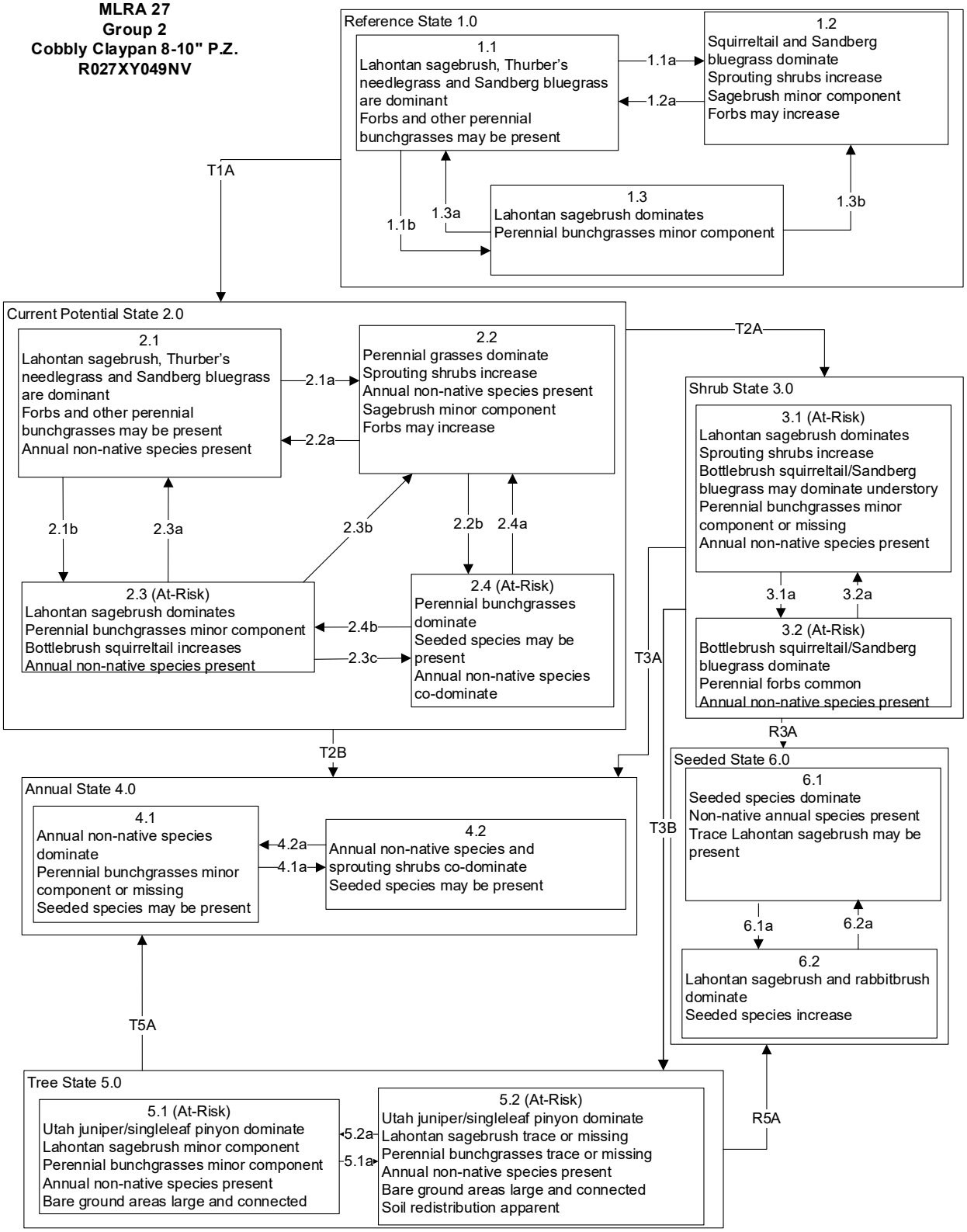
Annual State 4.0 Community Pathways
4.1a: Time and lack of disturbance allows rabbitbrush and/or other sprouting shrubs to recover after fire. Probability of sagebrush establishment is extremely low.
4.2a: Fire reduces or eliminates the overstory shrub component and allows annual non-native species to dominate the site.

Tree State 5.0 Community Pathways
5.1a: Time and lack of disturbance or management action allows Utah juniper and/or singleleaf pinyon to further mature and dominate site resources.
5.2a: Tree thinning treatment, typically for fuels management, reduces tree dominance and shifts the community toward the younger tree-dominated phase.

Transition T5A: Catastrophic stand-replacing fire or inappropriate tree removal practices with soil disturbance transitions the site to the Annual State.
Restoration Pathway R5A: Removal of trees and seeding of introduced or native species.

Seeded State 6.0 Community Pathways
6.1a: Time and lack of disturbance allows shrubs to increase. This pathway may be coupled with inappropriate grazing management, shifting the site toward a shrub/subshrub-dominated seeded phase.
6.2a: Fire or brush management coupled with proper grazing management.

MLRA 27
Group 2
Cobbly Claypan 8-10" P.Z.
R027XY049NV



MLRA 27
Group 2
Cobbly Claypan 8-10" P.Z.
R027XY049NV

Reference State 1.0 Community Pathways
1.1a: Fire decreases or eliminates the sagebrush overstory and allows perennial bunchgrasses to dominate. Low severity fire typically creates a mosaic pattern; insect infestation can also reduce sagebrush. High severity fire following an unusually wet spring may reduce sagebrush cover to trace amounts.
1.1b: Time and lack of disturbance such as fire allows sagebrush to increase and become decadent. Long-term drought, herbivory, or combinations of these reduce perennial bunchgrasses and fine fuels, reducing fire frequency and allowing sagebrush to dominate the site.
1.2a: Time and lack of disturbance allows sagebrush to increase and reestablish.
1.3a: Low severity fire, herbivory, insect infestation, or combinations will reduce the sagebrush overstory and create a sagebrush/grass mosaic.
1.3b: Fire decreases or eliminates the sagebrush overstory and allows perennial bunchgrasses to dominate. Fires may be high severity due to sagebrush dominance, resulting in removal of the overstory shrub community.

Transition T1A: Introduction of non-native annual plants.

Current Potential State 2.0 Community Pathways:
2.1a: Fire reduces the shrub overstory and allows perennial bunchgrasses to dominate. Low severity fire typically creates a mosaic pattern; insect infestation may also create a mosaic. High severity fire following an unusually wet spring or management that increases fine fuels may reduce sagebrush to trace amounts. Annual non-native species are likely to increase after fire.
2.1b: Time and lack of disturbance allows sagebrush to increase and become decadent. Long-term drought reduces fine fuels and fire frequency, allowing sagebrush to dominate. Inappropriate grazing management reduces the perennial bunchgrass understory.
2.2a: Time and lack of disturbance and/or grazing management that favors shrub establishment and growth allows the shrub component to recover.
2.2b: Higher than normal spring precipitation favors annual non-native species such as cheatgrass, increasing annual production and density throughout the site. Perennial bunchgrasses may also increase in production.
2.3a: Grazing management that reduces shrubs, heavy late-fall or winter grazing that mechanically damages sagebrush, brush treatments with minimal soil disturbance, or low severity fire decreases sagebrush and releases perennial bunchgrasses, creating a sagebrush/grass mosaic. Annual non-native species may increase.
2.3b: Fire eliminates or reduces the sagebrush overstory and allows understory perennial grasses to increase. Fire may be high severity due to sagebrush dominance, and annual non-native species may increase after burning.
2.3c: Fall, winter, and spring precipitation and temperatures mediate annual and perennial grass germination and survival. Higher than normal spring precipitation favors cheatgrass and other annual non-native species, increasing annual production and density throughout the site. Perennial bunchgrasses may also increase in production.
2.4a: Fall, winter, and spring precipitation and temperatures mediate annual and perennial grass germination and survival. Winter and spring conditions that reduce annual grass production may favor perennial bunchgrasses.
2.4b: Rainfall patterns favoring perennial bunchgrasses, especially less than normal spring precipitation followed by higher than normal summer precipitation, increase perennial bunchgrass production.

Transition T2A: Inappropriate grazing decreases or eliminates deep-rooted perennial bunchgrasses, increases bare ground and shallow-rooted grazing-tolerant grasses, and favors shrub growth and establishment. Severe fire in Phase 2.3 may remove sagebrush overstory, decrease perennial bunchgrasses, and enhance annual and perennial forb growth.
Transition T2B: Fire or soil-disturbing treatment transitions the site to the Annual State.

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 greatly reduce overstory shrubs.
3.2a: Time and lack of disturbance and/or grazing management that favors sagebrush establishment and growth allows the shrub component to recover.

Transition T3A: Fire and/or treatments that disturb soil and the existing plant community transition the site to the Annual State.
Transition T3B: Absence of disturbance over time allows Utah juniper and/or singleleaf pinyon dominance.
Restoration Pathway R3A: Wildfire restoration seeding of crested wheatgrass, forage kochia, and/or other desired species.

Annual State 4.0 Community Pathways
4.1a: Time and lack of disturbance allows rabbitbrush and/or other sprouting shrubs to recover after fire. Probability of sagebrush establishment is extremely low.
4.2a: Fire reduces or eliminates the overstory shrub component and allows annual non-native species to dominate the site.

Tree State 5.0 Community Pathways
5.1a: Time and lack of disturbance or management action allows Utah juniper and/or singleleaf pinyon to further mature and dominate site resources.
5.2a: Tree thinning treatment, typically for fuels management, reduces tree dominance and shifts the community toward the younger tree-dominated phase.

Transition T5A: Catastrophic stand-replacing fire or inappropriate tree removal practices with soil disturbance transitions the site to the Annual State.
Restoration Pathway R5A: Removal of trees and seeding of introduced or native species.

Seeded State 6.0 Community Pathways
6.1a: Time and lack of disturbance allows shrubs to increase. This pathway may be coupled with inappropriate grazing management, shifting the site toward a shrub/subshrub-dominated seeded phase.
6.2a: Fire or brush management coupled with proper grazing management.

References

Abella, S. R. 2009. Post-fire plant recovery in the Mojave and Sonoran Deserts of western North America. Journal of Arid Environments **73**:699-707.

Baker, W. L. 2006. Fire and restoration of sagebrush ecosystems. Wildlife Society Bulletin **34**:177-185.

Bates, J. D., T. Svejcar, R. F. Miller, and R. A. Angell. 2006. The effects of precipitation timing on sagebrush steppe vegetation. Journal of Arid Environments **64**:670-697.

Beardall, L. E., and V. E. Sylvester. 1976. Spring burning for removal of sagebrush competition in Nevada. Pages 539-547 *in* Proceedings, Tall Timbers Fire Ecology Conference and Fire and Land Management Symposium; Missoula, MT. Tall Timbers Research Station, Tallahassee, FL.

Beatley, J. C. 1975. Climates and vegetation pattern across the Mojave/Great Basin Desert transition of southern Nevada. The American Midland Naturalist **93**:53-70.

Beckstead, J., and C. K. Augspurger. 2004. An experimental test of resistance to cheatgrass invasion: Limiting resources at different life stages. Biological Invasions **6**:417-432.

Bertiller, M. B., A. M. Beeskow, and F. Coronato. 1991. Seasonal environmental variation and plant phenology in arid Patagonia (Argentina). Journal of Arid Environments **21**:1-11.

Bich, B. S., J. L. Butler, and C. A. Schmidt. 1995. Effects of differential livestock use on key plant species and rodent populations within selected *Oryzopsis hymenoides*/*Hilaria jamesii* communities of Glen Canyon National Recreation Area. The Southwestern Naturalist **40**:281-287.

Blackburn, W. H., P. T. Tueller, and R. E. Eckert Jr. 1968a. Vegetation and soils of the Crowley Creek Watershed. University of Nevada, Max C. Fleischmann College of Agriculture, Reno, NV.

Blackburn, W. H., P. T. Tueller, and R. E. Eckert Jr. 1968b. Vegetation and soils of the Duckwater Watershed. University of Nevada, Max C. Fleischmann College of Agriculture, Reno, NV.

Blackburn, W. H., P. T. Tueller, and R. E. Eckert Jr. 1969. Vegetation and soils of the Churchill Canyon Watershed. University of Nevada, Max C. Fleischmann College of Agriculture, Agricultural Experiment Station, Reno, NV.

Blaisdell, J. P., and R. C. Holmgren. 1984. Managing intermountain rangelands - salt-desert shrub ranges. General Technical Report INT-163, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Blaisdell, J. P., R. B. Murray, and E. D. McArthur. 1982. Managing intermountain rangelands - sagebrush-grass ranges. General Technical Report INT-134, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Booth, D. T., C. G. Howard, and C. E. Mowry. 1980. 'Nezpar' Indian ricegrass: description, justification for release, and recommendations for use. Rangelands **2**:53-54.

Bovey, W. R., D. Le Tourneau, and C. L. Erickson. 1961. The chemical composition of medusahead and downy brome. Weeds **9**:307-311.

Bradford, J. B., and W. K. Lauenroth. 2006. Controls over invasion of *Bromus tectorum*: the importance of climate, soil, disturbance and seed availability. Journal of Vegetation Science **17**:693-704.

Bradley, A. F., N. V. Noste, and W. C. Fischer. 1992. Fire ecology of forests and woodlands in Utah. General Technical Report INT-287, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Bradley, B. A., C. A. Curtis, E. J. Fusco, J. T. Abatzoglou, J. K. Balch, S. Dadashi, and M.-N. Tuanmu. 2018. Cheatgrass (*Bromus tectorum*) distribution in the intermountain Western United States and its relationship to fire frequency, seasonality, and ignitions. Biological Invasions **20**:1493-1506.

Braun, C. E., J. W. Connelly, and M. A. Schroeder. 2005. Seasonal habitat requirements for sage-grouse: spring, summer, fall, and winter. Pages 38-42 *in* Sage-grouse Habitat Restoration Symposium Proceedings. RMRS-P-38. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Britton, C. M., G. R. McPherson, and F. A. Sneva. 1990. Effects of burning and clipping on five bunchgrasses in eastern Oregon. The Great Basin Naturalist **50**:115-120.

Butler, M., F. Brummer, J. Weber, and R. Simmons. 2011. Restoring Central Oregon rangeland from ventenata and medusahead to a sustainable bunchgrass environment – Warm Springs and Ashwood. COARC 2011, Oregon State University, Central Oregon Agricultural Research and Extension Center, Corvallis, OR.

Caudle, D., J. DiBenedetto, M. Karl, H. Sanchez, and C. Talbot. 2013. Interagency ecological site handbook for rangelands. U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.

Chambers, J. C., B. A. Bradley, C. S. Brown, C. D'Antonio, M. J. Germino, J. B. Grace, S. P. Hardegree, R. F. Miller, and D. A. Pyke. 2013. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of western North America. Ecosystems **17**:360-375.

Chambers, J. C., B. A. Roundy, R. R. Blank, S. E. Meyer, and A. Whittaker. 2007. What makes Great Basin sagebrush ecosystems invasible by *Bromus tectorum*? Ecological Monographs **77**:117-145.

Comstock, J. P., and J. R. Ehleringer. 1992. Plant adaptation in the Great Basin and Colorado Plateau. The Great Basin Naturalist **52**:195-215.

Cook, C. W., and R. D. Child. 1971. Recovery of desert plants in various states of vigor. Rangeland Ecology & Management/Journal of Range Management Archives **24**:339-343.

Cook, C. W., K. Taylor, and L. E. Harris. 1962. The effect of range condition and intensity of grazing upon daily intake and nutritive value of the diet on desert ranges. Journal of Range Management **15**:1-6.

Daubenmire, R. 1970. Steppe vegetation of Washington. Technical Report 62, Washington State University, Washington Agricultural Experiment Station, Pullman, WA.

Daubenmire, R. 1975. Plant succession on abandoned fields, and fire influences in a steppe area in southeastern Washington. Northwest Science **49**:36-48.

Davies, K. W., C. S. Boyd, D. D. Johnson, A. M. Nafus, and M. D. Madsen. 2015b. Success of seeding native compared with introduced perennial vegetation for revegetating

medusahead-invaded sagebrush rangeland. Rangeland Ecology & Management **68**:224-230.

Davies, K. W., and D. D. Johnson. 2008. Managing medusahead in the intermountain west is at a critical threshold. Rangelands **30**:13-15.

Davies, K. W., A. M. Nafus, and M. D. Madsen. 2013. Medusahead invasion along unimproved roads, animal trails, and random transects. Western North American Naturalist **73**:54-59.

Dobrowolski, J. P., M. M. Caldwell, and J. H. Richards. 1990. Chapter 7: Basin hydrology and plant root systems. Pages 243-292 *in* C. B. Osmond, L. F. Pitelka, and G. M. Hidy, editors. Plant Biology of the Basin and Range. Springer-Verlag, New York City, NY.

Eckert, R. E., Jr., and J. S. Spencer. 1987. Growth and reproduction of grasses heavily grazed under rest-rotation management. Journal of Range Management **40**:156-159.

Everett, R. L., P. T. Tueller, J. B. Davis, and A. D. Brunner. 1980. Plant phenology in galleta-shadscale and galleta-sagebrush associations. Rangeland Ecology & Management/Journal of Range Management Archives **33**:446-450.

Evert, R. F. 2006. Esau's plant anatomy: Meristems, cells, and tissues of the plant body - Their structure, function, and development. Third Edition edition. John Wiley & Sons, Inc., Hoboken, New Jersey.

Fosberg, M. A., and M. Hironaka. 1964. Soil properties affecting the distribution of big and low sagebrush communities in southern Idaho. Pages 230-236 *in* Forage plant physiology and soil-range plant relationships. Annual Meetings of the American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America; Denver, CO; November 17-21, 1963. ASA Special Publication No. 5. American Society of Agronomy, Madison, WI.

Furbush, P. 1953. Control of medusa-head on California ranges. Journal of Forestry **51**:118-121.

Furniss, M. M., and W. F. Barr. 1975. Insects affecting important native shrubs of the Northwestern United States. General Technical Report INT-19, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Ganskopp, D., L. Aguilera, and M. Vavra. 2007. Livestock forage conditioning among six northern Great Basin grasses. Rangeland Ecology & Management **60**:71-78.

Ganskopp, D. L. 1988. Defoliation of Thurber needlegrass: herbage and root responses. Journal of Range Management **41**:472-476.

Harrington, H. D. 1954. Manual of the plants of Colorado: For the identification of the ferns and flowering plants of the state. Sage Books, Denver, CO.

Harris, G. A. 1967. Some competitive relationships between Agropyron spicatum and Bromus tectorum. Ecological Monographs **37**:89-111.

Hironaka, M. 1994. Medusahead: Natural successor to the cheatgrass type in the northern Great Basin. Pages 89-91 *in* Proceedings—Ecology and management of annual rangelands; September 1994; Boise, ID. General Technical Report INT-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Hironaka, M., M. A. Fosberg, and A. H. Winward. 1983. Sagebrush-grass habitat types of southern Idaho. Bulletin No. 35, University of Idaho, Forest, Wildlife and Range Experiment Station, Moscow, ID.

Hutchings, S. S., and G. Stewart. 1953. Increasing forage yields and sheep production on intermountain winter ranges. Circular No. 925, U.S. Department of Agriculture, Washington, D.C.

James, J. J., K. W. Davies, R. L. Sheley, and Z. T. Aanderud. 2008. Linking nitrogen partitioning and species abundance to invasion resistance in the Great Basin. Oecologia **156**:637-648.

Jensen, M. E. 1990. Interpretation of environmental gradients which influence sagebrush community distribution in northeastern Nevada. Journal of Range Management **43**:161-167.

Johnson, B. G., W. J. Dale, J. C. Chambers, and R. R. Blank. 2011. Fire effects on the mobilization and uptake of nitrogen by cheatgrass (*Bromus tectorum* L.). Plant Soil **341**:437-445.

Johnson, R., E. Leger, and K. Vance-Borland. 2017. Genecology of Thurber's Needlegrass (Achnatherum thurberianum [Piper] Barkworth) in the Western United States. Rangeland Ecology & Management **70**:509-517.

Jones, T. A. 1990. A viewpoint on Indian ricegrass research: its present status and future prospects. Journal of Range Management **43**:416-420.

Kearney, T. H., R. H. Peebles, J. T. Howell, and E. McClintock. 1960. Arizona flora. Second edition. University of California Press, Berkeley, CA.

Klemmedson, J. O., and J. G. Smith. 1964. Cheatgrass (*Bromus tectorum* L.). The Botanical Review **30**:226-262.

Knick, S. T., A. L. Holmes, and R. F. Miller. 2005. The role of fire in structuring sagebrush habitats and bird communities. Studies in Avian Biology **30**:1-13.

Koniak, S. 1985b. Succession in pinyon-juniper woodlands following wildfire in the Great Basin. The Great Basin Naturalist **45**:556-566.

Laycock, W. A. 1967. How heavy grazing and protection affect sagebrush-grass ranges. Journal of Range Management **20**:206-213.

Mack, R. N., and D. A. Pyke. 1983. The demography of *Bromus tectorum*: Variation in time and space. Journal of Ecology **71**:69-93.

MacMahon, J. A. 1980. Ecosystems over time: Succession and other types of change. Pages 27-58 *in* Forests: Fresh Perspectives from Ecosystem Analysis - Proceedings of the 40th Annual Biology Colloquium. Oregon State University Press, Corvallis, OR.

Mangla, S., R. L. Sheley, and J. J. James. 2011. Field growth comparisons of invasive alien annual and native perennial grasses in monocultures. Journal of Arid Environments **75**:206-210.

McAdoo, J. K., and G. N. Back. 2001. Sage grouse biology. FS-01-43, University of Nevada, Reno Extension, Reno, NV.

McArthur, E. D. 2005. Sagebrush, common and uncommon, palatable and unpalatable. Rangelands **27**:47-51.

Miller, H. C., D. Clausnitzer, and M. M. Borman. 1999a. Medusahead. Pages 272-281 *in* R. L. S. a. J. K. Petroff, editor. Biology and Management of Noxious Rangeland Weeds. Oregon State University Press, Oregon State University.

Miller, R. F., J. C. Chambers, D. A. Pyke, F. B. Pierson, and C. J. Williams. 2013. A review of fire effects on vegetation and soils in the Great Basin Region: Response and ecological site characteristics. General Technical Report RMRS-GTR-308, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Miller, R. F., and J. A. Rose. 1995. Historic expansion of *Juniperus occidentalis* (western juniper) in southeastern Oregon. The Great Basin Naturalist **55**:37-45.

Miller, R. F., and J. A. Rose. 1999. Fire history and western juniper encroachment in sagebrush steppe. Journal of Range Management **52**:550-559.

NRCS. 2022. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. Handbook 296, U.S. Department of Agriculture, Natural Resources Conservation Service.

Ogle, D., St. John, L, Tilley, D, Jones, T. 2006. Plant Guide for Thurber's Needlegrass. USDA NRCS, USDA NRCS Idaho State Office.

Pearson, L. C. 1964. Effect of harvest date on recovery of range grasses and shrubs. Agronomy Journal **56**:80-82.

Pearson, L. C. 1965. Primary production in grazed and ungrazed desert communities of eastern Idaho. Ecology **46**:278-285.

Pellant, M., and C. Hall. 1994. Distribution of two exotic grasses in intermountain rangelands: Status in 1992. Pages 109-112 *in* S. B. Monsen and S. G. Kitchen, editors. Proceedings—Ecology and management of annual rangelands; General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Perkins, S. 2008a. Plant fact sheet for desert needlegrass (*Achnatherum speciosum*). USDA NRCS Great Basin Plant Materials Center, Fallon, Nevada.

Perryman, B. L., and Q. D. Skinner. 2007. A Field Guide to Nevada Grasses. Indigenous Rangeland Management Press, Lander, WY.

Quinones, F. A. 1981. Indian ricegrass evaluation and breeding. Bulletin 681, New Mexico State University, Agricultural Experiment Station, Las Cruces, NM.

Ralphs, M. H., and F. E. Busby. 1979. Prescribed burning: vegetative change, forage production, cost, and returns on six demonstration burns in Utah. Journal of Range Management **32**:267-270.

Rice, P. M. 2005. Medusahead (*Taeniatherum caput-medusae* (L.) Nevski). Pages 171-178 *in* C. L. Duncan and J. K. Clark, editors. Invasive plants of range and wildlands and their environmental, economic, and societal impacts. Weed Science Society of America, Lawrence, KS.

Rosentreter, R. 2005. Sagebrush identification, ecology, and palatability relative to sage-grouse. Pages 3-16 *in* Sage-grouse habitat restoration symposium proceedings; Boise, ID; June 4-7, 2001. Proceedings RMRS-P-38. U.S. Department of AgricultureForest Service, Rocky Mountain Research Station, Fort Collins, CO.

Sampson, A. W., A. Chase, and D. W. Hedrick. 1951. California grasslands and range forage grasses. Bulletin 724, University of California, the College of Agriculture, California Agricultural Experiment Station, Berkeley, CA.

Schlaepfer, D. R., J. B. Bradford, W. K. Lauenroth, S. M. Munson, B. Tietjen, S. A. Hall, S. D. Wilson, M. C. Duniway, G. Jia, D. A. Pyke, A. Lkhagva, and K. Jamiyansharav. 2017. Climate change reduces extent of temperate drylands and intensifies drought in deep soils. Nature Communications **8**:14196.

Sheehy, D. P., and A. H. Winward. 1981. Relative palatability of seven *Artemisia* taxa to mule deer and sheep. Journal of Range Management **34**:397-399.

Sheley, R. L., E. A. Vasquez, A.-M. Chamberlain, and B. S. Smith. 2012. Landscape-scale rehabilitation of medusahead (*Taeniatherum caput-medusae*)-dominated sagebrush steppe. Invasive Plant Science and Management **5**:436-442.

Smith, M. A., and F. Busby. 1981. Prescribed burning, effective control of sagebrush in Wyoming. RJ-165, Agricultural Experiment Station, University of Wyoming, Laramie, WY.

Snyder, K. A., L. Evers, J. C. Chambers, J. Dunham, J. B. Bradford, and M. E. Loik. 2019. Effects of changing climate on the hydrological cycle in cold desert ecosystems of the Great Basin and Columbia Plateau. Rangeland Ecology & Management **72**:1-12.

Thatcher, P. A., and L. V. Hart. 1974. Spy Mesa yields better understanding of pinyon-juniper in range ecosystem. Journal of Range Management **27**:354.

Tisdale, E. W., and M. Hironaka. 1981. The sagebrush - grass region: A review of the ecological literature. Forest, Wildlife and Range Experiment Station, University of Idaho **209**.

Uresk, D. W., J. F. Cline, and W. H. Rickard. 1976b. Impact of wildfire on three perennial grasses in south-central Washington. Journal of Range Management **29**:309-310.

Vallentine, J. F. 1989. Range development and improvements. Academic Press, Inc., San Diego, CA.

Vollmer, J. L., and J. G. Vollmer. 2008. Controlling cheatgrass in winter range to restore habitat and endemic fire. Pages 57-60 *in* Proceedings—Shrublands under fire: Disturbance and recovery in a changing world. RMRS-P-52. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Cedar City, UT.

West, N. E. 1994. Effects of fire on salt-desert shrub rangelands. Pages 71-74 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, ID.

Whisenant, S. G. 1999. Repairing damaged wildlands: A process orientated, landscape-scale approach. Illustrated Edition edition. Cambridge University Press, New York, NY.

Winward, A. H. 1980. Taxonomy and ecology of sagebrush in Oregon. Station Bulletin 642, Oregon State University, Agricultural Experiment Station, Corvallis, OR.

Winward, A. H., and E. D. McArthur. 1995. Lahontan sagebrush (*Artemisia arbuscula* ssp. *longicaulis*): a new taxon. Great Basin Naturalist **55**:151-157.

Wright, H. A. 1985. Effects of fire on grasses and forbs in sagebrush-grass communities. Pages 12-21 *in* Rangeland fire effects: A symposium; Boise, ID; November 27-29, 1984. U.S. Department of the Interior, Bureau of Land Management, Boise, ID.

Wright, H. A., and J. O. Klemmedson. 1965. Effect of fire on bunchgrasses of the sagebrush-grass region in Southern Idaho. Ecology **46**:680-688.

Wright, H. A., L. F. Neuenschwander, and C. M. Dritton. 1979. The role and use of fire in sagebrush-grass and pinyon-juniper plant communities: A state-of-the-art review.

General Technical Report INT-58, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Wuebbles, D. J., D. W. Fahey, K. A. Hibbard, D. J. Dokken, B. C. Stewart, and T. K. Maycock. 2017. Climate science special report: Fourth national climate assessment. Volume 1, U.S. Global Change Research Program, Washington, D.C.

Young, R. P. 1983. Fire as a vegetation management tool in rangelands of the intermountain region. Pages 18-31 *in* Managing Intermountain rangelands—Improvement of range and wildlife habitats. Proceedings of Symposia: September 15-17, 1981, Twin Falls, Idaho June 22·24, 1982, Elko, Nevada. General Technical Report INT-GTR-157. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Zamora, B., and P. T. Tueller. 1973. *Artemisia arbuscula*, *A. longiloba*, and *A. nova* habitat types in northern Nevada. Great Basin Naturalist **33**:225-242.

MLRA 27 Group 3: Wyoming big sagebrush and needlegrasses

Description of MRLA 27 Disturbance Response Group 3

Disturbance Response Group (DRG) 3 consists of seven ecological sites. These sites occur on summits and sideslopes of piedmont slopes, inset fans, rock pediments, hills and lower mountains The precipitation zone ranges from 7 to 12 in. The elevation range for this group is 4,500 to 7,000 ft. Slopes range from 0 to 75%. The soils on these sites range from shallow to very deep and are well drained. Available water holding capacity for these sites is low to very low. Many of these sites exhibit a high volume of rock fragments throughout the soil profile which increases permeability. The reference plant communities are dominated by an overstory of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) or basin big sagebrush (*Artemisia tridentata* ssp. *tridentata*) and an understory of Thurber's needlegrass (*Achnatherum thurberianum*), Indian ricegrass (*Achnatherum hymenoides*) or desert needlegrass (*Achnatherum speciosum*). Other common plants include spiny hopsage (*Grayia spinosa*), Nevada jointfir (*Ephedra nevadensis*), winterfat (*Krascheninnikovia lanata*) and needle-and-thread (*Hesperostipa comata*), squirreltail (*Elymus elymoides*) and Sandberg bluegrass (*Poa secunda*). Total annual production for a normal year ranges from 350 to 700 lb/ac.

Disturbance Response Group 3 Ecological Sites:

Droughty Loam 8-10" P.Z. – Modal	R027XY008NV
Loamy Slope 8-10" P.Z.	R027XY007NV
South Slope 8-10" P.Z.	R027XY051NV
Sandy 8-10" P.Z.	R027XY045NV
Gravelly Fan 8-10" P.Z.	R027XY029NV
Granitic Loam 8-10" P.Z.	R027XY067NV
Granitic Slope 8-10" P.Z.	R027XY065NV

Modal Site:

The Droughty Loam 8-10" P.Z. (R027XY008NV) ecological site is the modal site for this group as it has the most acres mapped. This site occurs on summits and sideslopes of piedmont slopes, inset fans and rock pediments. Slopes range from 2 to 30%, but slope gradients of 2–15% are most typical. Elevations range from 4,500 to 5,000 ft. Mean annual precipitation is from 7 to 10 in. The soils on this site are shallow to very deep and well drained. Infiltration is moderate to moderately high. The available water capacity is low to moderate. Runoff is medium to very high and the potential for sheet and rill erosion is moderate. The reference plant community is dominated by Wyoming big sagebrush, spiny hopsage, Indian ricegrass and needle-and-thread.

Squirreltail, Sandberg bluegrass, Nevada jointfir, and winterfat are also common on this site. Average annual production ranges from 300 to 700 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 27 (MLRA 27 Fallon-Lovelock Area) is almost entirely in Nevada with < 1% in California. The entire area occurs in the rain shadow of the Sierra Nevada mountains and is influenced by Pleistocene Lake Lahontan. Extensive playas occur throughout the area and are a result of the drying of ancient Lake Lahontan. To the west, MLRA 27 has a gradual boundary with MLRA 26 (Carson Basin and Mountains) and to the east has a very gradual boundary with MLRA 24 (Humboldt Basin and Range Area). From west to east the soil temperature increases and the soil moisture decreases, resulting in vast areas dominated by salt-desert shrub communities. Isolated mountain ranges trending north to south are separated by broad desert plains and valleys. Elevations range from 3,300 to 5,900 ft with some mountain peaks over 7,800 ft. The average annual precipitation ranges from 4 to 11 in. and as much as 20 in. at the highest elevations. The majority of annual precipitation is received during late fall and winter occurring mainly as snow. High-intensity, convective thunderstorms also contribute significantly to annual precipitation (NRCS 2022). 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 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 1.0 to over 3.0 m (3–10 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). These shrubs have a flexible generalized root system with development of both deep taproots and laterals near the surface (Comstock and Ehleringer 1992).

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 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).

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).

Variability in plant community composition and production depends on soil surface texture and depth. Thurber's needlegrass will increase on gravelly soils, whereas Indian ricegrass will increase with sandy soil surfaces, and squirreltail will increase with silty soil surfaces. Production generally increases with soil depth. The amount of sagebrush in the plant community is dependent upon disturbances like fire, Aroga moth (*Aroga websteri*) infestations, and grazing.

Wyoming big sagebrush is the most drought tolerant of the big sagebrushes and 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.

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 moth infestations have occurred in the Great Basin in the 1960s, 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 moth can partially or entirely kill individual plants or entire stands of big sagebrush (Furniss and Barr 1975).

Spiny hopsage is a woody, summer deciduous, diffusely branched native shrub that reaches 1–5 ft in height (Blauer et al. 1976, Mozingo 1987b). This is one of the first shrubs to green up in the spring, usually in late February or early March, and sheds its leaves much earlier than other deciduous desert shrubs (Turner and Randall 1987, Roundy et al. 1995). Dormancy is one of the

longest of the desert shrubs and spiny hopsage will not break dormancy even after summer rains (Everett et al. 1980).

Nevada jointfir 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). Nevada jointfir does not compete well with cheatgrass, and may exhibit reduced shoot growth when growing in areas dominated by cheatgrass (Pendleton et al. 2007).

At the upper range of this group's precipitation range, there is potential for infilling by Utah juniper (*Juniperus osteosperma*) and/or singleleaf pinyon (*Pinus monophylla*). Infilling may also occur if the site is adjacent to woodland sites or other ecological sites with juniper present. Without disturbance in these areas, Utah juniper will eventually dominate the site and out-compete sagebrush for water and sunlight severely reducing both the shrub and herbaceous understory (Miller and Tausch 2001, Lett and Knapp 2005). The potential for soil erosion increases as the woodland matures and the understory plant community cover declines (Pierson et al. 2010).

The perennial bunchgrasses that are dominant include Thurber's needlegrass, Indian ricegrass or desert needlegrass. 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 results in resource partitioning in these shrub/grass systems.

Thurber's needlegrass is a native, cool-season grass common to the semiarid regions of the Intermountain West and is an important component of many sagebrush communities (Johnson et al. 2017). It is a deep-rooted perennial bunchgrass, 1–2 ft tall with fine, narrow in rolled leaves about 6–10 in. long (Perryman and Skinner 2007). It is very drought and cold tolerant and prefers well drained, fine sandy loam to silt loam soils. It is not tolerant of shade and saline or sodic soil conditions (Ogle 2006).

Indian ricegrass is a long-lived, cool-season perennial bunchgrass that grows 4–24 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).

Desert needlegrass is a cool-season, perennial bunchgrass that grows 12–24 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).

Millions of acres in the arid and semi-arid West were brush-beaten and planted with crested wheatgrass (*Agropyron cristatum*) in the mid-1900s for the purpose of competing with weed species and increasing grass production on rangelands. Success and longevity of these seeding projects have been mixed (Williams et al. 2017). Crested wheatgrass is a cool-season, medium height, exotic perennial bunchgrass native to Asia. Sites within this DRG may exhibit an understory of crested wheatgrass in areas where historical seedings have been allowed to return to sagebrush.

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

Annual Invasive Species:

The species most likely to invade these sites are cheatgrass, tall tumblemustard (*Sisymbrium altissimum*), Russian thistle (*Salsola tragus*) and redstem stork's bill (*Erodium cicutarium*). Cheatgrass is a cool-season annual grass that maintains an advantage over native plants in part because it is a prolific seed producer, able to germinate in the autumn or spring, tolerant of grazing and increases with frequent fire (Klemmedson and Smith 1964, Miller et al. 1999a). 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. Collectively, the body of research suggests that the continued invasion and dominance of medusahead onto native grasslands and cheatgrass infested grasslands will continue to increase in severity because conditions that favor native bunchgrasses or cheatgrass over medusahead are rare (Mangla et al. 2011).

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). 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 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), however caution in using these results is advised, as only one 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.

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 (*Purshia tridentata*), and multiple sagebrush species to three rates of imazapic and the same rates with methylated seed oil as a surfactant. They found 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.

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).

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 < 2 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 1998).

Tall tumblemustard is a cool-season annual forb, introduced from southern Europe, and found throughout most of North America (Holmgren et al. 2005). It is one of the most invasive species in the Great Basin and is characterized by early germination, rapid growth, production of numerous seeds and an effective dispersal mechanism (Holmgren et al. 2005). Tall tumblemustard has low palatability but is grazed when growth is young by cattle and sheep (USFS 1988a).

Redstem stork's bill is a cool-season annual forb, introduced from Europe, and found throughout North America (Cronquist et al. 1997). This plant is an aggressive invader and has an effective method of planting it's seeds by unwinding and boring into the soil (USFS 1988a). It provides spring forage for cattle, sheep and game animals and can provide winter forage in California and the Southwest, after fall rains (USFS 1988a).

Fire Ecology:

Fire is the principal means of renewal of decadent stands of Wyoming big sagebrush. Big sagebrush communities historically had low fuel loads, and patchy fires that burned in a mosaic pattern were common ranging from 10 to 70-year return intervals (Young and Evans 1978, West and Hassan 1985, Bunting et al. 1987). Davies et al. (2006) suggest fire return intervals in Wyoming big sagebrush communities were around 50–100 years.

Wyoming big sagebrush and basin big sagebrush are killed by fire and only regenerate from seed. Recovery time for Wyoming big sagebrush may require 50–120 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.

Spiny hopsage is generally top-killed by fire (Daubenmire 1970), but often sprouts after plants are damaged by fire or mechanical injury (Shaw 1992). Fires in spiny hopsage sites generally occur in late summer when plants are dormant, and sprouting generally does not occur until the following spring (Daubenmire 1970). Spiny hopsage is reported to be least susceptible to fire during summer dormancy (Rickard and McShane 1984). Plants often survive fires that kill adjacent sagebrush (Blauer et al. 1976).

Nevada jointfir vigorously sprouts after fire from extensive woody crowns (Young and Evans 1978). Sprouting after fire may vary by season of burn and fire severity, however. Spiny hopsage is a sprouting shrub (Daubenmire 1970) 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). 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).

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).

Indian ricegrass is fairly fire tolerant (Wright 1985), which is likely due to its low culm density and below-ground root 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 Indian ricegrass. Grazing management following fire to promote seed production and establishment of seedlings is important.

Burning has been found to decrease the vegetative and reproductive vigor of Thurber's needlegrass (Uresk et al. 1976b). 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). Thurber's needlegrass often survives fire and will continue growth or regenerate from tillers when conditions are favorable (Koniak 1985b, Britton et al. 1990). Thurber's needlegrass was shown to decrease in density following a spring fire, but it produced more reproductive culms the year after a fall fire (Ellsworth and Kauffman 2010). Reestablishment on burned sites has been found to be relatively slow due to low germination and competitive ability (Koniak 1985b). Cheatgrass has been found to be a highly successful competitor with seedlings of this needlegrass and may preclude reestablishment (Young and Evans 1978).

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.

Squirreltail is considered more fire tolerant than Indian ricegrass due to its small size, coarse stems, broad leaves and generally sparse leafy material (Wright 1971, Britton et al. 1990). Postfire regeneration occurs from surviving root crowns and from on-and off-site seed sources. 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 ability to grow at low temperatures contribute to the persistence of squirreltail among cheatgrass dominance (Hironaka and Tisdale 1973).

Sandberg bluegrass, a minor component of these ecological sites, has been found to increase following fire likely due to its low stature and productivity (Daubenmire 1975). 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. Sandberg bluegrass increases under grazing pressure (Tisdale and Hironaka 1981) and is capable of co-existing with cheatgrass. Excessive 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 squirreltail/Sandberg bluegrass and rabbitbrush.

Wildlife/Livestock Grazing Interpretations:

Grazing management considerations include timing, duration, intensity and frequency of grazing. Overgrazing leads to an increase in Wyoming big sagebrush and a decline in deep-rooted perennial bunchgrasses. Shallow-rooted bluegrasses (*Poa* spp.) will increase with further degradation. Reduced bunchgrass vigor or density provides an opportunity for expansion of bluegrass species in interspaces. Sandberg bluegrass and similar low-growing grasses increase under grazing pressure (Tisdale and Hironaka 1981). A combination of overgrazing and prolonged drought may lead to soil redistribution, increased bare ground and a loss in plant production.

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 (*Artemisia tridentata* ssp. *vaseyana*) (most palatable) and black sagebrush (*Artemisia nova*) (least palatable). Big sagebrush sites provide nesting, fall and winter habitat for sage grouse (*Centrocercus urophasianus*) (McAdoo and Back 2001). Sage grouse require sagebrush for food and cover during each stage of their life cycle.

Spiny hopsage is palatable to livestock, especially sheep, during the spring and early summer (Phillips et al. 1996, Simmons and Rickard 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 overgrazing, local populations of spiny hopsage may be lost (Simmons and Rickard 2003).

Nevada jointfir is used as winter forage by wild ungulates and livestock (Jameson 1962, Kufeld et al. 1973a). Keeler (1989) found Nevada jointfir to be toxic to cattle and sheep, but not to calves and lambs. Nevada joint fir is also an important component of bighorn sheep diets in the eastern Sierra Nevada (McCullough and Schneegas 1966).

Indian ricegrass is a preferred forage species for livestock and wildlife (Cook 1962). This species is often heavily utilized in winter because it cures well. 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) 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 (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.

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). Thurber’s needlegrass may increase in crude protein content after grazing (Ganskopp et al. 2007).

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 2008a).

Bottlebrush squirreltail is thought to be grazing tolerant but will decrease in basal area with heavy grazing (Eckert and Spencer 1987). Its grazing tolerance is likely due to its morphology

and early dormancy during the summer months (Wright 1967). Squirreltail is considered to be fair forage for livestock and wildlife until the heads develop (Dayton 1931). Big squirreltail (*Elymus multisetus*) also exhibits traits that allow it to be a good competitor with cheatgrass and make it a viable option when rehabilitating invaded rangelands (Rowe 2010).

State and Transition Model Narrative 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 27 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 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 Wyoming big sagebrush, spiny hopsage and Indian ricegrass. Spiny hopsage, Nevada jointfir, winterfat, needle-and-thread (*Hesperostipa comata*), and squirreltail are also common. Potential vegetative composition by air-dry weight is 40% grasses, 5% forbs and 55% shrubs. Approximate ground cover (basal and crown) is 20–30%. Total annual air-dry production ranges from 300 to 700 lb/ac.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
Fire would decrease or eliminate the overstory of big 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 big sagebrush cover to trace amounts. A severe infestation of Aroga moth could also cause a large decrease in big 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:
Long-term drought, time and/or herbivory favor an increase in Wyoming big sagebrush over deep-rooted perennial bunchgrasses. Combinations of these would allow the big sagebrush 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 to mid-seral community phase. Sprouting shrubs such as Nevada jointfir, spiny hopsage and yellow rabbitbrush (*Chrysothamnus viscidiflorus*) are dominant. Indian ricegrass and other perennial grasses are common. Perennial forbs may increase. Wyoming big sagebrush 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 1.1:
Time and lack of disturbance allows for shrub regeneration.

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 or from herbivory.

Community Phase Pathway 1.3a, from Phase 1.3 to 1.1:
Aroga moth infestation and/or release from growing season herbivory may reduce sagebrush dominance and allow recovery of the perennial bunchgrass understory.

Community Phase Pathway 1.3b, from Phase 1.3 to 1.2:
Fire 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.

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, Russian thistle, tall tumblemustard or redstem stork's bill dominate the understory.

Slow variables: Over time the annual non-native species 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 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:
Wyoming big sagebrush, spiny hopsage and Indian ricegrass dominate the site. Nevada jointfir, needle-and-thread, and squirreltail are also common. Non-native annual species are present in minor amounts.

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
Fire would decrease or eliminate the overstory of big 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 big sagebrush within the community, giving a competitive advantage to the perennial grasses and forbs. Annual non-native species generally respond well after fire and may be stable or increasing within the community.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.3:
Time, long-term drought, grazing management that favors shrubs or combinations of these would allow the sagebrush overstory to increase and dominate the site, causing a reduction in the perennial bunchgrasses. However, Sandberg bluegrass and/or squirreltail may increase in the understory depending on the grazing management. Heavy spring grazing will favor an increase in sagebrush. Annual non-native species may be stable or increasing within the understory.

Community Phase 2.2:
This community phase is characteristic of a post-disturbance, early seral community phase. Indian ricegrass, and other perennial bunchgrasses dominate the site. Sprouting shrubs such as yellow rabbitbrush, Nevada jointfir and spiny hopsage may increase. Wyoming big sagebrush is killed by fire, therefore decreasing within the burned community, although it could still be present in unburned patches. Perennial forbs may increase or dominate after fire for several years. Needle-and-thread responds well after fire. Annual non-native species generally respond well after fire and may be stable or increasing within the community. Yellow rabbitbrush may dominate the aspect for a number of years following wildfire.

Sandy 8-10" P.Z. (R027XY045NV), Current Potential 2.2, T. Stringham, May 2024

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Absence of disturbance over time allows for the sagebrush and other shrubs to recover may be combined with grazing management that favors shrubs.

Community Phase 2.3 (At-Risk):
Wyoming big sagebrush increases and the perennial understory is reduced. Decadent sagebrush dominates the overstory and the deep-rooted perennial bunchgrasses in the understory are reduced either from competition with shrubs or from inappropriate grazing management. Squirreltail will likely increase in the understory and may be the dominant grass on the site. Annual non-native species present.

Droughty Loam 8-10" P.Z. (R027XY008NV), Current Potential 2.3, T. Stringham, May 2024

Community Phase Pathway 2.3a, from Phase 2.3 to 2.1:
Low severity fire or Aroga moth infestation creates sagebrush/grass mosaic. Other disturbances/practices include brush management with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to shrubs.

Community Phase Pathway 2.3b, from Phase 2.3 to 2.2:
Fire 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.

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

Trigger: Inappropriate, long-term grazing of perennial bunchgrasses during growing season would favor shrubs and initiate transition to Community Phase 3.1. Soil-disturbing treatments, or fire would cause a transition to Community Phase 3.2.

Slow variables: Long-term decrease in deep-rooted perennial grass density resulting in a decrease in organic matter inputs and subsequent soil water decline.

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

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

Trigger: Fire or a failed range seeding with soil disturbance leads to plant community phase 4.1. Inappropriate grazing management that reduces perennial grasses and favors shrubs in the presence of non-native annual species leads to community phase 4.2.

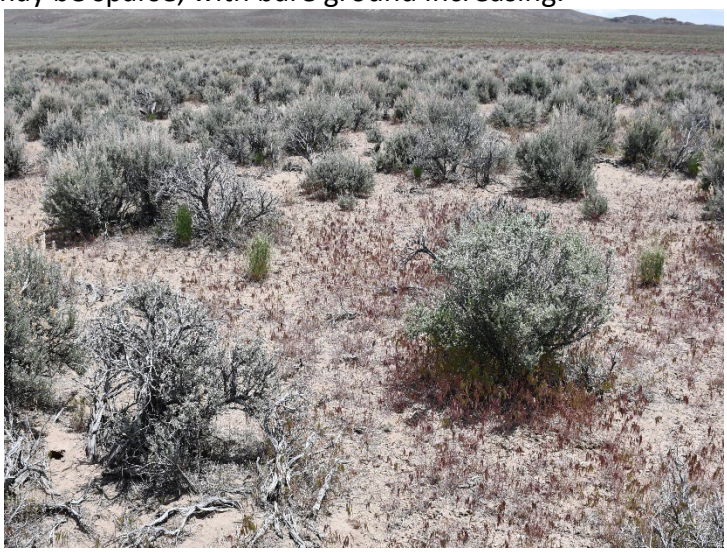
Slow variables: Increased production and cover of non-native annual species.

Threshold: Cheatgrass or other non-native annuals dominate the understory.

Shrub State 3.0:

This state has two community phases; a Wyoming big sagebrush-dominated phase and a sprouting shrub/grass-dominated phase. This state is a product of many years of heavy grazing during time periods harmful to perennial bunchgrasses. Squirreltail and/or Sandberg bluegrass 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 canopy cover is high and sagebrush 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 (At-Risk):
Wyoming big sagebrush dominates the overstory. Squirreltail and/or Sandberg bluegrass dominates the understory. Annual non-native species may be present. Understory may be sparse, with bare ground increasing.



Droughty Loam 8-10" P.Z. (R027XY008NV), Shrub State 3.1, T. Stringham, May 2024

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:
Fire would decrease or eliminate the overstory of big sagebrush. A severe infestation of Aroga moth could also cause a large decrease in big sagebrush within the community,

giving a competitive advantage to the grasses, forbs and sprouting shrubs. Heavy fall grazing causing mechanical damage to shrubs, and/or brush treatments with minimal soil disturbance, would greatly reduce the overstory shrubs and allow for Sandberg bluegrass and/or squirreltail to dominate the site.

Community Phase 3.2:
After wildfire, Sandberg bluegrass and/or squirreltail dominate the understory; annual non-natives are present but are not dominant. Trace amounts of big sagebrush may be present. Sprouting shrubs will increase and may dominate for a number of years following fire.

Community Phase Pathway 3.2a, from Phase 3.2 to 3.1:
Absence of disturbance over time would allow for sagebrush and other shrubs to recover.

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

Trigger: Fire and/or soil-disturbing treatments can eliminate the perennial grass understory and transition to community phase 4.1 or 4.2.

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 sagebrush truncate energy capture and impact the nutrient cycling and distribution.

R3A: Restoration from Shrub State 3.0 to Seeded State 5.0:

Brush management, herbicide application, and range seeding of wheatgrass (*Agropyron* spp.) and/or other native/non-native desired species.

Annual State 4.0:

This state has two community phases; one dominated by annual non-native species and the other a shrub-dominated phase. This state is characterized by the dominance of annual non-native species such as cheatgrass, Russian thistle, tall tumblemustard and/or redstem stork's bill in the understory. Yellow rabbitbrush and other sprouting shrubs dominate the overstory in community phase 4.2.

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.

Droughty Loam 8-10" P.Z. (R027XY008NV), Annual State 4.1, T. Stringham, May 2025

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 Nevada jointfir and yellow rabbitbrush will be the first to reappear after fire. Probability of sagebrush establishment is extremely low.

Community Phase 4.2:
Yellow rabbitbrush and other sprouting shrubs dominate the overstory with annual non-native species dominating the understory. Trace amounts of Wyoming big sagebrush and perennial bunchgrasses may be present.

Community Phase Pathway 4.2a, from Phase 4.2 to 4.1:
Fire allows for annual non-native species to dominate site.

R4A: Restoration from Annual State 4.0 to Seeded State 5.0:

Seeding of deep-rooted introduced bunchgrasses and other desired species; may be coupled with brush management and/or herbicide. Probability of success is low.

Seeded State 5.0:

This state has three community phases: a grass-dominated phase, a grass-shrub dominated phase and a shrub-dominated phase. This state is characterized by the dominance of seeded introduced species in the understory. Wyoming big sagebrush, non-native and native grasses and forbs may be present. Soil nutrients and soil organic matter distribution and cycling are primarily driven by deep-rooted bunchgrasses.

Community Phase 5.1:

Seeded wheatgrass and/or other seeded species dominate the community. Non-native annual species are present. Trace amounts of Wyoming big sagebrush may be present, especially if seeded. Annual non-native species are present.

Droughty Loam 8-10" P.Z. (R027XY008NV), Seeded State 5.1, T. Stringham, May 2024

Community Phase Pathway 5.1a, from Phase 5.1 to 5.2:
Inappropriate grazing management particularly during the growing season reduces perennial bunchgrass vigor and density and facilitates shrub establishment.

Community Phase 5.2:
Wyoming big sagebrush increases and becomes dominant in the overstory. Seeded species dominate understory. Annual non-native species stable to increasing.

Community Phase Pathway 5.2a, from Phase 5.2 to 5.1:
Low severity fire, brush management and/or Aroga moth infestation reduces sagebrush overstory and allows for seeded species to increase.

Community Phase Pathway 5.2b, from Phase 5.2 to 5.1:
Absence of shrub removal disturbances over time coupled with inappropriate grazing management that promotes a reduction in perennial bunchgrasses and facilitates shrub dominance.

Community Phase 5.3 (At-Risk):
Wyoming big sagebrush increases and becomes dominant in the overstory. Rabbitbrush may be a significant component. Seeded perennial grasses vigor and density reduced. Annual non-native species stable to increasing.

Community Phase Pathway 5.3a, from Phase 5.3 to 5.1:
Fire eliminates/reduces the overstory of sagebrush allows for the understory perennial grasses to increase. A severe infestation of Aroga moth would also cause a large reduction in sagebrush giving a competitive advantage to the perennial grasses and

forbs. Brush treatments with minimal soil disturbance would also decrease the sagebrush overstory and release the perennial understory. Annual non-native species may increase post-fire.

T5A: Transition from Seeded State 5.0 to Annual State 4.0:

Trigger: Catastrophic fire and inappropriate, long-term grazing of deep-rooted perennial seeded bunchgrasses during growing season.

Slow variables: Long-term decrease in deep-rooted perennial bunchgrass density, resulting in a decrease in organic matter inputs and subsequent soil water decline.

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

Potential Resilience Differences with other Ecological Sites

Loamy Slope 8-10" P.Z. (R027XY007NV):

The reference plant community of this site is similar to the modal site but has Thurber's needlegrass as the dominant grass species. This site occurs on sideslopes of rock pediments, hills and lower mountains. Slopes range from 15 to 75% but slope gradients of 30–50% are most typical. Elevations range from 5,000 to 6,500 ft. Soils are shallow to very shallow. The available water capacity is very low and the soils have an argillic horizon. Total annual production is similar with the modal site with 500 lb/ac in normal years. This site will have the same states as the modal.

Loamy Slope 8-10" P.Z. (R027XY007NV), Shrub State 3.1, T. Stringham, May 2024

South Slope 8-10" P.Z. (R027XY051NV):

The reference plant community is similar to the modal site but with desert needlegrass as the dominant grass species. This site occurs on southerly-facing sideslopes of dissected upper fan piedmonts, hills and lower elevation mountains. Slopes range from 30 to 50%. Elevations are slightly higher than the modal site at 4,800–7,000 ft. The soils of this site a typically very shallow to soft bedrock and well drained. The available water capacity is very low. In addition to the high temperature of a southerly exposure, the soil factors limit productivity and diversity of native plants on this site. Total annual production is lower than the modal site with 350 lb/ac in a normal year. This site is less resilient than the modal site and a Seeded State is unlikely due to the dry, southerly exposure.

Sandy 8-10" P.Z. (R027XY045NV):

The reference plant community is dominated by basin big sagebrush (*Artemisia tridentata* ssp. *tridentata*), Indian ricegrass, and thickspike wheatgrass (*Elymus lanceolatus* ssp. *lanceolatus*). This site occurs on fan skirts, fan remnants, inset fans and fan piedmonts. Slopes range from 0 to 8%. Elevations range from 4,000 to 7,400 ft. The soils are very deep and well drained. Surface soils are typically overblown with alluvial sand more than 10 in. thick. Available water capacity is moderate. Total annual production is slightly higher than the modal with 600 lb/ac in a normal year. This site has similar resilience as the modal and would have the same states.

Sandy 8-10" P.Z. (R027XY045NV), Current Potential 2.2, T. Stringham, May 2024

Gravelly Fan 8-10" P.Z. (R027XY029NV):

The reference plant community is dominated by big sagebrush, spiny hopsage, Indian ricegrass and basin wildrye (*Leymus cinereus*). This site occurs on inset fans along intermittent or ephemeral drainages. Slopes range from 0 to 15% and elevations range from 4,500 to 6,000 ft. The soils are very deep and well drained. Surface soils are moderately coarse-textured and modified with high amounts of gravel. Available water capacity is moderate. Total annual production is 500 lb/ac same as the modal site. This site would be slightly more resilient than the modal site because of the additional moisture provided by the intermittent/ephemeral channel. This site would have the same states as the modal.

Gravelly Fan 8-10" P.Z. (R027XY029NV), Shrub State 3.1, T. Stringham, May 2025

Granitic Loam 8-10" P.Z. (R027XY067NV):

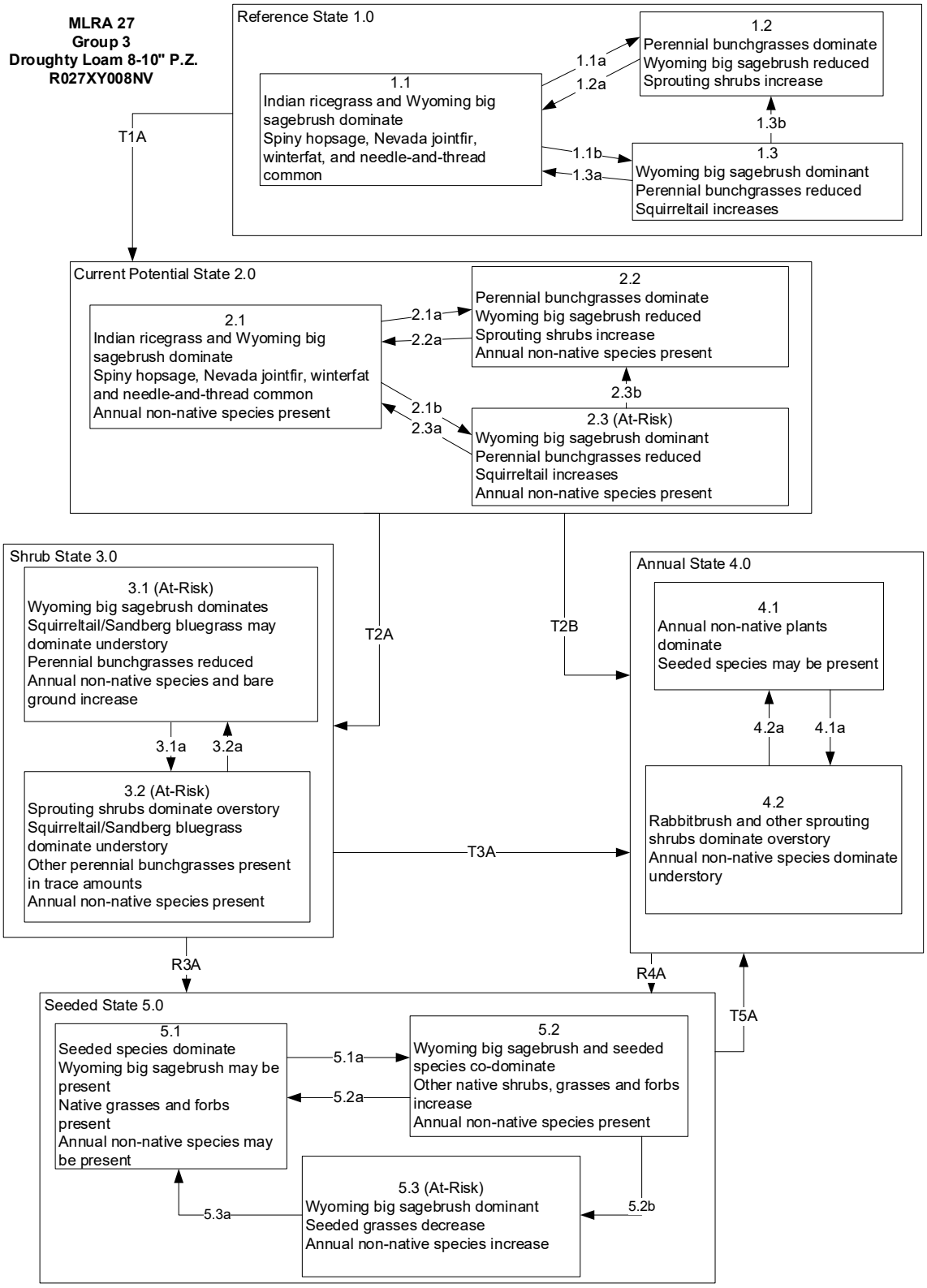
The reference plant community is dominated by Wyoming big sagebrush and desert needlegrass. This site occurs on sideslopes of mountains, hills and upper piedmont slopes. Slopes range from 2 to 15% and elevations range from 4,500 to 7,000 ft. The soils are very deep and somewhat excessively drained. Surface soils are coarse-textured and typically gravelly. Available water capacity is low. Total annual production is slightly higher than the modal with 700 lb/ac for a normal year. This site has similar resilience as the modal and would have the same states.

Granitic Slope 8-10" P.Z. (R027XY065NV):

The reference plant community is dominated by Wyoming big sagebrush and desert needlegrass. This site occurs on sideslopes of mountains and hills. Slopes range from 30 to 75% and elevations range from 4,400 to 7,000 ft. The soils are shallow to very shallow and well drained. Surface soils are coarse to moderately coarse textured over weathered granitic parent material. Available water capacity is very low. Total annual production is slightly higher than the modal with 600 lb/ac for a normal year. This site has similar resilience as the modal. Singleleaf pinyon (*Pinus monophylla*) and Utah juniper (*Juniperus osteosperma*) occur on this site, however a Tree State was not observed.

Granitic Slope 8-10" P.Z. (R027XY065NV), Shrub State 3.1, T. Stringham, June 2025

Modal State and Transition Model for Group 3 in MLRA 27



MLRA 27
Group 3
Droughty Loam 8-10" P.Z.
R027XY008NV

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, perennial grasses and forbs. A severe infestation of Aroga moth could also reduce sagebrush cover.
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 or Aroga moth significantly reduces sagebrush cover leading to early/mid-seral community dominated by sprouting shrubs, perennial grasses and forbs.

Transition T1A: Introduction of non-native species.

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, perennial grasses and forbs; non-native annual species present. A severe infestation of Aroga moth could also reduce sagebrush cover.
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 treatment with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire or Aroga moth significantly reduces sagebrush cover leading to early/mid-seral community dominated by sprouting shrubs, perennial grasses and forbs.

Transition T2A: Inappropriate grazing management favoring shrub dominance and reducing perennial bunchgrasses will lead to phase 3.1. Soil disturbing treatments and/or fire will lead to phase 3.2.
Transition T2B: Catastrophic fire and/or soil disturbing treatments (to 4.1); inappropriate cattle/horse grazing management that reduces bunchgrasses, favors shrubs and promotes the presence of non-native annual species (to 4.2)

Shrub State 3.0 Community Phase Pathways
3.1a: Low severity fire or Aroga moth infestation creates sagebrush/grass mosaic. Brush treatment with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
3.2a: Time and lack of disturbance may allow for sagebrush and other shrubs to re-establish.

Transition T3A: Fire and/or soil disturbing treatments.
Restoration R3A: Brush management and seeding of wheatgrass and/or other non-native/native desirable species.

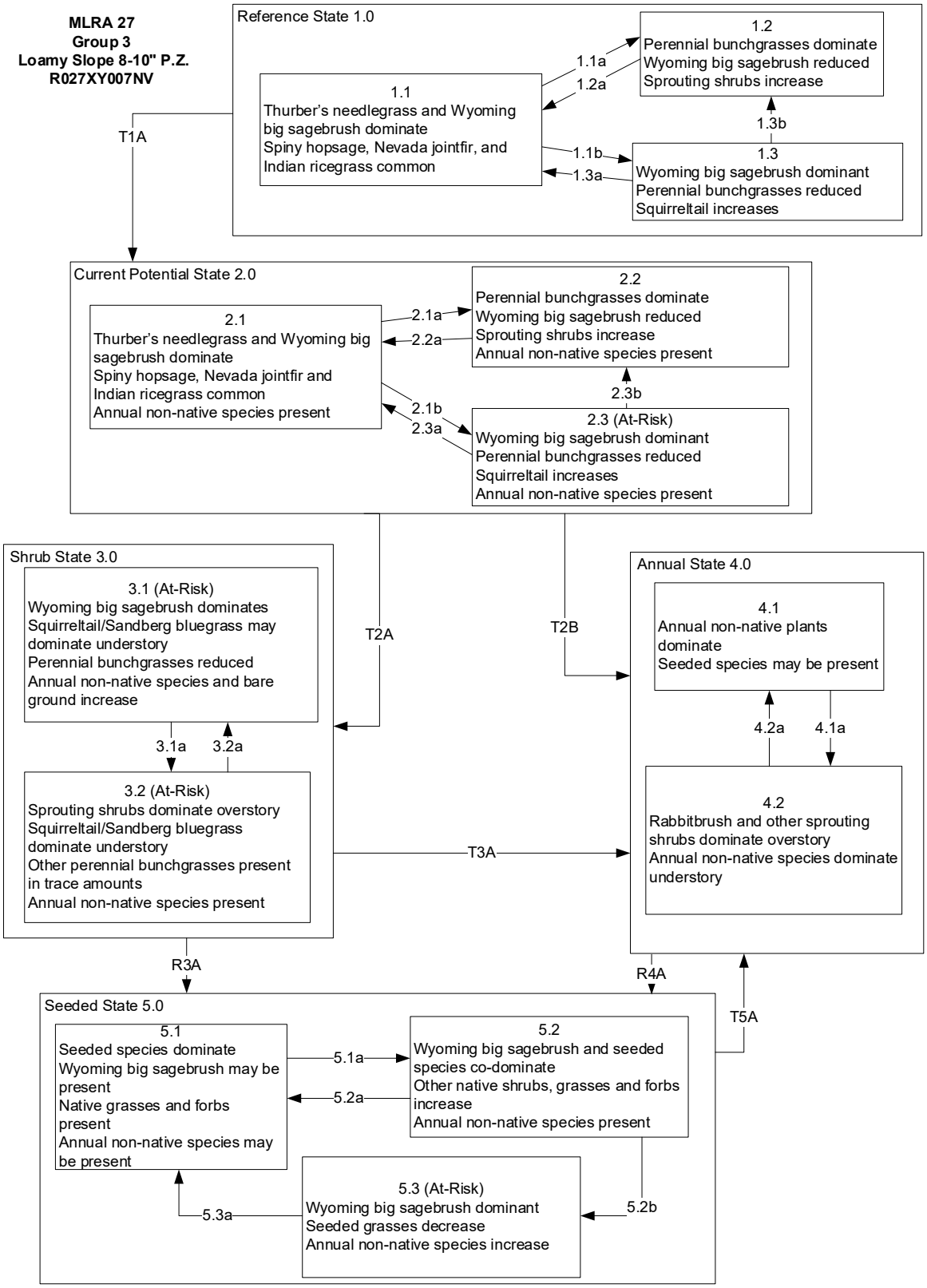
Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of disturbance. Wyoming big sagebrush is slow to reestablish and may take many years.
4.2a: High-severity fire.

Restoration R4A: Seeding of desired species, may be coupled with herbicide application or targeted grazing. Probability of success is low.

Seeded State 5.0 Community Phase Pathways
5.1a: Inappropriate grazing management facilitates shrub reestablishment. Time and lack of disturbance/management would also allow for shrubs to establish and increase.
5.2a: Fire, brush management, or Aroga moth infestation reduces shrub component.
5.2b: Time and lack of disturbance, may be coupled with inappropriate grazing management; usually a slow transition.
5.3a: Fire, Aroga moth infestation or brush treatment with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.

Transition T5A: Catastrophic fire and inappropriate grazing management that reduces perennial bunchgrasses.

Additional State and Transition Models for Group 3 in MLRA 27



MLRA 27
Group 3
Loamy Slope 8-10" P.Z.
R027XY007NV

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, perennial grasses and forbs. A severe infestation of Aroga moth could also reduce sagebrush cover.
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 or Aroga moth significantly reduces sagebrush cover leading to early/mid-seral community dominated by sprouting shrubs, perennial grasses and forbs.

Transition T1A: Introduction of non-native species.

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, perennial grasses and forbs; non-native annual species present. A severe infestation of Aroga moth could also reduce sagebrush cover.
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 treatment with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire or Aroga moth significantly reduces sagebrush cover leading to early/mid-seral community dominated by sprouting shrubs, perennial grasses and forbs.

Transition T2A: Inappropriate grazing management favoring shrub dominance and reducing perennial bunchgrasses will lead to phase 3.1. Soil disturbing treatments and/or fire will lead to phase 3.2.
Transition T2B: Catastrophic fire and/or soil disturbing treatments (to 4.1); inappropriate cattle/horse grazing management that reduces bunchgrasses, favors shrubs and promotes the presence of non-native annual species (to 4.2)

Shrub State 3.0 Community Phase Pathways
3.1a: Low severity fire or Aroga moth infestation creates sagebrush/grass mosaic. Brush treatment with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
3.2a: Time and lack of disturbance may allow for sagebrush and other shrubs to re-establish.

Transition T3A: Fire and/or soil disturbing treatments.
Restoration R3A: Brush management and seeding of wheatgrass and/or other non-native/native desirable species.

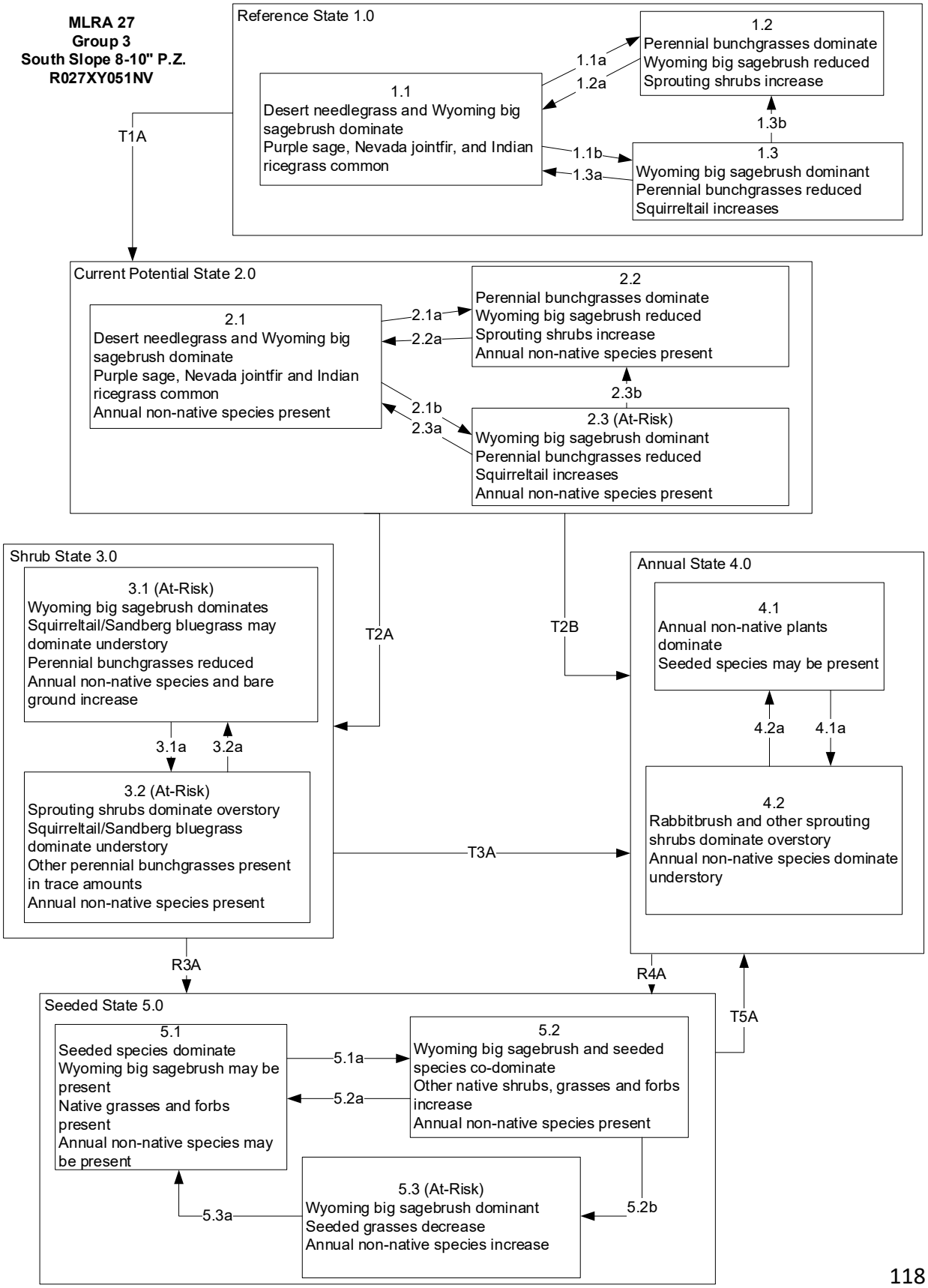
Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of disturbance. Wyoming big sagebrush is slow to reestablish and may take many years.
4.2a: High-severity fire.

Restoration R4A: Seeding of desired species, may be coupled with herbicide application or targeted grazing. Probability of success is low.

Seeded State 5.0 Community Phase Pathways
5.1a: Inappropriate grazing management facilitates shrub reestablishment. Time and lack of disturbance/management would also allow for shrubs to establish and increase.
5.2a: Fire, brush management, or Aroga moth infestation reduces shrub component.
5.2b: Time and lack of disturbance, may be coupled with inappropriate grazing management; usually a slow transition.
5.3a: Fire, Aroga moth infestation or brush treatment with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.

Transition T5A: Catastrophic fire and inappropriate grazing management that reduces perennial bunchgrasses.

MLRA 27
Group 3
South Slope 8-10" P.Z.
R027XY051NV



MLRA 27
Group 3
South Slope 8-10" P.Z.
R027XY051NV

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, perennial grasses and forbs. A severe infestation of Aroga moth could also reduce sagebrush cover.
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 or Aroga moth significantly reduces sagebrush cover leading to early/mid-seral community dominated by sprouting shrubs, perennial grasses and forbs.

Transition T1A: Introduction of non-native species.

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, perennial grasses and forbs; non-native annual species present. A severe infestation of Aroga moth could also reduce sagebrush cover.
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 treatment with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire or Aroga moth significantly reduces sagebrush cover leading to early/mid-seral community dominated by sprouting shrubs, perennial grasses and forbs.

Transition T2A: Inappropriate grazing management favoring shrub dominance and reducing perennial bunchgrasses will lead to phase 3.1. Soil disturbing treatments and/or fire will lead to phase 3.2.
Transition T2B: Catastrophic fire and/or soil disturbing treatments (to 4.1); inappropriate cattle/horse grazing management that reduces bunchgrasses, favors shrubs and promotes the presence of non-native annual species (to 4.2)

Shrub State 3.0 Community Phase Pathways
3.1a: Low severity fire or Aroga moth infestation creates sagebrush/grass mosaic. Brush treatment with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
3.2a: Time and lack of disturbance may allow for sagebrush and other shrubs to re-establish.

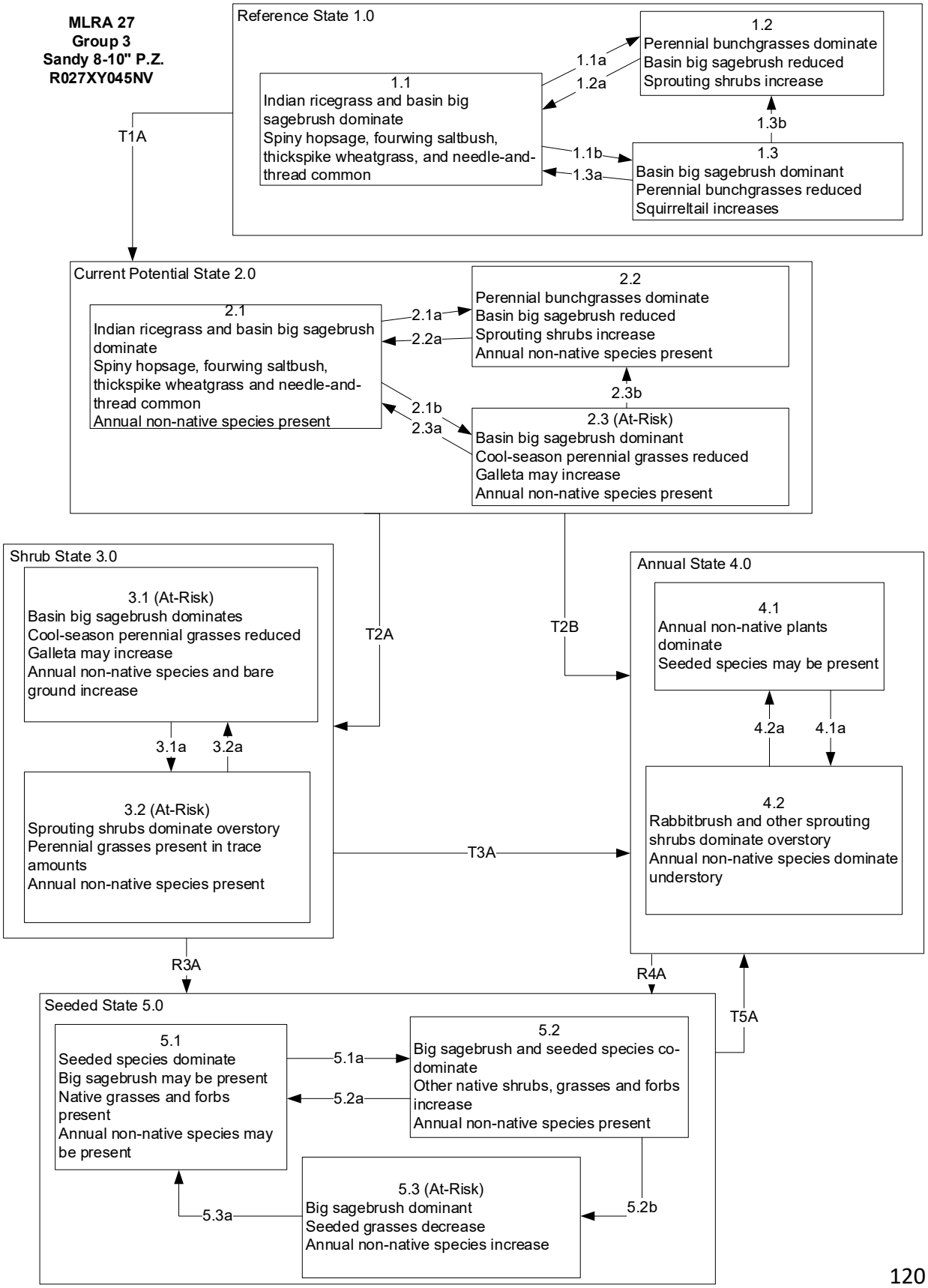
Transition T3A: Fire and/or soil disturbing treatments.
Restoration R3A: Brush management and seeding of wheatgrass and/or other non-native/native desirable species.

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of disturbance. Wyoming big sagebrush is slow to reestablish and may take many years.
4.2a: High-severity fire.

Restoration R4A: Seeding of desired species, may be coupled with herbicide application or targeted grazing. Probability of success is low.

Seeded State 5.0 Community Phase Pathways
5.1a: Inappropriate grazing management facilitates shrub reestablishment. Time and lack of disturbance/management would also allow for shrubs to establish and increase.
5.2a: Fire, brush management, or Aroga moth infestation reduces shrub component.
5.2b: Time and lack of disturbance, may be coupled with inappropriate grazing management; usually a slow transition.
5.3a: Fire, Aroga moth infestation or brush treatment with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.

Transition T5A: Catastrophic fire and inappropriate grazing management that reduces perennial bunchgrasses.


MLRA 27
Group 3
Sandy 8-10" P.Z.
R027XY045NV
Reference State 1.0
1.1
Indian ricegrass and basin big sagebrush dominate
Spiny hopsage, fourwing saltbush, thickspike wheatgrass, and needle-and-thread common
1.2
Perennial bunchgrasses dominate
Basin big sagebrush reduced
Sprouting shrubs increase
1.3
Basin big sagebrush dominant
Perennial bunchgrasses reduced
Squirreltail increases
1.1a
1.2a
1.1b
1.3a
1.3b
T1A
Current Potential State 2.0
2.1
Indian ricegrass and basin big sagebrush dominate
Spiny hopsage, fourwing saltbush, thickspike wheatgrass and needle-and-thread common
Annual non-native species present
2.2
Perennial bunchgrasses dominate
Basin big sagebrush reduced
Sprouting shrubs increase
Annual non-native species present
2.3 (At-Risk)
Basin big sagebrush dominant
Cool-season perennial grasses reduced
Galleta may increase
Annual non-native species present
2.1a
2.2a
2.1b
2.3a
2.3b
T2A
T2B
Shrub State 3.0
3.1 (At-Risk)
Basin big sagebrush dominates
Cool-season perennial grasses reduced
Galleta may increase
Annual non-native species and bare ground increase
3.2 (At-Risk)
Sprouting shrubs dominate overstory
Perennial grasses present in trace amounts
Annual non-native species present
3.1a
3.2a
T3A
Annual State 4.0
4.1
Annual non-native plants dominate
Seeded species may be present
4.2
Rabbitbrush and other sprouting shrubs dominate overstory
Annual non-native species dominate understory
4.2a
4.1a
R3A
R4A
T5A
Seeded State 5.0
5.1
Seeded species dominate
Big sagebrush may be present
Native grasses and forbs present
Annual non-native species may be present
5.2
Big sagebrush and seeded species co-dominate
Other native shrubs, grasses and forbs increase
Annual non-native species present
5.3 (At-Risk)
Big sagebrush dominant
Seeded grasses decrease
Annual non-native species increase
5.1a
5.2a
5.3a
5.2b

MLRA 27
Group 3
Sandy 8-10" P.Z.
R027XY045NV

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, perennial grasses and forbs. A severe infestation of Aroga moth could also reduce sagebrush cover.
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 or Aroga moth significantly reduces sagebrush cover leading to early/mid-seral community dominated by sprouting shrubs, perennial grasses and forbs.

Transition T1A: Introduction of non-native species.

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, perennial grasses and forbs; non-native annual species present. A severe infestation of Aroga moth could also reduce sagebrush cover.
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 treatment with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire or Aroga moth significantly reduces sagebrush cover leading to early/mid-seral community dominated by sprouting shrubs, perennial grasses and forbs.

Transition T2A: Inappropriate grazing management favoring shrub dominance and reducing perennial bunchgrasses will lead to phase 3.1. Soil disturbing treatments and/or fire will lead to phase 3.2.
Transition T2B: Catastrophic fire and/or soil disturbing treatments (to 4.1); inappropriate cattle/horse grazing management that reduces bunchgrasses, favors shrubs and promotes the presence of non-native annual species (to 4.2)

Shrub State 3.0 Community Phase Pathways
3.1a: Low severity fire or Aroga moth infestation creates sagebrush/grass mosaic. Brush treatment with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
3.2a: Time and lack of disturbance may allow for sagebrush and other shrubs to re-establish.

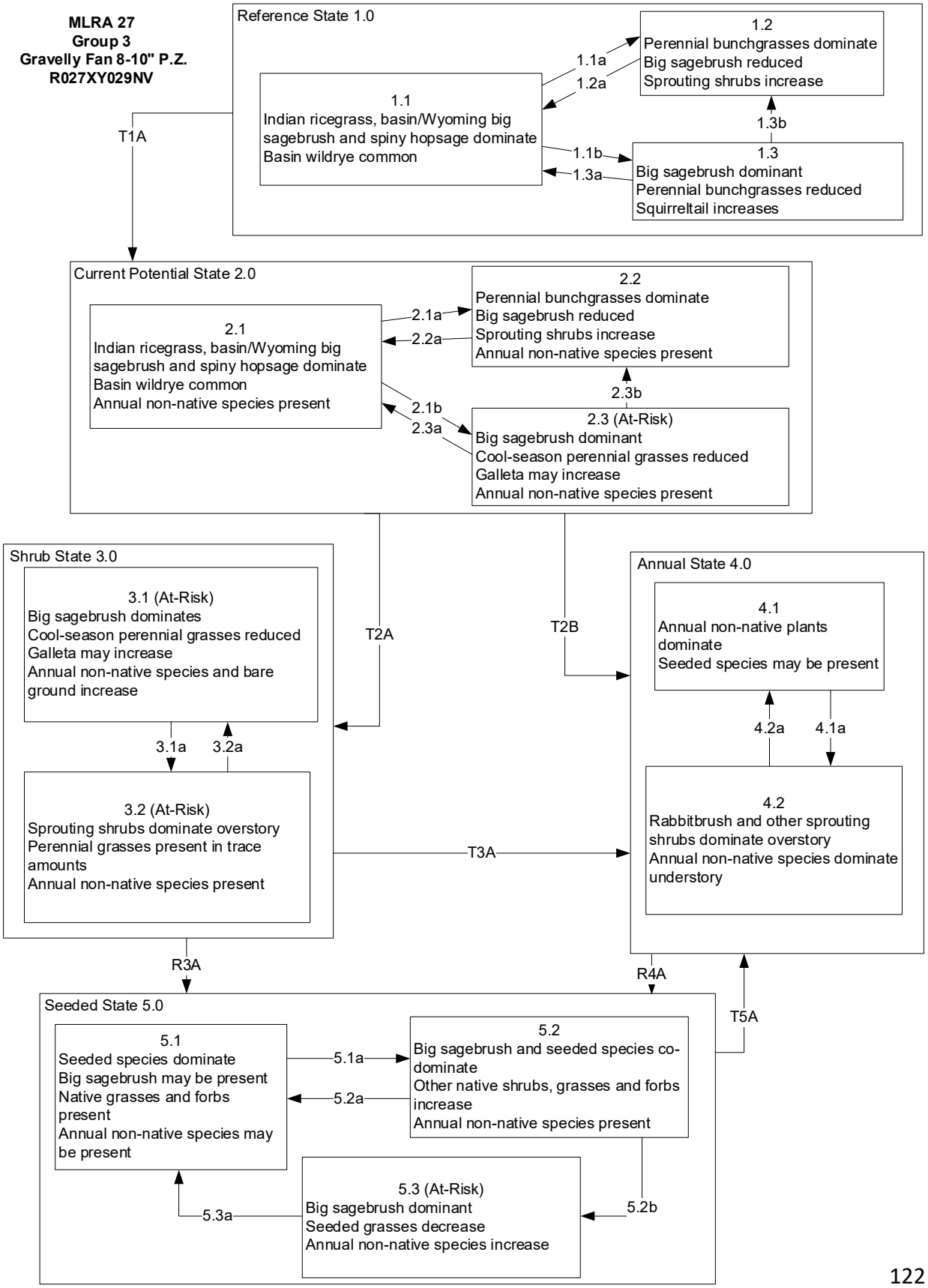
Transition T3A: Fire and/or soil disturbing treatments.
Restoration R3A: Brush management and seeding of wheatgrass and/or other non-native/native desirable species.

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of disturbance. Wyoming big sagebrush is slow to reestablish and may take many years.
4.2a: High-severity fire.

Restoration R4A: Seeding of desired species, may be coupled with herbicide application or targeted grazing. Probability of success is low.

Seeded State 5.0 Community Phase Pathways
5.1a: Inappropriate grazing management facilitates shrub reestablishment. Time and lack of disturbance/management would also allow for shrubs to establish and increase.
5.2a: Fire, brush management, or Aroga moth infestation reduces shrub component.
5.2b: Time and lack of disturbance, may be coupled with inappropriate grazing management; usually a slow transition.
5.3a: Fire, Aroga moth infestation or brush treatment with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.

Transition T5A: Catastrophic fire and inappropriate grazing management that reduces perennial bunchgrasses.


MLRA 27
Group 3
Gravelly Fan 8-10" P.Z.
R027XY029NV
Reference State 1.0
1.1
Indian ricegrass, basin/Wyoming big sagebrush and spiny hopsage dominate
Basin wildrye common
1.2
Perennial bunchgrasses dominate
Big sagebrush reduced
Sprouting shrubs increase
1.3
Big sagebrush dominant
Perennial bunchgrasses reduced
Squirreltail increases
1.1a
1.2a
1.1b
1.3a
1.3b
T1A
Current Potential State 2.0
2.1
Indian ricegrass, basin/Wyoming big sagebrush and spiny hopsage dominate
Basin wildrye common
Annual non-native species present
2.2
Perennial bunchgrasses dominate
Big sagebrush reduced
Sprouting shrubs increase
Annual non-native species present
2.3 (At-Risk)
Big sagebrush dominant
Cool-season perennial grasses reduced
Galleta may increase
Annual non-native species present
2.1a
2.2a
2.1b
2.3a
2.3b
T2A
T2B
Shrub State 3.0
3.1 (At-Risk)
Big sagebrush dominates
Cool-season perennial grasses reduced
Galleta may increase
Annual non-native species and bare ground increase
3.2 (At-Risk)
Sprouting shrubs dominate overstory
Perennial grasses present in trace amounts
Annual non-native species present
3.1a
3.2a
T3A
Annual State 4.0
4.1
Annual non-native plants dominate
Seeded species may be present
4.2
Rabbitbrush and other sprouting shrubs dominate overstory
Annual non-native species dominate understory
4.2a
4.1a
R3A
R4A
T5A
Seeded State 5.0
5.1
Seeded species dominate
Big sagebrush may be present
Native grasses and forbs present
Annual non-native species may be present
5.2
Big sagebrush and seeded species co-dominate
Other native shrubs, grasses and forbs increase
Annual non-native species present
5.3 (At-Risk)
Big sagebrush dominant
Seeded grasses decrease
Annual non-native species increase
5.1a
5.2a
5.3a
5.2b

MLRA 27
Group 3
Gravelly Fan 8-10" P.Z.
R027XY029NV

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, perennial grasses and forbs. A severe infestation of Aroga moth could also reduce sagebrush cover.
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 or Aroga moth significantly reduces sagebrush cover leading to early/mid-seral community dominated by sprouting shrubs, perennial grasses and forbs.

Transition T1A: Introduction of non-native species.

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, perennial grasses and forbs; non-native annual species present. A severe infestation of Aroga moth could also reduce sagebrush cover.
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 treatment with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire or Aroga moth significantly reduces sagebrush cover leading to early/mid-seral community dominated by sprouting shrubs, perennial grasses and forbs.

Transition T2A: Inappropriate grazing management favoring shrub dominance and reducing perennial bunchgrasses will lead to phase 3.1. Soil disturbing treatments and/or fire will lead to phase 3.2.
Transition T2B: Catastrophic fire and/or soil disturbing treatments (to 4.1); inappropriate cattle/horse grazing management that reduces bunchgrasses, favors shrubs and promotes the presence of non-native annual species (to 4.2)

Shrub State 3.0 Community Phase Pathways
3.1a: Low severity fire or Aroga moth infestation creates sagebrush/grass mosaic. Brush treatment with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
3.2a: Time and lack of disturbance may allow for sagebrush and other shrubs to re-establish.

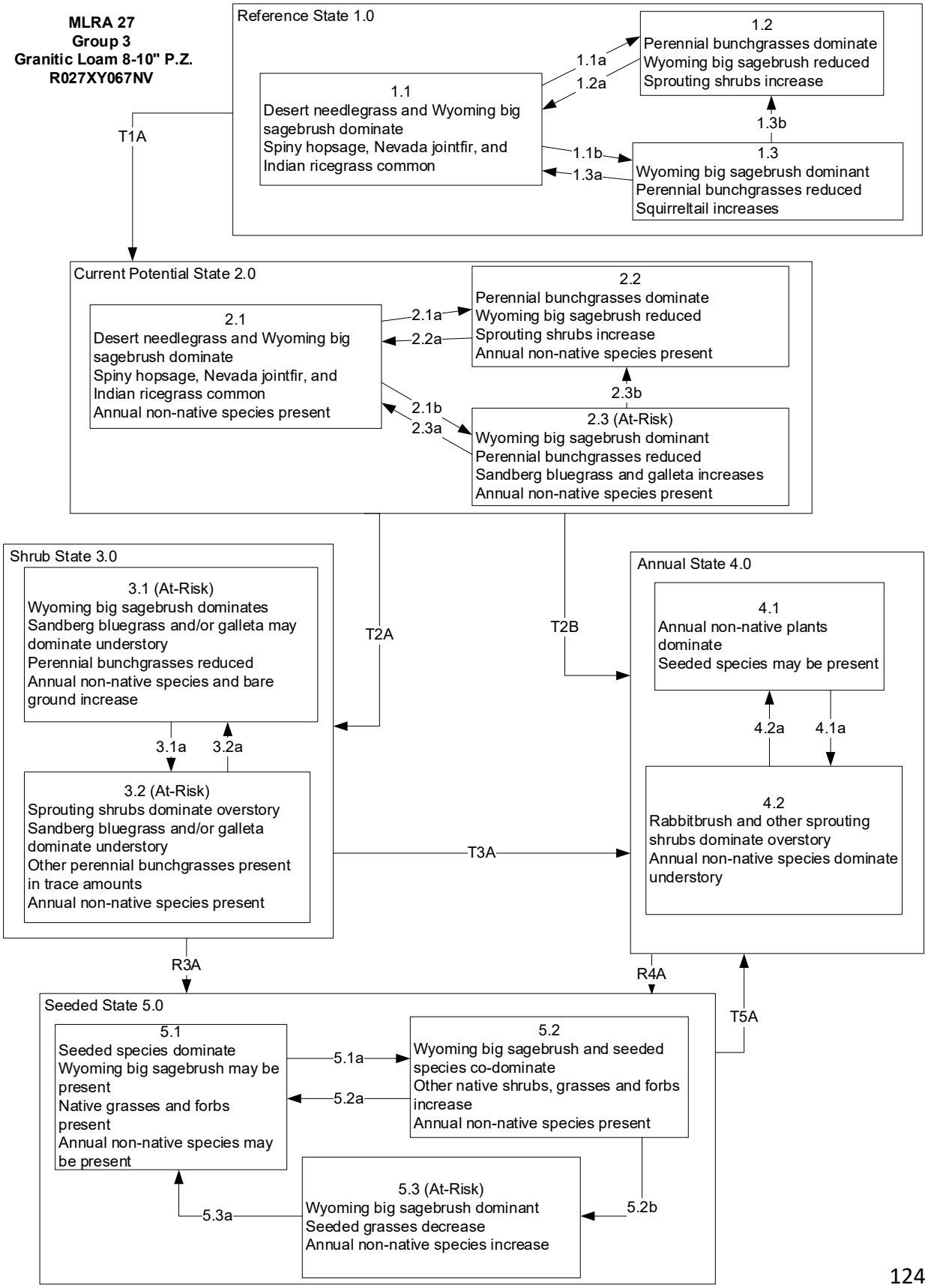
Transition T3A: Fire and/or soil disturbing treatments.
Restoration R3A: Brush management and seeding of wheatgrass and/or other non-native/native desirable species.

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of disturbance. Wyoming big sagebrush is slow to reestablish and may take many years.
4.2a: High-severity fire.

Restoration R4A: Seeding of desired species, may be coupled with herbicide application or targeted grazing. Probability of success is low.

Seeded State 5.0 Community Phase Pathways
5.1a: Inappropriate grazing management facilitates shrub reestablishment. Time and lack of disturbance/management would also allow for shrubs to establish and increase.
5.2a: Fire, brush management, or Aroga moth infestation reduces shrub component.
5.2b: Time and lack of disturbance, may be coupled with inappropriate grazing management; usually a slow transition.
5.3a: Fire, Aroga moth infestation or brush treatment with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.

Transition T5A: Catastrophic fire and inappropriate grazing management that reduces perennial bunchgrasses.


MLRA 27
Group 3
Granitic Loam 8-10" P.Z.
R027XY067NV
Reference State 1.0
1.1
Desert needlegrass and Wyoming big sagebrush dominate
Spiny hopsage, Nevada jointfir, and Indian ricegrass common
1.2
Perennial bunchgrasses dominate
Wyoming big sagebrush reduced
Sprouting shrubs increase
1.3
Wyoming big sagebrush dominant
Perennial bunchgrasses reduced
Squirreltail increases
1.1a
1.2a
1.1b
1.3a
1.3b
T1A
Current Potential State 2.0
2.1
Desert needlegrass and Wyoming big sagebrush dominate
Spiny hopsage, Nevada jointfir, and Indian ricegrass common
Annual non-native species present
2.2
Perennial bunchgrasses dominate
Wyoming big sagebrush reduced
Sprouting shrubs increase
Annual non-native species present
2.3 (At-Risk)
Wyoming big sagebrush dominant
Perennial bunchgrasses reduced
Sandberg bluegrass and galleta increases
Annual non-native species present
2.1a
2.2a
2.1b
2.3a
2.3b
T2A
T2B
Shrub State 3.0
3.1 (At-Risk)
Wyoming big sagebrush dominates
Sandberg bluegrass and/or galleta may dominate understory
Perennial bunchgrasses reduced
Annual non-native species and bare ground increase
3.2 (At-Risk)
Sprouting shrubs dominate overstory
Sandberg bluegrass and/or galleta dominate understory
Other perennial bunchgrasses present in trace amounts
Annual non-native species present
3.1a
3.2a
T3A
Annual State 4.0
4.1
Annual non-native plants dominate
Seeded species may be present
4.2
Rabbitbrush and other sprouting shrubs dominate overstory
Annual non-native species dominate understory
4.2a
4.1a
R3A
R4A
T5A
Seeded State 5.0
5.1
Seeded species dominate
Wyoming big sagebrush may be present
Native grasses and forbs present
Annual non-native species may be present
5.2
Wyoming big sagebrush and seeded species co-dominate
Other native shrubs, grasses and forbs increase
Annual non-native species present
5.3 (At-Risk)
Wyoming big sagebrush dominant
Seeded grasses decrease
Annual non-native species increase
5.1a
5.2a
5.3a
5.2b

MLRA 27
Group 3
Granitic Loam 8-10" P.Z.
R027XY067NV

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, perennial grasses and forbs. A severe infestation of Aroga moth could also reduce sagebrush cover.
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 or Aroga moth significantly reduces sagebrush cover leading to early/mid-seral community dominated by sprouting shrubs, perennial grasses and forbs.

Transition T1A: Introduction of non-native species.

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, perennial grasses and forbs; non-native annual species present. A severe infestation of Aroga moth could also reduce sagebrush cover.
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 treatment with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire or Aroga moth significantly reduces sagebrush cover leading to early/mid-seral community dominated by sprouting shrubs, perennial grasses and forbs.

Transition T2A: Inappropriate grazing management favoring shrub dominance and reducing perennial bunchgrasses will lead to phase 3.1. Soil disturbing treatments and/or fire will lead to phase 3.2.
Transition T2B: Catastrophic fire and/or soil disturbing treatments (to 4.1); inappropriate cattle/horse grazing management that reduces bunchgrasses, favors shrubs and promotes the presence of non-native annual species (to 4.2)

Shrub State 3.0 Community Phase Pathways
3.1a: Low severity fire or Aroga moth infestation creates sagebrush/grass mosaic. Brush treatment with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
3.2a: Time and lack of disturbance may allow for sagebrush and other shrubs to re-establish.

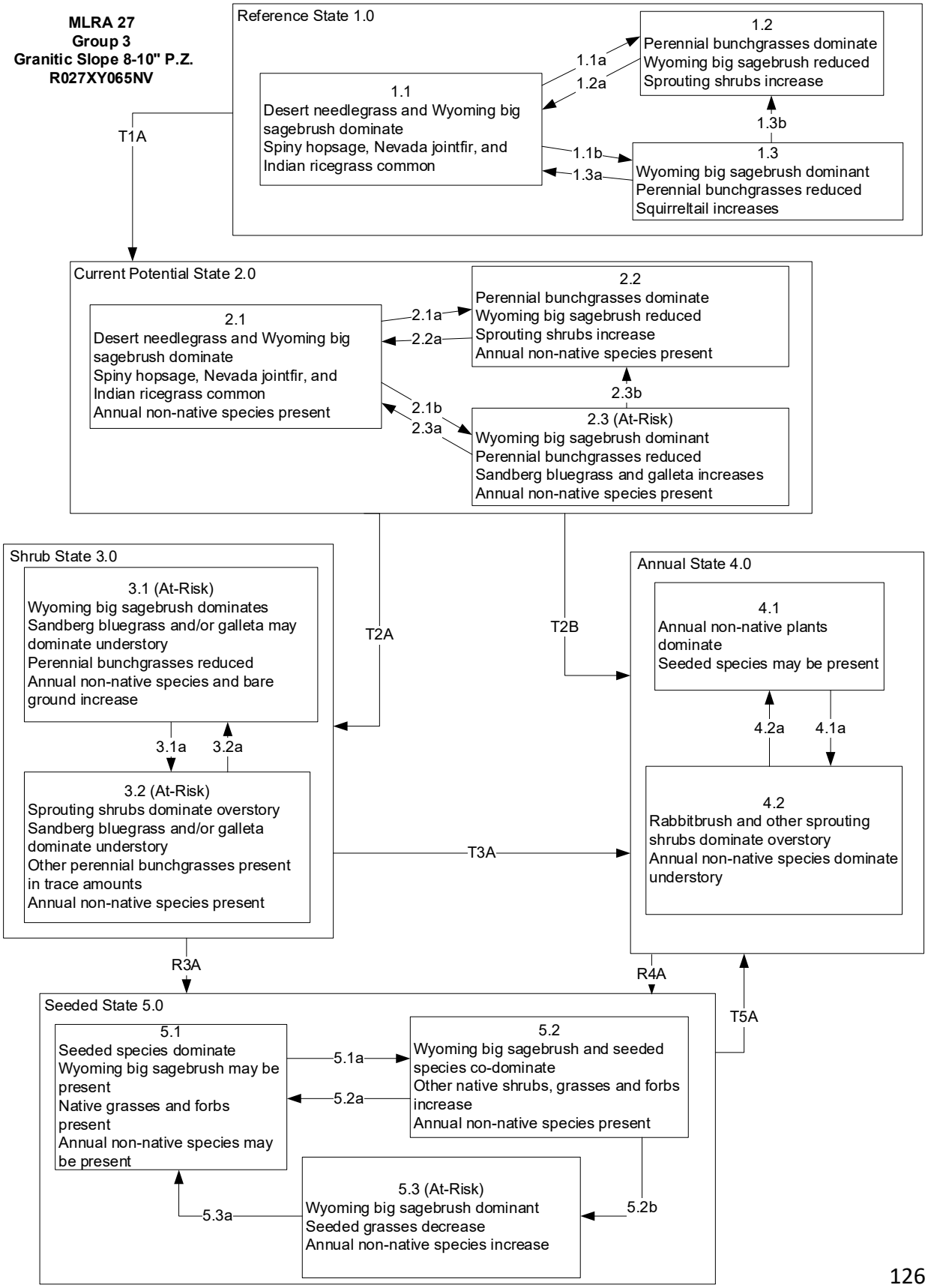
Transition T3A: Fire and/or soil disturbing treatments.
Restoration R3A: Brush management and seeding of wheatgrass and/or other non-native/native desirable species.

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of disturbance. Wyoming big sagebrush is slow to reestablish and may take many years.
4.2a: High-severity fire.

Restoration R4A: Seeding of desired species, may be coupled with herbicide application or targeted grazing. Probability of success is low.

Seeded State 5.0 Community Phase Pathways
5.1a: Inappropriate grazing management facilitates shrub reestablishment. Time and lack of disturbance/management would also allow for shrubs to establish and increase.
5.2a: Fire, brush management, or Aroga moth infestation reduces shrub component.
5.2b: Time and lack of disturbance, may be coupled with inappropriate grazing management; usually a slow transition.
5.3a: Fire, Aroga moth infestation or brush treatment with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.

Transition T5A: Catastrophic fire and inappropriate grazing management that reduces perennial bunchgrasses.


MLRA 27
Group 3
Granitic Slope 8-10" P.Z.
R027XY065NV
Reference State 1.0
1.1
Desert needlegrass and Wyoming big sagebrush dominate
Spiny hopsage, Nevada jointfir, and Indian ricegrass common
1.2
Perennial bunchgrasses dominate
Wyoming big sagebrush reduced
Sprouting shrubs increase
1.3
Wyoming big sagebrush dominant
Perennial bunchgrasses reduced
Squirreltail increases
1.1a
1.2a
1.1b
1.3a
1.3b
T1A
Current Potential State 2.0
2.1
Desert needlegrass and Wyoming big sagebrush dominate
Spiny hopsage, Nevada jointfir, and Indian ricegrass common
Annual non-native species present
2.2
Perennial bunchgrasses dominate
Wyoming big sagebrush reduced
Sprouting shrubs increase
Annual non-native species present
2.3 (At-Risk)
Wyoming big sagebrush dominant
Perennial bunchgrasses reduced
Sandberg bluegrass and galleta increases
Annual non-native species present
2.1a
2.2a
2.1b
2.3a
2.3b
T2A
T2B
Shrub State 3.0
3.1 (At-Risk)
Wyoming big sagebrush dominates
Sandberg bluegrass and/or galleta may dominate understory
Perennial bunchgrasses reduced
Annual non-native species and bare ground increase
3.2 (At-Risk)
Sprouting shrubs dominate overstory
Sandberg bluegrass and/or galleta dominate understory
Other perennial bunchgrasses present in trace amounts
Annual non-native species present
3.1a
3.2a
T3A
Annual State 4.0
4.1
Annual non-native plants dominate
Seeded species may be present
4.2
Rabbitbrush and other sprouting shrubs dominate overstory
Annual non-native species dominate understory
4.2a
4.1a
R3A
R4A
T5A
Seeded State 5.0
5.1
Seeded species dominate
Wyoming big sagebrush may be present
Native grasses and forbs present
Annual non-native species may be present
5.2
Wyoming big sagebrush and seeded species co-dominate
Other native shrubs, grasses and forbs increase
Annual non-native species present
5.3 (At-Risk)
Wyoming big sagebrush dominant
Seeded grasses decrease
Annual non-native species increase
5.1a
5.2a
5.3a
5.2b

MLRA 27
Group 3
Granitic Slope 8-10" P.Z.
R027XY065NV

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, perennial grasses and forbs. A severe infestation of Aroga moth could also reduce sagebrush cover.
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 or Aroga moth significantly reduces sagebrush cover leading to early/mid-seral community dominated by sprouting shrubs, perennial grasses and forbs.

Transition T1A: Introduction of non-native species.

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, perennial grasses and forbs; non-native annual species present. A severe infestation of Aroga moth could also reduce sagebrush cover.
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 treatment with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire or Aroga moth significantly reduces sagebrush cover leading to early/mid-seral community dominated by sprouting shrubs, perennial grasses and forbs.

Transition T2A: Inappropriate grazing management favoring shrub dominance and reducing perennial bunchgrasses will lead to phase 3.1. Soil disturbing treatments and/or fire will lead to phase 3.2.
Transition T2B: Catastrophic fire and/or soil disturbing treatments (to 4.1); inappropriate cattle/horse grazing management that reduces bunchgrasses, favors shrubs and promotes the presence of non-native annual species (to 4.2)

Shrub State 3.0 Community Phase Pathways
3.1a: Low severity fire or Aroga moth infestation creates sagebrush/grass mosaic. Brush treatment with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
3.2a: Time and lack of disturbance may allow for sagebrush and other shrubs to re-establish.

Transition T3A: Fire and/or soil disturbing treatments.
Restoration R3A: Brush management and seeding of wheatgrass and/or other non-native/native desirable species.

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of disturbance. Wyoming big sagebrush is slow to reestablish and may take many years.
4.2a: High-severity fire.

Restoration R4A: Seeding of desired species, may be coupled with herbicide application or targeted grazing. Probability of success is low.

Seeded State 5.0 Community Phase Pathways
5.1a: Inappropriate grazing management facilitates shrub reestablishment. Time and lack of disturbance/management would also allow for shrubs to establish and increase.
5.2a: Fire, brush management, or Aroga moth infestation reduces shrub component.
5.2b: Time and lack of disturbance, may be coupled with inappropriate grazing management; usually a slow transition.
5.3a: Fire, Aroga moth infestation or brush treatment with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.

Transition T5A: Catastrophic fire and inappropriate grazing management that reduces perennial bunchgrasses.

References

Allen, E. B., and M. F. Allen. 1988. Facilitation of succession by the nonmycotrophic colonizer *Salsola kali* (Chenopodiaceae) on a harsh site: effects of mycorrhizal fungi. American Journal of Botany **75**:257-266.

Baker, W. L. 2006. Fire and restoration of sagebrush ecosystems. Wildlife Society Bulletin **34**:177-185.

Balch, J. K., B. A. Bradley, C. M. D'Antonio, and J. Gómez-Dans. 2013. Introduced annual grass increases regional fire activity across the arid western USA (1980–2009). Global Change Biology **19**:173-183.

Bates, J. D., T. Svejcar, R. F. Miller, and R. A. Angell. 2006. The effects of precipitation timing on sagebrush steppe vegetation. Journal of Arid Environments **64**:670-697.

Beatley, J. C. 1975. Climates and vegetation pattern across the Mojave/Great Basin Desert transition of southern Nevada. The American Midland Naturalist **93**:53-70.

Bentz, B., D. Alston, and T. Evans. 2008. Great Basin insect outbreaks. Pages 45-48 *in* Collaborative management and research in the Great Basin - Examining the issues and developing a framework for action. General Technical Report RMRS-GTR-204. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Bertiller, M. B., A. M. Beeskow, and F. Coronato. 1991. Seasonal environmental variation and plant phenology in arid Patagonia (Argentina). Journal of Arid Environments **21**:1-11.

Blaisdell, J. P., and R. C. Holmgren. 1984. Managing intermountain rangelands - salt-desert shrub ranges. General Technical Report INT-163, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Blauer, A. C., A. P. Plummer, E. D. McArthur, R. Stevens, and B. C. Giunta. 1976. Characteristics and hybridization of important intermountain shrubs. II. Chenopod family. Research Paper INT-177, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Boerboom, C. 1993. Russian thistle (*Salsola iberica* Sennen & Pau).

Booth, D. T., C. G. Howard, and C. E. Mowry. 1980. 'Nezpar' Indian ricegrass: description, justification for release, and recommendations for use. Rangelands **2**:53-54.

Bradford, J. B., and W. K. Lauenroth. 2006. Controls over invasion of *Bromus tectorum*: the importance of climate, soil, disturbance and seed availability. Journal of Vegetation Science **17**:693-704.

Bray, R. O., C. L. Wambolt, and R. G. Kelsey. 1991. Influence of sagebrush terpenoids on mule deer preference. Journal of Chemical Ecology **17**:2053-2062.

Britton, C. M., G. R. McPherson, and F. A. Sneva. 1990. Effects of burning and clipping on five bunchgrasses in eastern Oregon. The Great Basin Naturalist **50**:115-120.

Bunting, S. C., B. M. Kilgore, and C. L. Bushey. 1987. Guidelines for prescribed burning sagebrush-grass rangelands in the Northern Great Basin. General Technical Report INT-231, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Butler, M., F. Brummer, J. Weber, and R. Simmons. 2011. Restoring Central Oregon rangeland from ventenata and medusahead to a sustainable bunchgrass environment – Warm Springs and Ashwood. COARC 2011, Oregon State University, Central Oregon Agricultural Research and Extension Center, Corvallis, OR.

Caudle, D., J. DiBenedetto, M. Karl, H. Sanchez, and C. Talbot. 2013. Interagency ecological site handbook for rangelands. U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.

Chambers, J. C., B. A. Bradley, C. S. Brown, C. D'Antonio, M. J. Germino, J. B. Grace, S. P. Hardegree, R. F. Miller, and D. A. Pyke. 2013. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of western North America. Ecosystems **17**:360-375.

Chambers, J. C., B. A. Roundy, R. R. Blank, S. E. Meyer, and A. Whittaker. 2007. What makes Great Basin sagebrush ecosystems invasible by *Bromus tectorum*? Ecological Monographs **77**:117-145.

Comstock, J. P., and J. R. Ehleringer. 1992. Plant adaptation in the Great Basin and Colorado Plateau. The Great Basin Naturalist **52**:195-215.

Cook, C. W. 1962. An evaluation of some common factors affecting utilization of desert range species. Journal of Range Management **15**:333-338.

Cook, C. W., and R. D. Child. 1971. Recovery of desert plants in various states of vigor. Rangeland Ecology & Management/Journal of Range Management Archives **24**:339-343.

Cronquist, A., N. H. Holmgren, and P. K. Holmgren. 1997. Intermountain flora: Vascular plants of the Intermountain West, U.S.A. Volume three, part A. Subclass Rosidae (except Fabales). The New York Botanical Garden, Bronx, NY.

Daubenmire, R. 1970. Steppe vegetation of Washington. Technical Report 62, Washington State University, Washington Agricultural Experiment Station, Pullman, WA.

Daubenmire, R. 1975. Plant succession on abandoned fields, and fire influences in a steppe area in southeastern Washington. Northwest Science **49**:36-48.

Davies, K. W., J. D. Bates, and R. F. Miller. 2006. Vegetation characteristics across part of the Wyoming big sagebrush alliance. Rangeland Ecology and Management **59**:567-575.

Davies, K. W., C. S. Boyd, J. D. Bates, and A. Hulet. 2015a. Dormant season grazing may decrease wildfire probability by increasing fuel moisture and reducing fuel amount and continuity. International Journal of Wildland Fire **24**:849-856.

Davies, K. W., C. S. Boyd, D. D. Johnson, A. M. Nafus, and M. D. Madsen. 2015b. Success of seeding native compared with introduced perennial vegetation for revegetating medusahead-invaded sagebrush rangeland. Rangeland Ecology & Management **68**:224-230.

Davies, K. W., A. M. Nafus, C. S. Boyd, A. Hulet, and J. D. Bates. 2016. Effects of using winter grazing as a fuel treatment on Wyoming big sagebrush plant communities. Rangeland Ecology & Management **69**:179-184.

Dayton, W. A. 1931. Important western browse plants. Misc. Publication No. 101, United States Department of Agriculture, Washington, D.C.

Dobrowolski, J. P., M. M. Caldwell, and J. H. Richards. 1990. Chapter 7: Basin hydrology and plant root systems. Pages 243-292 *in* C. B. Osmond, L. F. Pitelka, and G. M. Hidy, editors. Plant Biology of the Basin and Range. Springer-Verlag, New York City, NY.

Eckert, R. E., Jr., and J. S. Spencer. 1987. Growth and reproduction of grasses heavily grazed under rest-rotation management. Journal of Range Management **40**:156-159.

Ellsworth, L. M., and J. B. Kauffman. 2010. Native bunchgrass response to prescribed fire in ungrazed mountain big sagebrush ecosystems. Fire Ecology **6**:86-96.

Everett, R. L., P. T. Tueller, J. B. Davis, and A. D. Brunner. 1980. Plant phenology in galleta-shadscale and galleta-sagebrush associations. Rangeland Ecology & Management/Journal of Range Management Archives **33**:446-450.

Evert, R. F. 2006. Esau's plant anatomy: Meristems, cells, and tissues of the plant body - Their structure, function, and development. Third Edition edition. John Wiley & Sons, Inc., Hoboken, New Jersey.

Freeman, C. D., G. L. Klikoff, and T. K. Harper. 1976. Differential resource utilization by the sexes of dioecious plants. Science **193**:597-599.

Furbush, P. 1953. Control of medusa-head on California ranges. Journal of Forestry **51**:118-121.

Furniss, M. M., and W. F. Barr. 1975. Insects affecting important native shrubs of the Northwestern United States. General Technical Report INT-19, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Ganskopp, D., L. Aguilera, and M. Vavra. 2007. Livestock forage conditioning among six northern Great Basin grasses. Rangeland Ecology & Management **60**:71-78.

Ganskopp, D. L. 1988. Defoliation of Thurber needlegrass: herbage and root responses. Journal of Range Management **41**:472-476.

Green, L. R., L. A. Sharp, C. W. Cook, and L. E. Harris. 1951. Utilization of winter range forage by sheep. Journal of Range Management **4**:233-241.

Harrington, H. D. 1954. Manual of the plants of Colorado: For the identification of the ferns and flowering plants of the state. Sage Books, Denver, CO.

Harrison, B. J., Thatcher, A.P. 1970. Winter sheep grazing and forage preference in southwestern Wyoming. Journal of Range Management **23**:109-111.

Hironaka, M., and E. W. Tisdale. 1973. Growth and development of *Sitanion hystrix* and *Poa sandbergii*. Research Memorandum RM 73-16, U.S. International Biological Program, Desert Biome, Logan, UT.

Holmgren, N. H., P. K. Holmgren, and A. Cronquist. 2005. Intermountain flora: Vascular plants of the Intermountain West, U.S.A. Volume two, part B. Subclass Dilleniidae. The New York Botanical Garden Press, Bronx, NY.

Humphrey, L. D. 1984. Patterns and mechanisms of plant succession after fire on *Artemisia*-grass sites in southeastern Idaho. Vegetatio **57**:91-101.

Jameson, D. A. 1962. Effects of burning on a galleta-black grama range invaded by juniper. Ecology **43**:760-763.

Johnson, N. C. 1998. Responses of *Salsola kali* and *Panicum virgatum* to mycorrhizal fungi, phosphorus and soil organic matter: implications for reclamation. Journal of Applied Ecology **35**:86-94.

Johnson, R., E. Leger, and K. Vance-Borland. 2017. Genecology of Thurber's Needlegrass (Achnatherum thurberianum [Piper] Barkworth) in the Western United States. Rangeland Ecology & Management **70**:509-517.

Jones, T. A. 1990. A viewpoint on Indian ricegrass research: its present status and future prospects. Journal of Range Management **43**:416-420.

Kearney, T. H., R. H. Peebles, J. T. Howell, and E. McClintock. 1960. Arizona flora. Second edition. University of California Press, Berkeley, CA.

Keeler, R. F. 1989. Investigation of maternal and embryo-fetal toxicity of *Ephedra viridis* and *Ephedra nevadensis* in sheep and cattle. Journal of Range Management **42**:31-35.

Klemmedson, J. O., and J. G. Smith. 1964. Cheatgrass (*Bromus tectorum* L.). The Botanical Review **30**:226-262.

Koniak, S. 1985b. Succession in pinyon-juniper woodlands following wildfire in the Great Basin. The Great Basin Naturalist **45**:556-566.

Kufeld, R. C., O. C. Wallmo, and C. Feddema. 1973a. Foods of the Rocky Mountain mule deer. Rocky Mountain Forest and Range Experiment Station, Forest Service, US Department of Agriculture.

Lett, M. S., and A. K. Knapp. 2005. Woody plant encroachment and removal in mesic grassland: production and composition responses of herbaceous vegetation. American Midland Naturalist **153**:217-231.

Mack, R. N., and D. A. Pyke. 1983. The demography of *Bromus tectorum*: Variation in time and space. Journal of Ecology **71**:69-93.

Mangla, S., R. L. Sheley, and J. J. James. 2011. Field growth comparisons of invasive alien annual and native perennial grasses in monocultures. Journal of Arid Environments **75**:206-210.

McAdoo, J. K., and G. N. Back. 2001. Sage grouse biology. FS-01-43, University of Nevada, Reno Extension, Reno, NV.

McCullough, D. R., and E. R. Schneegas. 1966. Winter observations on the Sierra Nevada bighorn sheep. California Fish and Game **52**:68-84.

Miller, H. C., D. Clausnitzer, and M. M. Borman. 1999a. Medusahead. Pages 272-281 *in* R. L. S. a. J. K. Petroff, editor. Biology and Management of Noxious Rangeland Weeds. Oregon State University Press, Oregon State University.

Miller, R. F., and R. J. Tausch. 2001. The role of fire in juniper and pinyon woodlands: A descriptive analysis. Pages 15-30 *in* Fire conference 2000: the first national congress on fire ecology, prevention, and management; San Diego, CA. Misc. Pub. No. 11. Tall Timbers Research Station, Tallahassee, FL.

Monsen, S. B., R. Stevens, and N. L. Shaw. 2004b. Restoring western ranges and wildlands: Volume 2. General Technical Report RMRS-GTR-136-vol. 2, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Mozingo, H. N. 1987b. Shrubs of the Great Basin: A natural history. University of Nevada Press, Reno, NV.

Noy-Meir, I. 1973. Desert ecosystems: Environment and producers. Annual Review of Ecology and Systematics **4**:25-51.

NRCS. 2022. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. Handbook 296, U.S. Department of Agriculture, Natural Resources Conservation Service.

Ogle, D., St. John, L, Tilley, D, Jones, T. 2006. Plant Guide for Thurber's Needlegrass. USDA NRCS, USDA NRCS Idaho State Office.

Pearson, L. C. 1964. Effect of harvest date on recovery of range grasses and shrubs. Agronomy Journal **56**:80-82.

Pearson, L. C. 1965. Primary production in grazed and ungrazed desert communities of eastern Idaho. Ecology **46**:278-285.

Pellant, M., and C. Hall. 1994. Distribution of two exotic grasses in intermountain rangelands: Status in 1992. Pages 109-112 *in* S. B. Monsen and S. G. Kitchen, editors. Proceedings—Ecology and management of annual rangelands; General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Pendleton, R. L., B. K. Pendleton, S. D. Warren, J. R. Johansen, and L. L. S. Clair. 2007. Shrub establishment in the presence of cheatgrass: The effect of soil microorganisms.*in* Sosebee, Ronald E.; Wester, David B.; Britton, Carlton M.; McArthur, E. Durant; Kitchen, Stanley G., comps. Proceedings: Shrubland dynamics -- fire and water; RMRS-P-47. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Lubbock, TX.

Perkins, S. 2008a. Plant fact sheet for desert needlegrass (*Achnatherum speciosum*). USDA NRCS Great Basin Plant Materials Center, Fallon, Nevada.

Perryman, B. L., B. W. Schultz, M. Burrows, T. Shenkoru, and J. Wilker. 2020. Fall-grazing and grazing-exclusion effects on cheatgrass (*Bromus tectorum*) seed bank assays in Nevada, United States. Rangeland Ecology & Management **73**:343-347.

Perryman, B. L., and Q. D. Skinner. 2007. A Field Guide to Nevada Grasses. Indigenous Rangeland Management Press, Lander, WY.

Personius, T. L., C. L. Wambolt, J. R. Stephens, and R. G. Kelsey. 1987. Crude terpenoid influence on mule deer preference for sagebrush. Journal of Range Management **40**:84-88.

Phillips, R. L., N. K. McDougald, and J. Sullins. 1996. Plant preference of sheep grazing the Mojave desert. Rangelands **18**:141-144.

Pierson, F. B., C. J. Williams, P. R. Kormos, S. P. Hardegree, P. E. Clark, and B. M. Rau. 2010. Hydrologic vulnerability of sagebrush steppe following pinyon and juniper encroachment. Rangeland Ecology & Management **63**:614-629.

Quinones, F. A. 1981. Indian ricegrass evaluation and breeding. Bulletin 681, New Mexico State University, Agricultural Experiment Station, Las Cruces, NM.

Rice, B., and M. Westoby. 1978. Vegetative responses of some Great Basin shrub communities protected against jackrabbits or domestic stock. Journal of Range Management **31**:28-34.

Richards, J. H., and M. M. Caldwell. 1987. Hydraulic lift: substantial nocturnal water transport between soil layers by *Artemisia tridentata* roots. Oecologia **73**:486-489.

Rickard, W. H., and M. C. McShane. 1984. Demise of spiny hopsage shrubs following summer wildfire: An authentic record. Northwest Science **58**:282-285.

Roundy, B. A., E. D. McArthur, J. S. Haley, and D. K. Mann. 1995. Proceedings: wildland shrub and arid land restoration symposium; Las Vegas, NV; October 19-21, 1993. General Technical Report INT-GTR-315, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Rowe, C. L., and E.A Leger. 2010. Competitive seedlings and inherited traits: a test of rapid evolution of Elymus multisetus (big squirreltail) in response to cheatgrass invasion. Evolutionary Applications **4**:485-498.

Sampson, A. W., A. Chase, and D. W. Hedrick. 1951. California grasslands and range forage grasses. Bulletin 724, University of California, the College of Agriculture, California Agricultural Experiment Station, Berkeley, CA.

Sanderson, S. C., and H. C. Stutz. 1994. Woody chenopods useful for rangeland reclamation in western North America. Pages 374-378 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Shaw, N. L. 1992. Germination and seedling establishment of spiny hopsage (*Grayia spinosa* [Hook.] Moq.). PhD Dissertation. Oregon State University, Corvallis, OR.

Sheehy, D. P., and A. H. Winward. 1981. Relative palatability of seven *Artemisia* taxa to mule deer and sheep. Journal of Range Management **34**:397-399.

Sheley, R. L., E. A. Vasquez, A.-M. Chamberlain, and B. S. Smith. 2012. Landscape-scale rehabilitation of medusahead (*Taeniatherum caput-medusae*)-dominated sagebrush steppe. Invasive Plant Science and Management **5**:436-442.

Simmons, S. A., and W. H. Rickard. 2003. Fire effects on spiny hopsage in south central Washington. Western North American Naturalist **63**:524-528.

Stubbendieck, J. L., J. T. Nichols, and K. K. Roberts. 1985. Nebraska range and pasture grasses (including grass-like plants). University of Nebraska, Department of Agriculture, Cooperative Extension Service, Lincoln, NE.

Tisdale, E. W., and M. Hironaka. 1981. The sagebrush - grass region: A review of the ecological literature. Forest, Wildlife and Range Experiment Station, University of Idaho **209**.

Turner, F. B., and D. C. Randall. 1987. The phenology of desert shrubs in southern Nevada. Journal of Arid Environments **13**:119-128.

Tweit, S. J., and K. E. Houston. 1980. Grassland and shrubland habitat types of the Shoshone National Forest. U.S. Department of Agriculture, Forest Service, Rocky Mountain Region, Shoshone National Forest.

Uresk, D. W., J. F. Cline, and W. H. Rickard. 1976b. Impact of wildfire on three perennial grasses in south-central Washington. Journal of Range Management **29**:309-310.

USFS. 1988a. Range plant handbook. Reprint of 1937 edition. Dover Publications, New York, NY.

Vallentine, J. F. 1989. Range development and improvements. Academic Press, Inc., San Diego, CA.

Vollmer, J. L., and J. G. Vollmer. 2008. Controlling cheatgrass in winter range to restore habitat and endemic fire. Pages 57-60 *in* Proceedings—Shrublands under fire: Disturbance and recovery in a changing world. RMRS-P-52. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Cedar City, UT.

Wallace, A., W. Rhods, and E. Frolich. 1968. Germination behavior of *Salsola* as influenced by temperature, moisture, depth of planting, and gamma irradiation. Agronomy Journal **60**:76-78.

West, N. E. 1994. Effects of fire on salt-desert shrub rangelands. Pages 71-74 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, ID.

West, N. E., and M. A. Hassan. 1985. Recovery of sagebrush-grass vegetation following wildfire. Journal of Range Management **38**:131-134.

Williams, J. R., L. R. Morris, K. L. Gunnell, J. K. Johanson, and T. A. Monaco. 2017. Variation in sagebrush communities historically seeded with crested wheatgrass in the eastern Great Basin. Rangeland Ecology & Management **70**:683-690.

Wright, H. A. 1971. Why squirreltail is more tolerant to burning than needle-and-thread. Journal of Range Management **24**:277-284.

Wright, H. A. 1985. Effects of fire on grasses and forbs in sagebrush-grass communities. Pages 12-21 *in* Rangeland fire effects: A symposium; Boise, ID; November 27-29, 1984. U.S. Department of the Interior, Bureau of Land Management, Boise, ID.

Wright, H. A., and J. O. Klemmedson. 1965. Effect of fire on bunchgrasses of the sagebrush-grass region in Southern Idaho. Ecology **46**:680-688.

Young, F., R. Veseth, D. Thill, W. Schillinger, and D. Ball. 1995. Managing Russian thistle under conservation tillage in crop-fallow rotations.

Young, J. A., and R. A. Evans. 1977. Squirreltail seed germination. Journal of Range Management **30**:33-36.

Young, J. A., and R. A. Evans. 1978. Population dynamics after wildfires in sagebrush grasslands. Journal of Range Management **31**:283-289.

Young, R. P. 1983. Fire as a vegetation management tool in rangelands of the intermountain region. Pages 18-31 *in* Managing Intermountain rangelands—Improvement of range and wildlife habitats. Proceedings of Symposia: September 15-17, 1981, Twin Falls, Idaho June 22·24, 1982, Elko, Nevada. General Technical Report INT-GTR-157. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

MLRA 27 Group 4: Big sagebrush and needlegrasses

Description of MRLA 27 Disturbance Response Group 4

Disturbance Response Group (DRG) 4 consists of three ecological sites. These sites occur on footslopes, summits, shoulders, and sideslopes of hills and mountains. The precipitation zone ranges from 10 to 12 in. and elevations range from approximately 5,500 to 7,800 ft. Slopes range from 0 to 50%. The soils on these sites range from shallow to very deep and are well drained. The soil moisture regime is aridic bordering on xeric and the soil temperature regime is mesic. Available water holding capacity is low to moderate. The reference plant communities are dominated by an overstory of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*), mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*) and an understory of Thurber's needlegrass (*Achnatherum thurberianum*). Indian ricegrass (*Achnatherum hymenoides*), basin wildrye (*Leymus cinereus*) and Sandberg bluegrass (*Poa secunda*) are also common grasses. Total annual air-dry production ranges from 500 to 1,200 lb/ac.

Disturbance Response Group 4 Ecological Sites:

Granitic Slope 10-12" P.Z. – Modal	R027XY072NV
Loamy 10-12" P.Z.	R027XY058NV
Loamy Slope 10-12" P.Z.	R027XY054NV

Modal Site:

The Granitic Slope 10-12" P.Z. (R027XY072NV) ecological site is the modal site for this group as it has the most acres mapped. This site occurs on summits and sideslopes of hills and mountains. Slopes range from 15 to 50% and elevations range from 5,500 to 7,500 ft. Mean annual precipitation is 10–12 in. The soils on this site are typically shallow and well drained. The soils have formed in residuum and colluvium from granitic or metamorphic rock sources. The soil surface is coarse-textured and normally very gravelly. Infiltration is rapid and the available water capacity is low. Runoff is slow to medium and the potential for sheet and rill erosion is moderate. The reference plant community is dominated by Wyoming big sagebrush, mountain big sagebrush, spiny hopsage (*Grayia spinosa*) and Thurber's needlegrass. Indian ricegrass, Sandberg bluegrass, squirreltail (*Elymus elymoides*), and Nevada jointfir (*Ephedra nevadensis*) are also common on this site. Total annual air-dry production ranges from 400 to 800 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 27 (MLRA 27 Fallon-Lovelock Area) is almost entirely in Nevada with < 1% in California. The entire area occurs in the rain shadow of the Sierra Nevada mountains and is influenced by Pleistocene Lake Lahontan. Extensive playas occur throughout the area and are a result of the drying of ancient Lake Lahontan. To the west, MLRA 27 has a gradual boundary with MLRA 26 (Carson Basin and Mountains) and to the east has a very gradual boundary with MLRA 24 (Humboldt Basin and Range Area). From west to east the soil temperature increases and the soil moisture decreases, resulting in vast areas dominated by salt-desert shrub communities. Isolated mountain ranges trending north to south are separated by broad desert plains and valleys. Elevations range from 3,300 to 5,900 ft with some mountain peaks over 7,800 ft. The average annual precipitation ranges from 4 to 11 in. and as much as 20 in. at the highest elevations. The majority of annual precipitation is received during late fall and winter occurring mainly as snow. High-intensity, convective thunderstorms also contribute significantly to annual precipitation (NRCS 2022). 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 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 1.0 to over 3.0 m (3–10 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). These shrubs have a flexible generalized root system with development of both deep taproots and laterals near the surface (Comstock and Ehleringer 1992).

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 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).

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).

Variability in plant community composition and production depends on soil surface texture and depth. Thurber's needlegrass will increase on gravelly soils, whereas Indian ricegrass will increase with sandy soil surfaces, and squirreltail will increase with silty soil surfaces. Production generally increases with soil depth. The amount of sagebrush in the plant community is dependent upon disturbances like fire, Aroga moth (*Aroga websteri*) infestations, and grazing.

Wyoming big sagebrush is the most drought tolerant of the big sagebrushes and 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.

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. 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 (3–9 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).

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 moth infestations have occurred in the Great Basin in the 1960s, 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 moth can partially or entirely kill individual plants or entire stands of big sagebrush (Furniss and Barr 1975).

Spiny hopsage is a woody, summer deciduous, diffusely branched native shrub that reaches 1–5 ft in height (Blauer et al. 1976, Mozingo 1987b). This is one of the first shrubs to green up in the spring, usually in late February or early March, and sheds its leaves much earlier than other

deciduous desert shrubs (Turner and Randall 1987, Roundy et al. 1995). Dormancy is one of the longest of the desert shrubs and spiny hopsage will not break dormancy even after summer rains (Everett et al. 1980).

Nevada jointfir 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).

At the upper range of this group's precipitation range, there is potential for infilling by Utah juniper (*Juniperus osteosperma*) and/or singleleaf pinyon (*Pinus monophylla*). Infilling may occur if the site is adjacent to woodland sites or other ecological sites with juniper present. Without disturbance (wildfire) in these areas, the trees will eventually dominate the site and out-compete sagebrush for water and sunlight severely reducing both the shrub and herbaceous understory (Miller and Tausch 2001, Lett and Knapp 2005). The potential for soil erosion increases as the woodland matures and the understory plant community cover declines (Pierson et al. 2010).

The deep-rooted perennial bunchgrasses that occur on these sites include Thurber's needlegrass, Indian ricegrass, and basin wildrye. 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 results in resource partitioning in these shrub/grass systems.

Thurber's needlegrass is a native, cool-season grass common to the semiarid regions of the Intermountain West and is an important component of many sagebrush communities (Johnson et al. 2017). It is a deep-rooted perennial bunchgrass, 1–2 ft tall with fine, narrow in rolled leaves about 6–10 in. long (Perryman and Skinner 2007). It is very drought and cold tolerant and prefers well drained, fine sandy loam to silt loam soils. It is not tolerant of shade and saline or sodic soil conditions (Ogle 2006).

Indian ricegrass is a long-lived, cool-season perennial bunchgrass that grows from 4 to 24 in. tall (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 a long-lived cool season perennial bunchgrass with an extensive deep coarse fibrous root system and long leaf blades that reach lengths of 15–25 in. (Ogle 2000a). It can be

found at elevations from 2,000 up to 9,000 ft and grows best in areas with average annual precipitation of 8–20+ in. (Ogle 2000a).

Sandberg bluegrass is a low-growing, cool-season perennial bunchgrass that grows from 3 to 6.1 dm (12–24 in.) tall (Perryman and Skinner 2007). It is notable for its early growth and short season of vegetative activity (Tisdale and Hironaka 1981). It is one of the most drought resistant of the bluegrasses because of the mass of coarse fibrous roots, and its ability to make growth, produce flowers and mature its seeds early in the season while soil moisture is still available (USFS 1988a). Sandberg bluegrass is widely distributed and an important species in most of the West growing from 1,000 ft to as high as 12,000 ft elevation (USFS 1988a).

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

Annual Invasive Species:

The species most likely to invade these sites are cheatgrass (*Bromus tectorum*), tall tumblemustard (*Sisymbrium altissimum*), Russian thistle (*Salsola tragus*) and redstem stork's bill (*Erodium cicutarium*). Cheatgrass is a cool-season annual grass that maintains an advantage over native plants in part because it is a prolific seed producer, able to germinate in the autumn or spring, tolerant of grazing and increases with frequent fire (Klemmedson and Smith 1964, Miller et al. 1999a). 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. Collectively, the body of research suggests that the continued invasion and dominance of medusahead (onto native grasslands and cheatgrass infested grasslands will continue to increase in severity because conditions that favor native bunchgrasses or cheatgrass over medusahead are rare (Mangla et al. 2011).

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). 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 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), however caution in using these results is advised, as only one 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.

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 (*Purshia tridentata*), and multiple sagebrush species to three rates of imazapic and the same rates with methylated seed oil as a surfactant. They found 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.

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).

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 < 2 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 1998).

Tall tumblemustard is a cool-season annual forb, introduced from southern Europe, and found throughout most of North America (Holmgren et al. 2005). It is one of the most invasive species in the Great Basin and is characterized by early germination, rapid growth, production of numerous seeds and an effective dispersal mechanism (Holmgren et al. 2005). Tall tumblemustard has low palatability but is grazed when growth is young by cattle and sheep (USFS 1988a).

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 40–80 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).

Wyoming big sagebrush communities historically had low fuel loads, and patchy fires that burned in a mosaic pattern were common ranging from 10 to 70-year return intervals (Young and Evans 1978, West and Hassan 1985, Bunting et al. 1987). Davies et al. (2006) suggest fire return intervals in Wyoming big sagebrush communities were around 50–100 years. Wyoming big sagebrush is killed by fire and only regenerates from seed. Recovery time for Wyoming big sagebrush may require 50–120 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 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 3–5 years. Mountain big sagebrush may return to pre-burn density and cover within 15–20 years following fire, but establishment after severe fires may proceed more slowly (Bunting et al. 1987).

Spiny hopsage is generally top-killed by fire (Daubenmire 1970), but often sprouts after plants are damaged by fire or mechanical injury (Shaw 1992). Fires in spiny hopsage sites generally

occur in late summer when plants are dormant, and sprouting generally does not occur until the following spring (Daubenmire 1970). Spiny hopsage is reported to be least susceptible to fire during summer dormancy (Rickard and McShane 1984). Plants often survive fires that kill adjacent sagebrush (Blauer et al. 1976).

Nevada jointfir vigorously sprouts after fire from extensive woody crowns (Young and Evans 1978). Sprouting after fire may vary by season of burn and fire severity, however. Spiny hopsage is a sprouting shrub (Daubenmire 1970) 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). 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).

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).

Burning has been found to decrease the vegetative and reproductive vigor of Thurber's needlegrass (Uresk et al. 1976b). 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). Thurber's needlegrass often survives fire and will continue growth or regenerate from tillers when conditions are favorable (Koniak 1985b, Britton et al. 1990). Thurber's needlegrass was shown to decrease in density following a spring fire, but it produced more reproductive culms the year after a fall fire (Ellsworth and Kauffman 2010). Reestablishment on burned sites has been found to be relatively slow due to low germination and competitive ability (Koniak 1985b). Cheatgrass has been found to be a highly successful competitor with seedlings of this needlegrass and may preclude reestablishment (Young and Evans 1978).

Indian ricegrass is fairly fire tolerant (Wright 1985), which is likely due to its low culm density and below-ground root 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 Indian ricegrass. Grazing management following fire to promote seed production and establishment of seedlings is important.

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) and may retard reestablishment of deeper-rooted bunchgrasses.

Wildlife/Livestock Grazing Interpretations:

Grazing management considerations include timing, duration, intensity and frequency of grazing. Overgrazing leads to an increase in big sagebrush and a decline in deep-rooted perennial bunchgrasses. Shallow-rooted bluegrasses (*Poa* spp.) will increase with further degradation. Reduced bunchgrass vigor or density provides an opportunity for expansion of bluegrass species in interspaces. Sandberg bluegrass and similar low-growing grasses increase under grazing pressure (Tisdale and Hironaka 1981). A combination of overgrazing and prolonged drought may lead to soil redistribution, increased bare ground and a loss in plant production.

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 (*Artemisia tridentata* ssp. *tridentata*) to be intermediately palatable to mule deer when compared to mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*) (most palatable) and black sagebrush (*Artemisia nova*) (least palatable). Wyoming big sagebrush sites provide nesting, fall and winter habitat for sage grouse (*Centrocercus urophasianus*) (McAdoo and Back 2001). Sage grouse require sagebrush for food and cover during each stage of their life cycle.

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, 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).

Spiny hopsage is palatable to livestock, especially sheep, during the spring and early summer (Phillips et al. 1996, Simmons and Rickard 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 overgrazing, local populations of spiny hopsage may be lost (Simmons and Rickard 2003).

Nevada jointfir is used as winter forage by wild ungulates and livestock (Jameson 1962, Kufeld et al. 1973a). Keeler (1989) found Nevada jointfir to be toxic to cattle and sheep, but not to calves and lambs. Nevada joint fir is also an important component of bighorn sheep diets in the eastern Sierra Nevada (McCullough and Schneegas 1966).

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). Thurber’s needlegrass may increase in crude protein content after grazing (Ganskopp et al. 2007).

Indian ricegrass is a preferred forage species for livestock and wildlife (Cook 1962). This species is often heavily utilized in winter because it cures well. 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) 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.

Basin wildrye is palatable to domestic livestock (e.g., cattle, sheep, and horses) and wildlife (e.g., elk, deer, and pronghorn antelope). It is particularly preferred by horses during the spring growing season and is recognized as a desirable forage source for both cattle and horses during early summer, late autumn, and winter (Ogle 2000a).

Inappropriate grazing management during the spring growing season will cause a decline in understory plants such as Thurber's needlegrass, 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 (*Pleuraphis jamesii*) and/or Sandberg bluegrass expansion and/or cheatgrass and other invasive species such as halogeton (*Halogeton glomeratus*) 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 Group 4

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 27 Disturbance Response Group 4.

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 mountain big sagebrush and Thurber's needlegrass dominate the site. Spiny hopsage and Indian ricegrass are also common. Potential vegetative composition by air-dry weight is 60% grasses, 10% forbs and 30% shrubs. Approximate ground cover (basal and crown) is 20–30%. 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 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 Thurber's needlegrass and 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:
Long-term drought, time and/or herbivory favor an increase in big sagebrush over deep-rooted perennial bunchgrasses. Combinations of these would allow the sagebrush overstory to increase and dominate the site, causing a reduction in the perennial bunchgrasses. Sandberg bluegrass or squirreltail may increase in density depending on the grazing management.

Community Phase 1.2:
This community phase is characteristic of a post-disturbance, early to mid-seral community phase. Thurber's needlegrass can experience high mortality from fire and may be reduced in the community for several years. With low fire severity, Thurber's needlegrass may dominate the site post-fire. Sprouting shrubs such as Nevada jointfir, spiny hopsage and yellow rabbitbrush (*Chrysothamnus viscidiflorus*) increase. Indian ricegrass and other perennial grasses are common. Perennial forbs may increase or dominate after fire for several years. Big sagebrush is killed by fire, therefore decreasing within the burned community, however, sagebrush could still be present in unburned patches. Yellow rabbitbrush may dominate the aspect for a number of years following wildfire.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
Time and lack of disturbance allows for sagebrush to reestablish.

Community Phase 1.3 (At-Risk)
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 or from herbivory. Sandberg bluegrass or squirreltail will likely increase in the understory and may be the dominant grass on the site.

Community Phase Pathway 1.3a, from Phase 1.3 to 1.1:
Aroga moth infestation and/or release from growing season herbivory may reduce sagebrush dominance and allow recovery of the perennial bunchgrass understory.

Community Phase Pathway 1.3b, from Phase 1.3 to 1.2:
Fire 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.

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

Trigger: This transition is caused by the introduction of non-native species; such as cheatgrass, Russian thistle, tall tumblemustard or redstem stork's bill dominate the understory.

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 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:
Wyoming and/or mountain big sagebrush and Thurber's needlegrass dominate the site. Spiny hopsage and Indian ricegrass are also common on this site. Non-native annual species are present in minor amounts.

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
Fire 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. Annual non-native species generally respond well after fire and may be stable or increasing within the community.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.3:
Time, long-term drought, grazing management that favors shrubs or combinations of these would allow the sagebrush overstory to increase and dominate the site, causing a reduction in the perennial bunchgrasses. However, Sandberg bluegrass and/or squirreltail may increase in the understory depending on the grazing management. Heavy spring grazing will favor an increase in sagebrush. Annual non-native species may be stable or increasing within the understory.

Community Phase 2.2:
This community phase is characteristic of a post-disturbance, early seral community phase. Indian ricegrass, and other perennial bunchgrasses dominate the site. Sprouting shrubs such as yellow rabbitbrush, Nevada jointfir, and spiny hopsage may increase. Yellow rabbitbrush may dominate the aspect for a number of years following wildfire. Big sagebrush could still be present in unburned patches. Perennial forbs may increase or dominate after fire for several years. Thurber's needlegrass can experience high mortality from fire and may be reduced in the community for several years. 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 2.1:
Absence of disturbance over time allows for the sagebrush to recover may be combined with grazing management that favors shrubs.

Community Phase 2.3 (At-Risk):
Big sagebrush increases and the perennial understory is reduced. Decadent sagebrush dominates the overstory and the deep-rooted perennial bunchgrasses in the understory are reduced either from competition with shrubs or from inappropriate grazing management. Sandberg bluegrass or squirreltail will likely increase in the understory and may be the dominant grass on the site. Annual non-native species present. Singleleaf pinyon and/or Utah juniper may be present.

Granitic Slope 10-12" P.Z. (R027XY072V), Current Potential 2.3, T. Stringham, May 2025

Community Phase Pathway 2.3a, from Phase 2.3 to 2.1:
Low severity fire or Aroga moth infestation creates sagebrush/grass mosaic. Other disturbances/practices include brush management with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.

Community Phase Pathway 2.3b, from Phase 2.3 to 2.2:
Fire 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.

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

Trigger: Inappropriate, long-term grazing of perennial bunchgrasses 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 deep-rooted perennial grass density resulting in a decrease in organic matter inputs and subsequent soil water decline.

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

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

Trigger: Fire, a failed range seeding or brush management that causes soil disturbance leads to plant community phase 4.1. Inappropriate grazing management that favors shrubs in the presence of non-native annual species leads to community phase 4.2.

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

Threshold: Cheatgrass or other non-native annuals dominate the understory.

T2C: Transition from Current Potential State 2.0 to Tree State 5.0:

Trigger: Absence of disturbance over time allows for Utah juniper and/or singleleaf pinyon dominance may be coupled with long-term drought and/or inappropriate grazing management that reduces perennial grass density and increases tree establishment.

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; a big sagebrush-dominated phase and a Sandberg bluegrass or squirreltail dominated phase. This state is a product of many years of heavy grazing during time periods harmful to perennial bunchgrasses. Sandberg bluegrass or squirreltail 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 canopy cover is high and sagebrush 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):

Big sagebrush dominates the overstory. Sandberg bluegrass or squirreltail dominates the understory. Annual non-native species may be present. Understory may be sparse, with bare ground increasing.

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:
Fire would decrease or eliminate the overstory of sagebrush. A severe infestation of Aroga moth could also cause a large decrease in sagebrush within the community, giving a competitive advantage to the squirreltail, forbs and sprouting shrubs. Heavy fall grazing causing mechanical damage to shrubs, and/or brush treatments with minimal soil disturbance, would greatly reduce the overstory shrubs and allow for Sandberg bluegrass to dominate the site.

Community Phase 3.2 (At-Risk):
Sandberg bluegrass or squirreltail dominates the understory; annual non-natives are present and may be increasing. Trace amounts of sagebrush may be present. Sprouting shrubs may dominate for a number of years following fire.

Community Phase Pathway 3.2a, from Phase 3.2 to 3.1:
Absence of disturbance over time would allow for sagebrush and other shrubs to recover.

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

Trigger: Catastrophic fire and/or soil disturbance (4.1). Inappropriate grazing management in the presence of non-native annual species transition to community phase 4.2.

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 sagebrush truncate energy capture and impact the nutrient cycling and distribution.

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 may be coupled with long-term drought and/or inappropriate grazing management that reduces perennial grass density and increases tree establishment.

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 dominated by annual non-native species and the other is a shrub-dominated state. This state is characterized by the dominance of annual non-native species such as cheatgrass, Russian thistle, tumblemustard and/or redstem stork's bill in the understory. Yellow rabbitbrush and other sprouting shrubs may dominate the overstory.

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.

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 Nevada jointfir and yellow rabbitbrush will be the first to reappear after fire. Probability of sagebrush establishment is extremely low.

Community Phase 4.2:
Yellow rabbitbrush and other sprouting shrubs dominate the overstory and annual non-native species dominate the understory. Big sagebrush and perennial bunchgrasses occur in trace amounts.

Granitic Slope 10-12" P.Z. (R027XY072NV), Annual State 4.2, T. Stringham, May 2025

Community Phase Pathway 4.2a, from Phase 4.2 to 4.1:
Fire allows for annual non-native species to dominate site.

Tree State 5.0:

This state is characterized by a dominance of Utah juniper and/or singleleaf pinyon in the overstory. 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 (At-Risk):
Utah juniper and/or singleleaf pinyon trees dominate overstory. 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.

Granitic Slope 10-12" P.Z. (R027XY072NV), Tree State 5.1, T. Stringham, June 2024

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 native herbaceous understory species for sunlight and water.

Community Phase 5.2 (At-Risk):
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 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. Non-native species may be increasing in the understory.

Community Phase Pathway 5.2a, from phase 5.2 to 5.1:
Manual or mechanical thinning of trees allows understory regrowth due to less competition for resources. This treatment is typically done for fuel management.

T5A: Transition from Tree State 5.0 to Annual State 4.0:

Trigger: Catastrophic fire causing a stand-replacing 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.

States Not Observed in Group 4:

Seeded State: A Seeded State was not observed for these sites; however, a similar site in MLRA 26, DRG 9, ecological site Granitic Slope 10-12" P.Z. (R026XY026NV) has a documented seeded state (Stringham et al. 2021).

Thus, the sites in this DRG may have a successful seeding under favorable climatic conditions.

Potential Resilience Differences with other Ecological Sites

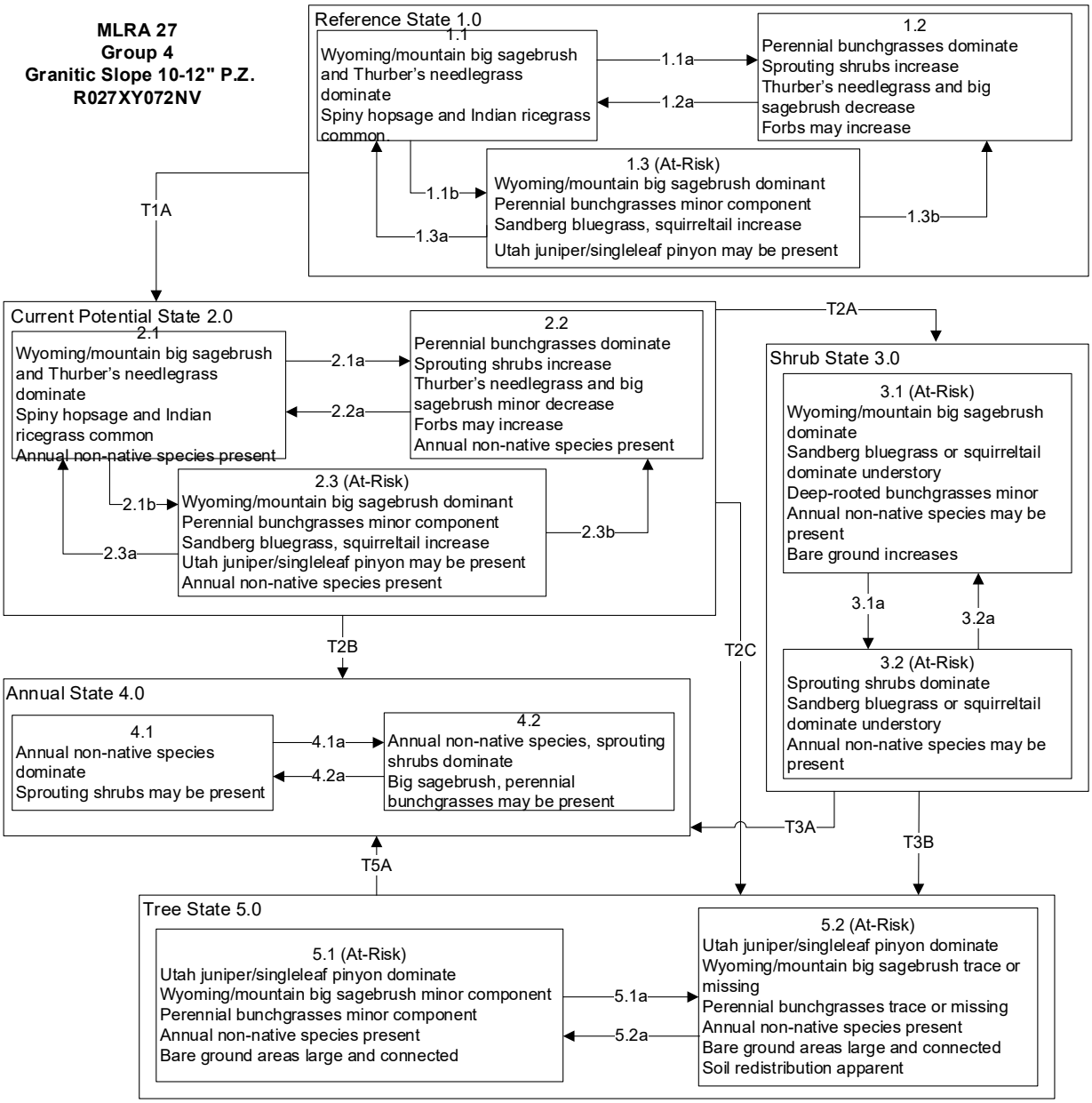
Loamy 10-12" P.Z. (R027XY058NV):

The reference plant community is dominated by mountain and/or Wyoming big sagebrush, Thurber's needlegrass and basin wildrye. This site occurs on mountain valley fans and mountain footslopes on deeper soils than the modal site. Slopes range from 2 to 30% but slopes of 4–15% are most typical. Elevations range from 6,500 to 7,800 ft. The soils of this site a typically shallow to moderately deep and well drained. The available water capacity is low to moderate. Total annual production is higher than the modal site with 1,000 lb/ac in a normal year. This site is more resilient because of more productivity than the modal site and occurs at slightly higher elevations. This site will have a Tree State where it occurs near singleleaf pinyon pine and/or Utah juniper woodlands.

Loamy Slope 10-12" P.Z. (R027XY054NV):

The reference plant community is dominated by mountain and/or Wyoming big sagebrush and Thurber's needlegrass. This site occurs on mountain sideslopes with slopes ranging from 30 to 50%. Elevations range from 6,500 to 7,800 ft. The soils are moderately deep and well drained. Available water capacity is moderate. Total annual production is slightly higher than the modal with 700 lb/ac in a normal year. This site has similar resilience as the modal and will have a Tree State where it occurs near singleleaf pinyon and/or Utah juniper woodlands.

Modal State and Transition Model for Group 4 in MLRA 27



MLRA 27
Group 4
Granitic Slope 10-12" P.Z.
R027XY072NV

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 deep-rooted perennial bunchgrass understory.
1.2a: Time and lack of disturbance allows for shrub regeneration.
1.3a: Aroga moth infestation and/or release from growing season herbivory resulting in a grass/sagebrush mosaic pattern.
1.3b: High severity fire and/or Aroga moth infestation significantly reduces sagebrush cover leading to early/mid-seral community dominated by perennial grasses and sprouting shrubs.

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

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: Grazing management and/or time and lack of disturbance allows for regeneration of sagebrush.
2.3a: Aroga moth infestation and/or release from growing season herbivory resulting in grass/sagebrush mosaic. Brush management with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire and/or Aroga moth infestation significantly reduces sagebrush cover leading to early mid-seral community dominated by sprouting shrubs, grasses and forbs.

Transition T2A: Time 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).
Transition T2C: Time and lack of disturbance allows for an increase in tree cover; inappropriate grazing management and/or chronic drought can reduce perennial grass density 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.

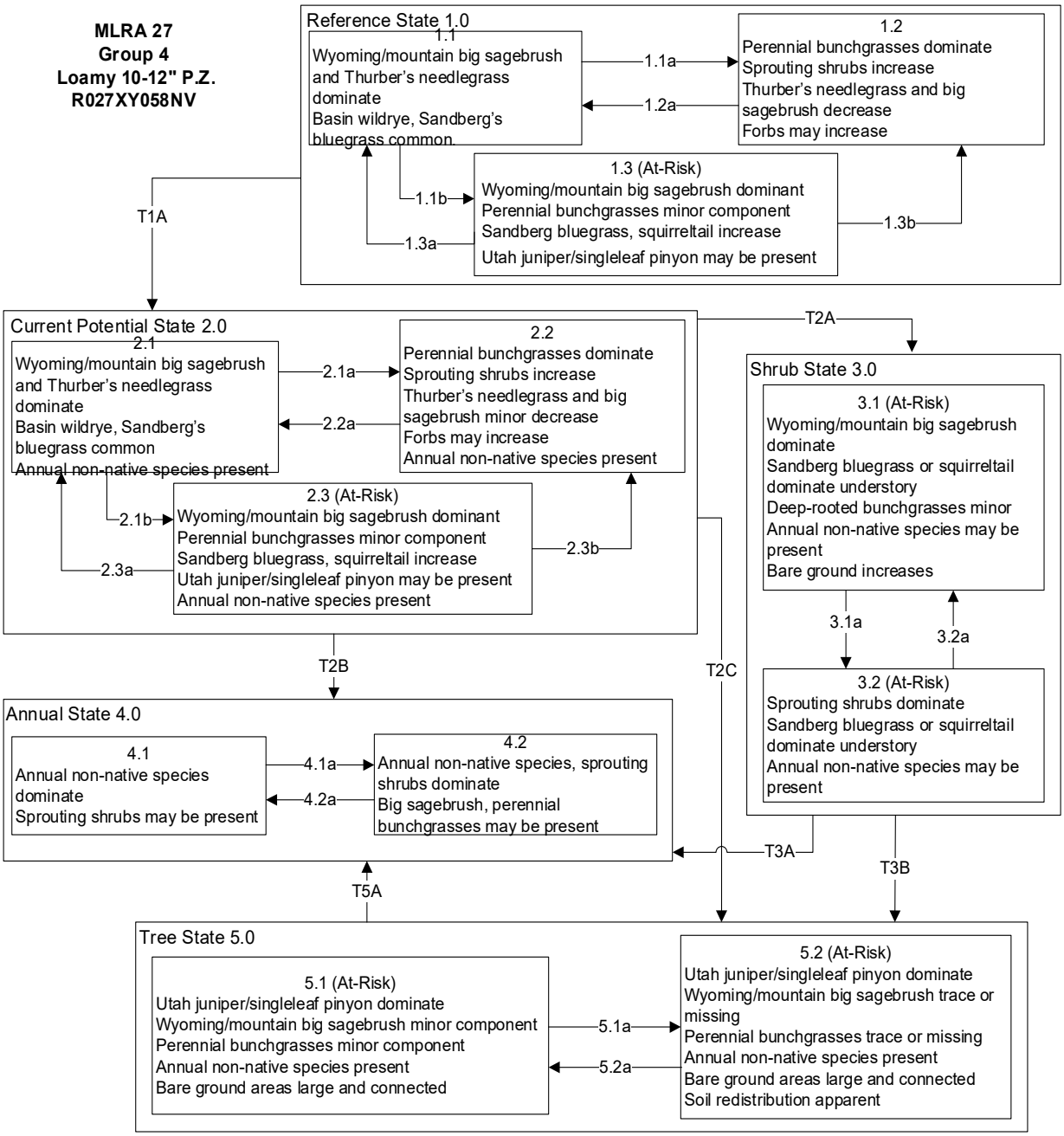
Transition T3A: Catastrophic fire and/or soil disturbance (4.1). Inappropriate grazing management in the presence of non-native annual species (4.2).
Transition T3B: Time and a lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management (5.1).

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of disturbance.
4.2a: Fire.

Tree State 5.0 Community Phase Pathways
5.1a: Time and lack of disturbance allows for tree maturation.
5.2a: Tree thinning treatment (typical for fuels management).

Transition T5A: Catastrophic fire, inappropriate tree removal practices with soil disturbance (5.1).

Additional State and Transition Models for Group 4 in MLRA 27



MLRA 27
Group 4
Loamy 10-12" P.Z.
R027XY058NV

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 deep-rooted perennial bunchgrass understory.
1.2a: Time and lack of disturbance allows for shrub regeneration.
1.3a: Aroga moth infestation and/or release from growing season herbivory resulting in a grass/sagebrush mosaic pattern.
1.3b: High severity fire and/or Aroga moth infestation significantly reduces sagebrush cover leading to early/mid-seral community dominated by perennial grasses and sprouting shrubs.

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

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: Grazing management and/or time and lack of disturbance allows for regeneration of sagebrush.
2.3a: Aroga moth infestation and/or release from growing season herbivory resulting in grass/sagebrush mosaic. Brush management with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire and/or Aroga moth infestation significantly reduces sagebrush cover leading to early mid-seral community dominated by sprouting shrubs, grasses and forbs.

Transition T2A: Time 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).
Transition T2C: Time and lack of disturbance allows for an increase in tree cover; inappropriate grazing management and/or chronic drought can reduce perennial grass density and lead to increased tree establishment and dominance (5.1).

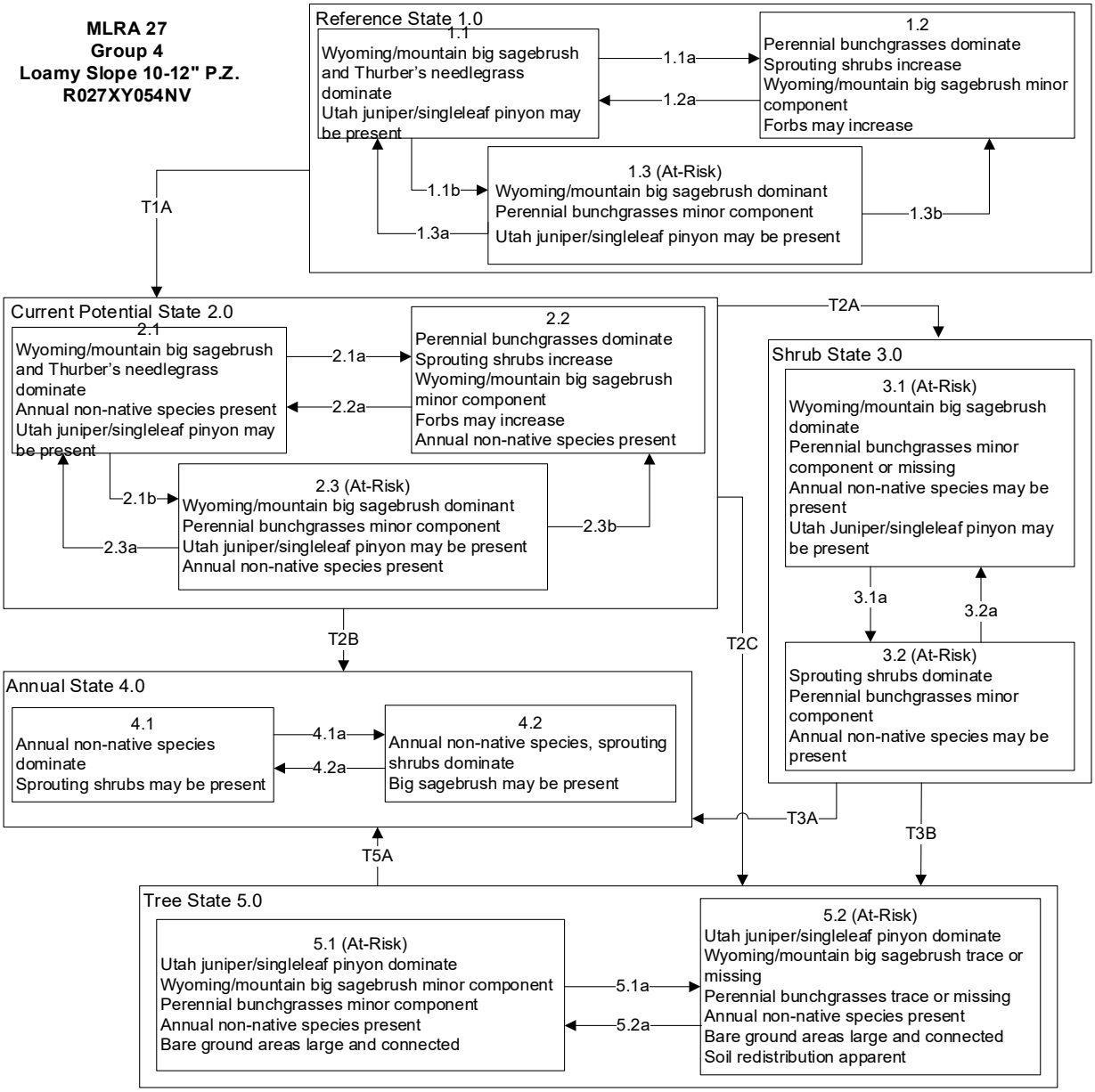
Shrub State 3.0 Community Phase Pathways
3.1a: Fire or brush treatments (i.e. mowing) with minimal soil disturbance.
3.2a: Time and lack of fire allows some shrubs to reestablish.

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).

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of disturbance.
4.2a: Fire.

Tree State 5.0 Community Phase Pathways
5.1a: Time and lack of disturbance allows for tree maturation.
5.2a: Tree thinning treatment (typical for fuels management).

Transition T5A: Catastrophic fire, inappropriate tree removal practices with soil disturbance (5.1).


MLRA 27
Group 4
Loamy Slope 10-12" P.Z.
R027XY054NV
Reference State 1.0
1.1
Wyoming/mountain big sagebrush and Thurber's needlegrass 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 (At-Risk)
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 Thurber's needlegrass 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 dominate
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
Sprouting shrubs may be present
4.1a
4.2a
4.2
Annual non-native species, sprouting shrubs dominate
Big sagebrush may be present
T3A
T3B
T5A
Tree State 5.0
5.1 (At-Risk)
Utah juniper/singleleaf pinyon dominate
Wyoming/mountain big sagebrush minor component
Perennial bunchgrasses minor component
Annual non-native species present
Bare ground areas large and connected
5.1a
5.2a
5.2 (At-Risk)
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

MLRA 27
Group 4
Loamy Slope 10-12" P.Z.
R027XY054NV

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 deep-rooted perennial bunchgrass understory.
1.2a: Time and lack of disturbance allows for shrub regeneration.
1.3a: Aroga moth infestation and/or release from growing season herbivory resulting in a grass/sagebrush mosaic pattern.
1.3b: High severity fire and/or Aroga moth infestation significantly reduces sagebrush cover leading to early/mid-seral community dominated by perennial grasses and sprouting shrubs.

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

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: Grazing management and/or time and lack of disturbance allows for regeneration of sagebrush.
2.3a: Aroga moth infestation and/or release from growing season herbivory resulting in grass/sagebrush mosaic. Brush management with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire and/or Aroga moth infestation significantly reduces sagebrush cover leading to early mid-seral community dominated by sprouting shrubs, grasses and forbs.

Transition T2A: Time 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).
Transition T2C: Time and lack of disturbance allows for an increase in tree cover; inappropriate grazing management and/or chronic drought can reduce perennial grass density 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).

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of disturbance.
4.2a: Fire.

Tree State 5.0 Community Phase Pathways
5.1a: Time and lack of disturbance allows for tree maturation.
5.2a: Tree thinning treatment (typical for fuels management).

Transition T5A: Catastrophic fire, inappropriate tree removal practices with soil disturbance (5.1).

References

Akinsoji, A. 1988. Postfire vegetation dynamics in a sagebrush steppe in southeastern Idaho, USA. Vegetatio **78**:151-155.

Allen, E. B., and M. F. Allen. 1988. Facilitation of succession by the nonmycotrophic colonizer *Salsola kali* (Chenopodiaceae) on a harsh site: effects of mycorrhizal fungi. American Journal of Botany **75**:257-266.

Baker, W. L. 2006. Fire and restoration of sagebrush ecosystems. Wildlife Society Bulletin **34**:177-185.

Balch, J. K., B. A. Bradley, C. M. D'Antonio, and J. Gómez-Dans. 2013. Introduced annual grass increases regional fire activity across the arid western USA (1980–2009). Global Change Biology **19**:173-183.

Bates, J. D., T. Svejcar, R. F. Miller, and R. A. Angell. 2006. The effects of precipitation timing on sagebrush steppe vegetation. Journal of Arid Environments **64**:670-697.

Beatley, J. C. 1975. Climates and vegetation pattern across the Mojave/Great Basin Desert transition of southern Nevada. The American Midland Naturalist **93**:53-70.

Bentz, B., D. Alston, and T. Evans. 2008. Great Basin insect outbreaks. Pages 45-48 *in* Collaborative management and research in the Great Basin - Examining the issues and developing a framework for action. General Technical Report RMRS-GTR-204. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Blaisdell, J. P. 1953. Ecological effects of planned burning of sagebrush-grass range on the upper Snake River plains. Technical Bulletin No. 1075, U.S. Department of Agriculture, Washington, D.C.

Blaisdell, J. P., and R. C. Holmgren. 1984. Managing intermountain rangelands - salt-desert shrub ranges. General Technical Report INT-163, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Blaisdell, J. P., R. B. Murray, and E. D. McArthur. 1982. Managing intermountain rangelands - sagebrush-grass ranges. General Technical Report INT-134, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Blauer, A. C., A. P. Plummer, E. D. McArthur, R. Stevens, and B. C. Giunta. 1976. Characteristics and hybridization of important intermountain shrubs. II. Chenopod family. Research Paper INT-177, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Boerboom, C. 1993. Russian thistle (*Salsola iberica* Sennen & Pau).

Booth, D. T., C. G. Howard, and C. E. Mowry. 1980. 'Nezpar' Indian ricegrass: description, justification for release, and recommendations for use. Rangelands **2**:53-54.

Bradford, J. B., and W. K. Lauenroth. 2006. Controls over invasion of *Bromus tectorum*: the importance of climate, soil, disturbance and seed availability. Journal of Vegetation Science **17**:693-704.

Bray, R. O., C. L. Wambolt, and R. G. Kelsey. 1991. Influence of sagebrush terpenoids on mule deer preference. Journal of Chemical Ecology **17**:2053-2062.

Britton, C. M., G. R. McPherson, and F. A. Sneva. 1990. Effects of burning and clipping on five bunchgrasses in eastern Oregon. The Great Basin Naturalist **50**:115-120.

Bunting, S. C., B. M. Kilgore, and C. L. Bushey. 1987. Guidelines for prescribed burning sagebrush-grass rangelands in the Northern Great Basin. General Technical Report INT-231, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Burkhardt, J. W., and E. W. Tisdale. 1969. Nature and successional status of western juniper vegetation in Idaho. Journal of Range Management **22**:264-270.

Butler, M., F. Brummer, J. Weber, and R. Simmons. 2011. Restoring Central Oregon rangeland from ventenata and medusahead to a sustainable bunchgrass environment – Warm Springs and Ashwood. COARC 2011, Oregon State University, Central Oregon Agricultural Research and Extension Center, Corvallis, OR.

Caudle, D., J. DiBenedetto, M. Karl, H. Sanchez, and C. Talbot. 2013. Interagency ecological site handbook for rangelands. U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.

Chambers, J. C., B. A. Bradley, C. S. Brown, C. D'Antonio, M. J. Germino, J. B. Grace, S. P. Hardegree, R. F. Miller, and D. A. Pyke. 2013. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of western North America. Ecosystems **17**:360-375.

Chambers, J. C., B. A. Roundy, R. R. Blank, S. E. Meyer, and A. Whittaker. 2007. What makes Great Basin sagebrush ecosystems invasible by *Bromus tectorum*? Ecological Monographs **77**:117-145.

Coates, P. S., B. G. Prochazka, M. A. Ricca, K. B. Gustafson, P. Ziegler, and M. L. Casazza. 2016. Pinyon and juniper encroachment into sagebrush ecosystems impacts distribution and survival of greater sage-grouse. Rangeland Ecology & Management **70**:25–38.

Comstock, J. P., and J. R. Ehleringer. 1992. Plant adaptation in the Great Basin and Colorado Plateau. The Great Basin Naturalist **52**:195-215.

Cook, C. W. 1962. An evaluation of some common factors affecting utilization of desert range species. Journal of Range Management **15**:333-338.

Cook, C. W., and R. D. Child. 1971. Recovery of desert plants in various states of vigor. Rangeland Ecology & Management/Journal of Range Management Archives **24**:339-343.

Crawford, J. A., R. A. Olson, N. E. West, J. C. Mosley, M. A. Schroeder, T. D. Whitson, R. F. Miller, M. A. Gregg, and C. S. Boyd. 2004. Synthesis paper - Ecology and management of sage-grouse and sage-grouse habitat. Journal of Range Management **57**:2-19.

Daubenmire, R. 1970. Steppe vegetation of Washington. Technical Report 62, Washington State University, Washington Agricultural Experiment Station, Pullman, WA.

Daubenmire, R. 1975. Plant succession on abandoned fields, and fire influences in a steppe area in southeastern Washington. Northwest Science **49**:36-48.

Davies, K. W., J. D. Bates, and R. F. Miller. 2006. Vegetation characteristics across part of the Wyoming big sagebrush alliance. Rangeland Ecology and Management **59**:567-575.

Davies, K. W., C. S. Boyd, J. D. Bates, and A. Hulet. 2015a. Dormant season grazing may decrease wildfire probability by increasing fuel moisture and reducing fuel amount and continuity. International Journal of Wildland Fire **24**:849-856.

Davies, K. W., C. S. Boyd, D. D. Johnson, A. M. Nafus, and M. D. Madsen. 2015b. Success of seeding native compared with introduced perennial vegetation for revegetating medusahead-invaded sagebrush rangeland. Rangeland Ecology & Management **68**:224-230.

Davies, K. W., A. M. Nafus, C. S. Boyd, A. Hulet, and J. D. Bates. 2016. Effects of using winter grazing as a fuel treatment on Wyoming big sagebrush plant communities. Rangeland Ecology & Management **69**:179-184.

Dobkin, D. S., and J. D. Sauder. 2004. Shrubsteppe landscapes in jeopardy: Distributions, abundances, and the uncertain future of birds and small mammals in the Intermountain West. High Desert Ecological Research Institute, Bend, OR.

Dobrowolski, J. P., M. M. Caldwell, and J. H. Richards. 1990. Chapter 7: Basin hydrology and plant root systems. Pages 243-292 *in* C. B. Osmond, L. F. Pitelka, and G. M. Hidy, editors. Plant Biology of the Basin and Range. Springer-Verlag, New York City, NY.

Eckert, R. E., Jr., A. D. Bruner, and G. J. Klomp. 1972. Response of understory species following herbicidal control of low sagebrush. Journal of Range Management **25**:280-285.

Eckert, R. E., Jr., and J. S. Spencer. 1987. Growth and reproduction of grasses heavily grazed under rest-rotation management. Journal of Range Management **40**:156-159.

Ellsworth, L. M., and J. B. Kauffman. 2010. Native bunchgrass response to prescribed fire in ungrazed mountain big sagebrush ecosystems. Fire Ecology **6**:86-96.

Everett, R. L., P. T. Tueller, J. B. Davis, and A. D. Brunner. 1980. Plant phenology in galleta-shadscale and galleta-sagebrush associations. Rangeland Ecology & Management/Journal of Range Management Archives **33**:446-450.

Freeman, C. D., G. L. Klikoff, and T. K. Harper. 1976. Differential resource utilization by the sexes of dioecious plants. Science **193**:597-599.

Furbush, P. 1953. Control of medusa-head on California ranges. Journal of Forestry **51**:118-121.

Furniss, M. M., and W. F. Barr. 1975. Insects affecting important native shrubs of the Northwestern United States. General Technical Report INT-19, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Ganskopp, D., L. Aguilera, and M. Vavra. 2007. Livestock forage conditioning among six northern Great Basin grasses. Rangeland Ecology & Management **60**:71-78.

Ganskopp, D. L. 1988. Defoliation of Thurber needlegrass: herbage and root responses. Journal of Range Management **41**:472-476.

Green, L. R., L. A. Sharp, C. W. Cook, and L. E. Harris. 1951. Utilization of winter range forage by sheep. Journal of Range Management **4**:233-241.

Harrison, B. J., Thatcher, A.P. 1970. Winter sheep grazing and forage preference in southwestern Wyoming. Journal of Range Management **23**:109-111.

Holmgren, N. H., P. K. Holmgren, and A. Cronquist. 2005. Intermountain flora: Vascular plants of the Intermountain West, U.S.A. Volume two, part B. Subclass Dilleniidae. The New York Botanical Garden Press, Bronx, NY.

Houston, D. B. 1973. Wildfires in northern Yellowstone National Park. Ecology **54**:1111-1117.

Jameson, D. A. 1962. Effects of burning on a galleta-black grama range invaded by juniper. Ecology **43**:760-763.

Johnson, N. C. 1998. Responses of *Salsola kali* and *Panicum virgatum* to mycorrhizal fungi, phosphorus and soil organic matter: implications for reclamation. Journal of Applied Ecology **35**:86-94.

Johnson, R., E. Leger, and K. Vance-Borland. 2017. Genecology of Thurber's Needlegrass (Achnatherum thurberianum [Piper] Barkworth) in the Western United States. Rangeland Ecology & Management **70**:509-517.

Jones, T. A. 1990. A viewpoint on Indian ricegrass research: its present status and future prospects. Journal of Range Management **43**:416-420.

Keeler, R. F. 1989. Investigation of maternal and embryo-fetal toxicity of *Ephedra viridis* and *Ephedra nevadensis* in sheep and cattle. Journal of Range Management **42**:31-35.

Kitchen, S. G., and E. D. McArthur. 2007. Big and black sagebrush landscapes. Pages 73-94 *in* Fire ecology and management of the major ecosystems of southern Utah. General Technical Report RMRS-GTR-202. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Klemmedson, J. O., and J. G. Smith. 1964. Cheatgrass (*Bromus tectorum* L.). The Botanical Review **30**:226-262.

Koniak, S. 1985b. Succession in pinyon-juniper woodlands following wildfire in the Great Basin. The Great Basin Naturalist **45**:556-566.

Kufeld, R. C., O. C. Wallmo, and C. Feddema. 1973a. Foods of the Rocky Mountain mule deer. Rocky Mountain Forest and Range Experiment Station, Forest Service, US Department of Agriculture.

Lett, M. S., and A. K. Knapp. 2005. Woody plant encroachment and removal in mesic grassland: production and composition responses of herbaceous vegetation. American Midland Naturalist **153**:217-231.

Mack, R. N., and D. A. Pyke. 1983. The demography of *Bromus tectorum*: Variation in time and space. Journal of Ecology **71**:69-93.

Mangla, S., R. L. Sheley, and J. J. James. 2011. Field growth comparisons of invasive alien annual and native perennial grasses in monocultures. Journal of Arid Environments **75**:206-210.

McAdoo, J. K., and G. N. Back. 2001. Sage grouse biology. FS-01-43, University of Nevada, Reno Extension, Reno, NV.

McCullough, D. R., and E. R. Schneegas. 1966. Winter observations on the Sierra Nevada bighorn sheep. California Fish and Game **52**:68-84.

Miller, H. C., D. Clausnitzer, and M. M. Borman. 1999a. Medusahead. Pages 272-281 *in* R. L. S. a. J. K. Petroff, editor. Biology and Management of Noxious Rangeland Weeds. Oregon State University Press, Oregon State University.

Miller, R. F., J. C. Chambers, D. A. Pyke, F. B. Pierson, and C. J. Williams. 2013. A review of fire effects on vegetation and soils in the Great Basin Region: Response and ecological site characteristics. General Technical Report RMRS-GTR-308, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Miller, R. F., T. J. Svejcar, and J. A. Rose. 2000. Impacts of western juniper on plant community composition and structure. Journal of Range Management **53**:574-585.

Miller, R. F., and R. J. Tausch. 2001. The role of fire in juniper and pinyon woodlands: A descriptive analysis. Pages 15-30 *in* Fire conference 2000: the first national congress on

fire ecology, prevention, and management; San Diego, CA. Misc. Pub. No. 11. Tall Timbers Research Station, Tallahassee, FL.

Monsen, S. B., R. Stevens, and N. L. Shaw. 2004b. Restoring western ranges and wildlands: Volume 2. General Technical Report RMRS-GTR-136-vol. 2, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Mozingo, H. N. 1987b. Shrubs of the Great Basin: A natural history. University of Nevada Press, Reno, NV.

Neuenschwander, L. F. 1980. Broadcast burning of sagebrush in the winter. Journal of Range Management **33**:233-236.

Noy-Meir, I. 1973. Desert ecosystems: Environment and producers. Annual Review of Ecology and Systematics **4**:25-51.

NRCS. 2022. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. Handbook 296, U.S. Department of Agriculture, Natural Resources Conservation Service.

Ogle, D., St. John, L, Tilley, D, Jones, T. 2006. Plant Guide for Thurber's Needlegrass. USDA NRCS, USDA NRCS Idaho State Office.

Ogle, D. G. 2000a. Plant guide for basin wildrye (*Leymus cinereus*). USDA NRCS, USDA NRCS Idaho State Office, Boise, Idaho.

Pearson, L. C. 1964. Effect of harvest date on recovery of range grasses and shrubs. Agronomy Journal **56**:80-82.

Pearson, L. C. 1965. Primary production in grazed and ungrazed desert communities of eastern Idaho. Ecology **46**:278-285.

Pellant, M., and C. Hall. 1994. Distribution of two exotic grasses in intermountain rangelands: Status in 1992. Pages 109-112 *in* S. B. Monsen and S. G. Kitchen, editors. Proceedings—Ecology and management of annual rangelands; General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Pendleton, R. L., B. K. Pendleton, S. D. Warren, J. R. Johansen, and L. L. S. Clair. 2007. Shrub establishment in the presence of cheatgrass: The effect of soil microorganisms.*in* Sosebee, Ronald E.; Wester, David B.; Britton, Carlton M.; McArthur, E. Durant; Kitchen, Stanley G., comps. Proceedings: Shrubland dynamics -- fire and water; RMRS-P-47. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Lubbock, TX.

Perryman, B. L., B. W. Schultz, M. Burrows, T. Shenkoru, and J. Wilker. 2020. Fall-grazing and grazing-exclusion effects on cheatgrass (*Bromus tectorum*) seed bank assays in Nevada, United States. Rangeland Ecology & Management **73**:343-347.

Perryman, B. L., and Q. D. Skinner. 2007. A Field Guide to Nevada Grasses. Indigenous Rangeland Management Press, Lander, WY.

Personius, T. L., C. L. Wambolt, J. R. Stephens, and R. G. Kelsey. 1987. Crude terpenoid influence on mule deer preference for sagebrush. Journal of Range Management **40**:84-88.

Phillips, R. L., N. K. McDougald, and J. Sullins. 1996. Plant preference of sheep grazing the Mojave desert. Rangelands **18**:141-144.

Pierson, F. B., C. J. Williams, P. R. Kormos, S. P. Hardegree, P. E. Clark, and B. M. Rau. 2010. Hydrologic vulnerability of sagebrush steppe following pinyon and juniper encroachment. Rangeland Ecology & Management **63**:614-629.

Quinones, F. A. 1981. Indian ricegrass evaluation and breeding. Bulletin 681, New Mexico State University, Agricultural Experiment Station, Las Cruces, NM.

Rice, B., and M. Westoby. 1978. Vegetative responses of some Great Basin shrub communities protected against jackrabbits or domestic stock. Journal of Range Management **31**:28-34.

Richards, J. H., and M. M. Caldwell. 1987. Hydraulic lift: substantial nocturnal water transport between soil layers by *Artemisia tridentata* roots. Oecologia **73**:486-489.

Rickard, W. H., and M. C. McShane. 1984. Demise of spiny hopsage shrubs following summer wildfire: An authentic record. Northwest Science **58**:282-285.

Roundy, B. A., E. D. McArthur, J. S. Haley, and D. K. Mann. 1995. Proceedings: wildland shrub and arid land restoration symposium; Las Vegas, NV; October 19-21, 1993. General Technical Report INT-GTR-315, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Sanderson, S. C., and H. C. Stutz. 1994. Woody chenopods useful for rangeland reclamation in western North America. Pages 374-378 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Shaw, N. L. 1992. Germination and seedling establishment of spiny hopsage (*Grayia spinosa* [Hook.] Moq.). PhD Dissertation. Oregon State University, Corvallis, OR.

Sheehy, D. P., and A. H. Winward. 1981. Relative palatability of seven *Artemisia* taxa to mule deer and sheep. Journal of Range Management **34**:397-399.

Sheley, R. L., E. A. Vasquez, A.-M. Chamberlain, and B. S. Smith. 2012. Landscape-scale rehabilitation of medusahead (*Taeniatherum caput-medusae*)-dominated sagebrush steppe. Invasive Plant Science and Management **5**:436-442.

Simmons, S. A., and W. H. Rickard. 2003. Fire effects on spiny hopsage in south central Washington. Western North American Naturalist **63**:524-528.

Stringham, T. K., D. K. Snyder, P. Novak-Echenique, K. O'Neill, A. Lyons, and M. Johns. 2021. Great Basin ecological site development project: State-and-transition models for Major Land Resource Area 26, Nevada and portions of California. Nevada Agricultural Experiment Station Research Report 2021-01, University of Nevada Reno, USA.

Stubbendieck, J. L., J. T. Nichols, and K. K. Roberts. 1985. Nebraska range and pasture grasses (including grass-like plants). University of Nebraska, Department of Agriculture, Cooperative Extension Service, Lincoln, NE.

Tisdale, E. W., and M. Hironaka. 1981. The sagebrush - grass region: A review of the ecological literature. Forest, Wildlife and Range Experiment Station, University of Idaho **209**.

Turner, F. B., and D. C. Randall. 1987. The phenology of desert shrubs in southern Nevada. Journal of Arid Environments **13**:119-128.

Tweit, S. J., and K. E. Houston. 1980. Grassland and shrubland habitat types of the Shoshone National Forest. U.S. Department of Agriculture, Forest Service, Rocky Mountain Region, Shoshone National Forest.

Uresk, D. W., J. F. Cline, and W. H. Rickard. 1976b. Impact of wildfire on three perennial grasses in south-central Washington. Journal of Range Management **29**:309-310.

USFS. 1937. Range plant handbook. U.S. Department of Agriculture, Forest Service, Washington, D.C.

USFS. 1988a. Range plant handbook. Reprint of 1937 edition. Dover Publications, New York, NY.

Vallentine, J. F. 1989. Range development and improvements. Academic Press, Inc., San Diego, CA.

Vollmer, J. L., and J. G. Vollmer. 2008. Controlling cheatgrass in winter range to restore habitat and endemic fire. Pages 57-60 *in* Proceedings—Shrublands under fire: Disturbance and recovery in a changing world. RMRS-P-52. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Cedar City, UT.

Wallace, A., W. Rhods, and E. Frolich. 1968. Germination behavior of *Salsola* as influenced by temperature, moisture, depth of planting, and gamma irradiation. Agronomy Journal **60**:76-78.

Welch, B. L. 2005. Big sagebrush: A sea fragmented into lakes, ponds, and puddles. General Technical Report RMRS-GTR-144, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

West, N. E. 1994. Effects of fire on salt-desert shrub rangelands. Pages 71-74 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, ID.

West, N. E., and M. A. Hassan. 1985. Recovery of sagebrush-grass vegetation following wildfire. Journal of Range Management **38**:131-134.

Wright, H. A. 1971. Why squirreltail is more tolerant to burning than needle-and-thread. Journal of Range Management **24**:277-284.

Wright, H. A. 1985. Effects of fire on grasses and forbs in sagebrush-grass communities. Pages 12-21 *in* Rangeland fire effects: A symposium; Boise, ID; November 27-29, 1984. U.S. Department of the Interior, Bureau of Land Management, Boise, ID.

Wright, H. A., and J. O. Klemmedson. 1965. Effect of fire on bunchgrasses of the sagebrush-grass region in Southern Idaho. Ecology **46**:680-688.

Young, F., R. Veseth, D. Thill, W. Schillinger, and D. Ball. 1995. Managing Russian thistle under conservation tillage in crop-fallow rotations.

Young, J. A., and R. A. Evans. 1978. Population dynamics after wildfires in sagebrush grasslands. Journal of Range Management **31**:283-289.

Young, R. P. 1983. Fire as a vegetation management tool in rangelands of the intermountain region. Pages 18-31 *in* Managing Intermountain rangelands—Improvement of range and wildlife habitats. Proceedings of Symposia: September 15-17, 1981, Twin Falls, Idaho June 22·24, 1982, Elko, Nevada. General Technical Report INT-GTR-157. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

MLRA 27 Group 5: Sites associated with ephemeral streams

Description of MLRA 27 Disturbance Response Group 5

Disturbance Response Group (DRG) 5 consists of one ecological site – Valley Wash 4-8" P.Z. (R027XY022NV). This site occurs on ephemeral channels of inset fans. These channels have down-cut through alluvial fans and lower piedmont slopes. Slope ranges from 0 to 8%. Elevations range from 3,400 to about 5,000 ft. The precipitation ranges from 4 to 8 in. The soils are formed in mixed alluvium and are very deep and excessively drained. The soils may have gravels distributed throughout the soil profile as well as at the surface. The soils are occasionally flooded thus they are stratified as they continue to be re-worked by water. Runoff is low or very low, and water holding capacity is very low to moderate. The soil moisture regime is typic aridic, and the soil temperature regime is mesic. The reference plant community is variable and many species from adjacent ecological sites may occur on this site. Typically, the reference plant community is dominated by burrobrush (*Hymenoclea salsola*), spiny hopsage (*Grayia spinosa*), Nevada dalea (*Psorothamnus polydenius*) and Indian ricegrass (*Achnatherum hymenoides*). Several other species are associated with this site including rubber rabbitbrush (*Ericameria nauseosa*), yellow rabbitbrush *(Chrysothamnus viscidiflorus*), fourwing saltbush (*Atriplex canescens*), big sagebrush (*Artemisia tridentata*), Bailey's greasewood (*Sarcobatus baileyi*) and desert needlegrass (*Achnatherum speciosum*). Total annual production by air-dry weight ranges from 50 to 400 lb/ac with 200 lb/ac for a normal year.

Disturbance Response Group 5 - Ecological Sites:

Valley Wash – Modal	R027XY022NV

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 27 (MLRA 27 Fallon-Lovelock Area) is almost entirely in Nevada with < 1% in California. The entire area occurs in the rain shadow of the Sierra Nevada mountains and is influenced by Pleistocene Lake Lahontan. Extensive playas occur throughout the area and are a result of the drying of ancient Lake Lahontan. To the west, MLRA 27 has a gradual

boundary with MLRA 26 (Carson Basin and Mountains) and to the east has a very gradual boundary with MLRA 24 (Humboldt Basin and Range Area). From west to east the soil temperature increases and the soil moisture decreases, resulting in vast areas dominated by salt-desert shrub communities. Isolated mountain ranges trending north to south are separated by broad desert plains and valleys. Elevations range from 3,300 to 5,900 ft with some mountain peaks over 7,800 ft. The average annual precipitation ranges from 4 to 11 in. and as much as 20 in. at the highest elevations. The majority of annual precipitation is received during late fall and winter occurring mainly as snow. High-intensity, convective thunderstorms also contribute significantly to annual precipitation (NRCS 2022). 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 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.
Burrobrush is a native, short-lived, drought-deciduous shrub, 1–2 m (3–6.5 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).

Nevada dalea is a native, short-lived, drought-deciduous shrub 0.5–2.5 m tall (1.6–8.2 ft). It mostly occurs on sandy soils of the Mojave and sagebrush deserts in eastern California, western to southern Nevada and southern Utah (Benson and Darrow 1981b). It occurs on sand sheets, partially stabilized sand dunes, alluvial flats and inset fans with intermittent water courses (Perryman 2014a). This shrub has the capability of breaking dormancy with summer rains,

producing new leaves and flowers (Mozingo 1987b). Nevada dalea develops a deep taproot (up to 5 ft) and several lateral roots in order to access water in the sandy soils where it occurs (Ting 1961).

Spiny hopsage is a rounded, summer-deciduous shrub standing 0.3–1.2 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 (525–7,000 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.

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 1–3 m (3–10 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 2004a).

Fourwing saltbush is the most widely distributed and abundant saltbush in the southwest United States (Mozingo 1987b). 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 (16–49 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 endomycorrhiza that allows absorption of soil moisture at very low water potentials (Newton and Goodin 1989, Dobrowolski et al. 1990, Cibils et al. 1998).

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 in. tall (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. 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 site in this DRG has 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 invasive weeds, soil disturbance could allow for further invasion into these ephemeral stream systems. 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, 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* sp.) 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) 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 1.5–1.7 m (5–5.5 ft)

The species most likely to invade this site 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. 1999b). 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, 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 (*Poa secunda*) has been found to be more successful at combating cheatgrass (and medusahead, *Taeniatherum caput-medusae*) 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, and North Africa grass (*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 (*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 one 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 snow melt 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 streams 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 1986b). 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). 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 (3–20 ft) deep (Robinson 1958). Rabbitbrush has the ability to resprout and survive long-term flooding (Groeneveld and Crowley 1988a). 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.

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.

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.

Spiny hopsage is generally top-killed by fire, but often sprouts after plants are damaged by fire or mechanical injury (Shaw 1992). Fires in spiny hopsage sites generally occur in late summer when plants are dormant, and sprouting generally does not occur until the following spring (Daubenmire 1970). Spiny hopsage is reported to be least susceptible to fire during summer dormancy (Rickard and McShane 1984).

Psorothamnus species (Nevada dalea) are generally weakly sprouting shrubs that are commonly top-killed by fire. Resprouting from the root crown or base may occur after low-intensity burns but experience high mortality from hotter fires. Reestablishment primarily occurs from off-site seed sources (Society 2009).

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).

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).

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.

Spiny hopsage is palatable to livestock, especially sheep, during the spring and early summer (Phillips et al. 1996, Simmons and Rickard 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 and Rickard 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).

*Psorothamnu*s species are thought to be poisonous to livestock, however Native Americans utilize the roots and stems for various treatments including gastrointestinal issues, toothaches and influenza (Society 2009).

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 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 and burrobrush. 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.

State and Transition Model Narrative 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 27 Disturbance Response Group 5.

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:
The reference plant community is variable and many species from adjacent ecological sites occur on this site. Typically, the reference plant community is dominated by burrobrush. Spiny hopsage, Nevada dalea and Indian ricegrass are other important species. Potential vegetative composition is approximately 10% grasses, 10% forbs and

80% shrubs. Approximate ground cover (basal and crown) is 5–20%. Total annual air-dry production ranges from 50 to 400 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 burrobush and rubber rabbitbrush. 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, Nevada jointfir 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 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 burrobush, spiny hopsage, Nevada dalea and Indian ricegrass. Rubber rabbitbrush, fourwing saltbush, Bailey's greasewood, and Nevada jointfir make up minor components. Other common perennial bunchgrasses include needle-and-thread, desert needlegrass, and squirreltail. Annual non-native species such as cheatgrass, mustards, and Russian thistle are present and may be increasing within the community.

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 (At-Risk):
After flooding, this plant community is dominated by burrobrush and rabbitbrush. 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, Nevada jointfir 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.

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 long-term, inappropriate grazing.

Slow variables: Long-term reduction in cover of shrubs, deep-rooted perennial bunchgrasses 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.

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

Trigger: Wildfire and/or 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:

This state has two community phases in which the overstory is dominated by sprouting shrubs such as burrobrush, rabbitbrush, spiny hopsage 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 (At-Risk):
Burrobrush, rubber rabbitbrush, spiny hopsage and fourwing saltbush 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.

Valley Wash 4-8" P.Z. (R027XY022NV), Shrub State 3.1, T. Stringham, May 2025

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 (At-Risk):
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.

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.

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

Trigger: Long-term inappropriate grazing, including wild horse and burro use, an unusually wet spring, and/or long-term, prolonged drought and/or fire.

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.

Annual State 4.0:

This state has two community phases. 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, Russian thistle, and tall tumblemustard (*Sisymbrium altissimum*) dominate the plant community. Bare ground may be abundant during low precipitation years.

Community Phase 4.1:
This community is dominated by annual non-native species including cheatgrass, tall tumblemustard and Russian thistle. Sprouting shrubs may be present. Bare ground may be abundant, especially during low precipitation years.

Valley Wash 4-8" P.Z. (R027XY022NV), Annual State 4.1, T. Stringham, June 2025

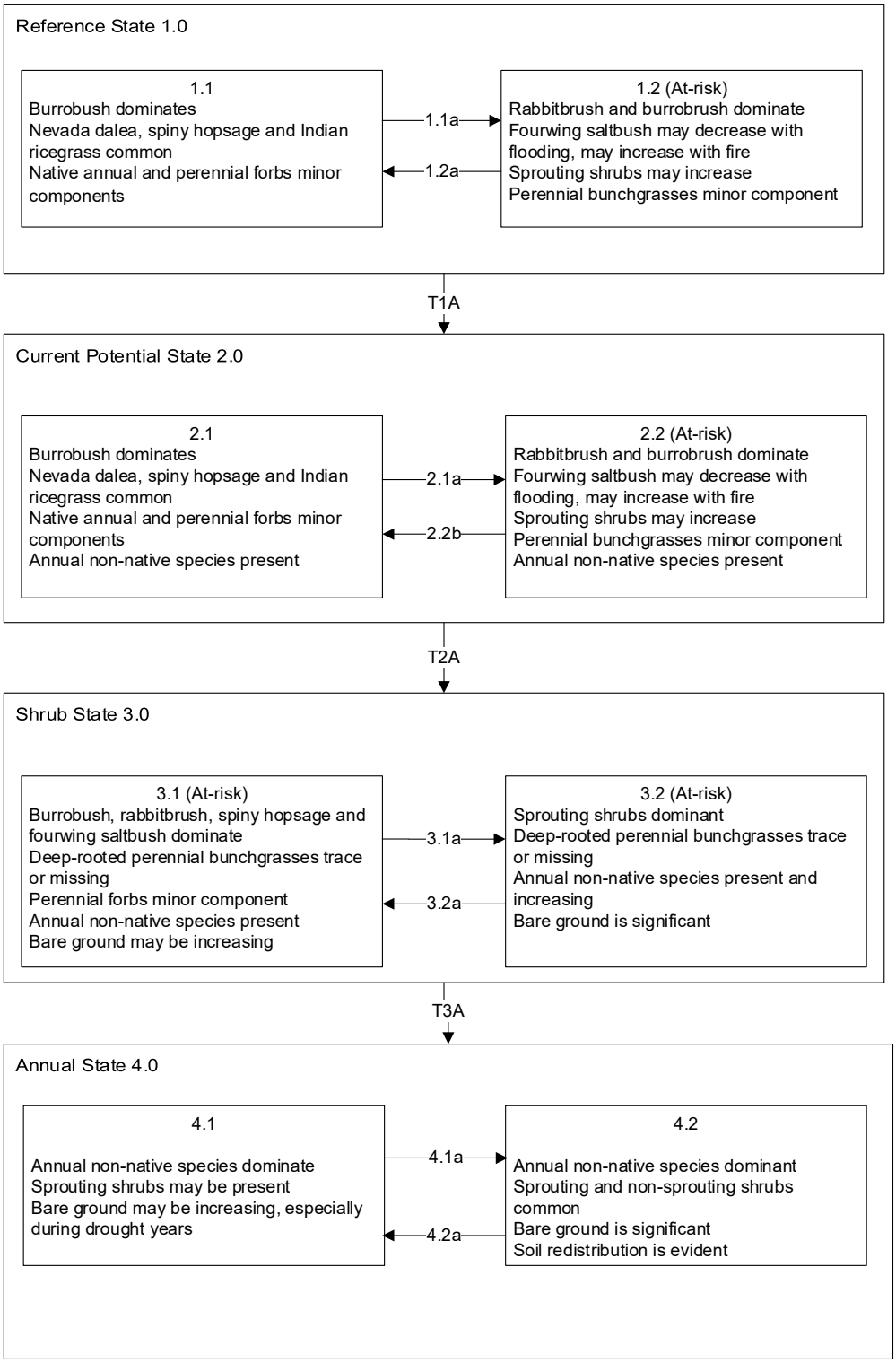
Community Phase Pathway 4.1a, from Phase 4.1 to 4.2:
Time and lack of disturbance allows for shrubs to reestablish. Sprouting shrubs such as Nevada jointfir and yellow rabbitbrush (*Chrysothamnus viscidiflorus*) will be the first to reappear.

Community Phase 4.2:
This community is dominated by annual non-native species including cheatgrass, tall tumblemustard and Russian thistle. Non-sprouting and weakly sprouting shrubs such as burrobush, Nevada dalea, sagebrush, and fourwing saltbush reestablish.

Community Phase Pathway 4.2a, from Phase 4.2 to 4.1:
Fire allows for annual non-native species to dominate site and removes non-sprouting shrubs. Extensive off-road vehicle use may eliminate all shrubs.

Modal State and Transition Model for Group 5 MLRA 27

MLRA 27
Group 5
Valley Wash
R027XY022NV



MLRA 27
Group 5
Valley Wash
R027XY022NV

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 palatable shrub and deep-rooted perennial bunchgrass 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.

Transition T3A: Prolonged drought, long-term inappropriate grazing, including wild horse and burro use, an unusually wet spring and/or wildfire.

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of disturbance.
4.2a: Fire or extensive off-road vehicle use.

References

Barrow, J. R. 1997. Natural asexual reproduction in fourwing saltbush *Atriplex canescens* (Pursh) Nutt. Journal of Arid Environments **36**:267-270.

Bates, J. D., T. Svejcar, R. F. Miller, and R. A. Angell. 2006. The effects of precipitation timing on sagebrush steppe vegetation. Journal of Arid Environments **64**:670-697.

Baughman, O. W., R. Burton, M. Williams, P. J. Weisberg, T. E. Dilts, and E. A. Leger. 2017. Cheatgrass die-offs: a unique restoration opportunity in northern Nevada. Rangelands **39**:165-173.

Baughman, O. W., S. E. Meyer, Z. T. Aanderud, and E. A. Leger. 2016. Cheatgrass die-offs as an opportunity for restoration in the Great Basin, USA: will local or commercial native plants succeed where exotic invaders fail? Journal of Arid Environments **124**:193-204.

Beatley, J. C. 1975. Climates and vegetation pattern across the Mojave/Great Basin Desert transition of southern Nevada. The American Midland Naturalist **93**:53-70.

Benson, L., and R. A. Darrow. 1981b. Trees and shrubs of the southwestern deserts.

Bich, B. S., J. L. Butler, and C. A. Schmidt. 1995. Effects of differential livestock use on key plant species and rodent populations within selected *Oryzopsis hymenoides*/*Hilaria jamesii* communities of Glen Canyon National Recreation Area. The Southwestern Naturalist **40**:281-287.

Blaisdell, J. P., and R. C. Holmgren. 1984. Managing intermountain rangelands - salt-desert shrub ranges. General Technical Report INT-163, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Blank, R. R., C. Clements, T. Morgan, D. Harmon, and F. Allen. 2020. Suppression of cheatgrass by perennial bunchgrasses. Rangeland Ecology & Management **73**:766-771.

Booth, D. T., C. G. Howard, and C. E. Mowry. 1980. 'Nezpar' Indian ricegrass: description, justification for release, and recommendations for use. Rangelands **2**:53-54.

Booth, E. G., J. F. Mount, and J. H. Viers. 2006. Hydrologic variability of the Cosumnes River floodplain. San Francisco Estuary and Watershed Science **4**:Article 2.

Bradford, J. B., and W. K. Lauenroth. 2006. Controls over invasion of *Bromus tectorum*: the importance of climate, soil, disturbance and seed availability. Journal of Vegetation Science **17**:693-704.

Brehm, J. R. 2019. Cheatgrass die-off in the Great Basin: a comparison of remote sensing detecting methods and identification of environments favorable to die-off. M.S. Thesis. University of Nevada, Reno, NV.

Briggs, M. K. 1996. Riparian ecosystem recovery in arid lands: Strategies and references. University of Arizona Press.

Butler, M., F. Brummer, J. Weber, and R. Simmons. 2011. Restoring Central Oregon rangeland from ventenata and medusahead to a sustainable bunchgrass environment – Warm Springs and Ashwood. COARC 2011, Oregon State University, Central Oregon Agricultural Research and Extension Center, Corvallis, OR.

Catlin, C. N. 1925. Composition of Arizona forages, with comparative data. Bulletin No. 113, University of Arizona, College of Agriculture, Agricultural Experiment Station, Tucson, AZ.

Caudle, D., J. DiBenedetto, M. Karl, H. Sanchez, and C. Talbot. 2013. Interagency ecological site handbook for rangelands. U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.

Chambers, J. C., B. A. Bradley, C. S. Brown, C. D'Antonio, M. J. Germino, J. B. Grace, S. P. Hardegree, R. F. Miller, and D. A. Pyke. 2013. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of western North America. Ecosystems **17**:360-375.

Cibils, A. F., S. M. David, and D. E. McArthur. 1998. Plant-herbivore interactions in *Atriplex*: current state of knowledge. General Technical Report RMRS-GTR-14, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Clements, C. D., D. N. Harmon, R. R. Blank, and M. Weltz. 2017. Improving seeding success on cheatgrass-infested rangelands in Northern Nevada. Rangelands **39**:174-181.

Colmer, T. D., and L. A. C. J. Voesenek. 2009. Flooding tolerance: Suites of plant traits in variable environments. Functional plant biology **36**:665-681.

Comstock, J. P., and J. R. Ehleringer. 1992. Plant adaptation in the Great Basin and Colorado Plateau. The Great Basin Naturalist **52**:195-215.

Cook, C. W. 1962. An evaluation of some common factors affecting utilization of desert range species. Journal of Range Management **15**:333-338.

Cook, C. W., and R. D. Child. 1971. Recovery of desert plants in various states of vigor. Rangeland Ecology & Management/Journal of Range Management Archives **24**:339-343.

Crofts, K. A., and G. V. Epps. 1975. The usefulness of shadscale in the revegetation of disturbed sites in the salt desert shrub type. Pages 151-152 *in* Proceedings: Symposium and workshop: Wildland shrubs. U.S. Department of Agriculture, Forest Service, Shrub Sciences Laboratory, Provo, UT.

Daubenmire, R. 1970. Steppe vegetation of Washington. Technical Report 62, Washington State University, Washington Agricultural Experiment Station, Pullman, WA.

Daubenmire, R. 1975. Plant succession on abandoned fields, and fire influences in a steppe area in southeastern Washington. Northwest Science **49**:36-48.

Davies, K. W., C. S. Boyd, D. D. Johnson, A. M. Nafus, and M. D. Madsen. 2015b. Success of seeding native compared with introduced perennial vegetation for revegetating medusahead-invaded sagebrush rangeland. Rangeland Ecology & Management **68**:224-230.

Davis, J. N. 1990. General ecology, wildlife use, and management of the mountain mahoganies in the Intermountain West. Pages 1-13 *in* Proceedings of the Fifth Utah Shrub Ecology Workshop: The Genus *Cercocarpus*; July, 1988; Logan, UT. Utah State University, College of Natural Resources, Logan, UT.

Dobrowolski, J. P., M. M. Caldwell, and J. H. Richards. 1990. Chapter 7: Basin hydrology and plant root systems. Pages 243-292 *in* C. B. Osmond, L. F. Pitelka, and G. M. Hidy, editors. Plant Biology of the Basin and Range. Springer-Verlag, New York City, NY.

Everett, R. L., P. T. Tueller, J. B. Davis, and A. D. Brunner. 1980. Plant phenology in galleta-shadscale and galleta-sagebrush associations. Rangeland Ecology & Management/Journal of Range Management Archives **33**:446-450.

Francis, J. K. 2004a. Francis, J. K. (2004). Wildland shrubs of the United States and its territories: Thamnic descriptions.

Furbush, P. 1953. Control of medusa-head on California ranges. Journal of Forestry **51**:118-121.

Ganskopp, D. C. 1986b. Tolerances of sagebrush, rabbitbrush, and greasewood to elevated water tables.

Green, L. R., L. A. Sharp, C. W. Cook, and L. E. Harris. 1951. Utilization of winter range forage by sheep. Journal of Range Management **4**:233-241.

Groeneveld, D., and D. Crowley. 1988a. Root system response to flooding in three desert shrub species. Functional Ecology:491-497.

Harrison, B. J., Thatcher, A.P. 1970. Winter sheep grazing and forage preference in southwestern Wyoming. Journal of Range Management **23**:109-111.

Henrickson, J. 1977. Saline habitats and halophytic vegetation of the Chihuahuan Desert region. Pages 289-314 *in* Transactions of the Symposium on the Biological Resources of the Chihuahuan Desert Region: United States and Mexico; Sul Ross State University, Alpine, TX; October 17-18, 1974. NPS Transactions and Proceedings Series No. 3. U.S. Department of the Interior, National Park Service.

Hickman, J. C. 1993. The Jepson Manual: Higher Plants of California. University of California Press, Los Angeles, CA, USA.

Klemmedson, J. O., and J. G. Smith. 1964. Cheatgrass (*Bromus tectorum* L.). The Botanical Review **30**:226-262.

Klepper, E. L., K. A. Gano, and L. L. Cadwell. 1985. Rooting depth and distribution of deep-rooted plants in the 200 Area Control Zone of the Hanford Site.

Levick, L., D. Goodrich, M. Hernandez, D. Semmens, J. Stromberg, R. Leidy, M. Apodaca, D. P. Guertin, M. Tlucek, and W. Kepner. 2007. Hydrology and ecology of intermittent stream and dry wash ecosystems.*in* Southwest Region Threatened, Endangered, and At-Risk Species Workshop: Managing within highly variable environments. Tucson, Arizona.

Lunt, O., J. Letey, and S. Clark. 1973. Oxygen requirements for root growth in three species of desert shrubs. Ecology **54**:1356-1362.

Mack, R. N., and D. A. Pyke. 1983. The demography of *Bromus tectorum*: Variation in time and space. Journal of Ecology **71**:69-93.

Meinzer, O. E. 1927. Plants as indicators of ground water. Water-Supply Paper 577, U.S. Department of the Interior, U.S. Geological Survey, Washington, D.C.

Miller, R. F., R. J. Tausch, and W. Waichler. 1999b. Old-growth juniper and pinyon woodlands. Pages 375-384 *in* Proceedings: ecology and management of pinyon-juniper communities within the interior west; September 15-18, 1997. Proceedings RMRS-P-9. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Brigham Young University Conference Center, Provo, UT.

Mohebby, A., M. Jafari, A. Tavili, S. A. Javadi, E. Zandi Esfahan, and M. Ramezani. 2012. Effect of livestock grazing on growth characteristics of *Atriplex canescens*. Desert **17**:290-303.

Mozingo, H. N. 1987b. Shrubs of the Great Basin: A natural history. University of Nevada Press, Reno, NV.

Newton, R. J., and J. R. Goodin. 1989. Moisture stress adaptation in shrubs. Pages 365-383 *in* C. M. McKell, editor. The biology and utilization of shrubs. Academic Press, San Diego, CA.

NRCS. 2022. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. Handbook 296, U.S. Department of Agriculture, Natural Resources Conservation Service.

O'Leary, J. F., and R. A. Minnich. 1981. Postfire recovery of creosote bush scrub vegetation in the western Colorado Desert. Madroño:61-66.

Ogle, D. G., L. St. John, and D. Tilley. 2012a. Plant guide for fourwing saltbush (*Atriplex canescens)*. U.S. Department of Agriculture, Natural Resource Conservation Service, Idaho Plants Material Center, Aberdeen, ID.

Otsyina, R., C. M. McKell, and G. Van Epps. 1982. Use of range shrubs to meet nutrient requirements of sheep grazing on crested wheatgrass during fall and early winter. Journal of Range Management **35**:751-753.

Parmenter, R. R. 2008. Long-term effects of a summer fire on desert grassland plant demographics in New Mexico. Rangeland Ecology & Management **61**:156-168.

Pearson, L. C. 1964. Effect of harvest date on recovery of range grasses and shrubs. Agronomy Journal **56**:80-82.

Pearson, L. C. 1965. Primary production in grazed and ungrazed desert communities of eastern Idaho. Ecology **46**:278-285.

Pellant, M., and C. Hall. 1994. Distribution of two exotic grasses in intermountain rangelands: Status in 1992. Pages 109-112 *in* S. B. Monsen and S. G. Kitchen, editors. Proceedings—Ecology and management of annual rangelands; General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Perryman, B. L. 2014a. A field guide to Nevada shrubs. Indigenous Rangeland Management Press, Lander, WY.

Peters, E. F., and S. C. Bunting. 1994. Fire conditions pre-and post-occurrence of annual grasses on the Snake River Plain. Pages 31-36 *in* Proceedings—Ecology and management of annual rangelands; September, 1994; Boise, ID. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Phillips, R. L., N. K. McDougald, and J. Sullins. 1996. Plant preference of sheep grazing the Mojave desert. Rangelands **18**:141-144.

Quinones, F. A. 1981. Indian ricegrass evaluation and breeding. Bulletin 681, New Mexico State University, Agricultural Experiment Station, Las Cruces, NM.

Rice, B., and M. Westoby. 1978. Vegetative responses of some Great Basin shrub communities protected against jackrabbits or domestic stock. Journal of Range Management **31**:28-34.

Rickard, W. H., and M. C. McShane. 1984. Demise of spiny hopsage shrubs following summer wildfire: An authentic record. Northwest Science **58**:282-285.

Rickard, W. H., and L. E. Rogers. 1983. Industrial land-use and the conservation of native biota in the shrub-steppe region of western North America. Environmental Conservation **10**:205-211.

Robinson, T. W. 1958. Phreatophytes. Geological survey water-supply paper 1423, US Deaprtment of Interior, US Geological Survey, Washington, D.C.

Sanderson, S. C., and H. C. Stutz. 1994. Woody chenopods useful for rangeland reclamation in western North America. Pages 374-378 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Sapsis, D. B. 1990. Ecological effects of spring and fall prescribed burning on basin big sagebrush: Idaho fescue--bluebunch wheatgrass communities.

Shaw, N. L. 1992. Germination and seedling establishment of spiny hopsage (*Grayia spinosa* [Hook.] Moq.). PhD Dissertation. Oregon State University, Corvallis, OR.

Shaw, N. L., M. R. Haferkamp, and E. G. Hurd. 2008. *Grayia spinosa* (Hook.) Moq: spiny hopsage. Pages 567-572 The Woody Plant Seed Manual Agric. Handbook No. 727. US Department of Agriculture, Forest Service, Washington DC.

Sheley, R. L., E. A. Vasquez, A.-M. Chamberlain, and B. S. Smith. 2012. Landscape-scale rehabilitation of medusahead (*Taeniatherum caput-medusae*)-dominated sagebrush steppe. Invasive Plant Science and Management **5**:436-442.

Simmons, S. A., and W. H. Rickard. 2003. Fire effects on spiny hopsage in south central Washington. Western North American Naturalist **63**:524-528.

Society, C. N. P. 2009. A Manual of California Vegetation Online. California Native Plant Society.

Stubbendieck, J. L., S. L. Hatch, N. M. Bryan, and C. D. Dunn. 2017. North American wildland plants. Third edition. University of Nebraska Press, Lincoln, NE.

Stubbendieck, J. L., J. T. Nichols, and K. K. Roberts. 1985. Nebraska range and pasture grasses (including grass-like plants). University of Nebraska, Department of Agriculture, Cooperative Extension Service, Lincoln, NE.

Stutz, H. C. 1979. The meaning of "rare" and "endangered" in the evolution of western shrubs. Pages 119-128 *in* The endangered species: A symposium: Proceedings; Provo, UT; December 7-8, 1978. Great Basin Naturalist Memoirs No. 3. Brigham Young University, Provo, UT.

Tesky, J. L. 1992. Lycium andersonii. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station,.

Ting, I. P. 1961. An ecological study of "Dalea Polyadenia" Torr. [publisher not identified], Place of publication not identified.

USFS. 1937. Range plant handbook. U.S. Department of Agriculture, Forest Service, Washington, D.C.

Vallentine, J. F. 1989. Range development and improvements. Academic Press, Inc., San Diego, CA.

Van Dersal, W. R. 1938. Native woody plants of the United States: Their erosion-control and wildlife values. U.S. Government Printing Office, Washington, D.C.

Wallace, A., S. A. Bamberg, and J. W. Cha. 1974. Quantitative studies of roots of perennial plants in the Mojave Desert. Ecology **55**:1160-1162.

Wasser, C. H. 1982. Ecology and culture of selected species useful in revegetating disturbed lands in the West. FWS/OBS-82/56, U.S. Department of the Interior, Fish & Wildlife Service, Fort Collins, CO.

Weisberg, P. J., T. E. Dilts, O. W. Baughman, S. E. Meyer, E. A. Leger, K. J. V. Gunst, and L. Cleeves. 2017. Development of remote sensing indicators for mapping episodic die-off

of an invasive annual grass (*Bromus tectorum*) from the Landsat archive. Ecological Indicators **79**:173-181.

West, N. E. 1994. Effects of fire on salt-desert shrub rangelands. Pages 71-74 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, ID.

Wright, H. A. 1985. Effects of fire on grasses and forbs in sagebrush-grass communities. Pages 12-21 *in* Rangeland fire effects: A symposium; Boise, ID; November 27-29, 1984. U.S. Department of the Interior, Bureau of Land Management, Boise, ID.

Young, R. P. 1983. Fire as a vegetation management tool in rangelands of the intermountain region. Pages 18-31 *in* Managing Intermountain rangelands—Improvement of range and wildlife habitats. Proceedings of Symposia: September 15-17, 1981, Twin Falls, Idaho June 22·24, 1982, Elko, Nevada. General Technical Report INT-GTR-157. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

MLRA 27 Group 6: Low sagebrush and Idaho fescue

Description of MRLA 27 Disturbance Response Group 6

Disturbance Response Group (DRG) 6 consists of one ecological site, Cobbly Claypan 12-14" P.Z. (R027XY046NV). This site occurs on summits and sideslopes of mountains. Elevations range from 6,000 to 9,200 ft and at lower elevations (6,000–7,000 ft) this site is restricted to northerly aspects. Slopes range from 4 to 75% but slope gradients of 30 to 75% are typical. The precipitation zone for this site ranges from 12 to 14 in. The soils are shallow to very deep and well drained. Soils exhibit root restrictive layers such as dense clays within the subsoil which limit plant growth and rooting on these sites. Available water capacity is moderate. The soil moisture regime is typically aridic bordering on xeric and the soil temperature regime is frigid. The reference plant community is dominated by low sagebrush (*A. arbuscula*) and Idaho fescue (*Festuca idahoensis*). Desert snowberry (*Symphoricarpos longifolia*), antelope bitterbrush (*Purshia tridentata*) and yellow rabbitbrush (*Chrysothamnus viscidiflorus*) are also common shrub species. The understory is dominated by deep-rooted perennial bunchgrasses including Idaho fescue, Cusick's bluegrass (*Poa cusickii*), Sandberg bluegrass (*Poa secunda*), Thurber's needlegrass (*Achnatherum thurberianum*), and western needlegrass (*Achnatherum occidentale* ssp. *occidentale*). Total annual air-dry production ranges from 250 to 600 lb/acre with 400 lb/ac in a normal year.

Disturbance Response Group 6 Ecological Sites:

Cobbly Claypan 12-14" P.Z. – Modal	R027XY046NV

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 27 (MLRA 27 Fallon-Lovelock Area) is almost entirely in Nevada with < 1% in California. The entire area occurs in the rain shadow of the Sierra Nevada mountains and is influenced by Pleistocene Lake Lahontan. Extensive playas occur throughout the area and

are a result of the drying of ancient Lake Lahontan. To the west, MLRA 27 has a gradual boundary with MLRA 26 (Carson Basin and Mountains) and to the east has a very gradual boundary with MLRA 24 (Humboldt Basin and Range Area). From west to east the soil temperature increases and the soil moisture decreases, resulting in vast areas dominated by salt-desert shrub communities. Isolated mountain ranges trending north to south are separated by broad desert plains and valleys. Elevations range from 3,300 to 5,900 ft with some mountain peaks over 7,800 ft. The average annual precipitation ranges from 4 to 11 in. and as much as 20 in. at the highest elevations. The majority of annual precipitation is received during late fall and winter occurring mainly as snow. High-intensity, convective thunderstorms also contribute significantly to annual precipitation (NRCS 2022). 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 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) and less than a 1.0 m (3.2 ft) for low sagebrush community types (Jensen 1990). These shrubs have a flexible generalized root system with development of both taproots and laterals near the surface (Comstock and Ehleringer 1992).

The dominant perennial bunchgrasses include Idaho fescue, bluegrasses and needlegrasses. Idaho fescue and needlegrasses are deep-rooted perennial grasses and 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 (19 in.) of the soil profile. General differences in root depth distributions between grasses and shrubs results in resource partitioning in these shrub/grass systems.

Idaho fescue, the dominant grass on this ecological site, is a densely tufted, cool-season perennial bunchgrass 1–3 ft tall. It is one of the most common and widely distributed grasses in the West (USFS 1988b). Idaho fescue occupies very diversified habitats typically occurring between 5,000 to 10,000 ft and grows on a wide variety of soils (Ogle 2008). Growth starts in March through April and seed maturity occurs in mid to late summer. With adequate moisture, Idaho fescue will produce a moderate amount of regrowth following seed maturity (Ogle 2008). Idaho fescue has excellent cold tolerance, moderate drought tolerance and moderate shade tolerance (Ogle 2008).

Cusick's bluegrass is an erect bluish-green tufted cool-season perennial bunchgrass without rootstocks. It is usually about 0.5–2 ft tall (Bunch 1979). Cusick's bluegrass occurs on sagebrush slopes and open wooded areas usually at middle elevations but can range up to timberline (Cronquist et al. 1977). It usually has abundant basal leaves from numerous innovations, often producing large bunches (Cronquist et al. 1977). Portions of large old clumps are sometimes interconnected with short rhizomes (Cronquist et al. 1977). This species grows vigorously in spring and early summer and usually sets seed by June. It is later maturing than Sandberg bluegrass but earlier maturing than other associated perennial bunchgrasses (Bunch 1979).

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 (< 1 in.) wide. It is found in lower elevations in the northern extent of its native range, and higher elevations in the south (Cronquist et al. 1977). 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 (Tilley et al. 2007). 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).

Thurber's needlegrass is a native, cool-season grass common to the semiarid regions of the Intermountain West and is an important component of many sagebrush communities (Johnson et al. 2017). It is a deep-rooted perennial bunchgrass, 1–2 ft tall with fine, narrow in rolled leaves about 6–10 in. long (Perryman and Skinner 2007). It is very drought and cold tolerant and prefers well drained, fine sandy loam to silt loam soils. It is not tolerant of shade and saline or sodic soil conditions (Ogle 2006).

Western needlegrass is a strongly tufted perennial grass that grows up to 4 dm (1 ft) in height (Cronquist 1994). It grows in dry, well-drained soils from upper foothills up into the higher areas of the mountains in the western United States (USFS 1988a). The roots of this grass are deep, fibrous and spreading, which allows it to be more resistant to trampling and drought (USFS 1988a).

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).

Low sagebrush, the dominant shrub on this site, 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). It grows on soils that have a strongly-structured argillic (clay

accumulation) 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.

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 changes resource uptake and increases nutrient availability, often to the benefit of non-native species. Native species are often damaged by disturbance and their ability to use resources is depressed for a time, even though resource pools may increase following disturbance from depressed used by plants and/or the decomposition of dead plant material (Whisenant 1999, Miller et al. 2013).

The introduction of annual weedy species, like cheatgrass, may cause an increase in fire frequency and eventually lead to an annual state. Conversely, as fire frequency decreases, sagebrush will increase and with inappropriate grazing management the perennial bunchgrasses and forbs may be reduced.

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 will dominate the site and 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 woodland matures and the understory plant community cover declines.

The ecological site in this DRG has 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. Thurber's or western needlegrass) whereas convex areas where runoff occurs are slightly less resilient and may have more shallow-rooted perennial grasses (i.e. bluegrass). 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 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 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 1.5–1.7 m (5–5.5 ft).

The species most likely to invade the site 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, able to germinate in the autumn or spring, tolerant of grazing and increases with frequent fire (Klemmedson and Smith 1964, Miller et al. 1999a). Cheatgrass originated from Eurasia 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) suggests that seasonal patterns of precipitation input and temperature are key factors determining regional variation in the growth, seed production, and spread of invasive annual grasses.

Methods to control cheatgrass include herbicide application, prescribed fire, targeted grazing, and rangeland seeding of primarily non-native wheatgrasses (*Agropyron* spp.). Mapping potential or current invasion vectors is a management method designed to increase the cost effectiveness of control methods. A study by Davies et al. (2013), found an increase in medusahead (*Taeniatherum caput-medusae*) cover near roads. Cover was higher near animal trails than random transects but the difference was less evident. This implies that vehicles and animals aid the spread of the weed; however, vehicles are the major vector of movement. 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). 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 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), however caution in using these results is advised, as only one 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 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.

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 (*Purshia tridentata*), and multiple sagebrush species to three rates of imazapic and the same rates with methylated seed oil as a surfactant. They found 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 return intervals are not well understood because the low sagebrush 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 100–400 lb/ac (110–450 kg/ha) but are occasionally as high as 600 lb/ac (680 kg/ha) in low sagebrush habitat types (Bradley et al. 1992).

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). 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 et al. 1982). We were unable to find any substantial research on success of seeding low sagebrush after fire.

Idaho fescue is a dense, fine-leaved bunchgrass, which allows fires to burn and smolder in the accumulated leaves at the base of the plant. Idaho fescue's response to fire varies with

condition and size of the plant, season and severity of fire, and ecological conditions. This bunchgrass can survive light-severity fires, but can be severely damaged by fire in all seasons (Wright et al. 1979, Wright 1985). Rapid tillering can occur after fire when root crowns are not killed and soil moisture is favorable (Robberecht and Defossé 1995).

Broad-leaved grasses like western needlegrass are relatively tolerant of fire (Blaisdell 1953, Wright and Klemmedson 1965, Bunting et al. 1987). Western needlegrass decreased the first year after an August wildfire in northeastern California, but increased by the third post-fire year, nearly doubling in basal area (Countryman 1982). Emergence of western needlegrass seeds was shown to significantly improve with additions of smoke and burned soil (Blank and Young 1998).

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. 1976b). 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 1985b). 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.

Cusick's bluegrass generally responds to burning with shortened culms, spikes and reduced basal area (Uresk et al. 1976b).

Muttongrass, a minor 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.

Sandberg bluegrass, a minor component on 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.

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.

Idaho fescue is valuable forage for livestock and wildlife. However, Idaho fescue decreases under heavy grazing by livestock (Eckert and Spencer 1987, Ogle 2008) and wildlife (Gaffney 1941).

Western needlegrass is slow to mature and remains green through most of the growing season. Since it can remain green into fall, it is higher quality forage compared to other species that have senesced by then (USFS 1988a). For livestock, this grass has good forage value, and it has fair forage value for wildlife (Stubbendieck et al. 1992). Seeds of this grass are avoided by grazing animals but are not necessarily injurious. Since seeds are avoided by grazing animals, a large amount of the seed produced grows to maturity (USFS 1988a).

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. "Heavy" was not defined in this study. 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). Thurber's needlegrass may increase in crude protein content after grazing (Ganskopp et al. 2007).

Reduced bunchgrass vigor or density may provide an opportunity for squirreltail or Sandberg bluegrass expansion. With further degradation, cheatgrass and other invasive species may occupy interspaces. Sandberg bluegrass increases under grazing pressure (Tisdale and Hironaka 1981) and is capable of co-existing with cheatgrass or other weedy species. Excessive 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, squirreltail, Sandberg bluegrass, or cheatgrass may become the dominant understory with inappropriate grazing management.

Low sagebrush is 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).

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 27 Disturbance Response Group 6.

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 low sagebrush, Idaho fescue and Sandberg bluegrass. Forbs and other perennial bunchgrasses make up smaller components. Potential vegetative composition by air-dry weight is approximately 50% grasses, 10% forbs and 35% shrubs and trees. Trees (singleleaf pinyon and Utah juniper) are less than 5%. Approximate ground cover (basal and crown) is 15–25%. Total annual air-dry production ranges from 250 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. An insect infestation can also result in a loss of sagebrush allowing the perennial bunchgrasses to increase. 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. Squirreltail and/or Sandberg bluegrass dominate. Depending on fire severity, patches of intact sagebrush may remain. Yellow rabbitbrush (*Chrysothamnus viscidiflorus*) and other sprouting shrubs may be sprouting. 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 and other shrubs and trees to increase.

Community Phase 1.3 (At-Risk):
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. Singleleaf pinyon and/or Utah juniper may be increasing.

Community Phase Pathway 1.3a, from Phase 1.3 to 1.1:
A low severity fire, herbivory, insect 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:
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 and clasping pepperweed (*Lepidium perfoliatum*).

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 four 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 in trace amounts. Low sagebrush and Idaho fescue dominate the site. Other shrubs and grasses, perennial forbs and trees make up smaller components of this site.

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. An insect infestation on the sagebrush may also result in a mosaic pattern. 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 and other shrub 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 Sandberg bluegrass 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, such as squirreltail and Sandberg bluegrass, and perennial forbs dominate the site. Depending on fire severity, patches of intact sagebrush may remain. Yellow rabbitbrush may be sprouting or dominant in the community. Perennial forbs may be a significant component for a number of years following fire. Annual non-native species are stable or increasing within the community. Singleleaf pinyon and Utah juniper may be increasing.

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 and other shrubs allows the shrub component to recover. The establishment of low sagebrush can take many years.

Community Phase Pathway 2.2b, from Phase 2.2 to 2.4:
Higher than normal spring precipitation favors annual non-native species such as cheatgrass. Non-native annual species will increase in production and density throughout the site. Perennial bunchgrasses may also increase in production.

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. Yellow rabbitbrush may be a significant component. Squirreltail or Sandberg bluegrass 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 is a 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 grazing will decrease or eliminate deep- rooted perennial bunchgrasses and increase bare ground and shallow-rooted 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 annual and perennial forb growth. Squirreltail and/or Sandberg bluegrass 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: Absence of disturbance over time allows for singleleaf pinyon and/or Utah juniper 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 singleleaf pinyon and/or Utah juniper density.

Threshold: Trees overtop low 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: Multiple fires 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 is a product of many years of heavy grazing during time periods harmful to perennial bunchgrasses. Squirreltail and/or Sandberg bluegrass increase with a reduction in deep-rooted perennial bunchgrass competition and become the dominant grasses. 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. 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. Rabbitbrush may be a significant component. Deep-rooted perennial bunchgrasses are present in trace amounts and may be absent from the community. Squirreltail, bluegrass species, and/or annual forbs dominate the understory. Non-native annual grasses present. Bare ground may be significant. Singleleaf pinyon and/or Utah juniper present.

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 Sandberg bluegrass to dominate the site.

Community Phase 3.2 (At-Risk):
Annual and perennial forbs dominate the site (i.e. arrowleaf balsamroot (*Balsamorhiza sagittata*), tapertip hawksbeard (*Crepis acuminata*) and phlox (*Phlox* spp). Squirreltail and/or Sandberg bluegrass may increase and be co-dominant with forbs. Deep-rooted perennial bunchgrasses are a minor component or missing. Annual non-native species are present but are not dominant. Trace amounts of sagebrush or rabbitbrush may be present. Singleleaf pinyon and/or Utah juniper present.

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.

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.

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

Trigger: Absence of disturbance over time allows for singleleaf pinyon and/or Utah juniper 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 and/or Utah juniper density.

Threshold: Trees overtop low 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:

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. Low 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 yellow rabbitbrush and/or other sprouting shrubs to recover after fire. Probability of low sagebrush establishment is extremely low.
>
> **Community Phase 4.2:**

Yellow rabbitbrush and snowberry are typically the dominant overstory shrubs. Low sagebrush is a minor component or missing. Annual non-native species dominate the understory.

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 pinyon and juniper 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 (At-Risk):
Pinyon and juniper dominate the overstory and site resources. Trees are actively growing with noticeable leader growth. Trace amounts of bunchgrass may be found under tree canopies with trace amounts of Sandberg bluegrass and forbs in the interspaces. 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 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 (At-Risk):
Pinyon and juniper dominate the overstory. Low sagebrush is decadent and dying with numerous skeletons present or sagebrush may be missing from the system. Bunchgrasses are 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 movement may be apparent.

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.

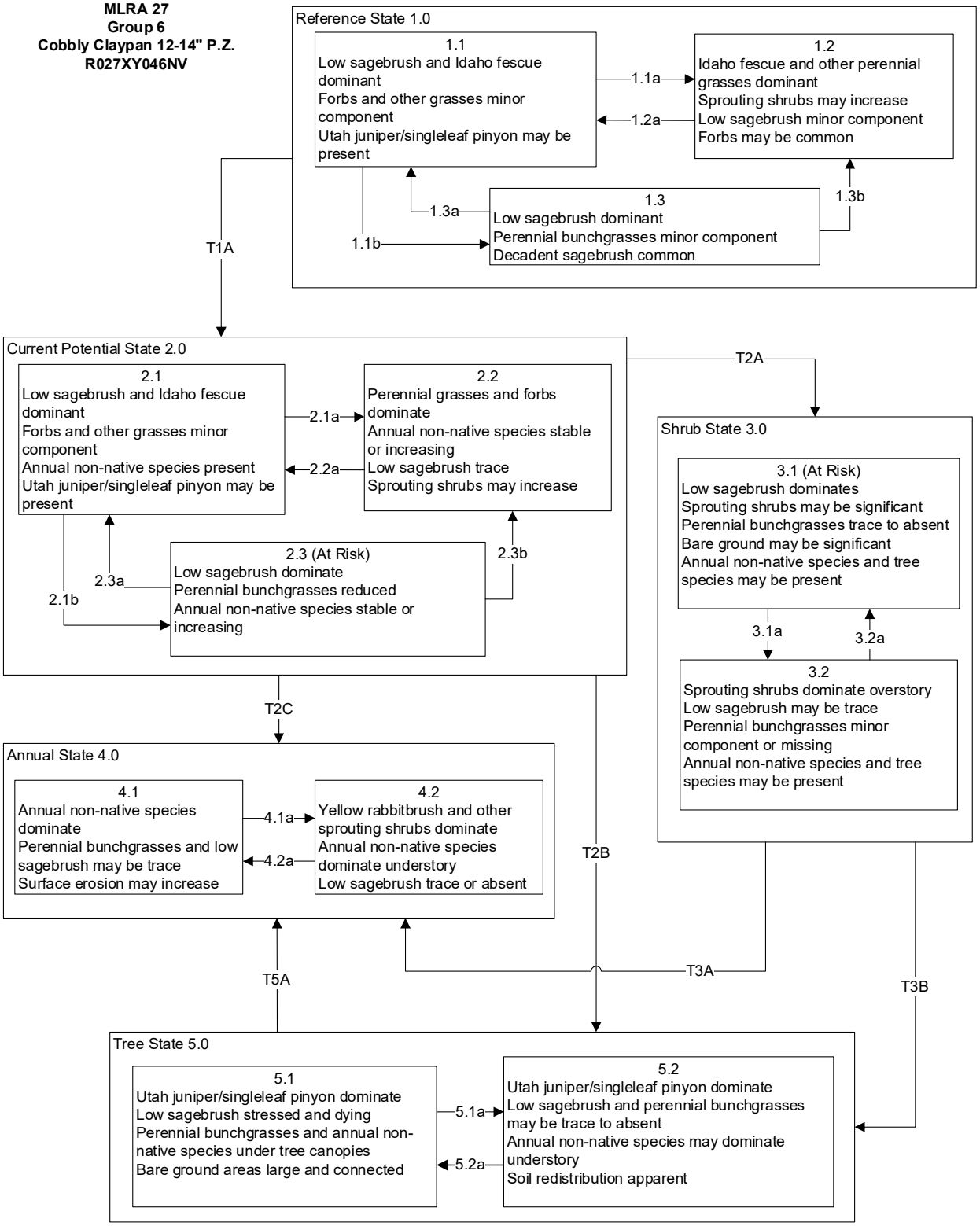
Slow variables: Increased production and cover of non-native annual species under tree canopies.

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.

States Not Observed in Group 6:

Current Potential, Shrub, Annual or Tree states were not observed during field work but these states were documented in a similar ecological site in MLRA 29 DRG 16 - Cobbly Claypan 12-14" P.Z. (R029XY163NV) (Stringham et al. 2026).

Modal State and Transition Model for Group 6 in MRLA 27



MLRA 27
Group 6
Cobbly Claypan 12-14" P.Z.
R027XY046NV

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 yellow rabbitbrush and 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.

References

Baker, W. L. 2006. Fire and restoration of sagebrush ecosystems. Wildlife Society Bulletin **34**:177-185.

Bates, J. D., T. Svejcar, R. F. Miller, and R. A. Angell. 2006. The effects of precipitation timing on sagebrush steppe vegetation. Journal of Arid Environments **64**:670-697.

Beardall, L. E., and V. E. Sylvester. 1976. Spring burning for removal of sagebrush competition in Nevada. Pages 539-547 *in* Proceedings, Tall Timbers Fire Ecology Conference and Fire and Land Management Symposium; Missoula, MT. Tall Timbers Research Station, Tallahassee, FL.

Beatley, J. C. 1975. Climates and vegetation pattern across the Mojave/Great Basin Desert transition of southern Nevada. The American Midland Naturalist **93**:53-70.

Beckstead, J., and C. K. Augspurger. 2004. An experimental test of resistance to cheatgrass invasion: Limiting resources at different life stages. Biological Invasions **6**:417-432.

Blackburn, W. H., P. T. Tueller, and R. E. Eckert Jr. 1968a. Vegetation and soils of the Crowley Creek Watershed. University of Nevada, Max C. Fleischmann College of Agriculture, Reno, NV.

Blackburn, W. H., P. T. Tueller, and R. E. Eckert Jr. 1968b. Vegetation and soils of the Duckwater Watershed. University of Nevada, Max C. Fleischmann College of Agriculture, Reno, NV.

Blackburn, W. H., P. T. Tueller, and R. E. Eckert Jr. 1969. Vegetation and soils of the Churchill Canyon Watershed. University of Nevada, Max C. Fleischmann College of Agriculture, Agricultural Experiment Station, Reno, NV.

Blaisdell, J. P. 1953. Ecological effects of planned burning of sagebrush-grass range on the upper Snake River plains. Technical Bulletin No. 1075, U.S. Department of Agriculture, Washington, D.C.

Blaisdell, J. P., R. B. Murray, and E. D. McArthur. 1982. Managing intermountain rangelands - sagebrush-grass ranges. General Technical Report INT-134, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Blank, R. R., and J. A. Young. 1998. Heated substrate and smoke: influence on seed emergence and plant growth.

Bradford, J. B., and W. K. Lauenroth. 2006. Controls over invasion of *Bromus tectorum*: the importance of climate, soil, disturbance and seed availability. Journal of Vegetation Science **17**:693-704.

Bradley, A. F., N. V. Noste, and W. C. Fischer. 1992. Fire ecology of forests and woodlands in Utah. General Technical Report INT-287, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Braun, C. E., J. W. Connelly, and M. A. Schroeder. 2005. Seasonal habitat requirements for sage-grouse: spring, summer, fall, and winter. Pages 38-42 *in* Sage-grouse Habitat Restoration Symposium Proceedings. RMRS-P-38. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Britton, C. M., G. R. McPherson, and F. A. Sneva. 1990. Effects of burning and clipping on five bunchgrasses in eastern Oregon. The Great Basin Naturalist **50**:115-120.

Bunch, T. R. 1979. Cusick's bluegrass (Poa cusickii).

Bunting, S. C., B. M. Kilgore, and C. L. Bushey. 1987. Guidelines for prescribed burning sagebrush-grass rangelands in the Northern Great Basin. General Technical Report INT-231, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Butler, M., F. Brummer, J. Weber, and R. Simmons. 2011. Restoring Central Oregon rangeland from ventenata and medusahead to a sustainable bunchgrass environment – Warm Springs and Ashwood. COARC 2011, Oregon State University, Central Oregon Agricultural Research and Extension Center, Corvallis, OR.

Caudle, D., J. DiBenedetto, M. Karl, H. Sanchez, and C. Talbot. 2013. Interagency ecological site handbook for rangelands. U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.

Chambers, J. C., B. A. Bradley, C. S. Brown, C. D'Antonio, M. J. Germino, J. B. Grace, S. P. Hardegree, R. F. Miller, and D. A. Pyke. 2013. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of western North America. Ecosystems **17**:360-375.

Chambers, J. C., B. A. Roundy, R. R. Blank, S. E. Meyer, and A. Whittaker. 2007. What makes Great Basin sagebrush ecosystems invasible by *Bromus tectorum*? Ecological Monographs **77**:117-145.

Comstock, J. P., and J. R. Ehleringer. 1992. Plant adaptation in the Great Basin and Colorado Plateau. The Great Basin Naturalist **52**:195-215.

Countryman, C. M. 1982. Physical characteristics of some northern California brush fuels. U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station.

Cronquist, A. 1994. Intermountain flora: Vascular plants of the Intermountain West, U.S.A. Volume five. Asterales. The New York Botanical Garden, Bronx, NY.

Cronquist, A., A. H. Holmgren, N. H. Holmgren, J. L. Reveal, and P. K. Holmgren. 1977. Intermountain flora: Vascular plants of the Intermountain West, U.S.A. Volume six. The Monocotyledons. Columbia University Press, New York, NY.

Daubenmire, R. 1970. Steppe vegetation of Washington. Technical Report 62, Washington State University, Washington Agricultural Experiment Station, Pullman, WA.

Daubenmire, R. 1975. Plant succession on abandoned fields, and fire influences in a steppe area in southeastern Washington. Northwest Science **49**:36-48.

Davies, K. W., C. S. Boyd, D. D. Johnson, A. M. Nafus, and M. D. Madsen. 2015b. Success of seeding native compared with introduced perennial vegetation for revegetating medusahead-invaded sagebrush rangeland. Rangeland Ecology & Management **68**:224-230.

Davies, K. W., A. M. Nafus, and M. D. Madsen. 2013. Medusahead invasion along unimproved roads, animal trails, and random transects. Western North American Naturalist **73**:54-59.

Dobrowolski, J. P., M. M. Caldwell, and J. H. Richards. 1990. Chapter 7: Basin hydrology and plant root systems. Pages 243-292 *in* C. B. Osmond, L. F. Pitelka, and G. M. Hidy, editors. Plant Biology of the Basin and Range. Springer-Verlag, New York City, NY.

Eckert, R. E., Jr., and J. S. Spencer. 1987. Growth and reproduction of grasses heavily grazed under rest-rotation management. Journal of Range Management **40**:156-159.

Everett, R. L., P. T. Tueller, J. B. Davis, and A. D. Brunner. 1980. Plant phenology in galleta-shadscale and galleta-sagebrush associations. Rangeland Ecology & Management/Journal of Range Management Archives **33**:446-450.

Fosberg, M. A., and M. Hironaka. 1964. Soil properties affecting the distribution of big and low sagebrush communities in southern Idaho. Pages 230-236 *in* Forage plant physiology and soil-range plant relationships. Annual Meetings of the American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America; Denver, CO; November 17-21, 1963. ASA Special Publication No. 5. American Society of Agronomy, Madison, WI.

Furbush, P. 1953. Control of medusa-head on California ranges. Journal of Forestry **51**:118-121.

Furniss, M. M., and W. F. Barr. 1975. Insects affecting important native shrubs of the Northwestern United States. General Technical Report INT-19, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Gaffney, W. S. 1941. The effects of winter elk browsing, South Fork of the Flathead River, Montana. The Journal of Wildlife Management **5**:427-453.

Ganskopp, D., L. Aguilera, and M. Vavra. 2007. Livestock forage conditioning among six northern Great Basin grasses. Rangeland Ecology & Management **60**:71-78.

Ganskopp, D. L. 1988. Defoliation of Thurber needlegrass: herbage and root responses. Journal of Range Management **41**:472-476.

Hironaka, M., M. A. Fosberg, and A. H. Winward. 1983. Sagebrush-grass habitat types of southern Idaho. Bulletin No. 35, University of Idaho, Forest, Wildlife and Range Experiment Station, Moscow, ID.

Jensen, M. E. 1990. Interpretation of environmental gradients which influence sagebrush community distribution in northeastern Nevada. Journal of Range Management **43**:161-167.

Johnson, B. G., W. J. Dale, J. C. Chambers, and R. R. Blank. 2011. Fire effects on the mobilization and uptake of nitrogen by cheatgrass (*Bromus tectorum* L.). Plant Soil **341**:437-445.

Johnson, R., E. Leger, and K. Vance-Borland. 2017. Genecology of Thurber's Needlegrass (Achnatherum thurberianum [Piper] Barkworth) in the Western United States. Rangeland Ecology & Management **70**:509-517.

Klemmedson, J. O., and J. G. Smith. 1964. Cheatgrass (*Bromus tectorum* L.). The Botanical Review **30**:226-262.

Knick, S. T., A. L. Holmes, and R. F. Miller. 2005. The role of fire in structuring sagebrush habitats and bird communities. Studies in Avian Biology **30**:1-13.

Koniak, S. 1985b. Succession in pinyon-juniper woodlands following wildfire in the Great Basin. The Great Basin Naturalist **45**:556-566.

Laycock, W. A. 1967. How heavy grazing and protection affect sagebrush-grass ranges. Journal of Range Management **20**:206-213.

Mack, R. N., and D. A. Pyke. 1983. The demography of *Bromus tectorum*: Variation in time and space. Journal of Ecology **71**:69-93.

MacMahon, J. A. 1980. Ecosystems over time: Succession and other types of change. Pages 27-58 *in* Forests: Fresh Perspectives from Ecosystem Analysis - Proceedings of the 40th Annual Biology Colloquium. Oregon State University Press, Corvallis, OR.

McAdoo, J. K., and G. N. Back. 2001. Sage grouse biology. FS-01-43, University of Nevada, Reno Extension, Reno, NV.

Miller, H. C., D. Clausnitzer, and M. M. Borman. 1999a. Medusahead. Pages 272-281 *in* R. L. S. a. J. K. Petroff, editor. Biology and Management of Noxious Rangeland Weeds. Oregon State University Press, Oregon State University.

Miller, R. F., J. C. Chambers, D. A. Pyke, F. B. Pierson, and C. J. Williams. 2013. A review of fire effects on vegetation and soils in the Great Basin Region: Response and ecological site characteristics. General Technical Report RMRS-GTR-308, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Miller, R. F., and J. A. Rose. 1995. Historic expansion of *Juniperus occidentalis* (western juniper) in southeastern Oregon. The Great Basin Naturalist **55**:37-45.

Miller, R. F., and J. A. Rose. 1999. Fire history and western juniper encroachment in sagebrush steppe. Journal of Range Management **52**:550-559.

NRCS. 2022. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. Handbook 296, U.S. Department of Agriculture, Natural Resources Conservation Service.

Ogle, D., J. Henson, M. Stannard. 2008. Plant Guide for Idaho Fescue. USDA-Natural Resources Conservation Service, USDA-NRCS Plant Materials Center, Boise, ID.

Ogle, D., St. John, L, Tilley, D, Jones, T. 2006. Plant Guide for Thurber's Needlegrass. USDA NRCS, USDA NRCS Idaho State Office.

Pellant, M., and C. Hall. 1994. Distribution of two exotic grasses in intermountain rangelands: Status in 1992. Pages 109-112 *in* S. B. Monsen and S. G. Kitchen, editors. Proceedings—Ecology and management of annual rangelands; General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Perryman, B. L., and Q. D. Skinner. 2007. A Field Guide to Nevada Grasses. Indigenous Rangeland Management Press, Lander, WY.

Peters, E. F., and S. C. Bunting. 1994. Fire conditions pre-and post-occurrence of annual grasses on the Snake River Plain. Pages 31-36 *in* Proceedings—Ecology and management of annual rangelands; September, 1994; Boise, ID. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Ralphs, M. H., and F. E. Busby. 1979. Prescribed burning: vegetative change, forage production, cost, and returns on six demonstration burns in Utah. Journal of Range Management **32**:267-270.

Robberecht, R., and G. Defossé. 1995. The relative sensitivity of two bunchgrass species to fire. International Journal of Wildland Fire **5**:127-134.

Schlaepfer, D. R., J. B. Bradford, W. K. Lauenroth, S. M. Munson, B. Tietjen, S. A. Hall, S. D. Wilson, M. C. Duniway, G. Jia, D. A. Pyke, A. Lkhagva, and K. Jamiyansharav. 2017.

Climate change reduces extent of temperate drylands and intensifies drought in deep soils. Nature Communications **8**:14196.
Sheehy, D. P., and A. H. Winward. 1981. Relative palatability of seven *Artemisia* taxa to mule deer and sheep. Journal of Range Management **34**:397-399.
Sheley, R. L., E. A. Vasquez, A.-M. Chamberlain, and B. S. Smith. 2012. Landscape-scale rehabilitation of medusahead (*Taeniatherum caput-medusae*)-dominated sagebrush steppe. Invasive Plant Science and Management **5**:436-442.
Smith, M. A., and F. Busby. 1981. Prescribed burning, effective control of sagebrush in Wyoming. RJ-165, Agricultural Experiment Station, University of Wyoming, Laramie, WY.
Snyder, K. A., L. Evers, J. C. Chambers, J. Dunham, J. B. Bradford, and M. E. Loik. 2019. Effects of changing climate on the hydrological cycle in cold desert ecosystems of the Great Basin and Columbia Plateau. Rangeland Ecology & Management **72**:1-12.
Stringham, T. K., W. C. P. Richardson, Lucas, W. Lieurance, D. K. Snyder, and P. Novak-Echenique. 2026. Great Basin ecological site development project: State-and-transition models for Major Land Resource Area 29, Nevada. Nevada Agricultural Experiment Station Research Report NAES-TR-26-01, University of Nevada Reno, USA.
Stubbendieck, J. L., S. L. Hatch, and C. H. Butterfield. 1992. North American range plants. Fourth edition. University of Nebraska Press, Lincoln, NE.
Tilley, D. J., D. Ogle, and L. St. John. 2007. Plant guide for muttongrass (*Poa fendleriana*). U.S. Department of Agriculture, Natural Resource Conservation Service.
Tisdale, E. W., and M. Hironaka. 1981. The sagebrush - grass region: A review of the ecological literature. Forest, Wildlife and Range Experiment Station, University of Idaho **209**.
Uresk, D. W., J. F. Cline, and W. H. Rickard. 1976b. Impact of wildfire on three perennial grasses in south-central Washington. Journal of Range Management **29**:309-310.
USFS. 1988a. Range plant handbook. Reprint of 1937 edition. Dover Publications, New York, NY.
USFS. 1988b. Shrub live oak. Pages 743-744 *in* W. A. Dayton, T. Lommasson, B. C. Park, C. A. Kutzleb, O. Julander, A. R. Standing, S. S. Hutchings, L. W. Swift, E. P. Cliff, D. W. Hayes, M. L. Bomhard, W. R. Chapline, R. R. Hill, and L. Ellison, editors. Range plant handbook. United States Department of Agriculture Forest Service.
Vollmer, J. L., and J. G. Vollmer. 2008. Controlling cheatgrass in winter range to restore habitat and endemic fire. Pages 57-60 *in* Proceedings—Shrublands under fire: Disturbance and recovery in a changing world. RMRS-P-52. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Cedar City, UT.
Vose, J. M., and A. S. White. 1991. Biomass response mechanisms of understory species the first year after prescribed burning in an Arizona ponderosa-pine community. Forest Ecology and Management **40**:175-187.
Whisenant, S. G. 1999. Repairing damaged wildlands: A process orientated, landscape-scale approach. Illustrated Edition edition. Cambridge University Press, New York, NY.
Winward, A. H. 1980. Taxonomy and ecology of sagebrush in Oregon. Station Bulletin 642, Oregon State University, Agricultural Experiment Station, Corvallis, OR.
Wright, H. A. 1985. Effects of fire on grasses and forbs in sagebrush-grass communities. Pages 12-21 *in* Rangeland fire effects: A symposium; Boise, ID; November 27-29, 1984. U.S. Department of the Interior, Bureau of Land Management, Boise, ID.

Wright, H. A., and J. O. Klemmedson. 1965. Effect of fire on bunchgrasses of the sagebrush-grass region in Southern Idaho. Ecology **46**:680-688.

Wright, H. A., L. F. Neuenschwander, and C. M. Dritton. 1979. The role and use of fire in sagebrush-grass and pinyon-juniper plant communities: A state-of-the-art review. General Technical Report INT-58, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Wuebbles, D. J., D. W. Fahey, K. A. Hibbard, D. J. Dokken, B. C. Stewart, and T. K. Maycock. 2017. Climate science special report: Fourth national climate assessment. Volume 1, U.S. Global Change Research Program, Washington, D.C.

Young, R. P. 1983. Fire as a vegetation management tool in rangelands of the intermountain region. Pages 18-31 *in* Managing Intermountain rangelands—Improvement of range and wildlife habitats. Proceedings of Symposia: September 15-17, 1981, Twin Falls, Idaho June 22·24, 1982, Elko, Nevada. General Technical Report INT-GTR-157. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Zamora, B., and P. T. Tueller. 1973. *Artemisia arbuscula*, *A. longiloba*, and *A. nova* habitat types in northern Nevada. Great Basin Naturalist **33**:225-242.

MLRA 27 Group 7: Loamy soils with mountain big sagebrush and needlegrasses

Description of MLRA 27 Disturbance Response Group 7

Disturbance Response Group (DRG) 7 consists of one ecological site, the Granitic Slope 12-14" P.Z. (R027XY073NV). This site occurs on concave mountain sideslopes. Precipitation ranges from 10 to 14 in. and slopes range from 15 to 50%. Elevations range from approximately 7,000 to 7,800 ft. The soils are moderately deep and well drained and are formed in residuum and colluvium from granitic rock sources. Soil surface textures are coarse and the soil profile is gravelly throughout. The soils have a mollic epipedon and an argillic horizon. The soil moisture regime is aridic bordering on xeric and the soil temperature regime is mesic. Available water hold capacity is very low and infiltration is rapid. The reference plant community is dominated by mountain big sagebrush *(Artemisia tridentata* ssp. *vaseyana)*, Mormon tea (*Ephedra viridis*), Thurber's needlegrass (*Achnatherum thurberianum*) and bluegrasses (*Poa cusickii, Poa secunda*). Total annual production ranges from 700 to 1,100 lb/ac with 900 lb/ac in a normal year.

Disturbance Response Group 7 Ecological Sites:

Granitic Slope 12-14" P.Z. – Modal	R027XY073NV

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 27 (MLRA 27 Fallon-Lovelock Area) is almost entirely in Nevada with < 1% in California. The entire area occurs in the rain shadow of the Sierra Nevada mountains and is influenced by Pleistocene Lake Lahontan. Extensive playas occur throughout the area and are a result of the drying of ancient Lake Lahontan. To the west, MLRA 27 has a gradual boundary with MLRA 26 (Carson Basin and Mountains) and to the east has a very gradual boundary with MLRA 24 (Humboldt Basin and Range Area). From west to east the soil temperature increases and the soil moisture decreases, resulting in vast areas dominated by salt-desert shrub communities. Isolated mountain ranges trending north to south are separated

by broad desert plains and valleys. Elevations range from 3,300 to 5,900 ft with some mountain peaks over 7,800 ft. The average annual precipitation ranges from 4 to 11 in. and as much as 20 in. at the highest elevations. The majority of annual precipitation is received during late fall and winter occurring mainly as snow. High-intensity, convective thunderstorms also contribute significantly to annual precipitation (NRCS 2022). 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 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 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, 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 (3–9 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).

Mormon tea 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). It 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).

Thurber's needlegrass is a native, cool-season grass common to the semiarid regions of the Intermountain West and is an important component of many sagebrush communities (Johnson et al. 2017). It is a deep-rooted perennial bunchgrass, 1–2 ft tall with fine, narrow in-rolled leaves about 6–10 in. long (Perryman and Skinner 2007). It is very drought and cold tolerant and prefers well drained, fine sandy loam to silt loam soils. It is not tolerant of shade and saline or sodic soil conditions (Ogle 2006).

Cusick's bluegrass is an erect bluish-green tufted cool-season perennial bunchgrass without rootstocks. It is usually about 0.5–2 ft tall (Bunch 1979). Cusick's bluegrass occurs on sagebrush slopes and open wooded areas usually at middle elevations but can range up to timberline (Cronquist et al. 1977). It usually has abundant basal leaves from numerous innovations, often producing large bunches (Cronquist et al. 1977). Portions of large old clumps are sometimes interconnected with short rhizomes (Cronquist et al. 1977). This species grows vigorously in spring and early summer and usually sets seed by June. It is later maturing than Sandberg bluegrass but earlier maturing than other associated perennial bunchgrasses (Bunch 1979).

The ecological site in this DRG has 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. needlegrass) whereas convex areas where runoff occurs are slightly less resilient and may support more shallow-rooted perennial grasses (i.e. bluegrass). North slopes are also more resilient than south slopes because lower soil surface temperatures operate to keep moisture content higher on northern exposures. Five 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 12 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 3–5 years. Mountain big sagebrush may return to pre-burn density and cover within 15–20 years following fire, but establishment after severe fires may proceed more slowly (Bunting et al. 1987).

Depending on fire severity, desert snowberry (*Symphoricarpos longiflorus*), Mormon tea and yellow rabbitbrush (*Chrysothamnus viscidiflorus*) may increase after fire. Yellow rabbitbrush, 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).

Mormon tea vigorously sprouts after fire from extensive woody crowns (Young and Evans 1978, Koniak 1985b). Sprouting after fire may vary by season of burn and fire severity. After fire,

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).

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 (*Achnatherum* spp.) are slightly to moderately damaged by fire depending on season of burn (Wright and Klemmedson 1965).

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. 1976b). 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 1985b). 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.

Cusick's bluegrass generally responds to burning with shortened culms, spikes and reduced basal area (Uresk et al. 1976b).

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).

Mormon tea 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). Mormon tea provides cover for pronghorn, small mammals, and both game and nongame birds (Dittberner and Olson 1983). Small mammals and birds eat the seeds (Meyer 2008c).

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. "Heavy" was not defined in this study. 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). Thurber's needlegrass may increase in crude protein content after grazing (Ganskopp et al. 2007).

Reduced bunchgrass vigor or density may provide an opportunity for squirreltail or Sandberg bluegrass expansion. With further degradation, cheatgrass and other invasive species may occupy interspaces. Sandberg bluegrass increases under grazing pressure (Tisdale and Hironaka 1981) and is capable of co-existing with cheatgrass or other weedy species. Excessive 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, squirreltail, Sandberg bluegrass, or cheatgrass may become the dominant understory with inappropriate grazing management.

State and Transition Model Narrative for Group 7

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for MLRA 27 Disturbance Response Group 7.

five possible states have been identified for this DRG including a Reference State, Current Potential State, Shrub State, Annual 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 and Thurber's needlegrass. Other common species include Mormon tea, desert snowberry, and bluegrasses. Potential vegetative composition by air-dry weight is approximately 60% grasses, 10% forbs and 30% shrubs. Approximate ground cover (basal and crown) is 25–35%. Total annual air-dry production ranges from 700 to 1,100 lb/ac.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
A low severity fire or an Aroga moth infestation would decrease the sagebrush overstory 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 sagebrush and Thurber's needlegrass 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 to mid-seral community phase. Thurber's needlegrass can experience high mortality from fire and may be reduced in the community for several years. With low fire severity, Thurber's needlegrass may dominate the site post-fire. Sprouting shrubs such as Mormon tea, Utah serviceberry (*Amelanchier utahensis*), snowberry, and yellow rabbitbrush increase. Bluegrass and other perennial grasses are common. Perennial forbs may increase or dominate after fire for several years. Mountain big sagebrush is killed by fire, therefore decreasing within the burned community, however, sagebrush could still be present in unburned patches. Yellow rabbitbrush may dominate the aspect for a number of years following wildfire. Perennial 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 (At-Risk):
Mountain big sagebrush dominates the plant community in the absence of disturbance and deep-rooted perennial bunchgrasses in the understory are reduced.

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: This transition is caused by the introduction of annual non-native species such as cheatgrass, Russian thistle and mustards (Brassicaceae family).

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 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. The 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, Mormon tea is also common. Thurber's needlegrass and bluegrasses are the dominant understory species. Annual non-native species are present.

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
A low severity fire or an Aroga moth infestation 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 and Thurber's needlegrass 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. Bluegrass and other perennial grasses dominate. Thurber's needlegrass may be killed by a high intensity fire. Snowberry, rabbitbrush, Utah serviceberry, and Mormon tea 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.

Granitic Slope 12-14" P.Z. (R027XY073NV), Current Potential 2.2, T. Stringham, May 2025

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 (At-Risk):
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. Non-native species may be increasing.

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 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 shallow-rooted 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 annual and perennial forb growth. Squirreltail and/or Sandberg bluegrass may increase. Annual non-native species are present and will likely increase with fire.

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 is a product of many years of heavy grazing during time periods harmful to perennial bunchgrasses. Squirreltail and/or Sandberg bluegrass increase with a reduction in deep-rooted perennial bunchgrass competition and become the dominant grasses. 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. Sagebrush dominates the overstory and yellow 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:
Decadent sagebrush dominates the overstory. Yellow rabbitbrush may be a significant component. Deep-rooted perennial bunchgrasses are present in trace amounts and may be absent from the community. Squirreltail, bluegrass species, and/or annual forbs dominate the understory. Bare ground may be significant. Annual non-native species present but not dominant.

Granitic Slope 12-14" P.Z. (R027XY073NV), Shrub State 3.1, T. Stringham, May 2025

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 Sandberg bluegrass to dominate the site.

Community Phase 3.2:
Annual and perennial forbs dominate the site (i.e. arrowleaf balsamroot (*Balsamorhiza sagitatta*) and tapertip hawksbeard (*Crepis acuminata*). Squirreltail and/or Sandberg bluegrass may increase and be co-dominant with forbs. Deep-rooted perennial bunchgrasses are a minor component or missing. Annual non-native species may be present but are not dominant. Trace amounts of sagebrush or rabbitbrush may be present.

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 big sagebrush can take many years.

Annual State 4.0:

This state has two community phases; one dominated by annual non-native species and the other is a shrub-dominated state. This state is characterized by the dominance of annual non-native species such as cheatgrass, Russian thistle, tumblemustard and/or redstem stork's bill in the understory. Yellow rabbitbrush and other sprouting shrubs may dominate the overstory.

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.

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 Nevada jointfir and yellow rabbitbrush will be the first to reappear after fire. Probability of sagebrush establishment is extremely low.

Community Phase 4.2:
Yellow rabbitbrush and other sprouting shrubs dominate the overstory and annual non-native species dominate the understory. Big sagebrush and perennial bunchgrasses occur in trace amounts.

Tree State 5.0:

This state is characterized by a dominance of Utah juniper and/or singleleaf pinyon in the overstory. Mountain 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 (At-Risk):
Utah juniper and/or singleleaf pinyon trees dominate overstory. Mountain 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.

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 native herbaceous understory species for sunlight and water.

Community Phase 5.2 (At-Risk):
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 mountain sagebrush may be present however dead skeletons will be more numerous than living sagebrush. Bunchgrasses may or may not be present. Sandberg bluegrass, squirreltail and mat-forming forbs may be present in trace amounts. Bare ground interspaces are large and connected. Soil redistribution is evident. Non-native species may be increasing in the understory.

Community Phase Pathway 5.2a, from phase 5.2 to 5.1:
Manual or mechanical thinning of trees allows understory regrowth due to less competition for resources. This treatment is typically done for fuel management.

T5A: Transition from Tree State 5.0 to Annual State 4.0:

Trigger: Catastrophic fire causing a stand-replacing 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.

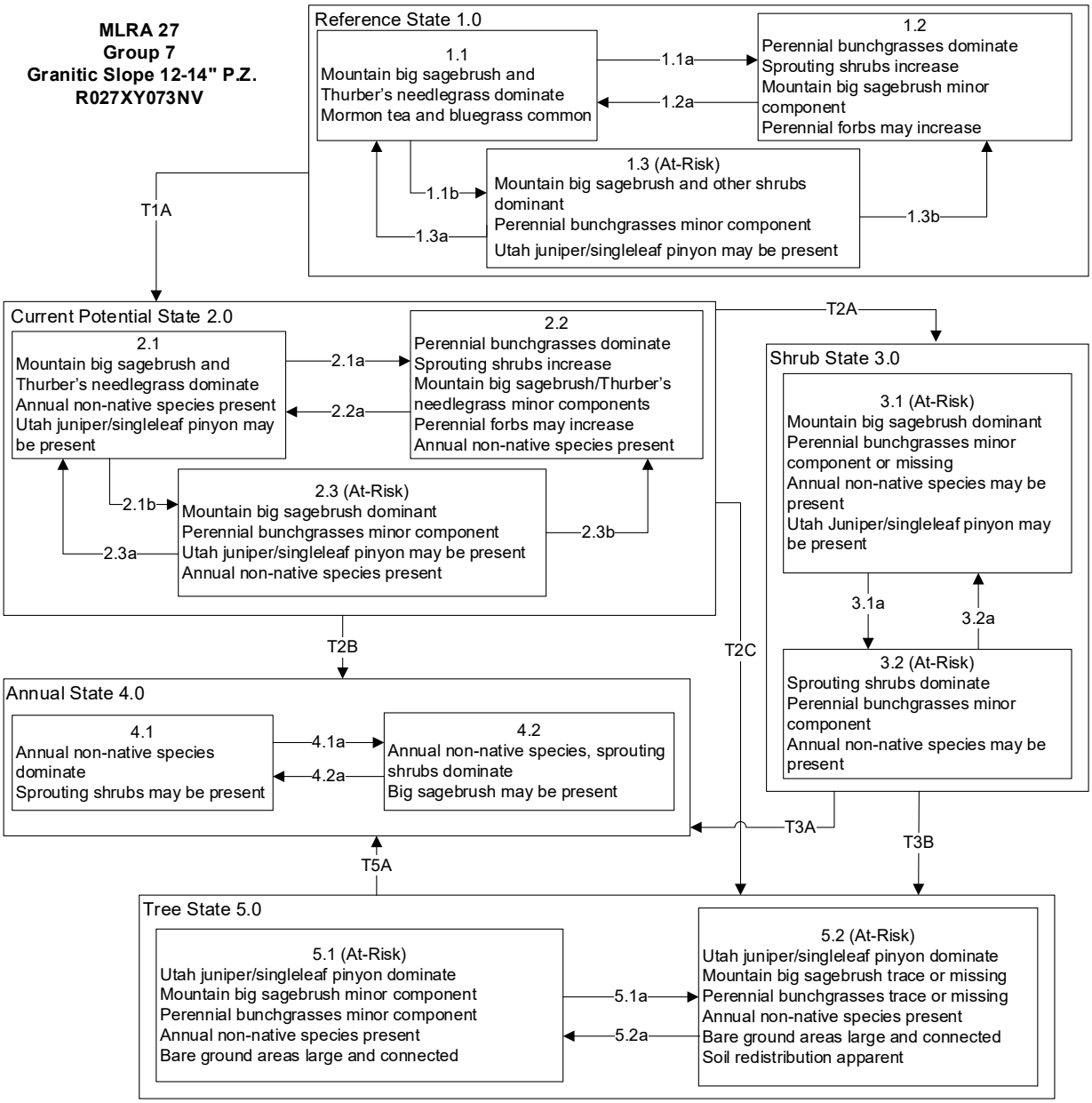
States Not Observed in Group 7:

Annual State: An Annual State was not observed for this site; however, this state could occur after a catastrophic wildfire, especially on south-facing slopes.

Seeded State: A Seeded State was not observed for this site; however, a similar site in MLRA 26, DRG 9, ecological site Granitic Slope 10-12" P.Z. (R026XY026NV) has a documented seeded state (Stringham et al. 2021). Thus, the sites in this DRG may have a successful seeding under favorable climatic conditions.

Tree State: A Tree State was not observed during field work for this site; however, aerial imagery indicates a Tree State is present in areas where this site occurs.

Modal State and Transition Model for Group 7 in MLRA 27



MLRA 27
Group 7
Granitic Slope 12-14" P.Z.
R027XY073NV

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 deep-rooted perennial bunchgrass understory.
1.2a: Time and lack of disturbance allows for shrub regeneration.
1.3a: Aroga moth infestation and/or release from growing season herbivory resulting in a grass/sagebrush mosaic pattern.
1.3b: High severity fire and/or Aroga moth infestation significantly reduces sagebrush cover leading to early/mid-seral community dominated by perennial grasses and sprouting shrubs.

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

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: Grazing management and/or time and lack of disturbance allows for regeneration of sagebrush.
2.3a: Aroga moth infestation and/or release from growing season herbivory resulting in grass/sagebrush mosaic. Brush management with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire, Aroga moth infestation or brush management treatments significantly reduces sagebrush cover leading to early mid-seral community dominated by sprouting shrubs, perennial grasses and forbs.

Transition T2A: Time 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).
Transition T2C: Time and lack of disturbance allows for an increase in tree cover; inappropriate grazing management and/or chronic drought can reduce perennial grass density 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).

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of disturbance.
4.2a: Fire.

Tree State 5.0 Community Phase Pathways
5.1a: Time and lack of disturbance allows for tree maturation.
5.2a: Tree thinning treatment (typical for fuels management).

Transition T5A: Catastrophic fire, inappropriate tree removal practices with soil disturbance (5.1).

References

Akinsoji, A. 1988. Postfire vegetation dynamics in a sagebrush steppe in southeastern Idaho, USA. Vegetatio **78**:151-155.

Bates, J. D., T. Svejcar, R. F. Miller, and R. A. Angell. 2006. The effects of precipitation timing on sagebrush steppe vegetation. Journal of Arid Environments **64**:670-697.

Beale, D. M., and A. D. Smith. 1970. Forage use, water consumption, and productivity of pronghorn antelope in western Utah. The Journal of Wildlife Management **34**:570-582.

Beatley, J. C. 1975. Climates and vegetation pattern across the Mojave/Great Basin Desert transition of southern Nevada. The American Midland Naturalist **93**:53-70.

Bentz, B., D. Alston, and T. Evans. 2008. Great Basin insect outbreaks. Pages 45-48 *in* Collaborative management and research in the Great Basin - Examining the issues and developing a framework for action. General Technical Report RMRS-GTR-204. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Blaisdell, J. P. 1953. Ecological effects of planned burning of sagebrush-grass range on the upper Snake River plains. Technical Bulletin No. 1075, U.S. Department of Agriculture, Washington, D.C.

Blaisdell, J. P., R. B. Murray, and E. D. McArthur. 1982. Managing intermountain rangelands - sagebrush-grass ranges. General Technical Report INT-134, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Britton, C. M., G. R. McPherson, and F. A. Sneva. 1990. Effects of burning and clipping on five bunchgrasses in eastern Oregon. The Great Basin Naturalist **50**:115-120.

Bunch, T. R. 1979. Cusick's bluegrass (Poa cusickii).

Bunting, S. C., B. M. Kilgore, and C. L. Bushey. 1987. Guidelines for prescribed burning sagebrush-grass rangelands in the Northern Great Basin. General Technical Report INT-231, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Burkhardt, J. W., and E. W. Tisdale. 1969. Nature and successional status of western juniper vegetation in Idaho. Journal of Range Management **22**:264-270.

Caudle, D., J. DiBenedetto, M. Karl, H. Sanchez, and C. Talbot. 2013. Interagency ecological site handbook for rangelands. U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.

Chambers, J. C., B. A. Bradley, C. S. Brown, C. D'Antonio, M. J. Germino, J. B. Grace, S. P. Hardegree, R. F. Miller, and D. A. Pyke. 2013. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of western North America. Ecosystems **17**:360-375.

Chambers, J. C., B. A. Roundy, R. R. Blank, S. E. Meyer, and A. Whittaker. 2007. What makes Great Basin sagebrush ecosystems invasible by *Bromus tectorum*? Ecological Monographs **77**:117-145.

Coates, P. S., B. G. Prochazka, M. A. Ricca, K. B. Gustafson, P. Ziegler, and M. L. Casazza. 2016. Pinyon and juniper encroachment into sagebrush ecosystems impacts distribution and survival of greater sage-grouse. Rangeland Ecology & Management **70**:25–38.

Comstock, J. P., and J. R. Ehleringer. 1992. Plant adaptation in the Great Basin and Colorado Plateau. The Great Basin Naturalist **52**:195-215.

Crawford, J. A., R. A. Olson, N. E. West, J. C. Mosley, M. A. Schroeder, T. D. Whitson, R. F. Miller, M. A. Gregg, and C. S. Boyd. 2004. Synthesis paper - Ecology and management of sage-grouse and sage-grouse habitat. Journal of Range Management **57**:2-19.

Cronquist, A., A. H. Holmgren, N. H. Holmgren, J. L. Reveal, and P. K. Holmgren. 1977. Intermountain flora: Vascular plants of the Intermountain West, U.S.A. Volume six. The Monocotyledons. Columbia University Press, New York, NY.

Daubenmire, R. 1970. Steppe vegetation of Washington. Technical Report 62, Washington State University, Washington Agricultural Experiment Station, Pullman, WA.

Dayton, W. A. 1931. Important western browse plants. Misc. Publication No. 101, United States Department of Agriculture, Washington, D.C.

Dittberner, P. L., and M. R. Olson. 1983. The plant information network (PIN) data base: Colorado, Montana, North Dakota, Utah, and Wyoming. FWS/OBS-83/36, U.S. Department of the Interior, Fish and Wildlife Service, Research and Development, Division of Biological Services, Western Energy and Land Use Team, Washington, D.C.

Dobkin, D. S., and J. D. Sauder. 2004. Shrubsteppe landscapes in jeopardy: Distributions, abundances, and the uncertain future of birds and small mammals in the Intermountain West. High Desert Ecological Research Institute, Bend, OR.

Dobrowolski, J. P., M. M. Caldwell, and J. H. Richards. 1990. Chapter 7: Basin hydrology and plant root systems. Pages 243-292 *in* C. B. Osmond, L. F. Pitelka, and G. M. Hidy, editors. Plant Biology of the Basin and Range. Springer-Verlag, New York City, NY.

Eckert, R. E., Jr., and J. S. Spencer. 1987. Growth and reproduction of grasses heavily grazed under rest-rotation management. Journal of Range Management **40**:156-159.

Ellsworth, L. M., and J. B. Kauffman. 2010. Native bunchgrass response to prescribed fire in ungrazed mountain big sagebrush ecosystems. Fire Ecology **6**:86-96.

Everett, R. L., P. T. Tueller, J. B. Davis, and A. D. Brunner. 1980. Plant phenology in galleta-shadscale and galleta-sagebrush associations. Rangeland Ecology & Management/Journal of Range Management Archives **33**:446-450.

Furniss, M. M., and W. F. Barr. 1975. Insects affecting important native shrubs of the Northwestern United States. General Technical Report INT-19, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Ganskopp, D., L. Aguilera, and M. Vavra. 2007. Livestock forage conditioning among six northern Great Basin grasses. Rangeland Ecology & Management **60**:71-78.

Ganskopp, D. L. 1988. Defoliation of Thurber needlegrass: herbage and root responses. Journal of Range Management **41**:472-476.

Houston, D. B. 1973. Wildfires in northern Yellowstone National Park. Ecology **54**:1111-1117.

Hunter, R., A. Wallace, and E. M. Romney. 1978. Persistent atrazine toxicity in Mohave Desert shrub communities. Journal of Range Management **31**:199-203.

Johnson, R., E. Leger, and K. Vance-Borland. 2017. Genecology of Thurber's Needlegrass (Achnatherum thurberianum [Piper] Barkworth) in the Western United States. Rangeland Ecology & Management **70**:509-517.

Kitchen, S. G., and E. D. McArthur. 2007. Big and black sagebrush landscapes. Pages 73-94 *in* Fire ecology and management of the major ecosystems of southern Utah. General Technical Report RMRS-GTR-202. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Koniak, S. 1985b. Succession in pinyon-juniper woodlands following wildfire in the Great Basin. The Great Basin Naturalist **45**:556-566.

Kuntz, D. E. 1982. Plant response following spring burning in an *Artemisia tridentata* subsp. *vaseyana*/*Festuca idahoensis* habitat type. Master's thesis. University of Idaho, Moscow, ID.

Leege, T. A., and W. O. Hickey. 1971. Sprouting of northern Idaho shrubs after prescribed burning. The Journal of Wildlife Management **35**:508-515.

McAdoo, J. K., and G. N. Back. 2001. Sage grouse biology. FS-01-43, University of Nevada, Reno Extension, Reno, NV.

Merrill, E. H., H. F. Mayland, and J. M. Peek. 1982. Shrub responses after fire in an Idaho ponderosa pine community. Journal of Wildlife Management **46**:496-502.

Meyer, S. E. 2008c. *Ephedra* L. or Mormon-tea. Pages 492-494 *in* F. T. Bonner and R. P. Karrfalt, editors. The woody plant seed manual; Agricultural handbook no. 727. U.S. Department of Agriculture, Forest Service, Washington D.C.

Miller, R. F., J. C. Chambers, D. A. Pyke, F. B. Pierson, and C. J. Williams. 2013. A review of fire effects on vegetation and soils in the Great Basin Region: Response and ecological site characteristics. General Technical Report RMRS-GTR-308, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Miller, R. F., T. J. Svejcar, and J. A. Rose. 2000. Impacts of western juniper on plant community composition and structure. Journal of Range Management **53**:574-585.

Miller, R. F., and R. J. Tausch. 2001. The role of fire in juniper and pinyon woodlands: A descriptive analysis. Pages 15-30 *in* Fire conference 2000: the first national congress on fire ecology, prevention, and management; San Diego, CA. Misc. Pub. No. 11. Tall Timbers Research Station, Tallahassee, FL.

Miller, R. F., R. J. Tausch, E. D. McArthur, D. D. Johnson, and S. C. Sanderson. 2008b. Age structure and expansion of piñon-juniper woodlands: A regional perspective in the Intermountain West. Research Paper Report RMRS-RP-69, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Monsen, S. B., R. Stevens, and N. L. Shaw. 2004a. Grasses. Pages 295-424 *in* S. B. Monsen, R. Stevens, and N. L. Shaw, editors. Restoring western ranges and wildlands, vol. 2. Gen. Tech. Rep. RMRS-GTR-136-vol-2. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Neuenschwander, L. F. 1980. Broadcast burning of sagebrush in the winter. Journal of Range Management **33**:233-236.

Noste, N. V., and C. L. Bushey. 1987. Fire response of shrubs of dry forest habitat types in Montana and Idaho. General Technical Report INT-239, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Noy-Meir, I. 1973. Desert ecosystems: Environment and producers. Annual Review of Ecology and Systematics **4**:25-51.

NRCS. 2022. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. Handbook 296, U.S. Department of Agriculture, Natural Resources Conservation Service.

Ogle, D., St. John, L, Tilley, D, Jones, T. 2006. Plant Guide for Thurber's Needlegrass. USDA NRCS, USDA NRCS Idaho State Office.

Perryman, B. L., and Q. D. Skinner. 2007. A Field Guide to Nevada Grasses. Indigenous Rangeland Management Press, Lander, WY.

Personius, T. L., C. L. Wambolt, J. R. Stephens, and R. G. Kelsey. 1987. Crude terpenoid influence on mule deer preference for sagebrush. Journal of Range Management **40**:84-88.

Richards, J. H., and M. M. Caldwell. 1987. Hydraulic lift: substantial nocturnal water transport between soil layers by *Artemisia tridentata* roots. Oecologia **73**:486-489.

Shaw, N. L. 1992. Germination and seedling establishment of spiny hopsage (*Grayia spinosa* [Hook.] Moq.). PhD Dissertation. Oregon State University, Corvallis, OR.

Sheehy, D. P., and A. H. Winward. 1981. Relative palatability of seven *Artemisia* taxa to mule deer and sheep. Journal of Range Management **34**:397-399.

Stanton, F. 1973. Wildlife guidelines for range fire rehabilitation. Technical Note 237, U.S. Department of the Interior, Bureau of Land Management, Denver, CO.

Stringham, T. K., D. K. Snyder, P. Novak-Echenique, K. O'Neill, A. Lyons, and M. Johns. 2021. Great Basin ecological site development project: State-and-transition models for Major Land Resource Area 26, Nevada and portions of California. Nevada Agricultural Experiment Station Research Report 2021-01, University of Nevada Reno, USA.

Tisdale, E. W., and M. Hironaka. 1981. The sagebrush - grass region: A review of the ecological literature. Forest, Wildlife and Range Experiment Station, University of Idaho **209**.

Uresk, D. W., J. F. Cline, and W. H. Rickard. 1976b. Impact of wildfire on three perennial grasses in south-central Washington. Journal of Range Management **29**:309-310.

USFS. 1937. Range plant handbook. U.S. Department of Agriculture, Forest Service, Washington, D.C.

Welch, B. L. 2005. Big sagebrush: A sea fragmented into lakes, ponds, and puddles. General Technical Report RMRS-GTR-144, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Welsh, S. L., N. D. Atwood, S. Goodrich, and L. C. Higgins. 1987. A Utah flora. Great Basin Naturalist Memoir No. 9 edition. Brigham Young University, Provo, Utah.

Wright, H. A. 1971. Why squirreltail is more tolerant to burning than needle-and-thread. Journal of Range Management **24**:277-284.

Wright, H. A., and J. O. Klemmedson. 1965. Effect of fire on bunchgrasses of the sagebrush-grass region in Southern Idaho. Ecology **46**:680-688.

Young, J. A., and R. A. Evans. 1978. Population dynamics after wildfires in sagebrush grasslands. Journal of Range Management **31**:283-289.

Young, R. P. 1983. Fire as a vegetation management tool in rangelands of the intermountain region. Pages 18-31 *in* Managing Intermountain rangelands—Improvement of range and wildlife habitats. Proceedings of Symposia: September 15-17, 1981, Twin Falls, Idaho June 22·24, 1982, Elko, Nevada. General Technical Report INT-GTR-157. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

MLRA 27 Group 8: Eroded soils with spiny hopsage and cool-season grasses

Description of MLRA 27 Disturbance Response Group 8

Disturbance Response Group (DRG) 8 consists of one ecological site, Eroded Granitic Slope (R027XY047NV). This site occurs on sideslopes of hills and mountains. Slopes range from 15 to 75%. Precipitation ranges from 5 to 8 in., and elevations range from 4,300 to 6,500 ft. The soils on these sites are typically shallow to very shallow and well drained. These soils are formed in residuum and colluvium derived from granitic rock sources and contain considerable amounts of gravel throughout the profile. Available water holding capacity is very low and runoff is medium. The soil temperature regime is mesic and the soil moisture regime in typic aridic. The reference plant community is dominated by spiny hopsage (*Grayia spinosa*), littleleaf horsebrush (*Tetradymia glabrata*), Nevada jointfir (*Ephedra nevadensis*), prickleleaf (*Hecastocleis shockleyi*) and desert needlegrass (*Achnatherum speciosum*). Other important species include Anderson wolfberry (*Lycium andersonii*), spiny menodora (*Menodora spinescens*), galleta grass (*Pleuraphis jamesii*), and desert needlegrass (*Achnatherum hymenoides*). Total annual production ranges from 200 to 500 lb/ac with 350 lb/ac in a normal year.

This ecological site is possibly a community phase of the Granitic Slope 8-10" P.Z. (R027XY065NV) or South Slope 8-10" P.Z. (R027XY051NV) ecological sites that are dominated by Wyoming big sagebrush. The reference plant community on the Eroded Granitic Slope ecological site may be a result of a wildfire and ensuing surface soil erosion. Severe erosion on these soils and continuing soil stability restricts Wyoming big sagebrush reproduction yet offers a suitable growing environment for more drought-tolerant species.

Disturbance Response Group 8 Ecological Sites:

Eroded Granitic Slope – Modal	R027XY047NV

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 27 (MLRA 27 Fallon-Lovelock Area) is almost entirely in Nevada with < 1% in California. The entire area occurs in the rain shadow of the Sierra Nevada mountains and is influenced by Pleistocene Lake Lahontan. Extensive playas occur throughout the area and are a result of the drying of ancient Lake Lahontan. To the west, MLRA 27 has a gradual boundary with MLRA 26 (Carson Basin and Mountains) and to the east has a very gradual boundary with MLRA 24 (Humboldt Basin and Range Area). From west to east the soil temperature increases and the soil moisture decreases, resulting in vast areas dominated by salt-desert shrub communities. Isolated mountain ranges trending north to south are separated by broad desert plains and valleys. Elevations range from 3,300 to 5,900 ft with some mountain peaks over 7,800 ft. The average annual precipitation ranges from 4 to 11 in. and as much as 20 in. at the highest elevations. The majority of annual precipitation is received during late fall and winter occurring mainly as snow. High-intensity, convective thunderstorms also contribute significantly to annual precipitation (NRCS 2022). 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 cool-season bunchgrasses on this site are desert needlegrass and Indian ricegrass. 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. tall (Blaisdell and Holmgren 1984).

Desert needlegrass is a cool-season, perennial bunchgrass that grows 12–24 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). 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).

Indian ricegrass is a long-lived, cool-season perennial bunchgrass that grows from 4 to 24 in. tall 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).

Galleta (*Pleuraphis jamesii*) is a minor warm-season perennial grass on this site. Galleta is a mat-forming, rhizomatous, native grass that is 11–19 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).

Spiny hopsage is a rounded, summer-deciduous shrub standing 0.3–1.2 m (1–3 ft) tall that is widely distributed throughout the western United States. It is commonly associated with Mojave Desert and Great Basin-Mojave Desert transition communities in elevations from 160 to 2,130 m (525–7,000 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.

Littleleaf horsebrush is a moderately-branched shrub between 30 cm and 1 m tall (12–39 in.) and typically as wide or wider (Mozingo 1987a, 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 of 0 to 50% at elevations between 3,500 and 8,000 ft (Perryman 2014a). 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 1987a). Littleleaf horsebrush separates itself from other shrubs due to its early leaf out - frequently beginning to leaf out in February, flowering from April to July, and transition to drier brown leaves by midsummer while other shrubs have just begun developing flower buds (Mozingo 1987a). However, it is an opportunistic shrub and can remain green and even produce new leaves and shoots if enough water is present (Mozingo 1987a). 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 (< 1 in.) by being quickly lost and follow by clusters of soft, narrow, elongate and succulent leaves about the same length or longer (Mozingo 1987a).

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 jointfir 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).

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 in elevation throughout the southwestern United States (Tesky 1992). It possesses an extensive, tough, and fibrous root system extending 25–30 ft from the plant and enabling it to reach depths 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).

The ecological site in this DRG has low 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. Three possible stable states were identified for this ecological site.

Annual Invasive Species:

The species most likely to invade this site is cheatgrass (*Bromus tectorum*). Cheatgrass is a cool-season annual grass that maintains 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 et al. 1999a, USFS 2017).

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. 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). Cheatgrass colonizes 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 2–4 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 non-native annual grasses (Smith et al. 2022).

Methods to control cheatgrass includes herbicide application, prescribed fire, targeted grazing, and rangeland 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 (*Agropyron cristatum*) (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. 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). Although these results are relevant for cheatgrass and medusahead, effectiveness on red brome (*Bromus rubens*) is unknown.

Other non-native annual species that may occur include red brome, redstem stork's bill (*Erodium cicutarium*) and annual mustards (Brassicaceae family).

Fire Ecology:

The historic fire regime of Intermountain Basins semi-desert shrub-steppe communities was infrequent and somewhat dependent on fire importation from the upper sagebrush zone. Replacement fire was the primary fire and increased with shrub development intermixed with grass (LandFire 2020). Mean fire intervals were typically greater than 200 years (LandFire 2020).

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. 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.

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.

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 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).

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.

Spiny hopsage is generally top-killed by fire, but often sprouts after plants are damaged by fire or mechanical injury (Shaw 1992). Fires in spiny hopsage sites generally occur in late summer when plants are dormant, and sprouting generally does not occur until the following spring (Daubenmire 1970). Spiny hopsage is reported to be least susceptible to fire during summer dormancy (Rickard and McShane 1984).

Littleleaf horsebrush is top-killed by fire and re-establishes by sprouting from the root crown (Ralphs and Busby 1979, Paysen et al. 2000).

Nevada jointfir vigorously sprouts after fire from extensive woody crowns (Young and Evans 1978, Koniak 1985b). 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).

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).

Livestock/Wildlife Grazing Interpretations:

This semi-desert shrub-steppe community is typically regarded as a browse-specific plant community. It is characterized by low productivity, which requires substantial acreage for grazing animals. Within this vegetation type, it is acknowledged that 65–90% of the available forage is browse (Costello 1944). This site is characterized by steep, rocky slopes which limit extensive grazing.

Spiny hopsage is palatable to livestock, especially sheep, during the spring and early summer (Phillips et al. 1996, Simmons and Rickard 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 and Rickard 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 jointfir 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 jointfir in the winter (Dayton 1931). When new growth is available in spring and summer, it is browsed by mule deer, bighorn sheep, and pronghorn (Beale and Smith 1970). Nevada jointfir provides cover for pronghorn,

small mammals, and both game and nongame birds (Dittberner and Olson 1983). Small mammals and birds eat the seeds (Meyer 2008c).

Littleleaf horsebrush plays a minor role as a browse species due to its low palatability (Mozingo 1987a).

Anderson wolfberry also 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).

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 at the base of the spikelets. Sheep generally avoid desert needlegrass after maturity while horses and cattle may use it moderately (NRCS 2008).

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 (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.

Galleta is a 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.

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 8

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model (STM) for the MLRA 27 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 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, littleleaf horsebrush, Anderson wolfberry, and desert needlegrass. Potential vegetative composition by air-dry weight is approximately 50% grasses, 5% forbs and 45% shrubs. Approximate ground cover (basal and crown) is less than 20%. Total annual air-dry production ranges from 200 to 500 lb/ac with 350 lb/ac in a normal year.

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. Long-term drought will reduce shrub cover and favor perennial grasses.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.3:
Time and lack of disturbance such as fire. Long-term drought may also decrease perennial grass understory. Drought reduces herbaceous vigor and seed production, allowing shrubs to gain a competitive edge.

Community Phase 1.2:
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 (At-Risk):
Spiny hopsage, littleleaf horsebrush, yellow rabbitbrush (*Chrysothamnus viscidiflorus*) and other shrubs dominate site while perennial bunchgrasses are reduced.

Community Phase Pathway 1.3a:
Low severity fire creates a grass/shrub mosaic.

Community Phase Pathway 1.3b:
High severity fire leads to an increase in perennial grasses and reduces shrubs.

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, redstem stork's bill, 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. 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, littleleaf horsebrush and desert needlegrass are dominant. Nevada jointfir, Anderson wolfberry and prickleleaf and Indian ricegrass are common. Annual non-natives are present in the understory.

Eroded Granitic Slope (R027XY047NV), Current Potential 2.1, T. Stringham, September 2025

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
Low severity fire that creates grass/shrub mosaic or managed herbivory. Long-term drought will reduce shrub cover and favor perennial grasses.

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 long-term drought may also reduce perennial understory.

Community Phase 2.2:
Desert needlegrass, Indian ricegrass 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.

Community Phase Pathway 2.3a:
Low severity fire and/or reduced grazing pressure creates a shrub/grass mosaic.

Community Phase Pathway 2.3b:
High severity fire and or reduced grazing pressure leads to an increase in perennial grasses and reduces shrub cover.

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. Long-term drought may also reduce deep-rooted perennial bunchgrasses.

Slow variables: Long-term decrease in deep-rooted perennial bunchgrasses density and an increase in perennial rhizomatous or shallow-rooted grasses.

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.

Shrub State 3.0:

This State is characterized by the dominance of shrubs, a reduced perennial bunchgrass 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 greatly reduced 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 (At-Risk):
Spiny hopsage, Nevada jointfir and other shrubs dominate, reducing deep-rooted perennial bunchgrasses to a minor component. Galleta and/or Sandberg's bluegrass are common. Annual non-native species present and may be increasing. Wind and water erosion may increase. Soil pedestalling and redistribution indicate loss of stabilizing vegetation.

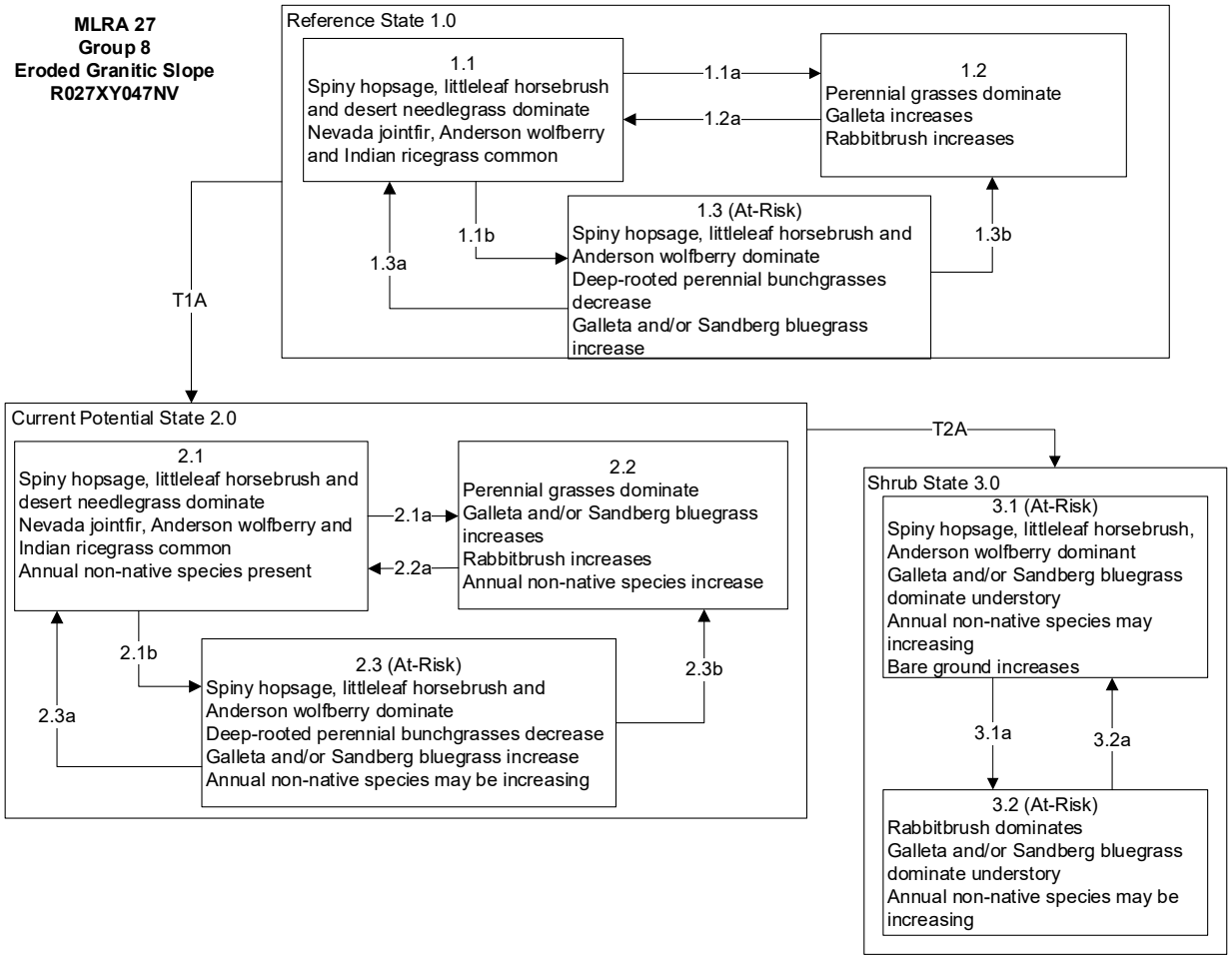
Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:
Fire, inappropriate grazing management, or long-term drought.

Community Phase 3.2 (At-Risk):
Sprouting shrubs, such as rabbitbrush dominate, reducing perennial bunchgrasses to trace or missing. Galleta and/or Sandberg's bluegrass may be increasing. Annual non-native species may be increasing.

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 Nevada jointfir and some deep-rooted perennial grasses to reestablish.

States Not Observed in Group 8:
Annual State: An Annual State was not observed but frequent wildfires could eliminate or reduce the sprouting shrubs allowing the non-native annual grasses to dominate.

Modal State and Transition Model for Group 8 in MLRA 27



MLRA 27
Group 8
Eroded Granitic Slope
R027XY047NV

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire creates grass/shrub mosaic which leads to early/mid-seral community, dominated by perennial grasses and sprouting shrubs. Long-term drought will reduce shrub cover and favor perennial grasses and forbs..
1.1b: Time and lack of disturbance such as fire. Long-term drought may also decrease perennial grasses.
1.2a: Time and lack of disturbance and favorable moisture allows for shrub regeneration.
1.3a: Low severity fire resulting in a grass/shrub mosaic pattern.
1.3b: High severity fire significantly reduces shrub cover and increases grass cover.

Transition T1A: Introduction of non-native species such as cheatgrass, red-stem stork's bill or annual mustards..

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire creates grass/sagebrush mosaic or managed herbivory. Long-term drought will reduce shrub cover and favor perennial 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 and favorable moisture conditions allow for shrub regeneration.
2.3a: Low severity fire and/or reduced grazing pressure leads to an increase in perennial grasses.
2.3b: High severity fire or reduced grazing pressure reduces shrub cover and increases grass cover.

Transition T2A: Time and lack of disturbance (fire, drought) and/or inappropriate grazing management.

Shrub State 3.0 Community Phase Pathways
3.1a: Fire, inappropriate grazing management or long-term drought.
3.2a: Time and lack of fire and favorable precipitation allows some shrubs to reestablish.

References

Balch, J. K., B. A. Bradley, C. M. D'Antonio, and J. Gómez-Dans. 2013. Introduced annual grass increases regional fire activity across the arid western USA (1980–2009). Global Change Biology **19**:173-183.

Banner, R., M. S. Pratt, and J. Bowns. 2011. Grasses and Grasslike Plants of Utah: A Field Guide. Utah State University Extension, Logan, UT.

Bates, J. D., T. Svejcar, R. F. Miller, and R. A. Angell. 2006. The effects of precipitation timing on sagebrush steppe vegetation. Journal of Arid Environments **64**:670-697.

Beale, D. M., and A. D. Smith. 1970. Forage use, water consumption, and productivity of pronghorn antelope in western Utah. The Journal of Wildlife Management **34**:570-582.

Beatley, J. C. 1975. Climates and vegetation pattern across the Mojave/Great Basin Desert transition of southern Nevada. The American Midland Naturalist **93**:53-70.

Bertiller, M. B., A. M. Beeskow, and F. Coronato. 1991. Seasonal environmental variation and plant phenology in arid Patagonia (Argentina). Journal of Arid Environments **21**:1-11.

Bich, B. S., J. L. Butler, and C. A. Schmidt. 1995. Effects of differential livestock use on key plant species and rodent populations within selected *Oryzopsis hymenoides*/*Hilaria jamesii* communities of Glen Canyon National Recreation Area. The Southwestern Naturalist **40**:281-287.

Blaisdell, J. P., and R. C. Holmgren. 1984. Managing intermountain rangelands - salt-desert shrub ranges. General Technical Report INT-163, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Booth, D. T., C. G. Howard, and C. E. Mowry. 1980. 'Nezpar' Indian ricegrass: description, justification for release, and recommendations for use. Rangelands **2**:53-54.

Boyd, C. S., K. W. Davies, and A. Hulet. 2015. Predicting fire-based perennial bunchgrass mortality in big sagebrush plant communities. International Journal of Wildland Fire **24**:527-533.

Bradley, B. A., C. A. Curtis, E. J. Fusco, J. T. Abatzoglou, J. K. Balch, S. Dadashi, and M.-N. Tuanmu. 2018. Cheatgrass (*Bromus tectorum*) distribution in the intermountain Western United States and its relationship to fire frequency, seasonality, and ignitions. Biological Invasions **20**:1493-1506.

Butler, M., F. Brummer, J. Weber, and R. Simmons. 2011. Restoring Central Oregon rangeland from ventenata and medusahead to a sustainable bunchgrass environment – Warm Springs and Ashwood. COARC 2011, Oregon State University, Central Oregon Agricultural Research and Extension Center, Corvallis, OR.

Caudle, D., J. DiBenedetto, M. Karl, H. Sanchez, and C. Talbot. 2013. Interagency ecological site handbook for rangelands. U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.

Chambers, J. C., B. A. Bradley, C. S. Brown, C. D'Antonio, M. J. Germino, J. B. Grace, S. P. Hardegree, R. F. Miller, and D. A. Pyke. 2013. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of western North America. Ecosystems **17**:360-375.

Comstock, J. P., and J. R. Ehleringer. 1992. Plant adaptation in the Great Basin and Colorado Plateau. The Great Basin Naturalist **52**:195-215.

Cook, C. W. 1962. An evaluation of some common factors affecting utilization of desert range species. Journal of Range Management **15**:333-338.

Cook, C. W., and R. D. Child. 1971. Recovery of desert plants in various states of vigor. Rangeland Ecology & Management/Journal of Range Management Archives **24**:339-343.

Costello, D. F. 1944. Important species of the major forage types in Colorado and Wyoming. Ecological Monographs **14**:107-134.

Daubenmire, R. 1970. Steppe vegetation of Washington. Technical Report 62, Washington State University, Washington Agricultural Experiment Station, Pullman, WA.

Davies, K. W., C. S. Boyd, D. D. Johnson, A. M. Nafus, and M. D. Madsen. 2015b. Success of seeding native compared with introduced perennial vegetation for revegetating medusahead-invaded sagebrush rangeland. Rangeland Ecology & Management **68**:224-230.

Davies, K. W., A. M. Nafus, and M. D. Madsen. 2013. Medusahead invasion along unimproved roads, animal trails, and random transects. Western North American Naturalist **73**:54-59.

Davies, K. W., A. M. Nafus, and R. L. Sheley. 2010. Non-native competitive perennial grass impedes the spread of an invasive annual grass. Biological Invasions **12**:3187-3194.

Dayton, W. A. 1931. Important western browse plants. Misc. Publication No. 101, United States Department of Agriculture, Washington, D.C.

Dittberner, P. L., and M. R. Olson. 1983. The plant information network (PIN) data base: Colorado, Montana, North Dakota, Utah, and Wyoming. FWS/OBS-83/36, U.S. Department of the Interior, Fish and Wildlife Service, Research and Development, Division of Biological Services, Western Energy and Land Use Team, Washington, D.C.

Eckert, R. E., Jr., A. D. Bruner, and G. J. Klomp. 1972. Response of understory species following herbicidal control of low sagebrush. Journal of Range Management **25**:280-285.

Eliason, S. A., and E. B. Allen. 1997. Exotic grass competition in suppressing native shrubland re-establishment. Restoration Ecology **5**:245-255.

Everett, R. L., P. T. Tueller, J. B. Davis, and A. D. Brunner. 1980. Plant phenology in galleta-shadscale and galleta-sagebrush associations. Rangeland Ecology & Management/Journal of Range Management Archives **33**:446-450.

Evert, R. F. 2006. Esau's plant anatomy: Meristems, cells, and tissues of the plant body - Their structure, function, and development. Third Edition edition. John Wiley & Sons, Inc., Hoboken, New Jersey.

Furbush, P. 1953. Control of medusa-head on California ranges. Journal of Forestry **51**:118-121.

Green, L. R., L. A. Sharp, C. W. Cook, and L. E. Harris. 1951. Utilization of winter range forage by sheep. Journal of Range Management **4**:233-241.

Harrington, H. D. 1954. Manual of the plants of Colorado: For the identification of the ferns and flowering plants of the state. Sage Books, Denver, CO.

Harrison, B. J., Thatcher, A.P. 1970. Winter sheep grazing and forage preference in southwestern Wyoming. Journal of Range Management **23**:109-111.

Humphrey, L. D. 1984. Patterns and mechanisms of plant succession after fire on *Artemisia*-grass sites in southeastern Idaho. Vegetatio **57**:91-101.

Hunter, R., A. Wallace, and E. M. Romney. 1978. Persistent atrazine toxicity in Mohave Desert shrub communities. Journal of Range Management **31**:199-203.

Jameson, D. A. 1962. Effects of burning on a galleta-black grama range invaded by juniper. Ecology **43**:760-763.

Jones, T. A. 1990. A viewpoint on Indian ricegrass research: its present status and future prospects. Journal of Range Management **43**:416-420.

Kearney, T. H., R. H. Peebles, J. T. Howell, and E. McClintock. 1960. Arizona flora. Second edition. University of California Press, Berkeley, CA.

Klemmedson, J. O., and J. G. Smith. 1964. Cheatgrass (*Bromus tectorum* L.). The Botanical Review **30**:226-262.

Koniak, S. 1985b. Succession in pinyon-juniper woodlands following wildfire in the Great Basin. The Great Basin Naturalist **45**:556-566.

LandFire. 2020. Inter-Mountain Basins Semi-Desert Shrub Steppe. USDA-Forest Service, US Department of Interior - Office of Wildland Fire.

Mack, R. N., and D. A. Pyke. 1983. The demography of *Bromus tectorum*: Variation in time and space. Journal of Ecology **71**:69-93.

Melgoza, G., R. S. Nowak, and R. J. Tausch. 1990. Soil water exploitation after fire: Competition between *Bromus tectorum* (cheatgrass) and two native species. Oecologia **83**:7-13.

Meyer, S. E. 2008c. *Ephedra* L. or Mormon-tea. Pages 492-494 *in* F. T. Bonner and R. P. Karrfalt, editors. The woody plant seed manual; Agricultural handbook no. 727. U.S. Department of Agriculture, Forest Service, Washington D.C.

Miller, H. C., D. Clausnitzer, and M. M. Borman. 1999a. Medusahead. Pages 272-281 *in* R. L. S. a. J. K. Petroff, editor. Biology and Management of Noxious Rangeland Weeds. Oregon State University Press, Oregon State University.

Miller, R. F., R. J. Tausch, E. D. McArthur, D. D. Johnson, and S. C. Sanderson. 2008b. Age structure and expansion of piñon-juniper woodlands: A regional perspective in the Intermountain West. Research Paper Report RMRS-RP-69, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Monsen, S. B., R. Stevens, and N. L. Shaw. 2004a. Grasses. Pages 295-424 *in* S. B. Monsen, R. Stevens, and N. L. Shaw, editors. Restoring western ranges and wildlands, vol. 2. Gen. Tech. Rep. RMRS-GTR-136-vol-2. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Mozingo, H. N. 1987a. Littleleaf horsebush (*Tetradymia glabrata*). Pages 310-314 Shrubs of the Great Basin: A natural history. University of Nevada Press, Reno, NV.

NRCS. 2008. Plant fact sheet for desert needlegrass (*Achnatherum speciosum*). U.S. Department of Agriculture, Natural Resources Conservation Service, Plant Materials Program.

NRCS. 2022. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. Handbook 296, U.S. Department of Agriculture, Natural Resources Conservation Service.

Paysen, T. E., R. J. Ansley, J. K. Brown, G. J. Gottfried, S. M. Haase, M. G. Harrington, M. G. Narog, S. S. Sackett, and R. C. Wilson. 2000. Chapter 6: Fire in western shrubland,

woodland, and grassland ecosystems. Pages 121-159 *in* J. K. Brown and J. K. Smith, editors. Wildland fire in ecosystems: Effects of fire on flora. General Technical Report RMRS-GTR-42-Vol. 2. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Pearson, L. 1979. Effects of temperature and moisture on phenology and productivity of Indian ricegrass. Rangeland Ecology & Management/Journal of Range Management Archives **32**:127-134.

Pearson, L. C. 1964. Effect of harvest date on recovery of range grasses and shrubs. Agronomy Journal **56**:80-82.

Pearson, L. C. 1965. Primary production in grazed and ungrazed desert communities of eastern Idaho. Ecology **46**:278-285.

Pellant, M., and C. Hall. 1994. Distribution of two exotic grasses in intermountain rangelands: Status in 1992. Pages 109-112 *in* S. B. Monsen and S. G. Kitchen, editors. Proceedings—Ecology and management of annual rangelands; General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Perryman, B. L. 2014b. Littleleaf Horsebush - *Tetradymia glabrata* Torr. & A. Gray. Pages 146-147 A Field Guide to Nevada Shrubs. Indigenous Rangeland Management Press, Lander, Wyoming.

Phillips, R. L., N. K. McDougald, and J. Sullins. 1996. Plant preference of sheep grazing the Mojave desert. Rangelands **18**:141-144.

Pratt, M. S., G. A. Rasmussen, and R. E. Banner. 2002. Range judging in Utah. NR 505, Utah State University Extension, Logan, UT.

Quinones, F. A. 1981. Indian ricegrass evaluation and breeding. Bulletin 681, New Mexico State University, Agricultural Experiment Station, Las Cruces, NM.

Ralphs, M. H., and F. E. Busby. 1979. Prescribed burning: vegetative change, forage production, cost, and returns on six demonstration burns in Utah. Journal of Range Management **32**:267-270.

Rice, B., and M. Westoby. 1978. Vegetative responses of some Great Basin shrub communities protected against jackrabbits or domestic stock. Journal of Range Management **31**:28-34.

Rickard, W. H., and M. C. McShane. 1984. Demise of spiny hopsage shrubs following summer wildfire: An authentic record. Northwest Science **58**:282-285.

Sampson, A. W., A. Chase, and D. W. Hedrick. 1951. California grasslands and range forage grasses. Bulletin 724, University of California, the College of Agriculture, California Agricultural Experiment Station, Berkeley, CA.

Sanderson, S. C., and H. C. Stutz. 1994. Woody chenopods useful for rangeland reclamation in western North America. Pages 374-378 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Shaw, N. L. 1992. Germination and seedling establishment of spiny hopsage (*Grayia spinosa* [Hook.] Moq.). PhD Dissertation. Oregon State University, Corvallis, OR.

Shaw, N. L., M. R. Haferkamp, and E. G. Hurd. 2008. *Grayia spinosa* (Hook.) Moq: spiny hopsage. Pages 567-572 The Woody Plant Seed Manual Agric. Handbook No. 727. US Department of Agriculture, Forest Service, Washington DC.

Sheley, R. L., E. A. Vasquez, A.-M. Chamberlain, and B. S. Smith. 2012. Landscape-scale rehabilitation of medusahead (*Taeniatherum caput-medusae*)-dominated sagebrush steppe. Invasive Plant Science and Management **5**:436-442.

Simmons, S. A., and W. H. Rickard. 2003. Fire effects on spiny hopsage in south central Washington. Western North American Naturalist **63**:524-528.

Smith, J. T., B. W. Allred, C. S. Boyd, K. W. Davies, M. O. Jones, A. R. Kleinhesselink, J. D. Maestas, S. L. Morford, and D. E. Naugle. 2022. The elevational ascent and spread of exotic annual grass dominance in the Great Basin, USA. Diversity and Distributions **28**:83-96.

Stanton, F. 1973. Wildlife guidelines for range fire rehabilitation. Technical Note 237, U.S. Department of the Interior, Bureau of Land Management, Denver, CO.

Stubbendieck, J. L., S. L. Hatch, N. M. Bryan, and C. D. Dunn. 2017. North American wildland plants. Third edition. University of Nebraska Press, Lincoln, NE.

Stubbendieck, J. L., S. L. Hatch, and L. M. Landholt. 2003. North American wildland plants. University of Nebraska Press, Lincoln, NE.

Tesky, J. L. 1992. Lycium andersonii. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station,.

USFS. 2017. Field guide for managing red brome in the southwest. TP-R3-16-19, United States Department of Agriculture, Forest Service, Southwestern Region, Albuquerque, NM.

Vallentine, J. F. 1989. Range development and improvements. Academic Press, Inc., San Diego, CA.

Vollmer, J. L., and J. G. Vollmer. 2008. Controlling cheatgrass in winter range to restore habitat and endemic fire. Pages 57-60 *in* Proceedings—Shrublands under fire: Disturbance and recovery in a changing world. RMRS-P-52. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Cedar City, UT.

Welsh, S. L., N. D. Atwood, S. Goodrich, and L. C. Higgins. 1987. A Utah flora. Great Basin Naturalist Memoir No. 9 edition. Brigham Young University, Provo, Utah.

West, N. E. 1994. Effects of fire on salt-desert shrub rangelands. Pages 71-74 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, ID.

Wright, H. A. 1971. Why squirreltail is more tolerant to burning than needle-and-thread. Journal of Range Management **24**:277-284.

Wright, H. A. 1985. Effects of fire on grasses and forbs in sagebrush-grass communities. Pages 12-21 *in* Rangeland fire effects: A symposium; Boise, ID; November 27-29, 1984. U.S. Department of the Interior, Bureau of Land Management, Boise, ID.

Young, J. A., and R. A. Evans. 1978. Population dynamics after wildfires in sagebrush grasslands. Journal of Range Management **31**:283-289.

Young, R. P. 1983. Fire as a vegetation management tool in rangelands of the intermountain region. Pages 18-31 *in* Managing Intermountain rangelands—Improvement of range and

wildlife habitats. Proceedings of Symposia: September 15-17, 1981, Twin Falls, Idaho June 22·24, 1982, Elko, Nevada. General Technical Report INT-GTR-157. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

MLRA 27 Group 9: Loamy soils with basin wildrye

Description of MLRA 27 Disturbance Response Group 9

Disturbance Response Group (DRG) 9 consists of one ecological site, Loamy Bottom (R027XY003NV). This site occurs on inset fans and axial stream floodplains. Slopes range from 0 to about 4%. Elevations range from 5,000 to about 7,500 ft. Average annual precipitation is 8–12 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 30–60 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 wildrye (*Leymus cinereus*). Western wheatgrass (*Pascopyrum smithii*) and beardless wildrye (*Leymus triticoides*) may be a sub-dominant component. Basin big sagebrush (*Artemisia tridentata ssp. tridentata*), Woods' rose (*Rosa woodsii*), and rubber rabbitbrush (*Ericameria nauseosa*) are common shrubs associated with this site. Total annual production ranges from 1,000 to 3,500 lb/ac with 2,000 lb/ac in a normal year.

Disturbance Response Group 9 Ecological Sites:

Loamy Bottom – Modal R027XY003NV

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 27 (MLRA 27 Fallon-Lovelock Area) is almost entirely in Nevada with < 1% in California. The entire area occurs in the rain shadow of the Sierra Nevada mountains and is influenced by Pleistocene Lake Lahontan. Extensive playas occur throughout the area and are a result of the drying of ancient Lake Lahontan. To the west, MLRA 27 has a gradual boundary with MLRA 26 (Carson Basin and Mountains) and to the east has a very gradual boundary with MLRA 24 (Humboldt Basin and Range Area). From west to east the soil

temperature increases and the soil moisture decreases, resulting in vast areas dominated by salt-desert shrub communities. Isolated mountain ranges trending north to south are separated by broad desert plains and valleys. Elevations range from 3,300 to 5,900 ft with some mountain peaks over 7,800 ft. The average annual precipitation ranges from 4 to 11 in. and as much as 20 in. at the highest elevations. The majority of annual precipitation is received during late fall and winter occurring mainly as snow. High-intensity, convective thunderstorms also contribute significantly to annual precipitation (NRCS 2022). 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 (3–9 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 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 10–12 in.

diameter basal height tree consumes approximately 10–68 liters per day (2.6–18 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 1–2 m (3–6.5 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 15–25 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).

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).

Western wheatgrass is a long-lived perennial cool-season species that possesses strong spreading rhizomes (NRCS 2002). Its relative drought tolerance combined with a strong rhizomatous root system and an adaptation to a variety of soils make this species ideal for reclamation in areas receiving 12–20 in. annual precipitation (Ogle 2000b). Western wheatgrass tolerates saline and saline-sodic soils, poor drainage, spring flooding, high-water tables and silt deposition (NRCS 2002).

Beardless wildrye is a cool-season perennial, sod-forming native grass. It is a long grass that is typically tall and strongly rhizomatous. In deep soils, the roots may reach 10 ft. Beardless

wildrye is a strong soil stabilizer and during high water flow periods, it lays flat and allows water flow while protecting the streambank (Dyer and O'Beck 2006).

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).

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 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 moth can partially or entirely kill individual plants or entire stands of big sagebrush (Furniss and Barr 1975).

Hydrology, Drought, Groundwater Interpretations:

Changes in depth to groundwater occur naturally but anthropogenic alterations may exacerbate these fluctuations and subsequently affect vegetation dependent on groundwater (Naumburg et al. 2005). Decreasing water tables often result in plant water stress and reduced live biomass. Rising water tables saturate rooting zones resulting in the death of roots and whole plant responses resemble symptoms of drought stress, including the closure of stomata and a decrease in photosynthetic activity (Naumburg et al. 2005).

The typical seasonal high-water table occurs at depths of 30–60 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 2,000 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 streambank 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.

The ecological site in this DRG has moderate resilience to disturbance and resistance to invasion because of the occurrence of a groundwater table, additional run-in moisture and high productivity. Possible disturbances include inappropriate grazing practices, drought, groundwater pumping, singleleaf pinyon and/or Utah juniper encroachment in the watershed, and/or fire. These disturbances may facilitate an increase in shrubs and a decrease in basin wildrye and alkali sacaton. 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 (*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. (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 1.5–1.7 m (5–5.5 ft). Other troublesome non-native weeds such as tall whitetop (broadleafed pepperweed) (*Lepidium latifolium*), scotch thistle (*Onopordum acanthium*) or bull thistle (*Cirsium vulgare*) are potential invaders on this site. 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 et al. 1999a). 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 inches 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/in. of stem or about 400 lb/ac of seed. 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 < 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 1998).

Fire Ecology:

Sagebrush, desert shrub and grassland communities with a basin wildrye component historically experiences infrequent to frequent, stand-replacing fires. Sagebrush communities experienced fire intervals of 20–70 years, and desert shrub communities and grassland communities experienced fire intervals of 35–100 years (Paysen et al. 2000).

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 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.

Western wheatgrass is generally unharmed by fire although rhizomes may be harmed. Western wheatgrass cover usually increases or changes little after fire and responses are variable by season of burn (Tirmenstein 1999).

Beardless wildrye is typically top-killed by fire but survives because of its extensive underground rhizome network. It recovers rapidly, especially following dormant-season fires (Young 1983).

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 of the parent shrub (Goodrich et al. 1985) with maximum seed dispersal at approximately 108 ft 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 50–120 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 basin big sagebrush and rubber rabbitbrush 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).

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).

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 40–60% 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 2006). 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 2006).

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 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 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 with subdominants of western wheatgrass and/or beardless wildrye. Basin big sagebrush and rubber rabbitbrush are common. Potential vegetative composition by air-dry weight is approximately 80% grasses, 5% forbs and 15% shrubs. Approximate ground cover (basal and canopy) is 30–60%. Total annual air-dry production ranges from 1,000 to 3,500 lb/ac.

Community Phase Pathway 1.1a, from 1.1 to 1.2:
Fire, flooding, and/or an Aroga moth (*Aroga websteri*) infestation would decrease or eliminate the basin 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. Rubber rabbitbrush and Woods' rose 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 (At-Risk):
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, flooding, 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 phase 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. Other perennial grasses, grass-likes and native perennial forbs make up a minor component of the 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 rubber rabbitbrush and Woods' rose will likely resprout. Flooding or a severe infestation of Aroga moth could also cause a large decrease in basin big 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 basin big sagebrush and rubber 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 basin big sagebrush and rubber 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. Rubber rabbitbrush and Woods' rose 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.

Loamy Bottom (R027XY003NV), Current Potential 2.2, T. Stringham, May 2024

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 basin big sagebrush and rubber rabbitbrush allows the shrub component to recover. The establishment of basin big sagebrush can take many years.

Community Phase 2.3 (At-Risk):
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. Rubber 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, flooding, 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 or flooding removes basin big sagebrush, favoring sprouting shrubs like rubber 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 grasses 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. Basin big sagebrush dominates the overstory and rubber rabbitbrush may be a significant component. Basin 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 (At-Risk):
Basin big sagebrush dominates the overstory. Rubber rabbitbrush may be a significant component. Basin wildrye and other perennial grasses and grass-likes may be present in

trace amounts or absent from the community. Annual non-natives forbs and grass may increase. Bare ground may have increased.

Loamy Bottom (R027XY003NV), Shrub State 3.1, T. Stringham, May 2025

Community Phase Pathway 3.1a, from 3.1 to 3.2:
Fire, flooding, 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 in trace amounts to non-existent. Annual invasive grass and forbs may be increasing.

Community Phase 3.2 (At-Risk):
Basin big sagebrush reduced to trace or absent. Perennial grass is trace to absent. Rubber 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.

R3A: Restoration Pathway from Shrub State 3.0 to Current Potential 2.0:

Brush management and/or low-intensity prescribed fire decreases shrub cover, allowing for perennial grasses to increase in density.

States Not Observed in Group 9:

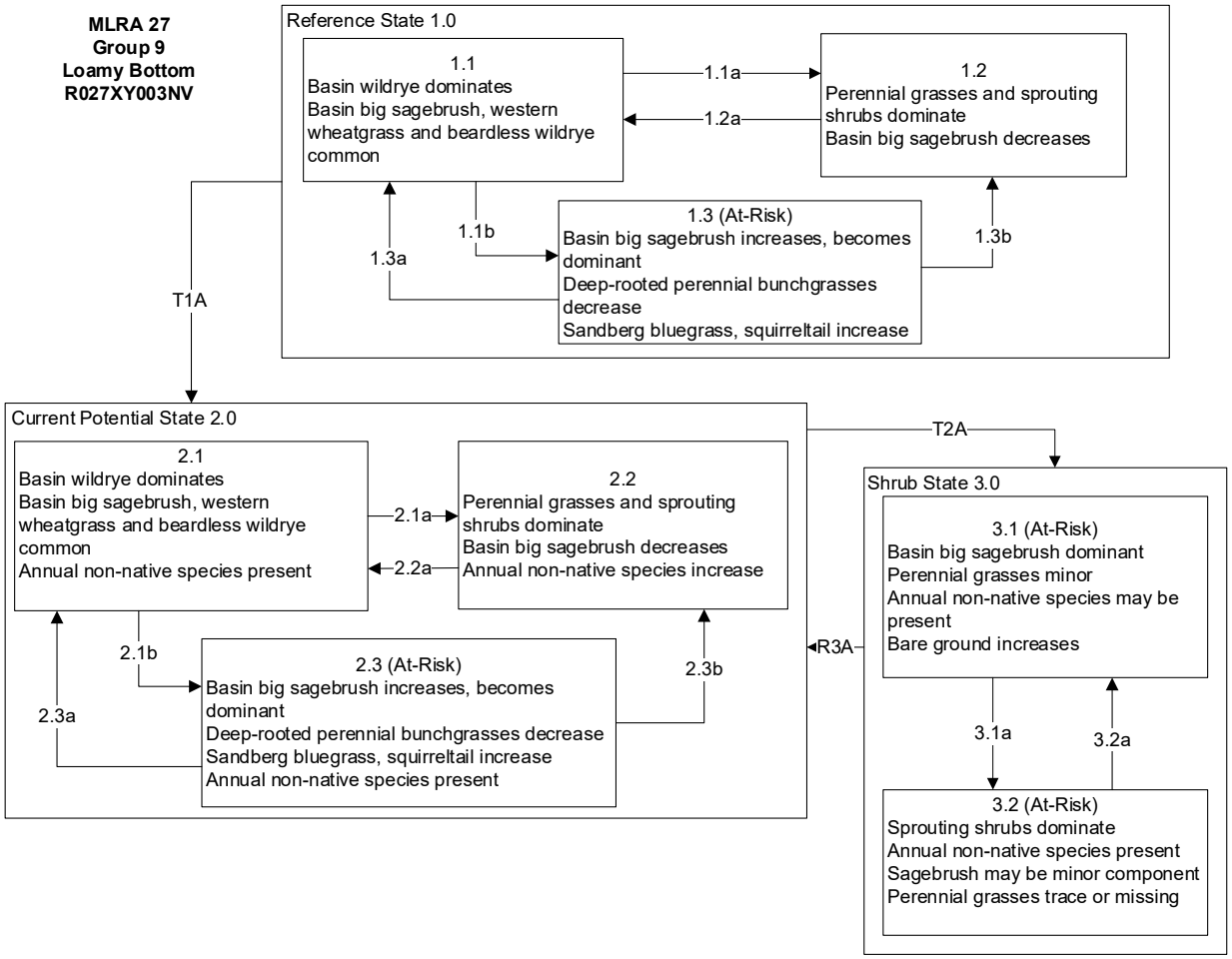
Annual State: An Annual State has been noted in MLRA 28B DRG 9 Loamy Bottom 10-14" P.Z. (Stringham et al. 2015), but was not observed in this DRG in MLRA 27 during field verification. It

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.

Seeded State: While a Seeded State was not observed for this group, a similar ecological site Loamy Bottom 10-14" P.Z. (R028BY003NV) in MLRA 28 DRG 9 (Stringham et al. 2015) contains a Seeded State with two community phases: (1) a non-native perennial bunchgrass-dominated phase; (2) and a basin big sagebrush, rubber rabbitbrush-non-native perennial bunchgrass, which are possible in this group.

Tree State: A Tree State was not observed for this group but has been documented in a similar DRG in MLRA 29 Loamy Bottom 8-12" P.Z. (R029XY003NV) (Stringham et al. 2026).

Modal State and Transition Model for Group 9 in MLRA 27



MLRA 27
Group 9
Loamy Bottom
R027XY003NV

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 perennial grasses and forbs. Sprouting shrubs will increase. Flooding can also eliminate big sagebrush.
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 perennial grasses and forbs; non-native annual species present. Sprouting shrubs will increase. Flooding can also eliminate big sagebrush.
2.1b: Time and lack of disturbance such as fire, flooding, 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.

Shrub State 3.0 Community Phase Pathways
3.1a: Fire, flooding, heavy fall grazing causing mechanical damage to shrubs, Aroga moth, or brush treatments (i.e. mowing) with minimal soil disturbance.
3.2a: Time and lack of fire allows some shrubs to reestablish.

Restoration R3A: Brush management or a low-intensity prescribed fire.

References

Abbott, M. L., L. Fraley Jr., and T. D. Reynolds. 1991. Root profiles of selected cold desert shrubs and grasses in disturbed and undisturbed soils. Environmental and Experimental Botany **31**:165-178.

Allen, E. B., and M. F. Allen. 1988. Facilitation of succession by the nonmycotrophic colonizer *Salsola kali* (Chenopodiaceae) on a harsh site: effects of mycorrhizal fungi. American Journal of Botany **75**:257-266.

Baker, W. L. 2006. Fire and restoration of sagebrush ecosystems. Wildlife Society Bulletin **34**:177-185.

Balch, J. K., B. A. Bradley, C. M. D'Antonio, and J. Gómez-Dans. 2013. Introduced annual grass increases regional fire activity across the arid western USA (1980–2009). Global Change Biology **19**:173-183.

Bates, J. D., T. Svejcar, R. F. Miller, and R. A. Angell. 2006. The effects of precipitation timing on sagebrush steppe vegetation. Journal of Arid Environments **64**:670-697.

Beatley, J. C. 1975. Climates and vegetation pattern across the Mojave/Great Basin Desert transition of southern Nevada. The American Midland Naturalist **93**:53-70.

Belsky, A. J., A. Matzke, and S. Uselman. 1999. Survey of livestock influences on stream and riparian ecosystems in the western United States. Journal of Soil and Water Conservation **54**:419-431.

Bentz, B., D. Alston, and T. Evans. 2008. Great Basin insect outbreaks. Pages 45-48 *in* Collaborative management and research in the Great Basin - Examining the issues and developing a framework for action. General Technical Report RMRS-GTR-204. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Boerboom, C. 1993. Russian thistle (*Salsola iberica* Sennen & Pau).

Bowns, J., A. Rasmussen, and R. Banner. 2025a. Range plants of Utah: Great Basin wildrye. Utah State University Extension, Logan, Utah.

Brisbin, H. 2024. Development of a State and Transition Model for Low Gradient, Perennial Streams in the Northern Great Basin Region. University of Nevada, Reno, Reno, Nevada.

Bunting, S. C., B. M. Kilgore, and C. L. Bushey. 1987. Guidelines for prescribed burning sagebrush-grass rangelands in the Northern Great Basin. General Technical Report INT-231, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Caudle, D., J. DiBenedetto, M. Karl, H. Sanchez, and C. Talbot. 2013. Interagency ecological site handbook for rangelands. U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.

Chambers, J. C., B. A. Bradley, C. S. Brown, C. D'Antonio, M. J. Germino, J. B. Grace, S. P. Hardegree, R. F. Miller, and D. A. Pyke. 2013. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of western North America. Ecosystems **17**:360-375.

Chambers, J. C., J. R. Miller, D. Germanoski, and D. A. Weixelman. 2004. Process-based approaches for managing and restoring riparian ecosystems. Pages 261-292 *in* J. C.

Chambers and J. R. Miller, editors. Great Basin Riparian Ecosystems: Ecology, Management, and Restoration. Island Press, Washington, D.C.

Chambers, J. C., B. A. Roundy, R. R. Blank, S. E. Meyer, and A. Whittaker. 2007. What makes Great Basin sagebrush ecosystems invasible by *Bromus tectorum*? Ecological Monographs **77**:117-145.

Comstock, J. P., and J. R. Ehleringer. 1992. Plant adaptation in the Great Basin and Colorado Plateau. The Great Basin Naturalist **52**:195-215.

Cornachione, E. 2021. Costs and benefits of pinyon-juniper removal for public and private land managers: A case study in Central Nevada. M.S. Thesis (Unpublished). University of Nevada, Reno, Reno, NV.

Davies, W. K., S. C. Boyd, L. J. Beck, D. J. Bates, J. T. Svejcar, and A. M. Gregg. 2011. Saving the sagebrush sea: An ecosystem conservation plan for big sagebrush plant communities. Biological Conservation **144**:2573-2584.

Dobrowolski, J. P., M. M. Caldwell, and J. H. Richards. 1990. Chapter 7: Basin hydrology and plant root systems. Pages 243-292 *in* C. B. Osmond, L. F. Pitelka, and G. M. Hidy, editors. Plant Biology of the Basin and Range. Springer-Verlag, New York City, NY.

Dyer, D., and R. O'Beck. 2006. Plant guide for beardless wildrye (*Leymus triticoides*). USDA NRCS Plant Materials Center, Lockeford, California.

Evans, R. A., and J. A. Young. 1978. Effectiveness of rehabilitation practices following wildfire in a degraded big sagebrush-downy brome community. Journal of Range Management **31**:185-188.

Everett, R. L., P. T. Tueller, J. B. Davis, and A. D. Brunner. 1980. Plant phenology in galleta-shadscale and galleta-sagebrush associations. Rangeland Ecology & Management/Journal of Range Management Archives **33**:446-450.

Forman, R. T. T., and R. D. Deblinger. 2000. The ecological road-effect zone of a Massachusetts (U.S.A.) suburban highway. Conservation Biology **14**:36-46.

Furbush, P. 1953. Control of medusa-head on California ranges. Journal of Forestry **51**:118-121.

Furniss, M. M., and W. F. Barr. 1975. Insects affecting important native shrubs of the Northwestern United States. General Technical Report INT-19, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Germanoski, D., and J. R. Miller. 2004. Basin sensitivity to channel incision in response to natural and anthropogenic disturbance. Pages 88–123 *in* J. C. Chambers and J. R. Miller, editors. Great Basin Riparian Ecosystems: Ecology, Management, and Restoration. Society for Ecological Restoration International; Island Press, Washington, D.C.

Goodrich, S., E. D. McArthur, and A. H. Winward. 1985. A new combination and a new variety in *Artemisia tridentata*. The Great Basin Naturalist **45**:99-104.

Hafenrichter, A. L., J. L. Schwendiman, H. L. Harris, R. S. Maclauchlan, and H. W. Miller. 1968. Western wheatgrass, *Agropyron smithii*. Page 28 Grasses and Legumes for Soil Conservation in the Pacific Northwest and Great Basin States. U.S. Department of Agriculture, Soil Conservation Service, Washington, D. C.

Hart, R. H., S. Clapp, and P. S. Test. 1993. Grazing strategies, stocking rates, and frequency and intensity of grazing on western wheatgrass and blue grama. Journal of Range Management **46**:122-126.

Humphrey, L. D. 1984. Patterns and mechanisms of plant succession after fire on *Artemisia*-grass sites in southeastern Idaho. Vegetatio **57**:91-101.

Johnson, J. R., and G. F. Payne. 1968. Sagebrush reinvasion as affected by some environmental influences. Journal of Range Management **21**:209-213.

Johnson, N. C. 1998. Responses of *Salsola kali* and *Panicum virgatum* to mycorrhizal fungi, phosphorus and soil organic matter: implications for reclamation. Journal of Applied Ecology **35**:86-94.

Klemmedson, J. O., and J. G. Smith. 1964. Cheatgrass (*Bromus tectorum* L.). The Botanical Review **30**:226-262.

Klepper, E. L., K. A. Gano, and L. L. Cadwell. 1985. Rooting depth and distribution of deep-rooted plants in the 200 Area Control Zone of the Hanford Site.

Krall, J. L., J. R. Stroh, C. S. Cooper, and S. R. Chapman. 1971. Effect of time and extent of harvesting basin wildrye. Journal of Range Management **24**:414-418.

Lossing, S. 2012. Singleleaf pinon and Utah juniper canopy interception and understory characteristics in central Nevada. M.S. Thesis. University of Idaho, Moscow, Idaho.

Mack, R. N., and D. A. Pyke. 1983. The demography of *Bromus tectorum*: Variation in time and space. Journal of Ecology **71**:69-93.

Miller, H. C., D. Clausnitzer, and M. M. Borman. 1999a. Medusahead. Pages 272-281 *in* R. L. S. a. J. K. Petroff, editor. Biology and Management of Noxious Rangeland Weeds. Oregon State University Press, Oregon State University.

Miller, R. F., J. D. Bates, T. J. Svejcar, F. B. Pierson, and L. E. Eddleman. 2005. Biology, ecology, and management of western juniper (*Juniperus occidentalis*). Technical Bulletin 152, Oregon State University, Agricultural Experiment Station, Corvallis, OR.

Miller, R. F., J. C. Chambers, D. A. Pyke, F. B. Pierson, and C. J. Williams. 2013. A review of fire effects on vegetation and soils in the Great Basin Region: Response and ecological site characteristics. General Technical Report RMRS-GTR-308, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Miller, R. F., and E. K. Heyerdahl. 2008. Fine-scale variation of historical fire regimes in sagebrush-steppe and juniper woodland: An example from California, USA. International Journal of Wildland Fire **17**:245-254.

Monsen, S. B., R. Stevens, and N. L. Shaw. 2004a. Grasses. Pages 295-424 *in* S. B. Monsen, R. Stevens, and N. L. Shaw, editors. Restoring western ranges and wildlands, vol. 2. Gen. Tech. Rep. RMRS-GTR-136-vol-2. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Monsen, S. B., R. Stevens, and N. L. Shaw. 2004b. Restoring western ranges and wildlands: Volume 2. General Technical Report RMRS-GTR-136-vol. 2, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Naumburg, E., R. Mata-Gonzalez, R. G. Hunter, T. McLendon, and D. W. Martin. 2005. Phreatophytic vegetation and groundwater fluctuations: A review of current research

and application of ecosystem response modeling with an emphasis on Great Basin vegetation. Environmental Management **35**:726-740.

Newton, B., C. Pringle, and R. Bjorkland. 1998. Stream visual assessment protocol. Technical Note 99-1, U.S. Department of Agriculture, Natural Resources Conservation Service, National Water and Climate Center, Portland, OR.

NRCS. 2002. Plant fact sheet for western wheatgrass (*Pascopyrum smithii*). U.S. Department of Agriculture, Natural Resources Conservation Service, Plant Materials Program.

NRCS. 2022. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. Handbook 296, U.S. Department of Agriculture, Natural Resources Conservation Service.

Ogle, D. G. 2000a. Plant guide for basin wildrye (*Leymus cinereus*). USDA NRCS, USDA NRCS Idaho State Office, Boise, Idaho.

Ogle, D. G. 2000b. Plant guide for western wheatgrass (*Pascopyrum smithii*). Pages 1-4. USDA NRCS, USDA, NRCS, Idaho State Office, Boise, Idaho.

Paysen, T. E., R. J. Ansley, J. K. Brown, G. J. Gottfried, S. M. Haase, M. G. Harrington, M. G. Narog, S. S. Sackett, and R. C. Wilson. 2000. Chapter 6: Fire in western shrubland, woodland, and grassland ecosystems. Pages 121-159 *in* J. K. Brown and J. K. Smith, editors. Wildland fire in ecosystems: Effects of fire on flora. General Technical Report RMRS-GTR-42-Vol. 2. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Pellant, M., and C. Hall. 1994. Distribution of two exotic grasses in intermountain rangelands: Status in 1992. Pages 109-112 *in* S. B. Monsen and S. G. Kitchen, editors. Proceedings—Ecology and management of annual rangelands; General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Peters, E. F., and S. C. Bunting. 1994. Fire conditions pre-and post-occurrence of annual grasses on the Snake River Plain. Pages 31-36 *in* Proceedings—Ecology and management of annual rangelands; September, 1994; Boise, ID. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Pierson, F. B., C. J. Williams, S. P. Hardegree, P. E. Clark, P. R. Kormos, and O. Z. Al-Hamdan. 2013. Hydrologic and erosion responses of sagebrush steppe following juniper encroachment, wildfire, and tree cutting. Rangeland Ecology & Management **66**:274-289.

Pierson, F. B., C. J. Williams, P. R. Kormos, S. P. Hardegree, P. E. Clark, and B. M. Rau. 2010. Hydrologic vulnerability of sagebrush steppe following pinyon and juniper encroachment. Rangeland Ecology & Management **63**:614-629.

Richards, J. H., and M. M. Caldwell. 1987. Hydraulic lift: substantial nocturnal water transport between soil layers by *Artemisia tridentata* roots. Oecologia **73**:486-489.

Rosgen, D. L. 1997. A geomorphological approach to restoration of incised rivers. Pages 12-22 *in* S. S. Y. Wang, E. J. Landendoen, and F. D. Shields, Jr., editors. Management of Landscapes Disturbed by Channel Incision. Center for Computational Hydroscience and Engineering, The University of Mississippi, University, MS.

Rosgen, D. L. 2006. Watershed assessment of river stability and sediment supply (WARSSS). Wildland Hydrology, Fort Collins, CO.

Roundy, B. A., R. F. Miller, R. J. Tausch, J. C. Chambers, and B. M. Rau. 2020. Long-term effects of tree expansion and reduction on soil climate in a semiarid ecosystem. Ecosphere **11**:e03241.

Shumar, M. L., and J. E. Anderson. 1986. Water relations of two subspecies of big sagebrush on sand dunes in southeastern Idaho. Northwest Science **60**:179-185.

Snyder, K. A., T. K. Stringham, J. Huntington, R. Carroll, A. C. Dittrich, and M. Weltz. 2013. Porter Canyon experimental watershed: Quantifying the effects of piñon and juniper control on ecosystem processes. Poster presented at Great Basin Landscape Coalition Conference, Reno, NV.

Stringham, T. K., P. Novak-Echenique, P. Blackburn, C. Coombs, D. Snyder, and A. Wartgow. 2015. Final report for USDA ecological site description state-and-transition models, Major Land Resource Area 28a and 28b Nevada (2021 revision). Nevada Agricultural Experiment Station Research Report 2015-01, University of Nevada Reno, USA.

Stringham, T. K., W. C. P. Richardson, Lucas, W. Lieurance, D. K. Snyder, and P. Novak-Echenique. 2026. Great Basin ecological site development project: State-and-transition models for Major Land Resource Area 29, Nevada. Nevada Agricultural Experiment Station Research Report NAES-TR-26-01, University of Nevada Reno, USA.

Stubbendieck, J. L., S. L. Hatch, N. M. Bryan, and C. D. Dunn. 2017. North American wildland plants. Third edition. University of Nebraska Press, Lincoln, NE.

Tilley, D., D. Ogle, and L. St. John. 2008. Plant guide for halogeton (*Halogeton glomeratus*). USDA NRCS, USDA NRCS Idaho State Office, Boise, ID.

Tilley, D. J., D. Ogle, L. St John, and B. Benson. 2002. Plant guide for big sagebrush (*Artemisia tridentata*).

Tirmenstein, D. 1999. *Pascopyrum smithii*. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, Fire Effects Information System [Online].

Trimble, S. W., and A. C. Mendel. 1995. The cow as a geomorphic agent—A critical review. Geomorphology **13**:233-253.

Trombulak, S. C., and C. A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology **14**:18-30.

USFS. 1937. Range plant handbook. U.S. Department of Agriculture, Forest Service, Washington, D.C.

Wallace, A., W. Rhods, and E. Frolich. 1968. Germination behavior of *Salsola* as influenced by temperature, moisture, depth of planting, and gamma irradiation. Agronomy Journal **60**:76-78.

Weber, W. A., and R. C. Wittmann. 2012. Colorado flora: Western slope. University Press of Colorado.

Wright, H. A. 1971. Why squirreltail is more tolerant to burning than needle-and-thread. Journal of Range Management **24**:277-284.

Young, F., R. Veseth, D. Thill, W. Schillinger, and D. Ball. 1995. Managing Russian thistle under conservation tillage in crop-fallow rotations.

Young, R. P. 1983. Fire as a vegetation management tool in rangelands of the intermountain region. Pages 18-31 *in* Managing Intermountain rangelands—Improvement of range and wildlife habitats. Proceedings of Symposia: September 15-17, 1981, Twin Falls, Idaho June 22·24, 1982, Elko, Nevada. General Technical Report INT-GTR-157. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Zschaechner, G. A. 1985. Studying rangeland fire effects: A case study in Nevada. Pages 66-84 *in* Rangeland fire effects: a symposium; Boise, ID; November 27-29, 1984. U.S. Department of the Interior, Bureau of Land Management, Idaho State Office, Boise, ID.

MLRA 27 Group 10: Alkaline soils with Torrey's saltbush and basin wildrye

Description of MLRA 27 Disturbance Response Group 10

Disturbance Response Group (DRG) 10 consists of two ecological sites. These sites occur on alluvial flats, lake plains, and floodplains. The precipitation ranges from 4 to 8 in. Slopes range from 0 to 4%. Elevation ranges from approximately 3,400 to 5,500 ft. The soils are formed in mixed alluvium and are typically very deep and somewhat poorly drained to poorly drained. Endosaturation is present with an apparent seasonal water table from 3–5 ft. The soil profile is affected by water table fluctuations and is salt and sodium affected. The soil temperature regime is mesic and the soil moisture regime is aquic or saturated. Runoff is high to very high, water holding capacity is moderate to high, and permeability is moderately slow to slow. The reference plant communities are dominated by Torrey's saltbush (*Atriplex torreyi*) and basin wildrye (*Leymus cinereus*). Other common species include black greasewood (*Sarcobatus vermiculatus*), basin big sagebrush (*Artemisia tridentata* ssp. *tridentata*), alkali sacaton (*Sporobolus airoides)*, and inland saltgrass (*Distichlis spicata*). Total annual air-dry production ranges from 200 to 1,500 lb/ac.

Disturbance Response Group 10 Ecological Sites:

Deep Sodic Fan – Modal	R027XY041NV
Saline Flat	R027XY044NV

Modal Site:

The Deep Sodic Fan ecological site (R027XY041NV) 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% and elevations range from approximately 4,000 to 5,000 ft. This site occurs on alluvial flats and lake plains. The soils on this site are very deep, well drained and formed in mixed alluvium. Soil surface textures are moderately-fine and subsurface textures are very fine. The soils are strongly to very strongly alkaline throughout the profile. Surface runoff is low. 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 have a mesic soil temperature regime and an aquic or typic arid soil moisture regime. The reference plant community is dominated by Torrey's saltbush, basin wildrye, and black greasewood. Total annual air-dry production ranges from 600 to 1,500 lb/ac with 1,000 lb/ac in a normal year.

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 27 (MLRA 27 Fallon-Lovelock Area) is almost entirely in Nevada with < 1% in California. The entire area occurs in the rain shadow of the Sierra Nevada mountains and is influenced by Pleistocene Lake Lahontan. Extensive playas occur throughout the area and are a result of the drying of ancient Lake Lahontan. To the west, MLRA 27 has a gradual boundary with MLRA 26 (Carson Basin and Mountains) and to the east has a very gradual boundary with MLRA 24 (Humboldt Basin and Range Area). From west to east the soil temperature increases and the soil moisture decreases, resulting in vast areas dominated by salt-desert shrub communities. Isolated mountain ranges trending north to south are separated by broad desert plains and valleys. Elevations range from 3,300 to 5,900 ft with some mountain peaks over 7,800 ft. The average annual precipitation ranges from 4 to 11 in. and as much as 20 in. at the highest elevations. The majority of annual precipitation is received during late fall and winter occurring mainly as snow. High-intensity, convective thunderstorms also contribute significantly to annual precipitation (NRCS 2022). 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 (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:

Changes in depth to groundwater occur naturally but anthropogenic alterations may exacerbate these fluctuations and subsequently affect vegetation dependent on groundwater

(Naumburg et al. 2005). Decreasing water tables often result in plant water stress and reduced live biomass (Groeneveld and Crowley 1988b). Rising water tables saturate rooting zones resulting in the death of roots and whole plant responses resemble symptoms of drought stress, including the closure of stomata and a decrease in photosynthetic activity (Naumburg et al. 2005).

Torrey's saltbush is a 3–10 ft tall, phreatophytic shrub spanning a large geographical area encapsulating portions of California, Nevada, and Utah (Mozingo 1987c, Perryman 2014c). It is characterized by its dense gray-farinose herbage, pale-green erect stems, pale to dark-gray bark, 2–4 mm (< 1 in.) long fruiting bracts, and inflorescence of its glomerules in axillary spikes and terminal (Perryman 2014c). Rooting depths are up to 4 m (13 ft) deep extending into the capillary fringe and spreading laterally to over 3 m (10 ft) (Groeneveld and Crowley 1988b). 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 1987c, 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 1987c).

Black greasewood, a common 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 1987b, Trent et al. 1997, Naumburg et al. 2005). Black greasewood covers roughly 2 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 1987b, 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 (12–49 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 (1986a) reported that water tables within 9.8–11.8 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 1988b, 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 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 1–2 m (3.3–6.6 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).

Rubber rabbitbrush (*Ericameria nauseosa*), a minor component on both ecological sites, 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 1–3 m (3.3–10 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 (3.3–20 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 2004b).

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).

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.

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 1988a). General differences in root depth distributions between grasses and shrubs results in resource partitioning in these shrub/grass systems (Lee and Lauenroth 1994).

Inland saltgrass, a common perennial grass in this group, is a warm-season, rhizomatous species that grows 10–60 cm (4–24 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 8–12 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 inland saltgrass, rubber rabbitbrush and other species in the absence of drought.

The ecological sites in this DRG have moderate resilience to disturbance and resistance to invasion because of the occurrence of a groundwater table, additional run-in moisture and high productivity. Possible disturbances include inappropriate grazing practices, drought, groundwater pumping, singleleaf pinyon and/or Utah juniper encroachment in the watershed, and/or fire. These disturbances may facilitate an increase in shrubs and a decrease in basin wildrye and alkali sacaton. Annual non-native species invade these sites where competition from perennial species is decreased. Six possible stable states have been identified for this DRG.

Agricultural History:

The two ecological sites in this DRG have large amounts of acreage mapped in the Fallon, Nevada area. Agricultural development began in the early 1850s when overland stage travel was at its peak (Strahorn 1909). The first permanent settlements were made on the Carson River and the South Branch of the Carson River at points where the overland trails crossed the rivers. Later settlements occurred on adjacent lands where it was possible to irrigate from the spring flow of the rivers to grow crops for local consumption. Large scale agricultural

development started after the construction of the Newlands Project by the U.S. Reclamation Service (Headley and Venstrom 1930).

Invasive Plant 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 (*Bromus tectorum*), 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. 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 1.5–1.7 m (60–67 in.).

Annual non-native species such as halogeton, Russian thistle, cheatgrass, tall tumblemustard (*Sisymbrium altissimum*) and annual wheatgrass (*Eremopyrum triticeum*) invade these sites where competition from perennial species is decreased. Perennial non-native species such as Russian knapweed (*Rhaponticum repens*) and whitetop (*Cardaria draba*) may also invade these sites.

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. 1999b). 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 lb 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 < 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 1998).

Tall tumblemustard is a cool-season annual forb, introduced from southern Europe, and found throughout most of North America (Holmgren et al. 2005). It is one of the most invasive species in the Great Basin and is characterized by early germination, rapid growth, production of numerous seeds and an effective dispersal mechanism (Holmgren et al. 2005). Tall tumblemustard has low palatability but is grazed when growth is young by cattle and sheep (USFS 1988a).

Russian knapweed is a non-native, perennial, noxious and invasive weed from Eurasia. It is a perennial herb with erect stems that grow from 18 to 36 in. tall. Flowers occur singly on shoot tips from June to September. The seeds develop in late summer and are viable in the soil for at least 2–3 years. Russian knapweed produces an extensive vertical and horizontal root system penetrating the soil to several meters (Graham and Johnson 2004). In Nevada, Russian knapweed occurs on rangelands, pasture and croplands (Foster et al. 2011).

Whitetop, also known as hoary cress, is a non-native, rhizomatous, long-lived perennial native to Russia, eastern European countries and the Middle East. It grows up to 2 ft and produces rosettes and flowering stems. Whitetop invades rangeland, pastures, croplands, moist meadows and floodplains (Jacobs 2007). It reproduces by seed or by horizontal growth of rootstocks (Miller 1991), although it relies on vegetative reproduction from extensive root systems to increase plant density and local population expansion (Jacobs 2007). Individual plants can produce from 50 to 450 stems depending on environmental conditions and competition from other plants (Jacobs 2007).

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).

Torrey's saltbush has been reported to sprout after fire, however post-fire regeneration strategy is by seed production (West 1994). This species has a naturally high moisture content and it's flammability is reduced (Meyer 2008b).

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.

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 of the parent shrub (Goodrich et al. 1985) with maximum seed dispersal at approximately 108 ft 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 50–120 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).

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).

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.

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 2–4 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 1988a). 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.

Torrey's saltbush is an important forage and cover species for wildlife and livestock (Mozingo 1987c) .

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 27 Disturbance Response Group 10.

Six possible stable states have been identified for this DRG including a shrub-dominated state, an abiotically controlled state and an Agricultural 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, groundwater fluctuations, periodic drought, and/or insect or disease attack.

Community Phase 1.1:
The reference plant community is dominated by Torreys's saltbush and basin wildrye. Other common species include black greasewood, basin big sagebrush, fourwing saltbush, and alkali sacaton. Potential vegetative composition by air-dry weight is approximately 75% grasses, 5% forbs and 20% shrubs. Approximate ground cover (basal and crown) is 20–30%. Total annual air-dry production ranges from 600 to 2,000 lb/acre with 1,000 lb/ac in a normal year.

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 Torrey's saltbush and black greasewood. A low severity fire would temporally decrease the overstory cover of Torrey's saltbush and 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 non-sprouting shrub 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 shrub overstory to increase and dominate the site. This will generally cause a reduction in perennial

bunchgrasses and an increase in shrubs. 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. Torrey's saltbush and black greasewood are minor components 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 (At-Risk):
Torrey's saltbush, black greasewood and rubber 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 Torrey's saltbush and black greasewood. Additionally, a low severity fire would decrease the overstory of Torrey's saltbush and 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 shrub 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.

T1B: Transition from Reference State 1.0 to Agricultural State 5.0:

Trigger: Settlement of the area which included damming of the Carson and Truckee rivers, construction of canals, diversion of water for irrigation, plowing and brush removal, land leveling and building furrows for irrigation.

Slow variables: Over time, local drainage improvement effectively lowered the water table. Increase in salt salinity from furrow irrigation. Reduction in soil organic carbon from the conversion of rangeland to cropland.

Threshold: Removal of native vegetation by soil disturbance causes loss of soil structure, soil compaction, reduced infiltration, increased wind and water erosion, loss of organic matter and nutrient-rich topsoil, and reduced moisture retention. These changes make restoration extremely challenging.

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 Torrey's saltbush, black greasewood, basin wildrye and alkali sacaton. 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 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 Torrey's saltbush and black greasewood. Additionally, a low severity fire would decrease the overstory of Torrey's saltbush and 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 Torrey's saltbush and 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 Torrey's saltbush and 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 Torrey's saltbush and black greasewood allows the shrub component to recover.

Community Phase 2.3 (At-Risk):
Torrey's saltbush and black greasewood dominate 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. Rubber 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).

Saline Flat (R027XY044NV), Current Potential 2.3, T. Stringham, September 2025

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 Torrey's saltbush and 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 the phreatophytic shrubs.

Community Phase Pathway 2.3b, from Phase 2.3 to 2.2:
High severity fires, due to the dominance of Torrey's saltbush, 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: 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 Torrey's saltbush and 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 shrubs, like Torrey's saltbush and 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 Torrey's saltbush and black greasewood. Other species that may be present include rubber rabbitbrush, basin big sagebrush, yellow rabbitbrush (*Chrysothamnus viscidiflorus*), and Mojave seablite (*Suaeda moquinii*). 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):
Torrey's saltbush and black greasewood dominate the overstory. Rabbitbrush may be a significant component. Deep-rooted perennial bunchgrasses such as basin wildrye have

significantly declined or are missing. Annual non-native species increase. Interconnected bare ground patches are common. Formation of black greasewood and Torrey's saltbush hummocks is prevalent due to soil displacement caused by water and wind erosion. Invasive forbs such as tall tumblemustard (*Sisymbrium altissimum*) likely dominate the understory.

Deep Sodic Fan (R027XY041NV), Shrub State 3.1, T. Stringham, May 2024

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

Trigger**:** Fire, 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 phreatophytic plant density due to fire, 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.

Annual State/Perennial Invasive State 4.0:

This state consists of one community phase in which annual and/or perennial non-native invasive species control site processes. It is characterized by the loss of cropland, hay, pasture

or native species and increased bare ground. Feedbacks contributing to the stability of this state include seed bank of annual and/or perennial non-native invasive species, water table reduction, soil surface degradation, loss, nutrient loss, and increased bare ground patch size.

Community Phase 4.1 (At-Risk):
This community phase is the result of loss of irrigation water and loss of cropland, hay or pasture species. Conservation (farming) practices are no longer implemented and the site is allowed to naturally recolonize. The vegetative cover is dominated by non-native annual and/or perennial invasive species. Bare ground may be extensive, especially during drought years, leaving the field susceptible to wind erosion. Trace amounts of desirable species may be present and bare ground interspaces are large and connected. Site function is controlled by non-native vegetation. Soil erosion and redistribution is occurring. Site is at-risk of transitioning to an Abiotic State.

Saline Flat (R027XY044NV), Annual State 4.1, T. Stringham, September 2025

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

Trigger**:** Cessation of farming practices including the removal of irrigation water and loss of cropland, hay or pasture species or non-native invasive species. Long-term drought or groundwater pumping reduces cover of annual/perennial non-native invasive species resulting in increased bare ground. Significant soil loss and redistribution is occurring. Soil compaction (plow pan) reduces infiltration and effective rooting depth. Soil surface is crusted.

Slow variables: Soil redistribution is significant and on-going. Reduction in soil organic matter inputs contributes to soil surface crusting and reduced infiltration. Reduced infiltration leads to reduced soil water promoting a continued reduction in vegetation.

Threshold: Soil compaction and soil surface changes due to long-term farming practices combined with removal of farming practices and irrigation leads to significant soil redistribution, soil temperature increases, organic matter loss, soil surface ponding, and reduced infiltration.

Abiotic State 5.0:

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 5.1:
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 native or seeded species may be present and bare ground interspaces are large and connected. Site function is controlled by soil erosion and redistribution and soil temperature.

Saline Flat (R027XY044NV), Abiotic State 5.1, T. Stringham, September 2025

Agricultural State 6.0:

This state is characterized by an irrigated agriculture phase with either cropland, hay or pasture. Irrigation water is critical to the production of crops in this MLRA because of low precipitation. Once irrigation water is removed the lasting effects on the soil include diminished soil stability, altered soil structure, compaction, reduced infiltration and increased wind and water erosion.

Community Phase 6.1 (Irrigated Agriculture)
This community phase is either cropland, hay or pasture actively maintained by irrigation water during the growing season. Typical crops include alfalfa, corn, oats and wheat. Conservation practices implemented include pasture and hay planting, irrigation water management, forage harvest management, nutrient management, conservation crop rotation, and cover crop.

Saline Flat (R027XY044NV), Agricultural State 6.1, T. Stringham, September 2025

T6A: Transition from Agricultural State 6.0 to Annual State 4.0:

Trigger**:** Cessation of farming practices including the removal of irrigation water and the loss of cropland, hay or pasture species. Residual nitrogen and phosphorus from fertilizer applications favors fast-growing, early-successional non-native invasive species which dominate the site.

Slow variables: Long-term increase in non-native annual and or perennial invasive species and their associated seed bank. Native seed banks are depleted. Soil redistribution is significant.

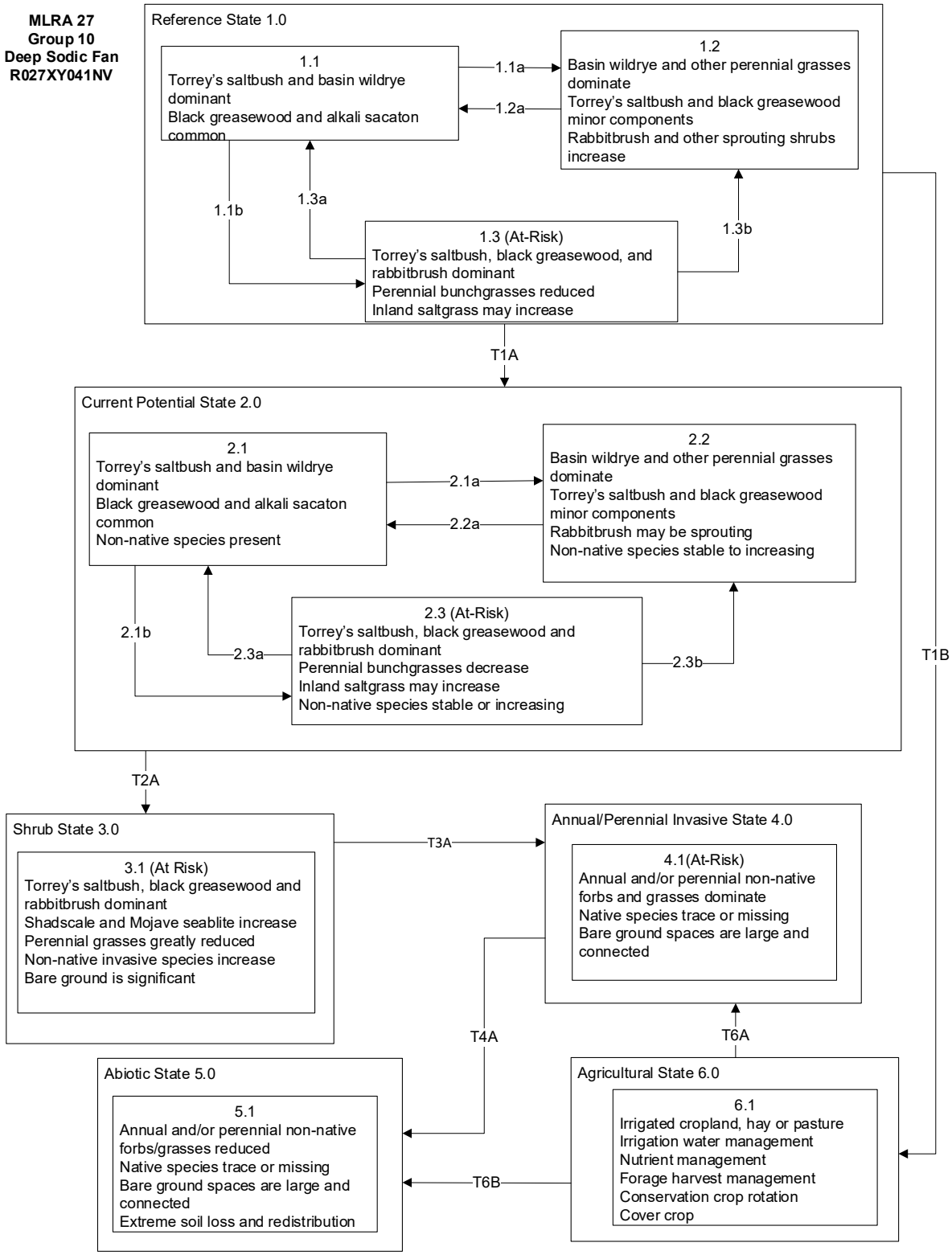
Threshold: Reduced cover of seeded, cropland, hay or pasture species due to the removal of irrigation and farming practices facilitates invasion of non-native annual species. Changes in plant community composition and spatial variability of vegetation due to the loss of crop, hay or pasture species truncates energy capture spatially and temporally thus impacting nutrient cycling and distribution. Soil compaction, soil surface degradation and redistribution lead to decreased infiltration, increased flow path length, crusting, salt accumulation on the soil surface and altered soil biology.

Potential Resilience Differences with Other Ecological Sites in this Group

Saline Flat (R027XY044NV):

This site occurs on lower piedmont slopes, fan skirts, inset fans and lake terraces. Slopes range from 2 to 8% and elevations range from 3,400 to 4,300 ft. The reference plant community is dominated by Torrey's saltbush. Basin wildrye, black greasewood and inland saltgrass are also common on this site. Potential vegetative composition is approximately 20% grasses, 5% forbs and 75% shrubs. Total annual air-dry production ranges from 200 to 600 lb/ac. 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. Species likely to invade this site include whitetop, Russian knapweed, Russian thistle, cheatgrass, annual wheatgrass, halogeton and annual mustards. This site will have the same states as the modal site.

Modal State and Transition Model for Group 10 in MLRA 27



MLRA 27
Group 10
Deep Sodic Fan
R027XY041NV
KEY

Reference State 1.0 Community Pathways
1.1a: Long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge, or low severity fire would reduce Torrey's saltbush and black greasewood and allow for the understory perennial grasses to increase. High severity fire would greatly reduce Torrey's saltbush and black greasewood.
1.1b: Time and lack of disturbance such as fire, long-term spring/summer drought, unusually wet periods or combinations of these. Torrey's saltbush, black greasewood, and perennial grasses increase.
1.2a: Time and lack of disturbance and/or release from chronic winter drought.
1.3a: Long-term reduction in winter snow accumulation may lead to reduced groundwater recharge, or low severity fire would reduce Torrey's saltbush and black greasewood and allow for the perennial grasses to dominate the site.
1.3b: High severity fire, due to shrub dominance, significantly reduces shrub cover and increases perennial grasses and sprouting shrubs.

Transition T1A: Introduction of non-native annual plants.

Transition T1B: Settlement of the area and beginning of agriculture.

Current Potential State 2.0 Community Pathways:
2.1a: Long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge, or low severity fire would reduce Torrey's saltbush and black greasewood and allow for the understory perennial grasses to increase. High severity fire would greatly reduce Torrey's saltbush and black greasewood. Non-native annual species are likely to increase after fire.
2.1b: Time and lack of disturbance such as fire, long-term spring/summer drought, inappropriate grazing management, and unusually wet spring, or combinations of these. Torrey's saltbush, black greasewood, rabbitbrush and inland saltgrass increase.
2.2a: Time, lack of disturbance, release from chronic winter drought, and/or grazing management that favors the establishment and growth of Torrey's saltbush and black greasewood and allows the shrub component to recover.
2.3a: Heavy late fall/winter grazing causing mechanical damage to shrubs, low severity fire, and/or reduced groundwater recharge due to a long-term reduction in winter snow accumulation.
2.3b: High severity fire, due to shrub dominance, significantly reduces shrub cover and increases perennial grasses.

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

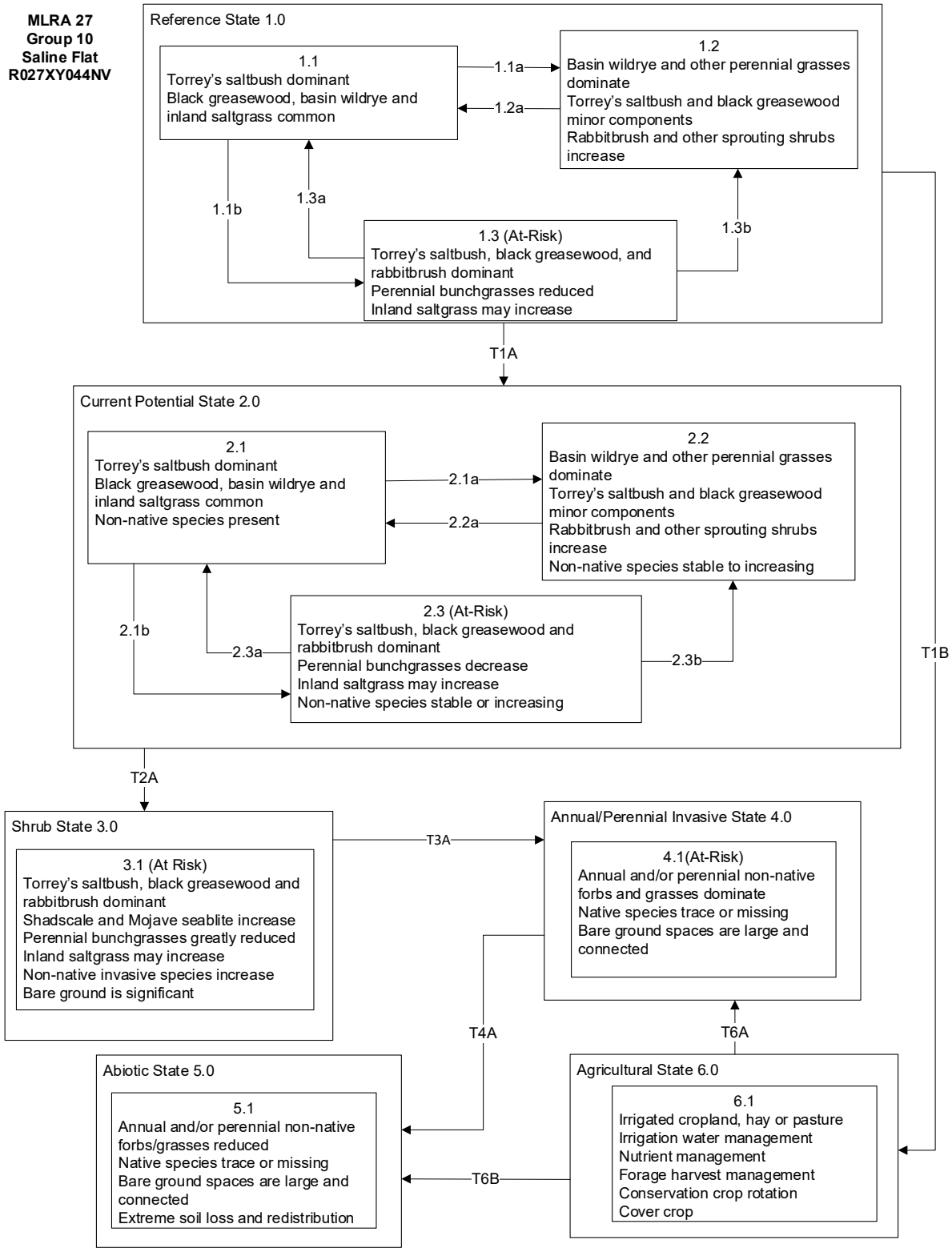
Transition T3A: Fire, flooding, long-term drought, groundwater pumping, or combinations. Significant soil loss and redistribution is occurring.

Transition T4A: Cessation of farming practices including the removal of irrigation water and loss of cropland, hay or pasture species or loss of non-native invasive species. Dominance of non-native species is reduced under long-term drought conditions or groundwater pumping, increasing bare ground and soil erosion.

Transition T6A: Cessation of farming practices including the removal of irrigation water and loss of cropland, hay or pasture species. Invasion by non-native species in average to above-average precipitation years leads to dominance of those species.

Transition T6B: Cessation of farming practices including the removal of irrigation water and loss of cropland, hay or pasture species. Invasion by non-native species is reduced under long-term drought conditions increasing bare ground and soil erosion.

Additional State and Transition Models for Group 10 in MLRA 27



MLRA 27
Group 10
Saline Flat
R027XY044NV
KEY

Reference State 1.0 Community Pathways
1.1a: Long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge, or low severity fire would reduce Torrey's saltbush and black greasewood and allow for the understory perennial grasses to increase. High severity fire would greatly reduce Torrey's saltbush and black greasewood.
1.1b: Time and lack of disturbance such as fire, long-term spring/summer drought, unusually wet periods or combinations of these. Torrey's saltbush, black greasewood, and perennial grasses increase.
1.2a: Time and lack of disturbance and/or release from chronic winter drought.
1.3a: Long-term reduction in winter snow accumulation may lead to reduced groundwater recharge, or low severity fire would reduce Torrey's saltbush and black greasewood and allow for the perennial grasses to dominate the site.
1.3b: High severity fire, due to shrub dominance, significantly reduces shrub cover and increases perennial grasses and sprouting shrubs.

Transition T1A: Introduction of non-native annual plants.

Transition T1B: Settlement of the area and beginning of agriculture.

Current Potential State 2.0 Community Pathways:
2.1a: Long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge, or low severity fire would reduce Torrey's saltbush and black greasewood and allow for the understory perennial grasses to increase. High severity fire would greatly reduce Torrey's saltbush and black greasewood. Non-native annual species are likely to increase after fire.
2.1b: Time and lack of disturbance such as fire, long-term spring/summer drought, inappropriate grazing management, and unusually wet spring, or combinations of these. Torrey's saltbush, black greasewood, rabbitbrush and inland saltgrass increase.
2.2a: Time, lack of disturbance, release from chronic winter drought, and/or grazing management that favors the establishment and growth of Torrey's saltbush and black greasewood and allows the shrub component to recover.
2.3a: Heavy late fall/winter grazing causing mechanical damage to shrubs, low severity fire, and/or reduced groundwater recharge due to a long-term reduction in winter snow accumulation.
2.3b: High severity fire, due to shrub dominance, significantly reduces shrub cover and increases perennial grasses.

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: Fire, flooding, long-term drought, groundwater pumping, or combinations. Significant soil loss and redistribution is occurring.

Transition T4A: Cessation of farming practices including the removal of irrigation water and loss of cropland, hay or pasture species or loss of non-native invasive species. Dominance of non-native species is reduced under long-term drought conditions or groundwater pumping, increasing bare ground and soil erosion.

Transition T6A: Cessation of farming practices including the removal of irrigation water and loss of cropland, hay or pasture species. Invasion by non-native species in average to above-average precipitation years leads to dominance of those species.

Transition T6B: Cessation of farming practices including the removal of irrigation water and loss of cropland, hay or pasture species. Invasion by non-native species is reduced under long-term drought conditions increasing bare ground and soil erosion.

References

Abbott, M. L., L. Fraley Jr., and T. D. Reynolds. 1991. Root profiles of selected cold desert shrubs and grasses in disturbed and undisturbed soils. Environmental and Experimental Botany **31**:165-178.

Allen, E. B., and M. F. Allen. 1988. Facilitation of succession by the nonmycotrophic colonizer *Salsola kali* (Chenopodiaceae) on a harsh site: effects of mycorrhizal fungi. American Journal of Botany **75**:257-266.

Alpert, P. 1990. Water sharing among ramets in a desert population of *Distichlis spicata* (Poaceae). American Journal of Botany **77**:1648-1651.

Anderson, M. D. 2004. *Sarcobatus vermiculatus*. In: Fire Effects Information System. U.S. Department of Agriculture, Forest Service,, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory.

Baker, W. L. 2006. Fire and restoration of sagebrush ecosystems. Wildlife Society Bulletin **34**:177-185.

Balch, J. K., B. A. Bradley, C. M. D'Antonio, and J. Gómez-Dans. 2013. Introduced annual grass increases regional fire activity across the arid western USA (1980–2009). Global Change Biology **19**:173-183.

Bates, J. D., T. Svejcar, R. F. Miller, and R. A. Angell. 2006. The effects of precipitation timing on sagebrush steppe vegetation. Journal of Arid Environments **64**:670-697.

Baughman, O. W., R. Burton, M. Williams, P. J. Weisberg, T. E. Dilts, and E. A. Leger. 2017. Cheatgrass die-offs: a unique restoration opportunity in northern Nevada. Rangelands **39**:165-173.

Baughman, O. W., S. E. Meyer, Z. T. Aanderud, and E. A. Leger. 2016. Cheatgrass die-offs as an opportunity for restoration in the Great Basin, USA: will local or commercial native plants succeed where exotic invaders fail? Journal of Arid Environments **124**:193-204.

Beatley, J. C. 1975. Climates and vegetation pattern across the Mojave/Great Basin Desert transition of southern Nevada. The American Midland Naturalist **93**:53-70.

Benson, B., S. Green, D. Ogle, D. Tilley, and L. St. John. 2011. Plant guide for black greasewood (*Sarcobatus vermiculatus*). U.S. Department of Agriculture, Natural Resource Conservation Service, Boise, ID.

Benson, B., D. Ogle, D. Tilley, and L. St. John. 2007. Technical Note: managing black greasewood sites. TN Plant Materials No. 15, U.S. Department of Agriculture - Natural Resources Conservation Service, Boise, ID - Salt Lake City, UT.

Benson, L., and R. A. Darrow. 1981a. Torrey Saltbush - *Atriplex lentiformis* (Torrey) S. Wats. var. Torreyi (S. Wats.) McMinn. Page 167 Trees and Shrubs of the Southwestern Deserts. University of Arizona Press, Tucson, Arizona.

Blaisdell, J. P., and R. C. Holmgren. 1984. Managing intermountain rangelands - salt-desert shrub ranges. General Technical Report INT-163, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Blauer, A. C., A. P. Plummer, E. D. McArthur, R. Stevens, and B. C. Giunta. 1976. Characteristics and hybridization of important intermountain shrubs. II. Chenopod family. Research

Paper INT-177, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Bock, C. E., and J. H. Bock. 1978. Response of birds, small mammals, and vegetation to burning sacaton grasslands in southeastern Arizona. Journal of Range Management **31**:296-300.

Boerboom, C. 1993. Russian thistle (*Salsola iberica* Sennen & Pau).

Bradley, B. A., C. A. Curtis, E. J. Fusco, J. T. Abatzoglou, J. K. Balch, S. Dadashi, and M.-N. Tuanmu. 2018. Cheatgrass (*Bromus tectorum*) distribution in the intermountain Western United States and its relationship to fire frequency, seasonality, and ignitions. Biological Invasions **20**:1493-1506.

Brakie, M. 2007. Plant guide for alkali sacaton (*Sporobolus airoides*). U.S. Department of Agriculture, Natural Resources Conservation Service, East Texas Plant Materials, Nacogdoches, TX.

Branson, F. A., R. F. Miller, and I. S. McQueen. 1976. Moisture relationships in twelve northern desert shrub communities near Grand Junction, Colorado. Ecology **57**:1104-1124.

Brehm, J. R. 2019. Cheatgrass die-off in the Great Basin: a comparison of remote sensing detecting methods and identification of environments favorable to die-off. M.S. Thesis. University of Nevada, Reno, NV.

Brown, R. W. 1971. Distribution of plant communities in southeastern Montana badlands. American Midland Naturalist **85**:458-477.

Bunting, S. C., B. M. Kilgore, and C. L. Bushey. 1987. Guidelines for prescribed burning sagebrush-grass rangelands in the Northern Great Basin. General Technical Report INT-231, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Call, C. A. 2021. Rabbitbrush: Classification, distribution, ecology, and control. Pages 342-351 Noxious Range Weeds. CRC Press.

Caudle, D., J. DiBenedetto, M. Karl, H. Sanchez, and C. Talbot. 2013. Interagency ecological site handbook for rangelands. U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.

Chambers, J. C., B. A. Bradley, C. S. Brown, C. D'Antonio, M. J. Germino, J. B. Grace, S. P. Hardegree, R. F. Miller, and D. A. Pyke. 2013. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of western North America. Ecosystems **17**:360-375.

Comstock, J. P., and J. R. Ehleringer. 1992. Plant adaptation in the Great Basin and Colorado Plateau. The Great Basin Naturalist **52**:195-215.

Davies, W. K., S. C. Boyd, L. J. Beck, D. J. Bates, J. T. Svejcar, and A. M. Gregg. 2011. Saving the sagebrush sea: An ecosystem conservation plan for big sagebrush plant communities. Biological Conservation **144**:2573-2584.

Dobrowolski, J. P., M. M. Caldwell, and J. H. Richards. 1990. Chapter 7: Basin hydrology and plant root systems. Pages 243-292 *in* C. B. Osmond, L. F. Pitelka, and G. M. Hidy, editors. Plant Biology of the Basin and Range. Springer-Verlag, New York City, NY.

Eckert Jr, R. E., A. D. Bruner, and G. J. Klomp. 1973. Productivity of tall wheatgrass and Great Basin wildrye under irrigation on a greasewood-rabbitbrush range site. Journal of Range Management **26**:286-288.

Eddleman, L. E. 2002. Restoration ecology of native plant species in Oregon's western juniper zone. Revised Project CSRS ORE00367, Oregon State University, Corvallis, OR.

Eddleman, L. E. 2008. *Sarcobatus vermiculatus* (Hook.) Torr. - black greasewood. Pages 1022-1024 *in* F. T. Bonner and R. P. Karrfalt, editors. The Woody Plant Seed Manual. Agriculture Handbook 727. U.S. Department of Agriculture, Forest Service, Washington, D.C.

Evans, R. A., and J. A. Young. 1978. Effectiveness of rehabilitation practices following wildfire in a degraded big sagebrush-downy brome community. Journal of Range Management **31**:185-188.

Everett, R. L., P. T. Tueller, J. B. Davis, and A. D. Brunner. 1980. Plant phenology in galleta-shadscale and galleta-sagebrush associations. Rangeland Ecology & Management/Journal of Range Management Archives **33**:446-450.

Foster, S., B. Schultz, and L. Singletary. 2011. Needs Assessment for Noxious Weeds in Pershing County: Part 1 of 5–Problem Weeds and Approaches and Methods of Control.

Francis, J. K. 2004b. Wildland shrubs of the United States and its territories: Thamnic descriptions: Volume 1. General Technical Report IITF-GTR-26, U.S. Department of Agriculture, Forest Service, International Institute of Tropical Forestry, San Juan, PR and Rocky Mountain Research Station, Fort Collins, CO.

Furbush, P. 1953. Control of medusa-head on California ranges. Journal of Forestry **51**:118-121.

Ganskopp, D., L. Aguilera, and M. Vavra. 2007. Livestock forage conditioning among six northern Great Basin grasses. Rangeland Ecology & Management **60**:71-78.

Ganskopp, D. C. 1986a. Tolerances of sagebrush, rabbitbrush, and greasewood to elevated water tables. Journal of Range Management **39**:334-337.

Goodrich, S., E. D. McArthur, and A. H. Winward. 1985. A new combination and a new variety in *Artemisia tridentata*. The Great Basin Naturalist **45**:99-104.

Graham, J., and W. Johnson. 2004. Managing russian knapweed. University of Nevada Coop. Ext. Fact Sheet:04-37.

Groeneveld, D. P. 1990. Shrub rooting and water acquisition on threatened shallow groundwater habitats in the Owens Valley, California. Pages 221-237 *in* Proceedings—Symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; Las Vegas, NV; April 5-7, 1989. General Technical Report INT-276. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Groeneveld, D. P., and D. E. Crowley. 1988b. Root system response to flooding in three desert shrub species. Functional Ecology **2**:491-497.

Harr, R. D., and K. R. Price. 1972. Evapotranspiration from a greasewood-cheatgrass community. Water Resources Research **8**:1199-1203.

Headley, F. B., and C. Venstrom. 1930. Economic History of the Newlands Irrigation Project. University of Nevada.

Hickey, W. C., Jr., and H. W. Springfield. 1966. Alkali sacaton: Its merits for forage and cover. Journal of Range Management **19**:71-74.

Hickman, J. C. 1993. The Jepson Manual: Higher Plants of California. University of California Press, Los Angeles, CA, USA.

Holmgren, N. H., P. K. Holmgren, and A. Cronquist. 2005. Intermountain flora: Vascular plants of the Intermountain West, U.S.A. Volume two, part B. Subclass Dilleniidae. The New York Botanical Garden Press, Bronx, NY.

Humphrey, L. D. 1984. Patterns and mechanisms of plant succession after fire on *Artemisia*-grass sites in southeastern Idaho. Vegetatio **57**:91-101.

Jacobs, J. 2007. Ecology and management of whitetop (Cardaria Draba (L.) Desv.). US Department of Agriculture, Natural Resources Conservation Service.

Johnson, J. R., and G. F. Payne. 1968. Sagebrush reinvasion as affected by some environmental influences. Journal of Range Management **21**:209-213.

Johnson, N. C. 1998. Responses of *Salsola kali* and *Panicum virgatum* to mycorrhizal fungi, phosphorus and soil organic matter: implications for reclamation. Journal of Applied Ecology **35**:86-94.

Klemmedson, J. O., and J. G. Smith. 1964. Cheatgrass (*Bromus tectorum* L.). The Botanical Review **30**:226-262.

Klepper, E. L., K. A. Gano, and L. L. Cadwell. 1985. Rooting depth and distribution of deep-rooted plants in the 200 Area Control Zone of the Hanford Site.

Krall, J. L., J. R. Stroh, C. S. Cooper, and S. R. Chapman. 1971. Effect of time and extent of harvesting basin wildrye. Journal of Range Management **24**:414-418.

Lauenroth, W., and J. Bradford. 2006. Ecohydrology and the partitioning AET between transpiration and evaporation in a semiarid steppe. Ecosystems **9**:756-767.

Lee, C. A., and W. K. Lauenroth. 1994. Spatial distributions of grass and shrub root systems in the shortgrass steppe. American Midland Naturalist **132**:117-123.

Mack, R. N., and D. A. Pyke. 1983. The demography of *Bromus tectorum*: Variation in time and space. Journal of Ecology **71**:69-93.

Majerus, M. E. 1992. High-stature grasses for winter grazing. Journal of Soil and Water Conservation **47**:224-225.

Marcum, K. B., and D. M. Kopec. 1997. Salinity tolerance of turfgrasses and alternative species in the subfamily Chloridoideae (Poaceae). International Turfgrass Society Research Journal **8**:735-742.

Mathie, A. M., T. L. Welborn, D. D. Susong, and M. L. Tumbusch. 2011. Phreatophytic land-cover map of the northern and central Great Basin ecoregion: California, Idaho, Nevada, Utah, Oregon, and Wyoming. Pamphlet to accompany Scientific Investigations Map 3169, U.S. Department of the Interior, U.S. Geological Survey, Reston, VA.

Meinzer, O. E. 1927. Plants as indicators of ground water. Water-Supply Paper 577, U.S. Department of the Interior, U.S. Geological Survey, Washington, D.C.

Meyer, S. E. 2008b. *Atriplex* L. saltbush. Pages 283-290 *in* The woody plant seed manual. Agriculture Handbook 727. U.S. Department of Agriculture, Forest Service, Washington, D.C.

Miller, R. F., J. C. Chambers, D. A. Pyke, F. B. Pierson, and C. J. Williams. 2013. A review of fire effects on vegetation and soils in the Great Basin Region: Response and ecological site characteristics. General Technical Report RMRS-GTR-308, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Miller, R. F., S. T. Knick, D. A. Pyke, C. W. Meinke, S. E. Hanser, M. J. Wisdom, and A. L. Hild. 2008a. Characteristics of sagebrush habitats and limitations to long-term conservation. Administrative Report, U.S. Department of the Interior; U.S. Geological Survey, Reston, VA.

Miller, R. F., R. J. Tausch, and W. Waichler. 1999b. Old-growth juniper and pinyon woodlands. Pages 375-384 *in* Proceedings: ecology and management of pinyon-juniper communities within the interior west; September 15-18, 1997. Proceedings RMRS-P-9. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Brigham Young University Conference Center, Provo, UT.

Miller, T. W. 1991. Hoary cress and related whitetops (Cardaria draba, C. pubescens and C. chalapensis).

Mozingo, H. N. 1987b. Shrubs of the Great Basin: A natural history. University of Nevada Press, Reno, NV.

Mozingo, H. N. 1987c. Torrey saltbush (*Atriplex torreyi*). Pages 60-62 Shrubs of the Great Basin: A natural history. University of Nevada Press, Reno, NV.

Naumburg, E., R. Mata-Gonzalez, R. G. Hunter, T. McLendon, and D. W. Martin. 2005. Phreatophytic vegetation and groundwater fluctuations: A review of current research and application of ecosystem response modeling with an emphasis on Great Basin vegetation. Environmental Management **35**:726-740.

Newman, S. D., and M. Gates. 2000. Plant guide for saltgrass (*Distichlis spicata*). U.S. Department of Agriculture, Natural Resource Conservation Service, Alexandria, LA.

NRCS. 2022. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. Handbook 296, U.S. Department of Agriculture, Natural Resources Conservation Service.

Paysen, T. E., R. J. Ansley, J. K. Brown, G. J. Gottfried, S. M. Haase, M. G. Harrington, M. G. Narog, S. S. Sackett, and R. C. Wilson. 2000. Chapter 6: Fire in western shrubland, woodland, and grassland ecosystems. Pages 121-159 *in* J. K. Brown and J. K. Smith, editors. Wildland fire in ecosystems: Effects of fire on flora. General Technical Report RMRS-GTR-42-Vol. 2. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Perryman, B. L. 2014c. Torrey quail bush; Torrey saltbush - *Atriplex torreyi* S. Wats. Pages 8-9 A Field Guide to Nevada Shrubs. Indigenous Rangeland Management Press, Lander, Wyoming.

Peters, E. F., and S. C. Bunting. 1994. Fire conditions pre-and post-occurrence of annual grasses on the Snake River Plain. Pages 31-36 *in* Proceedings—Ecology and management of annual rangelands; September, 1994; Boise, ID. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Qian, Y. L., J. A. Cosenza, S. J. Wilhelm, and D. Christensen. 2006. Techniques for enhancing saltgrass seed germination and establishment. Crop Science **46**:2613-2616.

Robertson, J. H. 1983. Greasewood (*Sarcobatus vermiculatus* (Hook.) Torr.). Phytologia **54**:309-324.

Robinson, T. W. 1958. Phreatophytes. Geological survey water-supply paper 1423, US Deaprtment of Interior, US Geological Survey, Washington, D.C.

Romo, J. T. 1984. Water relations in *Artemisia tridentata* subsp. *wyomingensis*, *Sarcobatus vermiculatus*, and *Kochia prostrata*. PhD Dissertation. Oregon State University, Corvallis, OR.

Roundy, B. A. 1985. Emergence and establishment of basin wildrye and tall wheatgrass in relation to moisture and salinity. Journal of Range Management **38**:126-131.

Saito, L., S. Byer, K. Badik, K. McGwire, L. Provencher, and B. Minor. 2020. Mapping indicators of groundwater dependent ecosystems in Nevada: Important resources for a water-limited state. Journal of the Nevada Water Resources Association **Winter 2020**:48-72.

Sanderson, S. C., and H. C. Stutz. 1994. Woody chenopods useful for rangeland reclamation in western North America. Pages 374-378 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Shumar, M. L., and J. E. Anderson. 1986. Water relations of two subspecies of big sagebrush on sand dunes in southeastern Idaho. Northwest Science **60**:179-185.

Skaradek, W., and C. Miller. 2010. Plant fact sheet for saltgrass (*Distichlis spicata*). USDA NRCS Cape May Plant Materials Center, Cape May, NJ.

Smith, J. T., B. W. Allred, C. S. Boyd, K. W. Davies, M. O. Jones, A. R. Kleinhesselink, J. D. Maestas, S. L. Morford, and D. E. Naugle. 2022. The elevational ascent and spread of exotic annual grass dominance in the Great Basin, USA. Diversity and Distributions **28**:83-96.

Smith, M. A., J. D. Rodgers, J. L. Dodd, and Q. D. Skinner. 1992. Habitat selection by cattle along an ephemeral channel. Journal of Range Management **45**:385-390.

Strahorn, A. T. a. C. V. D. 1909. Soil Survey of the Fallon Area, Nevada. USDA-Natural Resources Conservation Service.

Stuart, D. M., G. E. Schuman, and A. S. Dylla. 1971. Chemical characteristics of the coppice dune soils in Paradise Valley, Nevada. Soil Science Society of America Journal. Division S-5 - Soil Genesis, Morphology, and Classification **35**:607-611.

Stubbendieck, J. L., S. L. Hatch, N. M. Bryan, and C. D. Dunn. 2017. North American wildland plants. Third edition. University of Nebraska Press, Lincoln, NE.

Tilley, D., D. Ogle, and L. St. John. 2008. Plant guide for halogeton (*Halogeton glomeratus*). USDA NRCS, USDA NRCS Idaho State Office, Boise, ID.

Tilley, D. J., D. Ogle, L. St John, and B. Benson. 2002. Plant guide for big sagebrush (*Artemisia tridentata*).

Trent, J. D., R. R. Blank, and J. A. Young. 1997. Ecophysiology of the temperate desert halophytes: *Allenrolfea occidentalis* and *Sarcobatus vermiculatus*. Great Basin Naturalist **57**:57-65.

Tueller, P. E., and E. D. Payne. 1987. The ecology and management of the genus *Chrysothamnus*. Pages 1–8 *in* Proceedings, 4th Utah shrub ecology workshop: The genus Chrysothamnus. Utah State University, College of Natural Resources, Cedar City, Utah.

USFS. 1988a. Range plant handbook. Reprint of 1937 edition. Dover Publications, New York, NY.

Wallace, A., W. Rhods, and E. Frolich. 1968. Germination behavior of *Salsola* as influenced by temperature, moisture, depth of planting, and gamma irradiation. Agronomy Journal **60**:76-78.

Weber, W. A., and R. C. Wittmann. 2012. Colorado flora: Western slope. University Press of Colorado.

Weisberg, P. J., T. E. Dilts, O. W. Baughman, S. E. Meyer, E. A. Leger, K. J. V. Gunst, and L. Cleeves. 2017. Development of remote sensing indicators for mapping episodic die-off of an invasive annual grass (*Bromus tectorum*) from the Landsat archive. Ecological Indicators **79**:173-181.

West, N. E. 1994. Effects of fire on salt-desert shrub rangelands. Pages 71-74 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, ID.

Wright, H. A. 1971. Why squirreltail is more tolerant to burning than needle-and-thread. Journal of Range Management **24**:277-284.

Young, F., R. Veseth, D. Thill, W. Schillinger, and D. Ball. 1995. Managing Russian thistle under conservation tillage in crop-fallow rotations.

Young, J. A., R. A. Evans, and P. T. Tueller. 1976. Great Basin plant communities - pristine and grazed. Pages 186-215 *in* R. Elston, editor. Holocene Environmental Change in the Great Basin. Nevada Archeological Survey, University of Nevada, Reno, NV.

Young, R. P. 1983. Fire as a vegetation management tool in rangelands of the intermountain region. Pages 18-31 *in* Managing Intermountain rangelands—Improvement of range and wildlife habitats. Proceedings of Symposia: September 15-17, 1981, Twin Falls, Idaho June 22·24, 1982, Elko, Nevada. General Technical Report INT-GTR-157. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Zschaechner, G. A. 1985. Studying rangeland fire effects: A case study in Nevada. Pages 66-84 *in* Rangeland fire effects: a symposium; Boise, ID; November 27-29, 1984. U.S. Department of the Interior, Bureau of Land Management, Idaho State Office, Boise, ID.

MLRA 27 Group 11: Sandy sites dominated by saltbush and Indian ricegrass

Description of MLRA 27 Disturbance Response Group 11

Disturbance Response Group (DRG) 11 consists of three ecological sites. These sites occur on fan skirts, inset fans, and sand sheets of lower piedmont slopes and alluvial plains. Slopes range from 0 to 15% but slopes of 0–8% are most typical. Elevations range from 3,500 to about 5,000 ft. The soils are typically very deep and well drained or somewhat excessively drained. Parent materials consist of mixed alluvium and aeolian sands. Soil temperature regime is mesic and the soil moisture regime is typic aridic. 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. The reference plant communities are dominated by Indian ricegrass (*Achnatherum hymenoides*) and fourwing saltbush (*Atriplex canescens*). Other important plants include and winterfat (*Krascheninnikovia lanata*), Nevada jointfir (*Ephedra nevadensis*) and needle-and-thread (*Hesperostipa comata*). Total annual air-dry production ranges from 250 to 700 lb/ac.

Disturbance Response Group 11 Ecological Sites:

Sandy 5-8" P.Z. – Modal	R027XY009NV
Sandy 3-5" P.Z.	R027XY060NV
Outwash Plain	R027XY078NV

Modal Site:

The Sandy 5-8" P.Z. ecological site (R027XY009NV) is the modal site for this group as it has the most acres mapped. It occurs on sand sheets of lower piedmont slopes and alluvial plains. Elevation ranges from 3,500 to about 4,500 ft. Slopes range from 0 to 15%, but slope gradients of 2–8% are typical. Soils correlated to this site are very deep and somewhat excessively drained. They are formed in alluvium and aeolian sands from mixed rock sources. Soil temperature regime is mesic, and the soil moisture regime is typic aridic. Runoff is low and water infiltration is high. The potential for rill and sheet erosion is slight but wind erosion potential is high. This site is dominated by fourwing saltbush, winterfat, and Indian ricegrass. Other important species are spiny hopsage (*Grayia spinosa*), Nevada dalea (*Psorothamnus polydenius*) and needle-and-thread. Total annual air-dry production ranges from 250 to 700 lb/ac with 450 lb/ac in a normal year.

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 27 (MLRA 27 Fallon-Lovelock Area) is almost entirely in Nevada with < 1% in California. The entire area occurs in the rain shadow of the Sierra Nevada mountains and is influenced by Pleistocene Lake Lahontan. Extensive playas occur throughout the area and are a result of the drying of ancient Lake Lahontan. To the west, MLRA 27 has a gradual boundary with MLRA 26 (Carson Basin and Mountains) and to the east has a very gradual boundary with MLRA 24 (Humboldt Basin and Range Area). From west to east the soil temperature increases and the soil moisture decreases, resulting in vast areas dominated by salt-desert shrub communities. Isolated mountain ranges trending north to south are separated by broad desert plains and valleys. Elevations range from 3,300 to 5,900 ft with some mountain peaks over 7,800 ft. The average annual precipitation ranges from 4 to 11 in. and as much as 20 in. at the highest elevations. The majority of annual precipitation is received during late fall and winter occurring mainly as snow. High-intensity, convective thunderstorms also contribute significantly to annual precipitation (NRCS 2022). 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 (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 (*Sporobolus cryptandrus*) occur in two of the ecological

sites included in this DRG, however, this species is generally sub-dominant in reference condition.

Fourwing saltbush is the most widely distributed and abundant saltbush in the southwest USA (Mozingo 1987b). 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 6–12 m (20–40 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 4–24 in. tall (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 (*Atriplex confertifolia*), and winterfat and in elevations up to 10,000 ft. It can be found throughout MLRA 27, 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).

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).

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 low resilience to disturbance and resistance to invasion. Increased resilience generally increases with elevation, aspect, increased precipitation, and increased nutrient availability. Five 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.

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. 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 non-native 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 non-native 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. 1999b). 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). Dobrowolski et al. (1990) cite multiple authors on the extent of the soil profile exploited by 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 1.5–1.7 m (59–67 in.).

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 North Africa grass (*Ventenata dubia*) within residual stands of native bunchgrasses. 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). 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, medusahead, North Africa grass, 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).

Russian thistle and halogeton 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.

Russian thistle is a taprooted, C4 photosynthesis (warm-season) annual forb of the goosefoot family (Chenopodiaceae) 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 < 2 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 1998).

Halogeton is a non-native 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 taproot that penetrates 4–5 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:

Historically fires in salt-desert shrub communities were rare except following high precipitation years where native annual forbs were abundant (West 1983, West 1994). The invasion of cheatgrass into these communities has altered natural fire regimes. Cheatgrass is extremely flammable and grows in dense stands in shrub interspaces, providing the accumulation of fine fuels necessary to carry fire to widely spaced woody plants (Young and Evans 1978, Whisenant 1990).

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, spiny hopsage (*Grayia spinosa*), and horsebrush (*Tetradymia* spp.) (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).

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.

Sand dropseed tends to be top-killed by fire and significantly reduces post fire, however it 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 yellow rabbitbrush (*Chrysothamnus viscidiflorus*), the predominant sprouting shrub in this community along with Nevada jointfir (*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:

This 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.

Within this vegetation type, it is acknowledged that 65–90% 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.), pronghorn (*Antilocapra americana*), 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 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 (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.

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 (*Pleuraphis jamesii*) will 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).

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 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 11

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 27 Disturbance Response Group 11.

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) and/or insect or disease attack (Nelson et al. 1989, Ewing and Dobrowolski 1992).

Community Phase 1.1:
Fourwing saltbush and Indian ricegrass dominate the site. Winterfat, Nevada dalea and spiny hopsage are also common. Needle-and-thread, 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 75% grasses, 5% forbs and 20% shrubs. Approximate ground cover (basal and canopy) is 10–20%. Total annual air-dry production ranges from 250 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 and palatable shrubs such as fourwing saltbush and winterfat. Sand dropseed, galleta and squirreltail (*Elymus elymoides*) may increase.

Community Phase 1.2:

Fourwing saltbush and winterfat are reduced as well as Indian ricegrass. Shallow-rooted perennials including squirreltail and sand dropseed will increase alongside less palatable shrubs including yellow rabbitbrush, Bailey's greasewood (*Sarcobatus baileyi*) and horsebrush.

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 deep-rooted perennial bunchgrasses 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 species, 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 and Indian ricegrass dominate the site. Winterfat, Nevada dalea and spiny hopsage are also common. Needle-and-thread, sand dropseed, and other perennial grasses may also be present in the understory. Perennial and annual forbs are present but not abundant. Non-native annual species are present.

Sandy 5-8" P.Z. (R027XY009NV), Current Potential 2.1, T. Stringham, June 2025

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
Long-term drought and repeated, chronic grazing from domestic livestock and/or wild horses/burros favor an increase in unpalatable shrubs, such as Bailey's greasewood and yellow rabbitbrush, over deep-rooted perennial bunchgrasses and palatable shrubs such as fourwing saltbush and winterfat. Sand dropseed, galleta and squirreltail may increase. A high-intensity wildfire will reduce fourwing saltbush and winterfat. Sprouting shrubs such as Nevada jointfir and yellow rabbitbrush will 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. Long-term sheep grazing during winter months will reduce palatable shrub cover and maintain grass cover.

Community Phase 2.2:
Fourwing saltbush and winterfat are reduced. Sand dropseed, galleta and/or squirreltail will increase along with less palatable shrubs, including yellow rabbitbrush, Bailey's greasewood, and horsebrush. Annual, non-native species are present and may be increasing.

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 Bailey's greasewood dominate the overstory. Indian ricegrass and needle-and-thread are reduced while galleta and sand dropseed have increased. Continuous growing season grazing favors the shrub component and reduces Indian ricegrass and needle-and-thread while sand dropseed and galleta increase. Annual non-native species are present.

Sandy 5-8" P.Z. (R027XY009NV), Current Potential State 2.3, T. Stringham, June 2025

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 shrubs and facilitate an increase in perennial bunchgrasses. 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 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 bunchgrass 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.

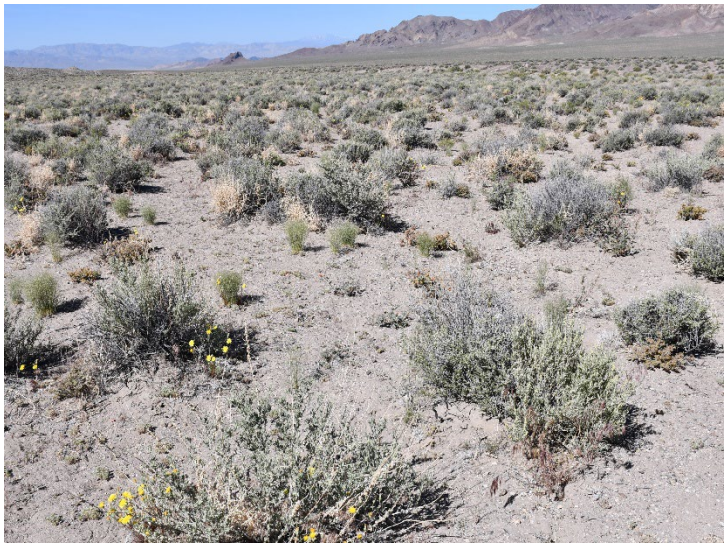
Slow variables: Increased production and cover of non-native annual species.

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 (At-Risk):
Perennial bunchgrasses like Indian ricegrass are reduced and the site is dominated by fourwing saltbush and Bailey's greasewood. Other shrubs like Nevada dalea 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.



Sandy 3-5" P.Z. (R027XY060NV), Shrub State 3.1, T. Stringham, May 2024

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 spiny hopsage.

Community Phase 3.2 (At-Risk):
Non-palatable shrubs such as Bailey's greasewood, Nevada dalea and/or littleleaf horsebrush (*Tetradymia glabrata*) 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 5-8" P.Z. (R027XY009NV), Shrub State 3.2, P. Novak-Echenique, May 2021

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. Land-clearing and abandoned agriculture will also result in an 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 non-native annual species. Russian thistle, halogeton, tall tumblemustard (*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. Cheatgrass, Russian thistle and halogeton most commonly invades these sites. Fourwing saltbush and other native 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. (R027XY009NV), Annual State 4.1, T. Stringham, June 2025

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

Trigger: Long-term, inappropriate grazing management, long-term drought, land-clearing, and/or abandoned agriculture 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 that leads 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 scattered shrubs or introduced non-native forbs and/or grasses. Native annual forbs may be present in wet years. Bare ground interspaces are large and connected. Site function is controlled by soil erosion and soil temperature.

Sandy 5-8" P.Z. (R027XY009NV), Abiotic State 5.1, P. Novak-Echenique, October 2025

Sandy 5-8" P.Z. (R027XY009NV), Abiotic State 5.1, P. Novak-Echenique, March 2026

Potential Resilience Differences with Other Ecological Sites in this Group

Sandy 3-5" P.Z. (R027XY060NV):

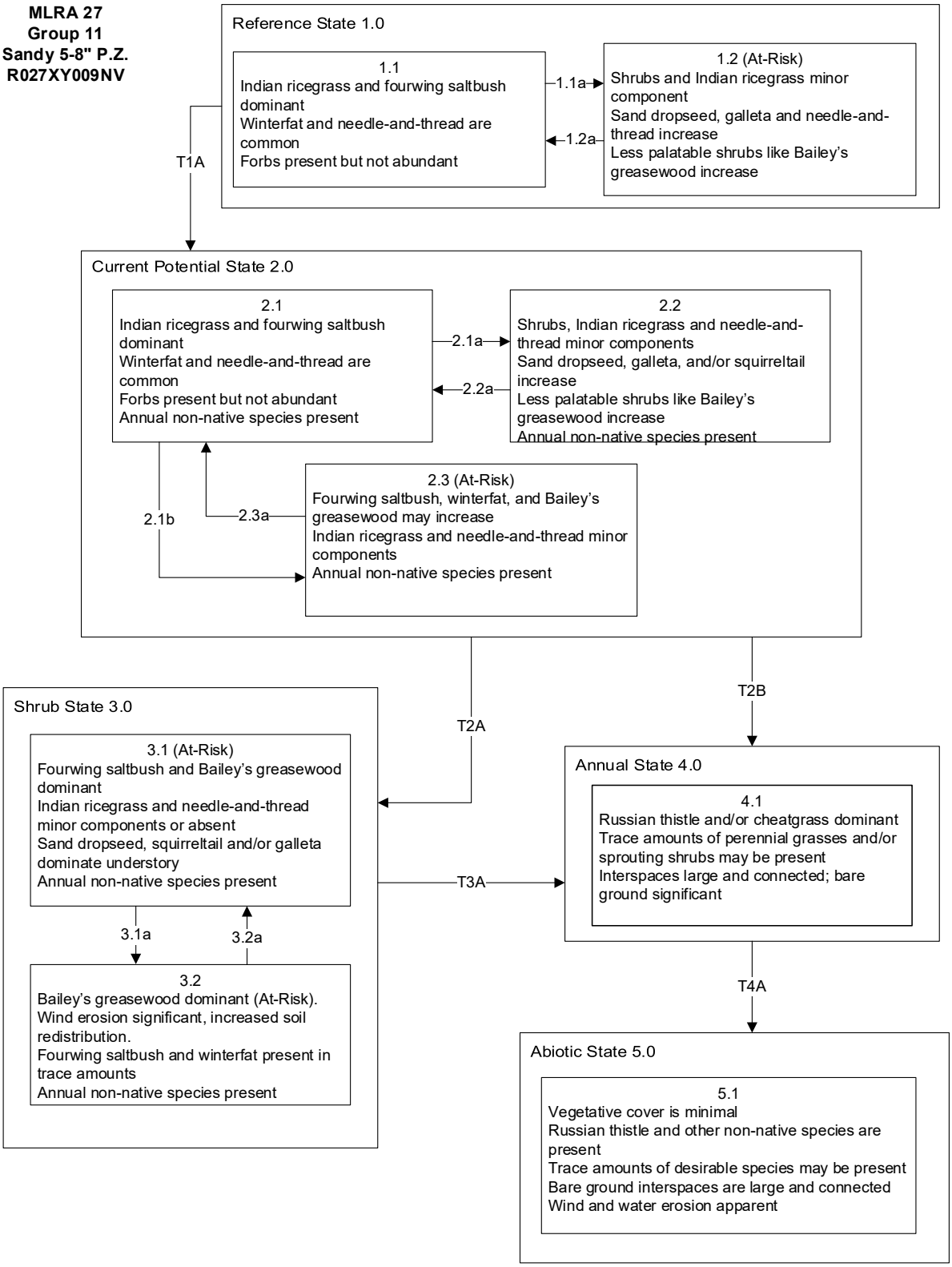
This site occurs on sand sheets over fan skirts and lower piedmont slopes. Slopes range from 2 to 4% and elevations range from 3,500 to 4,300 ft. The soils are somewhat excessively drained, available water capacity is low and organic matter is low, making it a very challenging site for plant establishment. The reference plant community is dominated by fourwing saltbush and Indian ricegrass. Potential vegetative composition is approximately 50% grasses, 5% forbs and 45% shrubs. Total annual air-dry production ranges from 100 to 450 lb/ac. 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.

Sandy 3-5" P.Z. (R027XY060NV), Abiotic State 5.1, P. Novak-Echenique, May 2021

Outwash Plain (R027XY078NV):

This site occurs on fan skirts and inset fans on slopes from 0 to 4%. Elevations range from 4,000 to 5,400 ft. The soils are very deep, well drained and have silt loam textures. This site receives additional run-in moisture from adjacent landscapes. The reference plant community is dominated by fourwing saltbush and Indian ricegrass. Potential vegetative composition is about 35% grasses, 5% forbs and 60% shrubs. Total annual air-dry production ranges from 250 to 600 lb/ac. This site is more resilient than the modal site because of the additional moisture it receives and more total production of grasses. An Abiotic State was not identified for this site.

Modal State and Transition Model for Group 11 in MLRA 27



MLRA 27
Group 11
Sandy 5-8" P.Z.
R027XY009NV

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, squirreltail and sand dropseed may increase.
1.2a: Time and lack of disturbance and/or release from drought allows saltbush, winterfat, Indian ricegrass and needle-and-thread to recover.

Transition T1A: Introduction of non-native annual species such as cheatgrass, 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, winterfat, needle-and-thread and Indian ricegrass and galleta, squirreltail and sand dropseed increase. Bailey's greasewood, rabbitbrush and horsebrush will also increase. A high-intensity wildfire will reduce fourwing saltbush and winterfat and sprouting shrubs will 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 and facilitates shrub dominance. Long-term sheep grazing during the winter months will reduce palatable shrub cover and maintain grass cover.
2.2a: Time, lack of disturbance allows 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.
2.3a: Grazing management that reduces palatable shrubs, such as late-summer through winter grazing may reduce palatable shrubs and facilitate an increase in perennial bunchgrasses. 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.

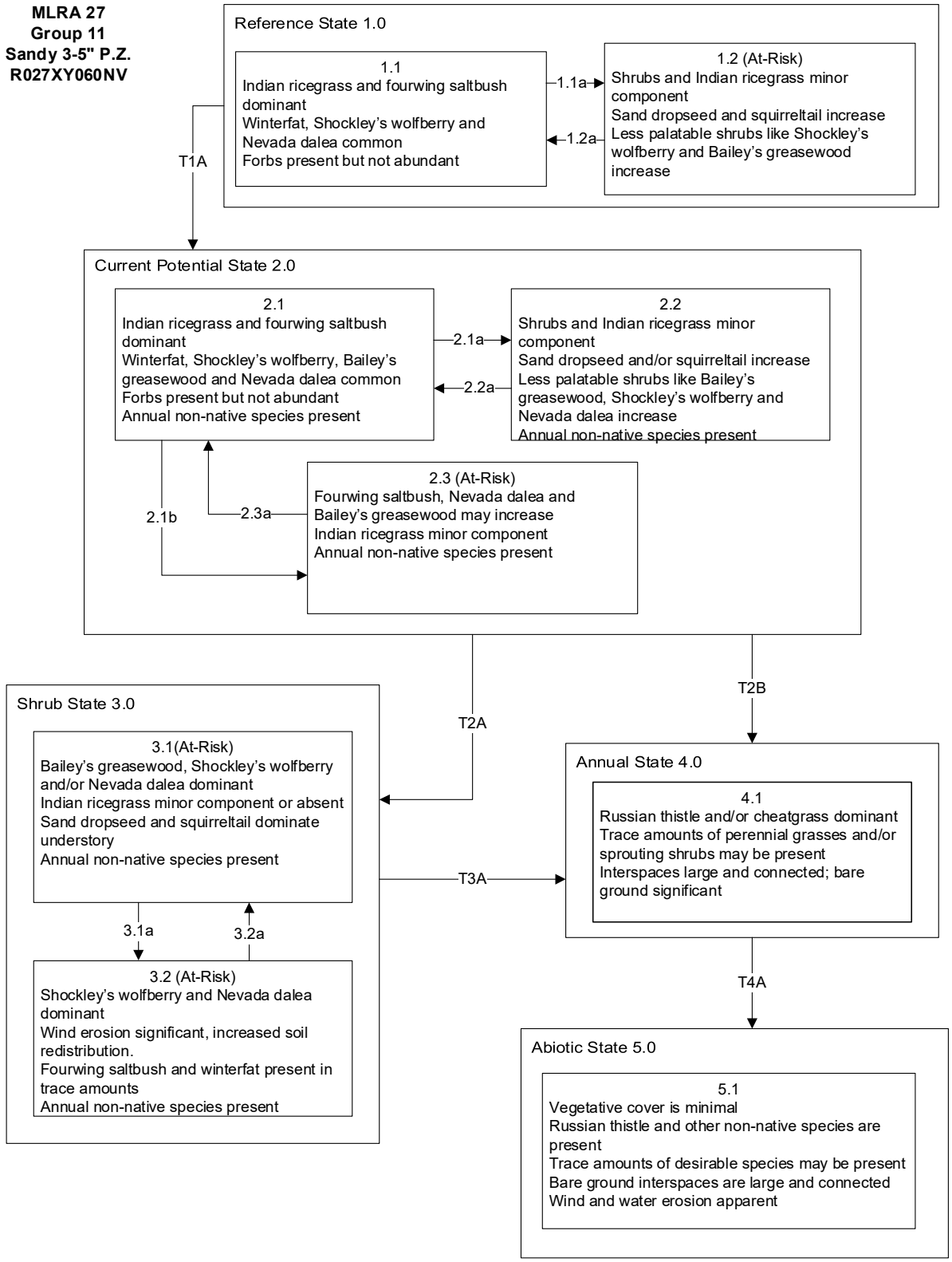
Transition T2B: Catastrophic fire.

Shrub State 3.0 Community Phase Pathways
3.1a: Severe drought and/or chronic, inappropriate late-summer to early spring grazing management decreases or eliminates the overstory of palatable shrubs. Bailey's greasewood will dominate.
3.2a: Time, lack of disturbance and years of favorable moisture 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, abandoned agriculture, and/or soil disturbing treatments, combined with significant soil loss and redistribution.

Additional State and Transition Models for Group 11 in MLRA 27



MLRA 27
Group 11
Sandy 3-5" P.Z.
R027XY060NV

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. Squirreltail and sand dropseed may increase.
1.2a: Time and lack of disturbance and/or release from drought allows saltbush, winterfat, Shockley's wolfberry and Indian ricegrass to recover.

Transition T1A: Introduction of non-native annual species such as cheatgrass, 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 decreases and galleta, squirreltail and sand dropseed increase. Bailey's greasewood, Shockley's wolfberry and Nevada dalea will also increase. A high-intensity wildfire will reduce fourwing saltbush and winterfat and sprouting shrubs will 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 and facilitates shrub dominance. Long-term sheep grazing during the winter months will reduce palatable shrub cover and maintain grass cover.
2.2a: Time, lack of disturbance allows 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.
2.3a: Grazing management that reduces palatable shrubs, such as late-summer through winter grazing may reduce palatable shrubs and facilitate an increase in perennial bunchgrasses. 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.

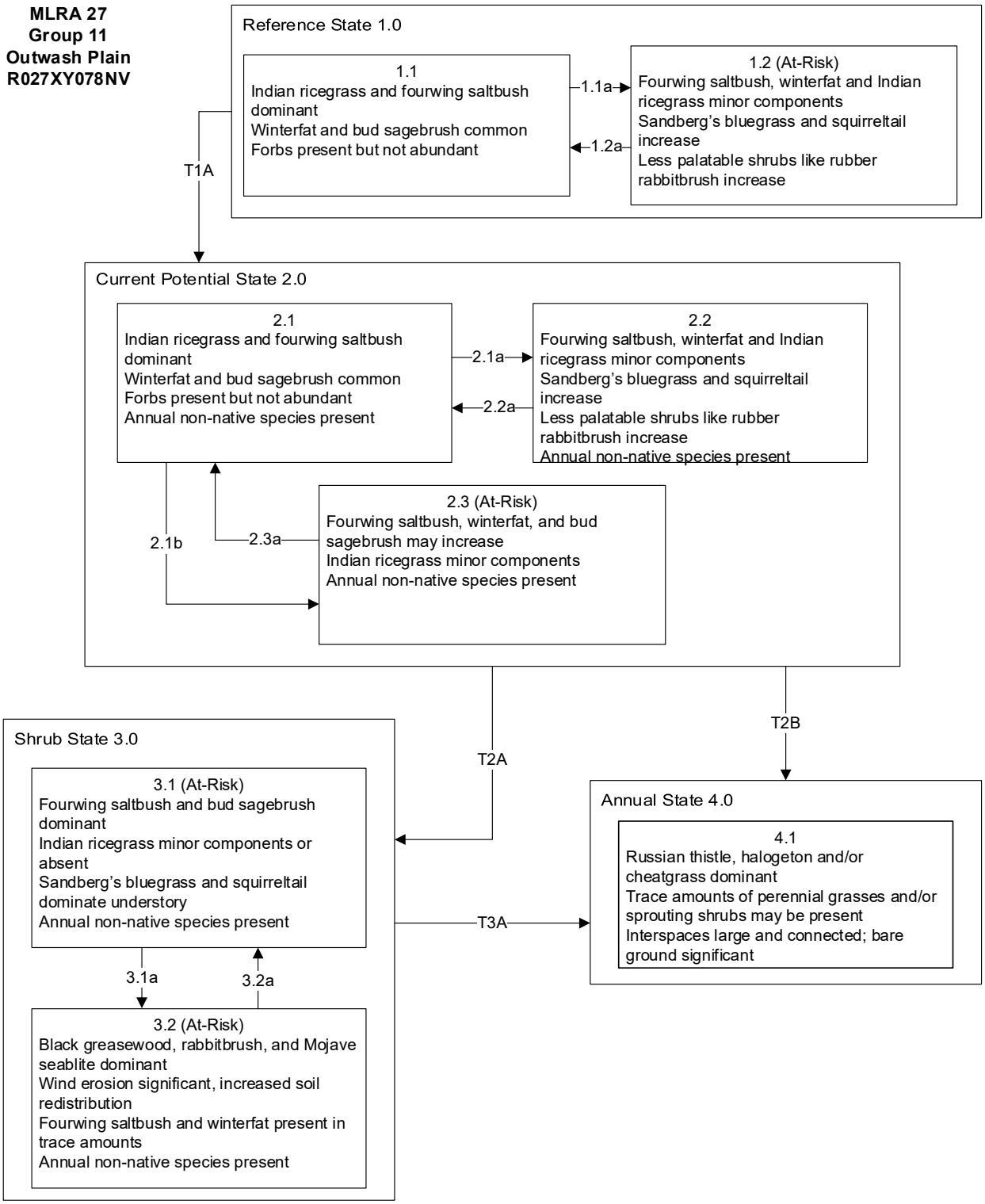
Transition T2B: Catastrophic fire.

Shrub State 3.0 Community Phase Pathways
3.1a: Severe drought and/or chronic, inappropriate 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 27
Group 11
Outwash Plain
R027XY078NV



MLRA 27
Group 11
Outwash Plain
R027XY078NV

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. Sandberg's bluegrass and squirreltail 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, winterfat, and Indian ricegrass while Sandberg's bluegrass and squirreltail increase. Black greasewood and rubber rabbitbrush will also increase. A high-intensity wildfire will reduce fourwing saltbush and winterfat and sprouting shrubs will increase.
2.1b: Time, lack of disturbance allows fourwing saltbush, winterfat and bud sagebrush to increase in density. Inappropriate growing season grazing reduces deep-rooted perennial bunchgrasses and facilitates shrub dominance. Long-term sheep grazing during the winter months will reduce palatable shrub cover and maintain grass cover.
2.2a: Time, lack of disturbance allows fourwing saltbush, winterfat and bud sagebrush 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.
2.3a: Grazing management that reduces palatable shrubs, such as late-summer through winter grazing may reduce palatable shrubs and facilitate an increase in perennial bunchgrasses. 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, inappropriate 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).

References

Abrams, M. D. 1988. Effects of burning regime on buried seed banks and canopy coverage in a Kansas tallgrass prairie. The Southwestern Naturalist:65-70.

Akinsoji, A. 1988. Postfire vegetation dynamics in a sagebrush steppe in southeastern Idaho, USA. Vegetatio **78**:151-155.

Allen, E. B., and M. F. Allen. 1988. Facilitation of succession by the nonmycotrophic colonizer *Salsola kali* (Chenopodiaceae) on a harsh site: effects of mycorrhizal fungi. American Journal of Botany **75**:257-266.

Anderson, E. W., and R. J. Scherzinger. 1975. Improving quality of winter forage for elk by cattle grazing. Journal of Range Management **28**:120-125.

Barrow, J. R., K. M. Havstad, and B. D. McCaslin. 1997. Fungal root endophytes in fourwing saltbush, *Atriplex canescens*, on arid rangelands of southwestern USA. Arid Soil Research and Rehabilitation **11**:177-185.

Bates, J. D., T. Svejcar, R. F. Miller, and R. A. Angell. 2006. The effects of precipitation timing on sagebrush steppe vegetation. Journal of Arid Environments **64**:670-697.

Beatley, J. C. 1975. Climates and vegetation pattern across the Mojave/Great Basin Desert transition of southern Nevada. The American Midland Naturalist **93**:53-70.

Blaisdell, J. P., and R. C. Holmgren. 1984. Managing intermountain rangelands - salt-desert shrub ranges. General Technical Report INT-163, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Blank, R. R., C. Clements, T. Morgan, D. Harmon, and F. Allen. 2020. Suppression of cheatgrass by perennial bunchgrasses. Rangeland Ecology & Management **73**:766-771.

Boerboom, C. 1993. Russian thistle (*Salsola iberica* Sennen & Pau).

Booth, D. T., C. G. Howard, and C. E. Mowry. 1980. 'Nezpar' Indian ricegrass: description, justification for release, and recommendations for use. Rangelands **2**:53-54.

Booth, T. D. 1989. Seedbed ecology of winterfat: cations in diaspore bracts and their effect on germination and early plant growth. Journal of Range Management **42**:178-182.

Bradley, A. F., N. V. Noste, and W. C. Fischer. 1992. Fire ecology of forests and woodlands in Utah. General Technical Report INT-287, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Bradley, B. A., C. A. Curtis, E. J. Fusco, J. T. Abatzoglou, J. K. Balch, S. Dadashi, and M.-N. Tuanmu. 2018. Cheatgrass (*Bromus tectorum*) distribution in the intermountain Western United States and its relationship to fire frequency, seasonality, and ignitions. Biological Invasions **20**:1493-1506.

Butler, M., F. Brummer, J. Weber, and R. Simmons. 2011. Restoring Central Oregon rangeland from ventenata and medusahead to a sustainable bunchgrass environment – Warm Springs and Ashwood. COARC 2011, Oregon State University, Central Oregon Agricultural Research and Extension Center, Corvallis, OR.

Buwai, M., and M. Trlica. 1977. Multiple defoliation effects on herbage yield, vigor, and total nonstructural carbohydrates of five range species. Rangeland Ecology & Management/Journal of Range Management Archives **30**:164-171.

Catlin, C. N. 1925. Composition of Arizona forages, with comparative data. Bulletin No. 113, University of Arizona, College of Agriculture, Agricultural Experiment Station, Tucson, AZ.

Caudle, D., J. DiBenedetto, M. Karl, H. Sanchez, and C. Talbot. 2013. Interagency ecological site handbook for rangelands. U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.

Chambers, J. C., B. A. Bradley, C. S. Brown, C. D'Antonio, M. J. Germino, J. B. Grace, S. P. Hardegree, R. F. Miller, and D. A. Pyke. 2013. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of western North America. Ecosystems **17**:360-375.

Cibils, A. F., S. M. David, and D. E. McArthur. 1998. Plant-herbivore interactions in *Atriplex*: current state of knowledge. General Technical Report RMRS-GTR-14, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Clark, S. L., D. J. Sebastian, S. J. Nissen, and J. R. Sebastian. 2019. Effect of indaziflam on native species in natural areas and rangeland. Invasive Plant Science and Management **12**:60-67.

Clements, C. D., D. N. Harmon, and R. R. Blank. 2022. Seed mix performance and cheatgrass suppression on arid rangelands. Rangelands **44**:129-135.

Comstock, J. P., and J. R. Ehleringer. 1992. Plant adaptation in the Great Basin and Colorado Plateau. The Great Basin Naturalist **52**:195-215.

Cook, C. W. 1962. An evaluation of some common factors affecting utilization of desert range species. Journal of Range Management **15**:333-338.

Cook, C. W., and R. D. Child. 1971. Recovery of desert plants in various states of vigor. Rangeland Ecology & Management/Journal of Range Management Archives **24**:339-343.

Costello, D. F. 1944. Important species of the major forage types in Colorado and Wyoming. Ecological Monographs **14**:107-134.

Courkamp, J. S., P. J. Meiman, and M. W. Paschke. 2022. Indaziflam reduces seed bank richness and density but not sagebrush-grassland plant diversity. Rangeland Ecology & Management **84**:31-44.

Cronin, E. H. 1965. Ecological and physiological factors influencing chemical control of *Halogeton glomeratus*. US Department of Agriculture.

Davies, K. W., C. S. Boyd, J. D. Bates, and A. Hulet. 2015a. Dormant season grazing may decrease wildfire probability by increasing fuel moisture and reducing fuel amount and continuity. International Journal of Wildland Fire **24**:849-856.

Davies, K. W., A. M. Nafus, C. S. Boyd, A. Hulet, and J. D. Bates. 2016. Effects of using winter grazing as a fuel treatment on Wyoming big sagebrush plant communities. Rangeland Ecology & Management **69**:179-184.

Dobrowolski, J. P., M. M. Caldwell, and J. H. Richards. 1990. Chapter 7: Basin hydrology and plant root systems. Pages 243-292 *in* C. B. Osmond, L. F. Pitelka, and G. M. Hidy, editors. Plant Biology of the Basin and Range. Springer-Verlag, New York City, NY.

Dwyer, D. D., and R. D. Pieper. 1967. Fire effects on blue grama-pinyon-juniper rangeland in New Mexico. Rangeland Ecology & Management/Journal of Range Management Archives **20**:359-362.

Eckert, R. E., Jr. 1954. A study of competition between whitesage and halogeton in Nevada. Journal of Range Management **7**:223-225.

Eckert, R. E., Jr., A. D. Bruner, and G. J. Klomp. 1972. Response of understory species following herbicidal control of low sagebrush. Journal of Range Management **25**:280-285.

Everett, R. L., P. T. Tueller, J. B. Davis, and A. D. Brunner. 1980. Plant phenology in galleta-shadscale and galleta-sagebrush associations. Rangeland Ecology & Management/Journal of Range Management Archives **33**:446-450.

Ewing, K., and J. P. Dobrowolski. 1992. Dynamics of shrub die-off in a salt desert plant community. Rangeland Ecology & Management/Journal of Range Management Archives **45**:194-199.

Freeman, D. C., and M. J. Emlen. 1995. Assessment of interspecific interactions in plant communities: an illustration from the cold desert saltbush grasslands of North America. Journal of Arid Environments **31**:179-198.

Furbush, P. 1953. Control of medusa-head on California ranges. Journal of Forestry **51**:118-121.

Henrickson, J. 1977. Saline habitats and halophytic vegetation of the Chihuahuan Desert region. Pages 289-314 *in* Transactions of the Symposium on the Biological Resources of the Chihuahuan Desert Region: United States and Mexico; Sul Ross State University, Alpine, TX; October 17-18, 1974. NPS Transactions and Proceedings Series No. 3. U.S. Department of the Interior, National Park Service.

Hild, A. L., J. M. Muscha, and N. L. Shaw. 2007. Emergence and growth of four winterfat accessions in the presence of the exotic annual cheatgrass. Pages 147-152 *in* Proceedings: Shrubland dynamics - fire and water; Lubbock, TX; August 10-12, 2004; RMRS-P-47. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Hilton, J. W. 1941. Effects of certain micro-ecological factors on the germinability and early development of *Eurotia lanata*. Northwest Science **15**:89-92.

Jameson, D. A. 1962. Effects of burning on a galleta-black grama range invaded by juniper. Ecology **43**:760-763.

Johnson, N. C. 1998. Responses of *Salsola kali* and *Panicum virgatum* to mycorrhizal fungi, phosphorus and soil organic matter: implications for reclamation. Journal of Applied Ecology **35**:86-94.

Johnson, R. D., and J. E. Anderson. 1984. Diets of black-tailed jack rabbits in relation to population density and vegetation. Journal of Range Management **37**:79-83.

Kaapro, J., and J. Hall. 2012. Indaziflam - a new herbicide for pre-emergent control of weeds in turf, forestry, industrial vegetation and ornamentals. Pages 224-227 *in* 23rd Asian-Pacific Weed Science Society Conference: Conference Proceedings Volume 1; Queensland, Australia; September 26-29 2011. Asian-Pacific Weed Science Society.

Klemmedson, J. O., and J. G. Smith. 1964. Cheatgrass (*Bromus tectorum* L.). The Botanical Review **30**:226-262.

Mack, R. N., and D. A. Pyke. 1983. The demography of *Bromus tectorum*: Variation in time and space. Journal of Ecology **71**:69-93.

Majerus, M. E. 2003. Production and conditioning of winterfat seeds (*Krascheninnikovia lanata*). Native Plants Journal **4**:10-15.

Meinzer, O. E. 1927. Plants as indicators of ground water. Water-Supply Paper 577, U.S. Department of the Interior, U.S. Geological Survey, Washington, D.C.

Miller, R. F., J. C. Chambers, D. A. Pyke, F. B. Pierson, and C. J. Williams. 2013. A review of fire effects on vegetation and soils in the Great Basin Region: Response and ecological site characteristics. General Technical Report RMRS-GTR-308, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Miller, R. F., S. T. Knick, D. A. Pyke, C. W. Meinke, S. E. Hanser, M. J. Wisdom, and A. L. Hild. 2008a. Characteristics of sagebrush habitats and limitations to long-term conservation. Administrative Report, U.S. Department of the Interior; U.S. Geological Survey, Reston, VA.

Miller, R. F., and R. J. Tausch. 2001. The role of fire in juniper and pinyon woodlands: A descriptive analysis. Pages 15-30 *in* Fire conference 2000: the first national congress on fire ecology, prevention, and management; San Diego, CA. Misc. Pub. No. 11. Tall Timbers Research Station, Tallahassee, FL.

Miller, R. F., R. J. Tausch, and W. Waichler. 1999b. Old-growth juniper and pinyon woodlands. Pages 375-384 *in* Proceedings: ecology and management of pinyon-juniper communities within the interior west; September 15-18, 1997. Proceedings RMRS-P-9. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Brigham Young University Conference Center, Provo, UT.

Mozingo, H. N. 1987b. Shrubs of the Great Basin: A natural history. University of Nevada Press, Reno, NV.

Nelson, D. L., K. T. Harper, K. C. Boyer, D. J. Weber, B. A. Haws, and J. R. Marble. 1989. Wildland shrub dieoffs in Utah: An approach to understanding the cause. Pages 119-135 *in* Proceedings—Symposium on shrub ecophysiology and biotechnology; General Technical Report INT-256. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Logan, UT.

Newton, R. J., and J. R. Goodin. 1989. Moisture stress adaptation in shrubs. Pages 365-383 *in* C. M. McKell, editor. The biology and utilization of shrubs. Academic Press, San Diego, CA.

NRCS. 2022. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. Handbook 296, U.S. Department of Agriculture, Natural Resources Conservation Service.

Ogle, D. G., L. St. John, and L. Holzworth. 2001. Plant guide for management and use of winterfat. U.S. Department of Agriculture, Natural Resource Conservation Service, Boise, ID.

Ogle, D. G., L. St. John, and D. Tilley. 2012a. Plant guide for fourwing saltbush (*Atriplex canescens)*. U.S. Department of Agriculture, Natural Resource Conservation Service, Idaho Plants Material Center, Aberdeen, ID.

Otsyina, R., C. M. McKell, and G. Van Epps. 1982. Use of range shrubs to meet nutrient requirements of sheep grazing on crested wheatgrass during fall and early winter. Journal of Range Management **35**:751-753.

Parmenter, R. R. 2008. Long-term effects of a summer fire on desert grassland plant demographics in New Mexico. Rangeland Ecology & Management **61**:156-168.

Pearson, L. 1979. Effects of temperature and moisture on phenology and productivity of Indian ricegrass. Rangeland Ecology & Management/Journal of Range Management Archives **32**:127-134.

Pearson, L. C. 1964. Effect of harvest date on recovery of range grasses and shrubs. Agronomy Journal **56**:80-82.

Pellant, M., and L. Reichert. 1984. Management and rehabilitation of a burned winterfat community in southwestern Idaho. Pages 281-285 *in* Proceedings—Symposium on the biology of *Atriplex* and related chenopods; Provo, UT; May 2-6, 1983; General Technical Report INT-172. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Perryman, B. L., B. W. Schultz, M. Burrows, T. Shenkoru, and J. Wilker. 2020. Fall-grazing and grazing-exclusion effects on cheatgrass (*Bromus tectorum*) seed bank assays in Nevada, United States. Rangeland Ecology & Management **73**:343-347.

Peters, E. F., and S. C. Bunting. 1994. Fire conditions pre-and post-occurrence of annual grasses on the Snake River Plain. Pages 31-36 *in* Proceedings—Ecology and management of annual rangelands; September, 1994; Boise, ID. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Quinones, F. A. 1981. Indian ricegrass evaluation and breeding. Bulletin 681, New Mexico State University, Agricultural Experiment Station, Las Cruces, NM.

Rasmussen, L. L., and J. D. Brotherson. 1986. Response of winterfat (*Ceratoides lanata*) communities to release from grazing pressure. Great Basin Naturalist **46**:148-156.

Rice, B., and M. Westoby. 1978. Vegetative responses of some Great Basin shrub communities protected against jackrabbits or domestic stock. Journal of Range Management **31**:28-34.

Romo, J. T., R. E. Redmann, B. L. Kowalenko, and A. R. Nicholson. 1995. Growth of winterfat following defoliation in northern mixed prairie of Saskatchewan. Journal of Range Management **48**:240-245.

Rood, K. A., K. E. Panter, D. R. Gardner, B. L. Stegelmeier, and J. O. Hall. 2014. Halogeton (*H. glomeratus*) poisoning in cattle: Case report. Animal, Dairy, and Veterinary Science Faculty Publications - Utah State **3**:23-26.

Sebastian, D. J., M. B. Fleming, E. L. Patterson, J. R. Sebastian, and S. J. Nissen. 2017a. Indaziflam: A new cellulose-biosynthesis-inhibiting herbicide provides long-term control of invasive winter annual grasses. Pest Management Science **73**:2149-2162.

Sheley, R. L., E. A. Vasquez, A.-M. Chamberlain, and B. S. Smith. 2012. Landscape-scale rehabilitation of medusahead (*Taeniatherum caput-medusae*)-dominated sagebrush steppe. Invasive Plant Science and Management **5**:436-442.

Smith, J. T., B. W. Allred, C. S. Boyd, K. W. Davies, M. O. Jones, A. R. Kleinhesselink, J. D. Maestas, S. L. Morford, and D. E. Naugle. 2022. The elevational ascent and spread of exotic annual grass dominance in the Great Basin, USA. Diversity and Distributions **28**:83-96.

Smoliak, S., J. F. Dormaar, and A. Johnston. 1972. Long-term grazing effects on *Stipa-bouteloua* prairie soils. Journal of Range Management **25**:246-250.

Soil Survey Staff. 2024. Soil survey geographic (SSURGO) database for Nevada. Natural Resources Conservation Service, United States Department of Agriculture.

Statler, G. D. 1967. *Eurotia lanata* establishment trials. Journal of Range Management **20**:253-255.

Stevens, R., B. C. Giunta, K. Jorgensen, and A. P. Plummer. 1977. Winterfat (*Ceratoides lanata*). Federal Aid Project W-82-R, Utah State Division of Wildlife Resources, Salt Lake City, UT.

Stubbendieck, J. L., S. L. Hatch, and L. M. Landholt. 2003. North American wildland plants. University of Nebraska Press, Lincoln, NE.

Stutz, H. C. 1979. The meaning of "rare" and "endangered" in the evolution of western shrubs. Pages 119-128 *in* The endangered species: A symposium: Proceedings; Provo, UT; December 7-8, 1978. Great Basin Naturalist Memoirs No. 3. Brigham Young University, Provo, UT.

Tiedemann, A. R., E. D. McArthur, H. C. Stutz, R. Stevens, and K. L. Johnson. 1984. Proceedings—Symposium on the biology of *Atriplex* and related chenopods. General Technical Report INT-172, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Tilley, D., L. St John, and D. Ogle. 2010. Plant guide for sand dropseed (*Sporobolus cryptandrus*). United States Department of Agriculture Natural Resources Conservation Service, USDA NRCS Idaho Plant Materials Program.

Tisdale, E. W., and G. Zappetini. 1953. Halogeton studies on Idaho ranges. Journal of Range Management **6**:225-236.

Tueller, P. T., and W. H. Blackburn. 1974. Condition and trend of the big sagebrush/needleandthread habitat type in Nevada. Journal of Range Management **27**:36-40.

USFS. 1937. Range plant handbook. U.S. Department of Agriculture, Forest Service, Washington, D.C.

Vallentine, J. F. 1989. Range development and improvements. Academic Press, Inc., San Diego, CA.

Van Dersal, W. R. 1938. Native woody plants of the United States: Their erosion-control and wildlife values. U.S. Government Printing Office, Washington, D.C.

Van Epps, G. A. 1975. Winter injury to fourwing saltbush. Journal of Range Management Archives **28**:157-159.

Wallace, A., S. A. Bamberg, and J. W. Cha. 1974. Quantitative studies of roots of perennial plants in the Mojave Desert. Ecology **55**:1160-1162.

Wallace, A., W. Rhods, and E. Frolich. 1968. Germination behavior of *Salsola* as influenced by temperature, moisture, depth of planting, and gamma irradiation. Agronomy Journal **60**:76-78.

Wasser, C. H. 1982. Ecology and culture of selected species useful in revegetating disturbed lands in the West. FWS/OBS-82/56, U.S. Department of the Interior, Fish & Wildlife Service, Fort Collins, CO.

Weaver, J. E. 1958. Summary and interpretation of underground development in natural grassland communities. Ecological Monographs **28**:55-78.

Welch, B. L. 1989. Chapter 18: Nutritive value of shrubs. Pages 405-424 *in* C. McKell, editor. Biology and utilization of shrubs. Academic Press, Inc., San Diego, CA.

Welsh, S. L., N. D. Atwood, S. Goodrich, and L. C. Higgins. 1987. A Utah flora. Great Basin Naturalist Memoir No. 9 edition. Brigham Young University, Provo, Utah.

West, N. E. 1983. Temperate deserts and semi-deserts. Elsevier Science.

West, N. E. 1994. Effects of fire on salt-desert shrub rangelands. Pages 71-74 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, ID.

West, N. E., and J. Gasto. 1978. Phenology of the aerial portions of shadscale and winterfat in Curlew Valley, Utah. Journal of Range Management **31**:43-45.

Whisenant, S. G. 1990. Changing fire frequencies on Idaho's Snake River Plains: ecological and management implications. Pages 4-10 Proceedings--Symposium on Cheatgrass Invasion, Shrub Die-off and Other Aspects of Shrub Biology and Management: Las Vegas, NV, April 5-7, 1989. Gen. Tech. Rep. INT-GTR-276. Intermountain Research Station, Forest Service, U.S. Department of Agriculture, Ogden, UT.

Wright, H. A. 1985. Effects of fire on grasses and forbs in sagebrush-grass communities. Pages 12-21 *in* Rangeland fire effects: A symposium; Boise, ID; November 27-29, 1984. U.S. Department of the Interior, Bureau of Land Management, Boise, ID.

Wright, H. A., and J. O. Klemmedson. 1965. Effect of fire on bunchgrasses of the sagebrush-grass region in Southern Idaho. Ecology **46**:680-688.

Young, F., R. Veseth, D. Thill, W. Schillinger, and D. Ball. 1995. Managing Russian thistle under conservation tillage in crop-fallow rotations.

Young, J. A. 2002. Halogeton grazing management: Historical perspective. Journal of Range Management **55**:309.

Young, J. A., and R. A. Evans. 1978. Population dynamics after wildfires in sagebrush grasslands. Journal of Range Management **31**:283-289.

Young, R. P. 1983. Fire as a vegetation management tool in rangelands of the intermountain region. Pages 18-31 *in* Managing Intermountain rangelands—Improvement of range and wildlife habitats. Proceedings of Symposia: September 15-17, 1981, Twin Falls, Idaho June 22·24, 1982, Elko, Nevada. General Technical Report INT-GTR-157. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

MLRA 27 Group 12: Alkaline soils with shadscale and black greasewood

Description of MLRA 27 Disturbance Response Group 12

Disturbance Response Group (DRG) 12 consists of three ecological sites. These sites occur on alluvial flats, lake plains, beach plains and terraces, and fan skirts. The precipitation ranges from 3 to 8 in. Slopes range from 0 to 8%, but slopes of 0–2% are most typical. Elevations range from 3,000 to about 6,000 ft. Soils were formed in alluvium and lacustrine deposits, typically have coarse-textured soil surfaces, and are deep to very deep and are poorly to well drained. Soils are moderately to strongly alkaline and 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 Bailey's greasewood *(Sarcobatus baileyi)*, bud sagebrush *(Picrothamnus desertorum)*, green molly *(Bassia americana),* Mojave seablite (*Suaeda moquinii*), squirreltail *(Elymus elymoides)* and inland saltgrass (*Distichlis spicata*). Total annual air-dry production ranges from 100 to 350 lb/ac for a normal year with 75% to 80% of total production coming from the shrub component.

Disturbance Response Group 12 Ecological Sites:

Sodic Terrace – Modal	R027XY024NV
Dry Sodic Terrace	R027XY036NV
Dry Sodic Flat	R027XY094NV

Modal Site:

The Sodic Terrace (R027XY024NV) ecological site is the modal site that represents this DRG, as it has the most acres mapped. This site occurs on beach plains, alluvial flats, beach terraces, fan skirts, and lake plain terraces. Average annual precipitation ranges from 4 to 8 in. Slope gradients of 0–4% are most typical. Elevations are 3,300 to about 4,500 ft. The soils are deep to very deep and moderately well to 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 moderately to strongly alkaline and surface runoff is very slow to medium 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. Total annual air-dry production ranges from 150 to 500 lb/ac with 350 lb/ac for a normal year.

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 27 (MLRA 27 Fallon-Lovelock Area) is almost entirely in Nevada with < 1% in California. The entire area occurs in the rain shadow of the Sierra Nevada mountains and is influenced by Pleistocene Lake Lahontan. Extensive playas occur throughout the area and are a result of the drying of ancient Lake Lahontan. To the west, MLRA 27 has a gradual boundary with MLRA 26 (Carson Basin and Mountains) and to the east has a very gradual boundary with MLRA 24 (Humboldt Basin and Range Area). From west to east the soil temperature increases and the soil moisture decreases, resulting in vast areas dominated by salt-desert shrub communities. Isolated mountain ranges trending north to south are separated by broad desert plains and valleys. Elevations range from 3,300 to 5,900 ft with some mountain peaks over 7,800 ft. The average annual precipitation ranges from 4 to 11 in. and as much as 20 in. at the highest elevations. The majority of annual precipitation is received during late fall and winter occurring mainly as snow. High-intensity, convective thunderstorms also contribute significantly to annual precipitation (NRCS 2022). 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). Altered precipitation regimes combined with historical anthropogenic land uses (i.e. grazing, farming) 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 40–60 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 shadscale (Ewing and Dobrowolski 1992). Concerns with die-off include replacement by non-native species including cheatgrass (*Bromus tectorum*), halogeton (*Halogeton glomeratus*), Russian thistle *(Salsola tragus*) and western 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 1987b). Meinzer (1927) discovered that the taproots of black greasewood could penetrate from 20 to 57 ft below the surface (Meinzer 1927). Romo (Romo 1984) found water tables ranging from 3.5 to 15 m (11–49 ft) under black greasewood-dominated communities in Oregon. Black greasewood stands develop best where moisture is readily available, either from surface ponding or subsurface groundwater (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 (1986a) reported that water tables within 9.8–11.8 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 1988b, 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 tall (1.6 ft). 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).

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 4–10 in. and a spread of 8–12 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 9.8–11.8 in. (Chambers and Norton 1993). 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.

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).

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 (1–2 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 squirreltail.

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 in. tall (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 27, 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).

Squirreltail is a short, cool-season perennial bunchgrass that grows between 10 to 45 cm tall (4–19 in.). 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) (Tilley et al. 2006). 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 (Cronquist et al. 1977).

Inland saltgrass, a common perennial grass in this group, is a warm-season, rhizomatous species that grows 10–60 cm (4–24 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 8–12 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). 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 black greasewood which is replaced by an increase in saltgrass, rabbitbrush, shadscale and other species in the absence of drought.

The ecological sites in this DRG have low 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 halogeton and Russian thistle invade these sites where competition from perennial species is decreased.

Five possible stable states have been identified for this DRG: Reference, Current Potential State, Shrub State, Invasive Annual/Perennial State and Abiotic State.

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*), annual wheatgrass (*Eremopyrum triticeum*), 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. Dobrowolski et al. (1990) cite multiple authors on the extent of the soil profile exploited by the competitive exotic annual cheatgrass (Dobrowolski et al. 1990). 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 1.5–1.7 m (1.5–5.5 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 soil chemistry and limited winter precipitation. The annual invasive species most likely to invade this DRG are two tap-rooted forbs: Russian thistle and halogeton and a cool-season annual grass - annual wheatgrass. The forb species are summer annuals, germinating and growing in late spring and maturing in late summer/early fall. The summer rainfall associated with this MLRA likely facilitates the growth of the two tap-rooted, invasive forbs.

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 4–5 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).

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 2 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 1998).

Annual wheatgrass is a cool-season annual grass growing alone or in small tufts, 5–16 in. tall. It starts growth in late fall or early spring, depending on moisture availability, and flowers in late spring much like the growth habit of cheatgrass (Cronquist et al. 1977).

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 2 years following fire. They also counted 185 shrubs before wildfire and 210 shrubs 2 years following fire.

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).

Bud sagebrush does not sprout, and establishment occurs only from seed (Banner 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. 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). 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).

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:

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 15–20% 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 2+ years may be 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.

Bud sagebrush is 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 (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.

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 inland saltgrass following fire (Pritchett and Manning 2009).

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 inland saltgrass, sand dropseed, squirreltail 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 inland saltgrass, squirreltail, or invasive annual forbs may become the dominant understory with inappropriate grazing management.

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 27 Disturbance Response Group 12.

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:
The reference plant community is dominated by shadscale, black greasewood and Indian ricegrass. Other common species are squirreltail, inland saltgrass, bud sagebrush and Bailey's greasewood. 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 25% grasses, 5% forbs and 70% shrubs. Approximate ground cover (basal and crown) is 10–20%. 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 squirreltail decline in cover and frequency, while black greasewood, and occasionally rubber rabbitbrush (*Ericameria nauseosa*) 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, shadscale 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 inhibit annual dominance of non-natives.

Sodic Terrace (R027XY024NV), Shrub State 2.1, T. Stringham, June 2025

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. Fire is a rare occurrence but could occur in a wet year that facilitates abundant growth of annual non-natives.

Community Phase 2.2 (At-Risk):
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, deposition) suggests elevated risk of transition to an abiotic condition.

Community Phase 3.1 (At-Risk):
This community phase is dominated by black greasewood and other shrubs. Shadscale is present but often declining. Indian ricegrass and other bunchgrasses are reduced to trace amounts. Inland saltgrass may increase due to its grazing tolerance. Annual non-natives are present; wind erosion and crusting may increase. Soil deposition and redistribution indicate loss of stabilizing vegetation.

Sodic Terrace (R027XY024NV), Shrub State 3.1, T. Stringham, June 2025

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:
Long-term drought causes additional shrub mortality; black greasewood may dieback. 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.

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.

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. 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.

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

Trigger: 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.

Annual State 4.0:

This state has one community phase characterized by the dominance of non-native species such as halogeton, Russian thistle, and/or 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 (At-Risk):**
> 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 Terrace (R027XY024NV). Annual State 4.1 at risk to Abiotic State, T. Stringham, September 2024

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

Trigger: A mixture of climatic variables (drought/excessively wet), and/or chronic inappropriate cattle/sheep/horse grazing, and/or soil disturbing activities, which will eliminate annual forbs and any remaining perennials.

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

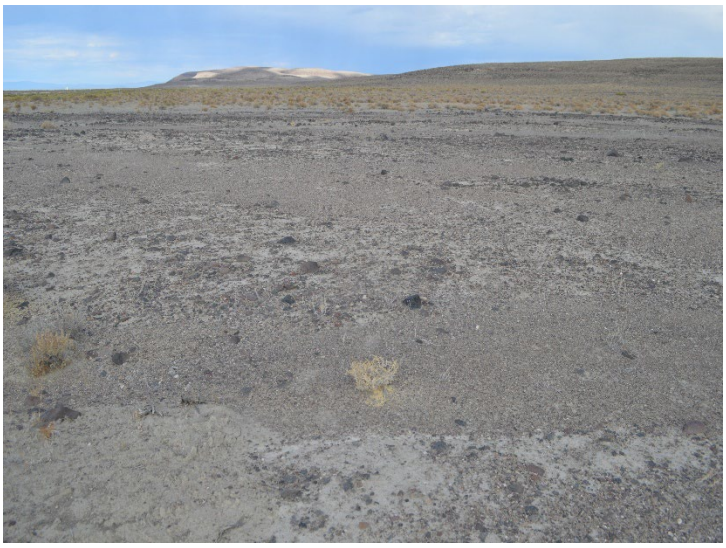
Threshold: Increased wind or water erosion resulting in soil loss preventing the establishment of native perennials. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and shrubs truncate energy capture spatially and temporally thus 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 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 (R027XY024NV), Abiotic State 5.1, T. Stringham, September 2025

Potential Resilience Differences with Other Ecological Sites in this Group

Dry Sodic Terrace (R027XY036NV):

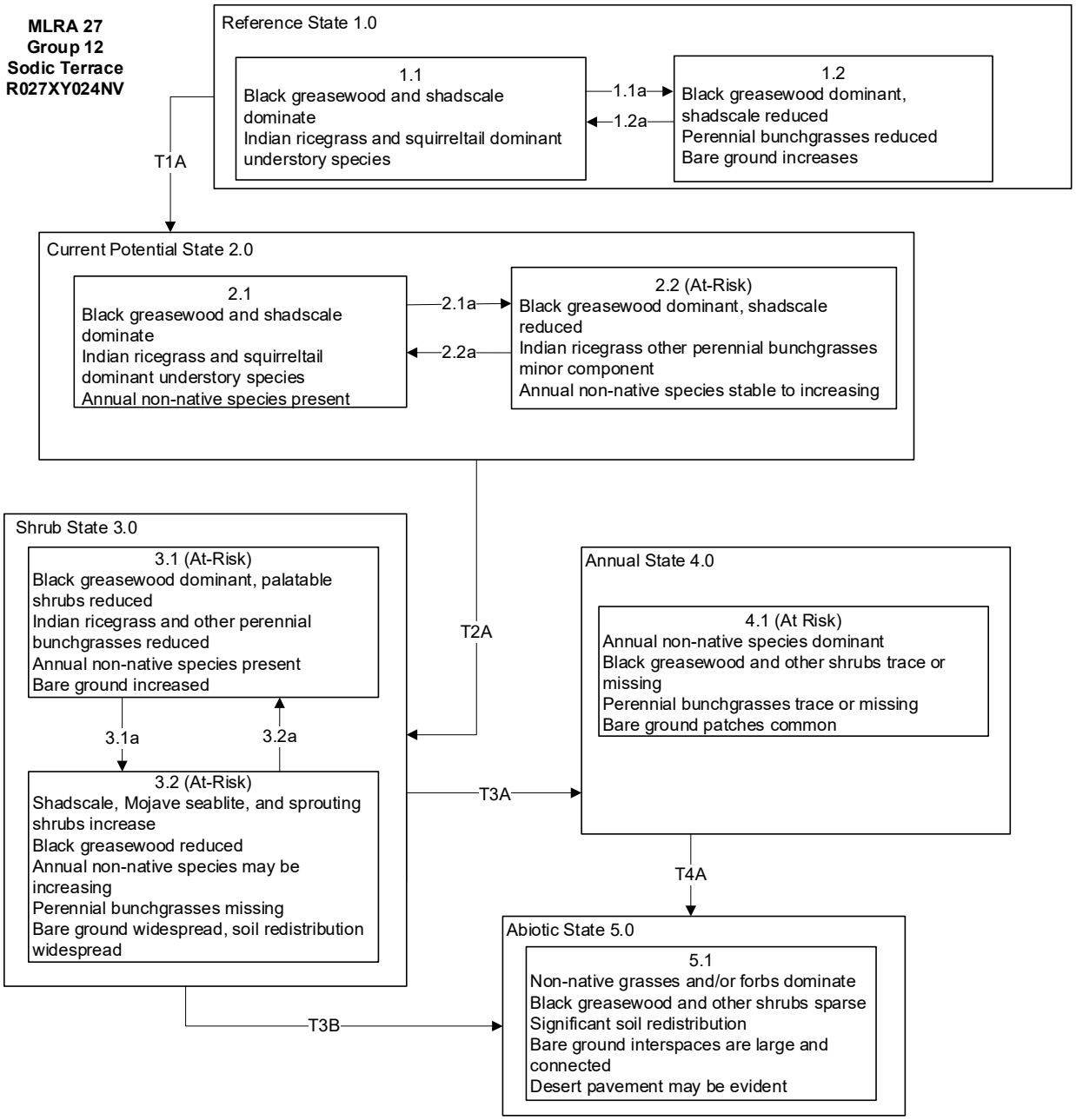
This site occurs on alluvial flats and fan skirts with slopes ranging from 0 to 4%. The reference plant community is dominated by shadscale and black greasewood. Although black greasewood makes up most of the annual production, shadscale is often prevalent enough to dominate the visual aspect. The resilience 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. An Annual State and Abiotic State were not observed during fieldwork.

Dry Sodic Terrace (R027XY036NV), Shrub State 3.2, T. Stringham, May 2024

Dry Sodic Flat (R027XY094NV):

This site occurs on lake plains and lake terraces on slopes ranging from 0 to 2%. A seasonal water table occurs 4–6 ft below the soil surface and the site is also subject to rare flooding events. Soils are affected by alkaline or sodic conditions and have clay or silty clay textures that limit water drainage. The reference plant community is dominated by Mojave seablite. Other species that occur include black greasewood, iodinebush, Indian ricegrass, foxtail barley and inland saltgrass. Potential vegetative composition by air-dry weight is approximately 90% shrubs, 5% grasses, and 5% forbs. Total annual air-dry production ranges from 75 to 300 lb/ac. The Annual and Abiotic states were not observed for this site and likely would not occur.

Modal State and Transition Model for Group 12 in MLRA 27



MLRA 27
Group 12
Sodic Terrace
R027XY024NV

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. An unusually wet spring reduces shadscale due to insect infestation and/or disease.
1.2a: Time, lack of disturbance and recovery from drought, insect infestation and/or disease would allow the deep-rooted bunchgrasses 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 perennial bunchgrasses. An unusually wet spring reduces shadscale due to insect infestation and/or disease. Less palatable shrubs and grasses may increase.
2.2a: Release from long-term drought, insect infestation and/or disease and/or appropriate grazing management (livestock and/or horse and burro grazing) allows recovery of deep-rooted bunchgrasses, bud sagebrush and other palatable shrubs.

Transition T2A: To Community Phase 3.1: Long-term 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 other shrubs to increase.

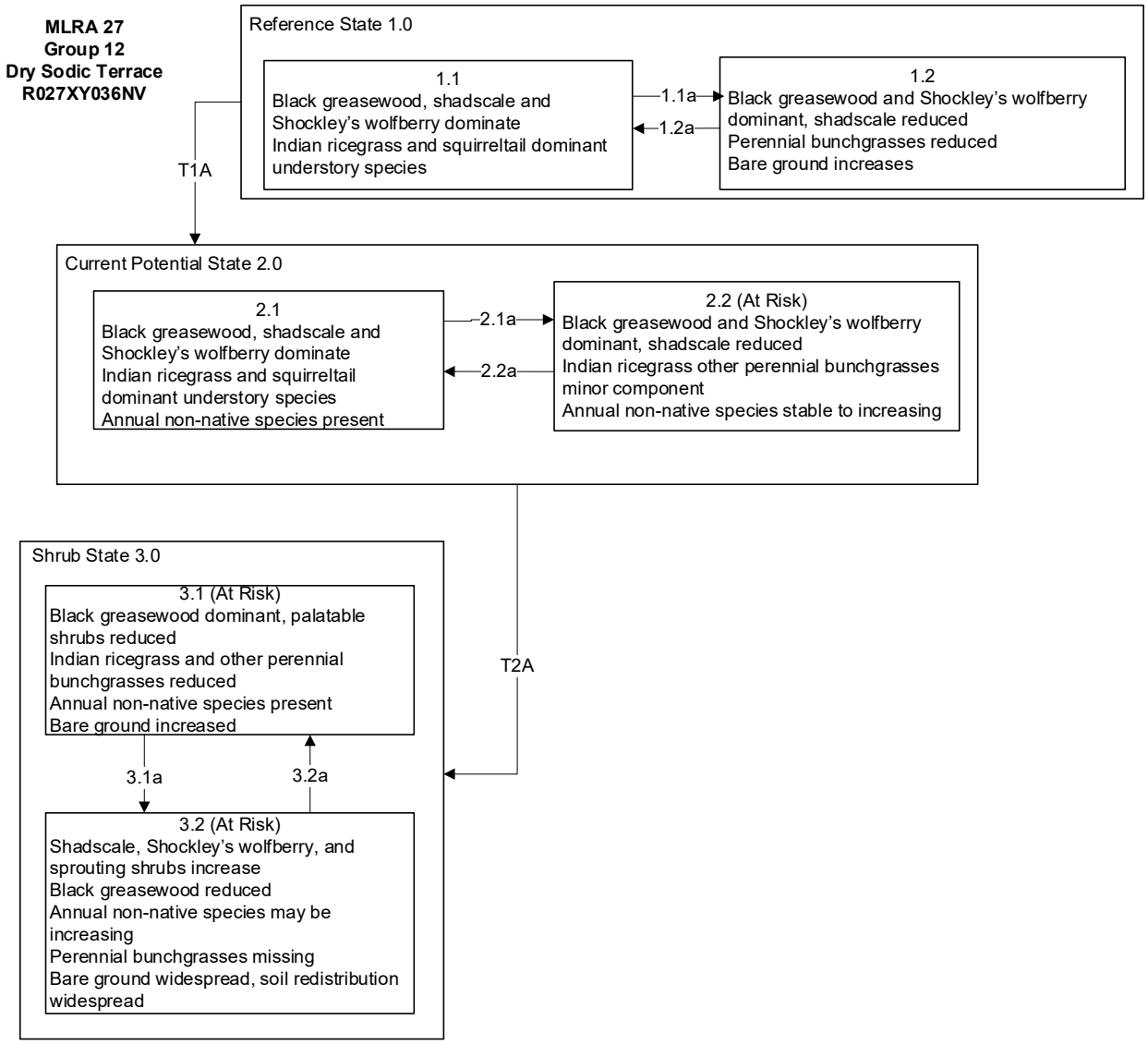
Shrub State 3.0 Community Phase Pathways
3.1a: Long-term drought causes additional shrub mortality. Groundwater declines may also reduce black greasewood cover.
3.2a: Appropriate grazing management and a sequence of favorable precipitation years may allow black greasewood and some perennial bunchgrasses to reestablish.

Transition T3A: Long-term winter drought and/or groundwater pumping lowers groundwater, reducing black greasewood vigor. May be combined with inappropriate grazing facilitating an increase in density and production on annual non-native forbs.

Transition T3B: A mixture of climatic variables (drought/excessively wet) and/or chronic inappropriate cattle/sheep/horse grazing and/or soil disturbing treatments which eliminate shrubs combined with significant soil loss and redistribution.

Transition T4A: A mixture of climatic variables (drought/excessively wet) and/or chronic inappropriate cattle/sheep/horse grazing, and/or soil disturbing activities, which will eliminate annual forbs and any remaining perennials.

Additional State and Transition Models for Group 12 in MLRA 27



MLRA 27
Group 12
Dry Sodic Terrace
R027XY036NV

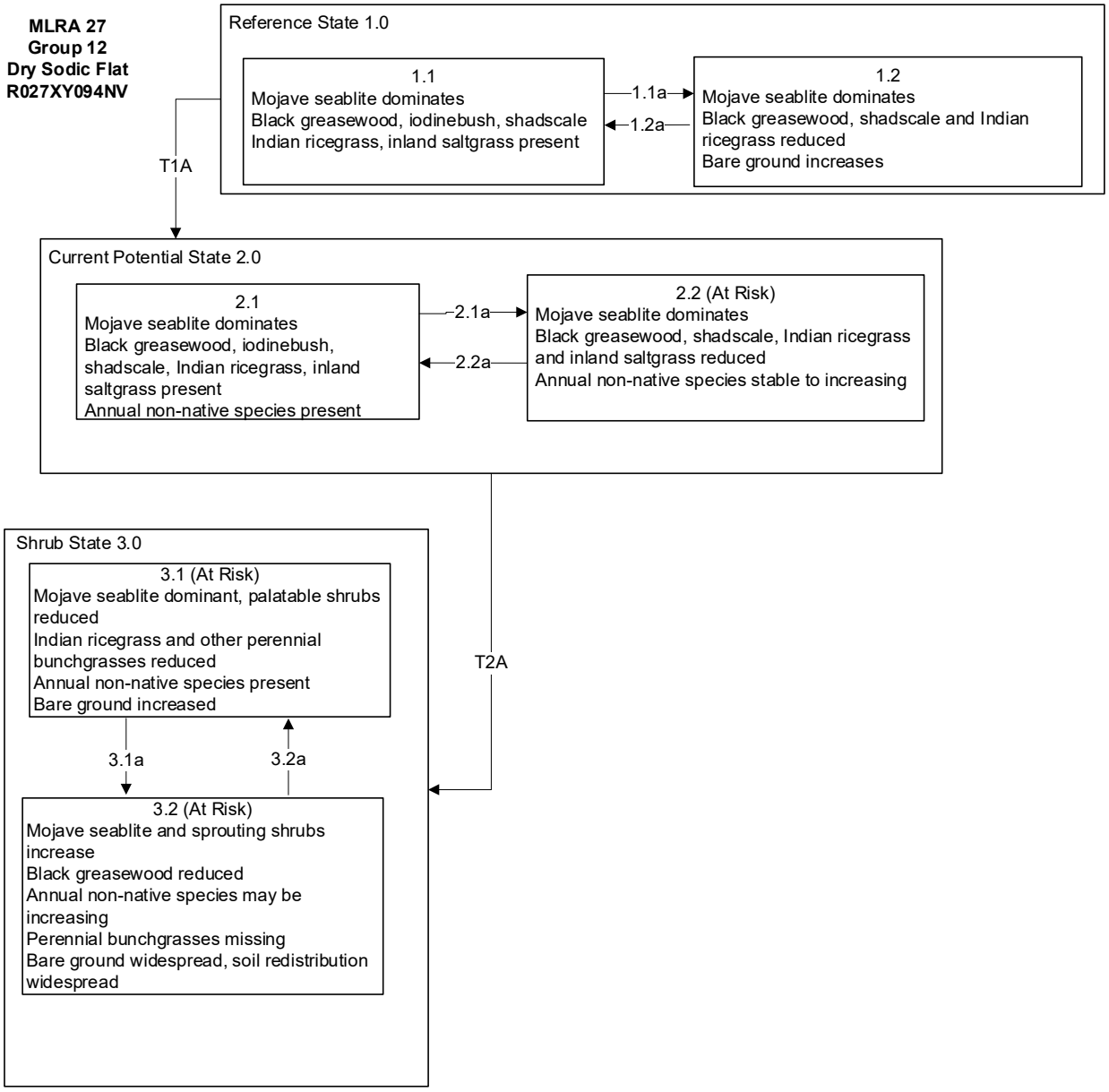
Reference State 1.0 Community Phase Pathways
1.1a: Prolonged drought and/or excessive herbivory reduces deep-rooted perennial grass density and production. Fires would also decrease vegetation on these sites but would be infrequent and patchy due to low fuel loads. An unusually wet spring reduces shadscale due to insect infestation and/or disease.
1.2a: Time, lack of disturbance and recovery from drought, insect infestation and/or disease 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 perennial bunchgrasses. An unusually wet spring reduces shadscale due to insect infestation and/or disease. Less palatable shrubs and grasses may increase.
2.2a: Release from long term drought, insect infestation and/or disease and/or growing season livestock and/or horse and burro grazing allows recovery of Indian ricegrass, bud sagebrush and other palatable shrubs.

Transition T2A: To Community Phase 3.1: Long-term 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 other shrubs to increase.

Shrub State 3.0 Community Phase Pathways
3.1a: Long-term drought causes additional shrub mortality. Inappropriate grazing will reduce perennial bunchgrasses and palatable shrub. Brush treatments with minimal soil disturbance reduce black greasewood and allow increase in sprouting shrubs.
3.2a: Grazing and/or horse and burro management and a sequence of favorable precipitation years may allow black greasewood and some perennial grasses to reestablish.


MLRA 27
Group 12
Dry Sodic Flat
R027XY094NV
Reference State 1.0
1.1
Mojave seablite dominates
Black greasewood, iodinebush, shadscale
Indian ricegrass, inland saltgrass present
1.1a
1.2a
1.2
Mojave seablite dominates
Black greasewood, shadscale and Indian ricegrass reduced
Bare ground increases
T1A
Current Potential State 2.0
2.1
Mojave seablite dominates
Black greasewood, iodinebush, shadscale, Indian ricegrass, inland saltgrass present
Annual non-native species present
2.1a
2.2a
2.2 (At Risk)
Mojave seablite dominates
Black greasewood, shadscale, Indian ricegrass and inland saltgrass reduced
Annual non-native species stable to increasing
T2A
Shrub State 3.0
3.1 (At Risk)
Mojave seablite dominant, palatable shrubs reduced
Indian ricegrass and other perennial bunchgrasses reduced
Annual non-native species present
Bare ground increased
3.1a
3.2a
3.2 (At Risk)
Mojave seablite and sprouting shrubs increase
Black greasewood reduced
Annual non-native species may be increasing
Perennial bunchgrasses missing
Bare ground widespread, soil redistribution widespread

MLRA 27
Group 12
Dry Sodic Flat
R027XY094NV

Reference State 1.0 Community Phase Pathways
1.1a: Prolonged drought and/or excessive herbivory reduces deep-rooted perennial grass density and production. An unusually wet spring reduces shadscale due to insect infestation and/or disease.
1.2a: Time, lack of disturbance and recovery from drought, insect infestation and/or disease 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, annual wheatgrass, 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 perennial bunchgrasses. An unusually wet spring reduces shadscale due to insect infestation and/or disease. Less palatable shrubs and grasses may increase.
2.2a: Release from long term drought, insect infestation and/or disease and/or growing season livestock and/or horse and burro grazing allows recovery of Indian ricegrass, bud sagebrush and other palatable shrubs.

Transition T2A: To Community Phase 3.1: Long-term inappropriate cattle/sheep/horse grazing will decrease deep-rooted perennial bunchgrasses and favor shrub growth and establishment. To Community Phase 3.2: Lowering of the water table due to groundwater pumping will also decrease black greasewood and iodinebush and allow the non-phreatophytic shrubs to increase.

Shrub State 3.0 Community Phase Pathways
3.1a: Long-term drought causes additional shrub mortality. Inappropriate grazing will reduce perennial bunchgrasses and palatable shrubs.
3.2a: Grazing and/or horse and burro management and a sequence of favorable precipitation years may allow black greasewood and some perennial grasses to reestablish.

References

Allen, E. B., and M. F. Allen. 1988. Facilitation of succession by the nonmycotrophic colonizer *Salsola kali* (Chenopodiaceae) on a harsh site: effects of mycorrhizal fungi. American Journal of Botany **75**:257-266.

Alpert, P. 1990. Water sharing among ramets in a desert population of *Distichlis spicata* (Poaceae). American Journal of Botany **77**:1648-1651.

Banner, R. E. 1992. Vegetation types of Utah. Rangelands **14**:109-114.

Bates, J. D., T. Svejcar, R. F. Miller, and R. A. Angell. 2006. The effects of precipitation timing on sagebrush steppe vegetation. Journal of Arid Environments **64**:670-697.

Beatley, J. C. 1975. Climates and vegetation pattern across the Mojave/Great Basin Desert transition of southern Nevada. The American Midland Naturalist **93**:53-70.

Benson, B., S. Green, D. Ogle, D. Tilley, and L. St. John. 2011. Plant guide for black greasewood (*Sarcobatus vermiculatus*). U.S. Department of Agriculture, Natural Resource Conservation Service, Boise, ID.

Bentz, B., D. Alston, and T. Evans. 2008. Great Basin insect outbreaks. Pages 45-48 *in* Collaborative management and research in the Great Basin - Examining the issues and developing a framework for action. General Technical Report RMRS-GTR-204. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Bich, B. S., J. L. Butler, and C. A. Schmidt. 1995. Effects of differential livestock use on key plant species and rodent populations within selected *Oryzopsis hymenoides*/*Hilaria jamesii* communities of Glen Canyon National Recreation Area. The Southwestern Naturalist **40**:281-287.

Blaisdell, J. P., and R. C. Holmgren. 1984. Managing intermountain rangelands - salt-desert shrub ranges. General Technical Report INT-163, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Blauer, A. C., A. P. Plummer, E. D. McArthur, R. Stevens, and B. C. Giunta. 1976. Characteristics and hybridization of important intermountain shrubs. II. Chenopod family. Research Paper INT-177, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Boerboom, C. 1993. Russian thistle (*Salsola iberica* Sennen & Pau).

Booth, D. T., C. G. Howard, and C. E. Mowry. 1980. 'Nezpar' Indian ricegrass: description, justification for release, and recommendations for use. Rangelands **2**:53-54.

Booth, E. G., J. F. Mount, and J. H. Viers. 2006. Hydrologic variability of the Cosumnes River floodplain. San Francisco Estuary and Watershed Science **4**:Article 2.

Bradbury, E. S., and D. L. Parrot, Jr. . 2020. Shoreline plants of Great Salt Lake. Great Saly Lake Biology **1**:369-396.

Bradley, A. F., N. V. Noste, and W. C. Fischer. 1992. Fire ecology of forests and woodlands in Utah. General Technical Report INT-287, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Branson, F. A., R. F. Miller, and I. S. McQueen. 1976. Moisture relationships in twelve northern desert shrub communities near Grand Junction, Colorado. Ecology **57**:1104-1124.

Britton, C. M., G. R. McPherson, and F. A. Sneva. 1990. Effects of burning and clipping on five bunchgrasses in eastern Oregon. The Great Basin Naturalist **50**:115-120.

Brown, R. W. 1971. Distribution of plant communities in southeastern Montana badlands. American Midland Naturalist **85**:458-477.

Buwai, M., and M. Trlica. 1977. Multiple defoliation effects on herbage yield, vigor, and total nonstructural carbohydrates of five range species. Rangeland Ecology & Management/Journal of Range Management Archives **30**:164-171.

Carlson, J. R. 1984. *Atriplex* cultivar development. Pages 176-182 *in* Proceedings—Symposium on the biology of *Atriplex* and related chenopods; May 2-6, 1983; Provo, UT. General Technical Report INT-172. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station.

Caudle, D., J. DiBenedetto, M. Karl, H. Sanchez, and C. Talbot. 2013. Interagency ecological site handbook for rangelands. U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.

Chambers, J. C., B. A. Bradley, C. S. Brown, C. D'Antonio, M. J. Germino, J. B. Grace, S. P. Hardegree, R. F. Miller, and D. A. Pyke. 2013. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of western North America. Ecosystems **17**:360-375.

Chambers, J. C., and B. E. Norton. 1993. Effects of grazing and drought on population dynamics of salt desert shrub species on the Desert Experimental Range, Utah. Journal of Arid Environments **24**:261-275.

Cibils, A. F., S. M. David, and D. E. McArthur. 1998. Plant-herbivore interactions in *Atriplex*: current state of knowledge. General Technical Report RMRS-GTR-14, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Clark, W. R., and F. H. Wagner. 1984. Role of livestock and black-tailed jackrabbits in changing abundance of *Kochia americana*. Great Basin Naturalist **44**:635-646.

Comstock, J. P., and J. R. Ehleringer. 1992. Plant adaptation in the Great Basin and Colorado Plateau. The Great Basin Naturalist **52**:195-215.

Cook, C. W. 1962. An evaluation of some common factors affecting utilization of desert range species. Journal of Range Management **15**:333-338.

Cook, C. W., and R. D. Child. 1971. Recovery of desert plants in various states of vigor. Rangeland Ecology & Management/Journal of Range Management Archives **24**:339-343.

Cook, C. W., and L. A. Stoddart. 1953. Bulletin No. 364 - The halogeton problem in Utah. UAES Bulletins.

Crofts, K. A., and G. V. Epps. 1975. The usefulness of shadscale in the revegetation of disturbed sites in the salt desert shrub type. Pages 151-152 *in* Proceedings: Symposium and workshop: Wildland shrubs. U.S. Department of Agriculture, Forest Service, Shrub Sciences Laboratory, Provo, UT.

Cronin, E. H. 1965. Ecological and physiological factors influencing chemical control of *Halogeton glomeratus*. US Department of Agriculture.

Cronquist, A., A. H. Holmgren, N. H. Holmgren, J. L. Reveal, and P. K. Holmgren. 1977. Intermountain flora: Vascular plants of the Intermountain West, U.S.A. Volume six. The Monocotyledons. Columbia University Press, New York, NY.

Dobrowolski, J. P., M. M. Caldwell, and J. H. Richards. 1990. Chapter 7: Basin hydrology and plant root systems. Pages 243-292 *in* C. B. Osmond, L. F. Pitelka, and G. M. Hidy, editors. Plant Biology of the Basin and Range. Springer-Verlag, New York City, NY.

Eckert, R. E., Jr., A. D. Bruner, and G. J. Klomp. 1972. Response of understory species following herbicidal control of low sagebrush. Journal of Range Management **25**:280-285.

Eckert, R. E., Jr., and J. S. Spencer. 1987. Growth and reproduction of grasses heavily grazed under rest-rotation management. Journal of Range Management **40**:156-159.

Eddleman, L. E. 2008. *Sarcobatus vermiculatus* (Hook.) Torr. - black greasewood. Pages 1022-1024 *in* F. T. Bonner and R. P. Karrfalt, editors. The Woody Plant Seed Manual. Agriculture Handbook 727. U.S. Department of Agriculture, Forest Service, Washington, D.C.

Everett, R. L., P. T. Tueller, J. B. Davis, and A. D. Brunner. 1980. Plant phenology in galleta-shadscale and galleta-sagebrush associations. Rangeland Ecology & Management/Journal of Range Management Archives **33**:446-450.

Ewing, K., and J. P. Dobrowolski. 1992. Dynamics of shrub die-off in a salt desert plant community. Rangeland Ecology & Management/Journal of Range Management Archives **45**:194-199.

Ganskopp, D. C. 1986a. Tolerances of sagebrush, rabbitbrush, and greasewood to elevated water tables. Journal of Range Management **39**:334-337.

Groeneveld, D. P. 1990. Shrub rooting and water acquisition on threatened shallow groundwater habitats in the Owens Valley, California. Pages 221-237 *in* Proceedings—Symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; Las Vegas, NV; April 5-7, 1989. General Technical Report INT-276. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Groeneveld, D. P., and D. E. Crowley. 1988b. Root system response to flooding in three desert shrub species. Functional Ecology **2**:491-497.

Harper, K. T., F. J. Wagstaff, and W. P. Clary. 1990. Shrub mortality over a 54-year period in shadscale desert, west-central Utah. Pages 119-126 *in* Proceedings—Symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; Las Vegas, NV, April 5-7, 1989; General Technical Report INT-276. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Harr, R. D., and K. R. Price. 1972. Evapotranspiration from a greasewood-cheatgrass community. Water Resources Research **8**:1199-1203.

Hironaka, M. 1994. Medusahead: Natural successor to the cheatgrass type in the northern Great Basin. Pages 89-91 *in* Proceedings—Ecology and management of annual rangelands; September 1994; Boise, ID. General Technical Report INT-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Hironaka, M., and E. Tisdale. 1963. Secondary succession in annual vegetation in southern Idaho. Ecology **44**:810-812.

Hironaka, M., and E. W. Tisdale. 1973. Growth and development of *Sitanion hystrix* and *Poa sandbergii*. Research Memorandum RM 73-16, U.S. International Biological Program, Desert Biome, Logan, UT.

Hutchings, S. S., and G. Stewart. 1953. Increasing forage yields and sheep production on intermountain winter ranges. Circular No. 925, U.S. Department of Agriculture, Washington, D.C.

Johnson, K. L. 1978. Wyoming shrublands: Proceedings of the 7th Wyoming shrub ecology workshop; Rock Springs, WY; May 31 - June 1, 1978. University of Wyoming, Range Management Division, Wyoming Shrub Ecology Workshop.

Johnson, N. C. 1998. Responses of *Salsola kali* and *Panicum virgatum* to mycorrhizal fungi, phosphorus and soil organic matter: implications for reclamation. Journal of Applied Ecology **35**:86-94.

Kadereit, G., and H. Freitag. 2011. Molecular phylogeny of Camphoromeae (Camphorsmoideae, Chenopodiaceae): Implications for biogeography, evolution of C4-photosynthesis and taxonomy. TAXON **60**:51-78.

Kulpa, S. M., and E. A. Leger. 2013. Strong natural selection during plant restoration favors an unexpected suite of plant traits. Evolutionary Applications **6**:510-523.

Marlette, G. M., and J. E. Anderson. 1986. Seed banks and propagule dispersal in crested-wheatgrass stands. Journal of Applied Ecology **23**:161-175.

Medin, D. E. 1990. Birds of a shadscale (*Atriplex confertifolia*) habitat in east central Nevada. The Great Basin Naturalist **50**:295-298.

Meinzer, O. E. 1927. Plants as indicators of ground water. Water-Supply Paper 577, U.S. Department of the Interior, U.S. Geological Survey, Washington, D.C.

Miller, R. F., S. T. Knick, D. A. Pyke, C. W. Meinke, S. E. Hanser, M. J. Wisdom, and A. L. Hild. 2008a. Characteristics of sagebrush habitats and limitations to long-term conservation. Administrative Report, U.S. Department of the Interior; U.S. Geological Survey, Reston, VA.

Mohebby, A., M. Jafari, A. Tavili, S. A. Javadi, E. Zandi Esfahan, and M. Ramezani. 2012. Effect of livestock grazing on growth characteristics of *Atriplex canescens*. Desert **17**:290-303.

Monsen, S. B., R. Stevens, and N. L. Shaw. 2004a. Grasses. Pages 295-424 *in* S. B. Monsen, R. Stevens, and N. L. Shaw, editors. Restoring western ranges and wildlands, vol. 2. Gen. Tech. Rep. RMRS-GTR-136-vol-2. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Mozingo, H. N. 1987b. Shrubs of the Great Basin: A natural history. University of Nevada Press, Reno, NV.

Nelson, D. L., K. T. Harper, K. C. Boyer, D. J. Weber, B. A. Haws, and J. R. Marble. 1989. Wildland shrub dieoffs in Utah: An approach to understanding the cause. Pages 119-135 *in* Proceedings—Symposium on shrub ecophysiology and biotechnology; General Technical Report INT-256. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Logan, UT.

Newman, S. D., and M. Gates. 2000. Plant guide for saltgrass (*Distichlis spicata*). U.S. Department of Agriculture, Natural Resource Conservation Service, Alexandria, LA.

NRCS. 2022. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. Handbook 296, U.S. Department of Agriculture, Natural Resources Conservation Service.

Paysen, T. E., R. J. Ansley, J. K. Brown, G. J. Gottfried, S. M. Haase, M. G. Harrington, M. G. Narog, S. S. Sackett, and R. C. Wilson. 2000. Chapter 6: Fire in western shrubland, woodland, and grassland ecosystems. Pages 121-159 *in* J. K. Brown and J. K. Smith, editors. Wildland fire in ecosystems: Effects of fire on flora. General Technical Report RMRS-GTR-42-Vol. 2. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Pearson, L. 1979. Effects of temperature and moisture on phenology and productivity of Indian ricegrass. Rangeland Ecology & Management/Journal of Range Management Archives **32**:127-134.

Pearson, L. C. 1964. Effect of harvest date on recovery of range grasses and shrubs. Agronomy Journal **56**:80-82.

Pearson, L. C. 1965. Primary production in grazed and ungrazed desert communities of eastern Idaho. Ecology **46**:278-285.

Peters, E. F., and S. C. Bunting. 1994. Fire conditions pre-and post-occurrence of annual grasses on the Snake River Plain. Pages 31-36 *in* Proceedings—Ecology and management of annual rangelands; September, 1994; Boise, ID. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Pritchett, D. W., and S. J. Manning. 2009. Effects of fire and groundwater extraction on alkali meadow habitat in Owens Valley, California. Madroño **56**:89-98.

Qian, Y. L., J. A. Cosenza, S. J. Wilhelm, and D. Christensen. 2006. Techniques for enhancing saltgrass seed germination and establishment. Crop Science **46**:2613-2616.

Quinones, F. A. 1981. Indian ricegrass evaluation and breeding. Bulletin 681, New Mexico State University, Agricultural Experiment Station, Las Cruces, NM.

Reynolds, T. D., and L. Fraley, Jr. 1989. Root profiles of some native and exotic plant species in southeastern Idaho. Environmental and Experimental Botany **29**:241-248.

Rickard, W. H., and M. C. McShane. 1984. Demise of spiny hopsage shrubs following summer wildfire: An authentic record. Northwest Science **58**:282-285.

Romo, J. T. 1984. Water relations in *Artemisia tridentata* subsp. *wyomingensis*, *Sarcobatus vermiculatus*, and *Kochia prostrata*. PhD Dissertation. Oregon State University, Corvallis, OR.

Rood, K. A., K. E. Panter, D. R. Gardner, B. L. Stegelmeier, and J. O. Hall. 2014. Halogeton (*H. glomeratus*) poisoning in cattle: Case report. Animal, Dairy, and Veterinary Science Faculty Publications - Utah State **3**:23-26.

Sanderson, S. C., H. C. Stutz, and E. D. McArthur. 1990. Geographic differentiation in *Atriplex confertifolia*. American Journal of Botany **77**:490-498.

Smith, M. A., J. D. Rodgers, J. L. Dodd, and Q. D. Skinner. 1992. Habitat selection by cattle along an ephemeral channel. Journal of Range Management **45**:385-390.

Smith, S. D., and P. S. Nobel. 1986. Photosynthesis in contrasting environments. Elsevier Science Publishers, Amsterdam, New York.

Stubbendieck, J. L., S. L. Hatch, N. M. Bryan, and C. D. Dunn. 2017. North American wildland plants. Third edition. University of Nebraska Press, Lincoln, NE.

Stubbendieck, J. L., S. L. Hatch, and C. H. Butterfield. 1992. North American range plants. Fourth edition. University of Nebraska Press, Lincoln, NE.

Stubbendieck, J. L., J. T. Nichols, and K. K. Roberts. 1985. Nebraska range and pasture grasses (including grass-like plants). University of Nebraska, Department of Agriculture, Cooperative Extension Service, Lincoln, NE.

Tilley, D. J., D. Ogle, L. St. John, L. Holzworth, T. A. Jones, and S. R. Winslow. 2006. Plant guide for bottlebrush squirreltail & big squirreltail (*Elymus elymoides* & *Elymus multisetus*). U.S. Department of Agriculture, Natural Resources Conservation Service.

Tisdale, E. W., and G. Zappetini. 1953. Halogeton studies on Idaho ranges. Journal of Range Management **6**:225-236.

Vallentine, J. F. 1989. Range development and improvements. Academic Press, Inc., San Diego, CA.

Wallace, A., W. Rhods, and E. Frolich. 1968. Germination behavior of *Salsola* as influenced by temperature, moisture, depth of planting, and gamma irradiation. Agronomy Journal **60**:76-78.

West, N. E. 1994. Effects of fire on salt-desert shrub rangelands. Pages 71-74 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, ID.

Wood, B. W., and J. D. Brotherson. 1986. Ecological adaptation and grazing response of budsage (*Artemisia spinescens*). Pages 75-92 *in* Symposium on the biology of *Artemisia* and *Chrysothamnus*; Provo, UT; July 9-13, 1984; General Technical Report INT-200. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Wood, M. K., B. A. Buchanan, and W. Skeet. 1995. Shrub preference and utilization by big game on New Mexico reclaimed mine land. Journal of Range Management **48**:431-437.

Wright, H. A. 1971. Why squirreltail is more tolerant to burning than needle-and-thread. Journal of Range Management **24**:277-284.

Wright, H. A. 1985. Effects of fire on grasses and forbs in sagebrush-grass communities. Pages 12-21 *in* Rangeland fire effects: A symposium; Boise, ID; November 27-29, 1984. U.S. Department of the Interior, Bureau of Land Management, Boise, ID.

Wright, H. A., and J. O. Klemmedson. 1965. Effect of fire on bunchgrasses of the sagebrush-grass region in Southern Idaho. Ecology **46**:680-688.

Young, F., R. Veseth, D. Thill, W. Schillinger, and D. Ball. 1995. Managing Russian thistle under conservation tillage in crop-fallow rotations.

Young, J. A., and C. D. Clements. 2006. Nevada rangelands. Rangelands **28**:10-15.

Young, J. A., and R. A. Evans. 1977. Squirreltail seed germination. Journal of Range Management **30**:33-36.

Young, J. A., and F. Tipton. 1990. Invasion of cheatgrass into arid environments of the Lahontan Basin. Pages 37-40 *in* Proceedings—Symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; Las Vegas, NV; April 5-7, 1989; General Technical Report INT-276. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Young, R. P. 1983. Fire as a vegetation management tool in rangelands of the intermountain region. Pages 18-31 *in* Managing Intermountain rangelands—Improvement of range and wildlife habitats. Proceedings of Symposia: September 15-17, 1981, Twin Falls, Idaho June 22·24, 1982, Elko, Nevada. General Technical Report INT-GTR-157. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Zielinski, M. J. 1994. Controlling erosion on lands administered by the Bureau of Land Management, Winnemucca District, Nevada. Pages 143-146 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

MLRA 27 Group 13: Seasonally flooded areas with black greasewood and basin wildrye

Description of MLRA 27 Disturbance Response Group 13

Disturbance Response Group (DRG) 13 consists of one ecological site, Saline Bottom (R027XY006NV). This site occurs on stream terraces, floodplains and lake plains. The precipitation ranges from 4 to 8 in. Slopes range from 0 to 4%. Elevation ranges from approximately 3,000 to 5,500 ft. The soils on these sites are very deep and poorly drained. The soils are formed in lacustrine sediments and/or alluvium from mixed rock sources. The soils are subject to flooding and ponding 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 and the soil moisture regime is aridic bordering on xeric. Runoff is very slow, water holding capacity is low to moderate, and permeability is moderately slow to slow. The reference plant community is dominated by basin wildrye (*Leymus cinereus*). Other common grasses include inland saltgrass (*Distichlis spicata*), beardless wildrye (*Leymus triticoides*) and alkali sacaton (*Sporobolus airoides).* Shrubs that occur on this site include black greasewood (*Sarcobatus vermiculatus*), rubber rabbitbrush (*Ericameria nauseosa*) and shadscale (*Atriplex confertifolia*). Total annual production ranges from 800 to 2,000 lb/acre with 1,500 lb/ac in a normal year.

Disturbance Response Group 13 Ecological Sites:

Saline Bottom – Modal R027XY006NV

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 27 (MLRA 27 Fallon-Lovelock Area) is almost entirely in Nevada with < 1% in California. The entire area occurs in the rain shadow of the Sierra Nevada mountains and is influenced by Pleistocene Lake Lahontan. Extensive playas occur throughout the area and are a result of the drying of ancient Lake Lahontan. To the west, MLRA 27 has a gradual

boundary with MLRA 26 (Carson Basin and Mountains) and to the east has a very gradual boundary with MLRA 24 (Humboldt Basin and Range Area). From west to east the soil temperature increases and the soil moisture decreases, resulting in vast areas dominated by salt-desert shrub communities. Isolated mountain ranges trending north to south are separated by broad desert plains and valleys. Elevations range from 3,300 to 5,900 ft with some mountain peaks over 7,800 ft. The average annual precipitation ranges from 4 to 11 in. and as much as 20 in. at the highest elevations. The majority of annual precipitation is received during late fall and winter occurring mainly as snow. High-intensity, convective thunderstorms also contribute significantly to annual precipitation (NRCS 2022). 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 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).

Agricultural History:

This ecological site is mapped in the Fallon and Yerington areas with many locations now under cultivation. Agricultural development in the Fallon area began in the early 1850s when overland stage travel was at its peak (Strahorn 1909). The first permanent settlements were made on the Carson River and the South Branch of the Carson at points where the overland trails crossed the rivers. Later settlements occurred on adjacent lands where it was possible to irrigate from the spring flow of the rivers to grow crops for local consumption. Large scale agricultural development started after the construction of the Newlands Project by the U.S. Reclamation Service (Headley and Venstrom 1930).

In the Yerington area, the major sources of irrigation water are the east and west forks of the Walker River and the Carson River. The Walker River Irrigation District was organized in April 1919 to improve irrigation operations on the river. Water is distributed through a complex system of ditches throughout the Mason and Smith valleys (Archer 1984). Main crops of importance include alfalfa, wheat, oats, lettuce, onions, garlic and pasture.

Hydrology, Drought, Groundwater Interpretations:

Black greasewood, the dominant shrub of this group, is a cool-season (C3), spiny, semi-evergreen shrub that grows 3–10 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 1987b, Trent et al. 1997, Naumburg et al. 2005). Black greasewood covers roughly 2 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 1987b, 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 (12–49 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 (1986a) reported that water tables within 9.8–11.8 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 1988b, 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).

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 1–3 m (3.3–10 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 (3.3–20 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 2004b).

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 10–60 cm (4–24 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 8–12 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 black greasewood, alkali sacaton, and basin wildrye, which is replaced by an increase in saltgrass, rabbitbrush, shadscale and other species in the absence of drought.

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 4–27 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 1988a). General differences in root depth distributions between grasses and shrubs results in resource partitioning in these shrub/grass systems (Lee and Lauenroth 1994).

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 non-native species and bare ground will increase.

The ecological site in this DRG has moderate resilience to disturbance and resistance to invasion because of the occurrence of a groundwater table, additional run-in moisture and high productivity. Possible disturbances include inappropriate grazing practices, drought,

groundwater pumping, singleleaf pinyon and/or Utah juniper encroachment in the watershed, agriculture, and/or fire. These disturbances may facilitate a decrease in native species and an increase in non-native species. Non-native species invade these sites where competition from perennial species is decreased. Six stable states have been identified for this DRG.

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 (*Bromus tectorum*), 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. 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 1.5–1.7 m (60–67 in.).

Annual non-native species such as halogeton, Russian thistle, tall tumblemustard (*Sisymbrium altissimum*), kochia or burning bush (*Bassia scoparia*) and mouse barley (*Hordeum murinum*) invade this site where competition from perennial species is decreases. Perennial non-native species such as Russian knapweed (*Rhaponticum repens*) and whitetop (*Cardaria draba*) may also invade this site.

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 lb 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 < 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 1998).

Kochia is a non-native, erect, annual forb and is common throughout the western and northern US and throughout Canada (Friesen 2009). Kochia is native to central and eastern Europe and Asia and is particularly adapted to arid and semi-arid regions (Casey 2014). It was likely introduced as an ornamental in the mid-to late 1800s (Friesen 2009). Kochia exhibits early germination making it capable of utilizing spring moisture and seeds will continue to germinate throughout the growing season as long as moisture is available (Friesen 2009). In Nevada, kochia occurs in most counties.

Mouse barley is a small winter annual grass, native to central Europe, south to northern Africa and east to western Asia and the Caucasus (Cronquist et al. 1977). It was introduced, likely associated with wool and farm animals, to North and South America, Australia and New Zealand (Davison 1977). It occurs along roadsides, ditch banks and other disturbed areas where there is good soil moisture (Cronquist et al. 1977). In Nevada, mouse barley occurs mostly in central to southern Nevada.

Russian knapweed is a non-native, perennial, noxious and invasive weed from Eurasia. It is a perennial herb with erect stems that grow from 18 to 36 in. tall. Flowers occur singly on shoot tips from June to September (Holmgren and Holmgren 1977). The seeds develop in late summer and are viable in the soil for at least 2–3 years (Foster et al. 2011). Russian knapweed produces an extensive vertical and horizontal root system penetrating the soil to several meters (Graham and Johnson 2004). In Nevada, Russian knapweed occurs on rangelands, pasture and croplands (Foster et al. 2011).

Whitetop, also known as hoary cress, is a non-native, rhizomatous, long-lived perennial, that is native to Russia, eastern European countries and the Middle East. It grows up to 2 ft tall and produces rosettes and flowering stems (Holmgren et al. 2005). Whitetop invades rangeland, pastures, croplands, moist meadows and floodplains (Jacobs 2007). It reproduces by seed or by horizontal growth of rootstocks (Miller 1991), although it relies on vegetative reproduction from extensive root systems to increase plant density and local population expansion (Jacobs 2007). Individual plants can produce from 50 to 450 stems depending on environmental conditions and competition from other plants (Jacobs 2007).

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). These communities 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.

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.

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.

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.

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.

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 2–4 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 1988a). 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.

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 27 Disturbance Response Group 13.

Six possible alternative stable states have been identified for this DRG including a shrub-dominated state, a non-native invasive state, an abiotically controlled state, and an agricultural 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, groundwater fluctuations, periodic drought and/or insect or disease attack.

Community Phase 1.1:
The reference plant community is dominated by basin wildrye and black greasewood. Inland saltgrass, alkali sacaton, 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 25–40%. Total annual air-dry production ranges from 800 to 2,000 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. Low severity fires typically create a mosaic pattern of grass and shrubs. A high severity fire will reduce black greasewood cover to trace amounts.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.3:
Absence of disturbance (fire) over time, 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 dominates 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 rubber 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 rubber 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 and 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 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.

T1B: Transition from Reference State 1.0 to Agricultural State 6.0:

Trigger: Settlement of the area which included damming of the Carson, Truckee, and Walker rivers, construction of canals, diversion of water for irrigation, plowing and brush removal, land leveling and building furrows for irrigation.

Slow variables: Over time, local drainage improvement effectively lowered the water table. Increase in salt salinity from furrow irrigation. Reduction in soil organic carbon from the conversion of rangeland to cropland.

Threshold: Removal of native vegetation by soil disturbance causes loss of soil structure, soil compaction, reduced infiltration, increased wind and water erosion, loss of organic matter and nutrient-rich topsoil, and reduced moisture retention. These changes make restoration extremely challenging.

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 and black greasewood. Rubber rabbitbrush and other shrubs make up the minor components. Non-native annual species such as halogeton, Russian thistle and kochia 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 decrease the overstory of black greasewood and allow for the understory perennial grasses to increase. Low severity fires typically create a mosaic pattern of grass and shrubs. A high severity fire will 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. Basin wildrye dominates the site while inland saltgrass and alkali sacaton are minor components. 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.

Saline Bottom (R027XY006NV), Current Potential 2.2, T. Stringham, June 2024

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. Rubber 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 basin wildrye. 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: 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 perennial grasses 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. Shrub mounds may be present.

> **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 mounds is prevalent due to soil displacement caused by water and wind erosion. Invasive forbs likely dominate the understory.

T3A: Transition from Shrub State 3.0 to Abiotic State 5.0:

Trigger**:** Long-term, inappropriate grazing management, flooding, severe drought, long-term groundwater pumping, land clearing 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 soil surfaces.

Annual State 4.0:

This state consists of one community phase in which annual invasive species control site processes. It is characterized by the loss of cropland, hay or pasture plant species and increased bare ground. Feedbacks contributing to the stability of this state include a seed bank of annual invasive species, water table reduction, soil surface degradation and loss, nutrient loss, and increased bare ground patch size.

Community Phase 4.1 (At-Risk):
This community phase is the result of loss of irrigation water and loss of cropland, hay or pasture plant species. Conservation (farming) practices are no longer implemented and the site is allowed to naturally recolonize. The vegetative cover is dominated by non-native annual species. Bare ground is extensive, leaving the field susceptible to wind erosion. Trace amounts of native species may be present and bare ground interspaces are large and connected. Site function is controlled by non-native vegetation. Soil erosion and redistribution is occurring. Site is at-risk of transitioning to an Abiotic State.

Saline Bottom (R027XY006NV), Annual State 4.1, T. Stringham, June 2025

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

Trigger**:** Cessation of farming practices including the removal of irrigation water and loss of cropland, hay or pasture species. Long-term drought reduces cover of annual invasive species resulting in increased bare ground. Significant soil loss and redistribution is occurring. Soil compaction (plow pan) reduces infiltration and effective rooting depth. Soil surface is crusted.

Slow variables: Soil redistribution is significant and on-going. Reduction in soil organic matter inputs contributes to soil surface crusting and reduced infiltration. Reduced infiltration leads to reduced soil water promoting a continued reduction in vegetation.

Threshold: Soil compaction and soil surface changes due to long-term farming practices combined with removal of farming practices and irrigation leads to significant soil redistribution, soil temperature increases, organic matter loss, soil surface ponding, and reduced infiltration.

Abiotic State 5.0:

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 5.1:
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 native species may be present and bare ground interspaces are large and connected. Site function is controlled by soil erosion and redistribution and soil temperature.

Saline Bottom (R027XY006NV), Abiotic State 5.1, T. Stringham, June 2024

Agricultural State 6.0:

This state is characterized by an irrigated agriculture phase with either cropland, hayland or pasture. Irrigation water is critical to the production of crops in this MLRA because of low precipitation. Once irrigation water is removed the lasting effects on the soil include diminished soil stability, altered soil structure, compaction, reduced infiltration and increased wind and water erosion.

Community Phase 6.1 (Irrigated Agriculture):
This community phase is either cropland, hayland or pasture actively maintained by irrigation water during the growing season. Typical crops include alfalfa, corn, oats and wheat. Conservation practices implemented include pasture and hay planting, irrigation water management, nutrient management, forest harvest management, conservation crop rotation, and cover crop.

Saline Bottom (R027XY006NV), Agricultural State 6.1, T. Stringham, June 2025

T6A: Transition from Agricultural State 6.0 to Annual State 4.0:

Trigger**:** Cessation of farming practices including the removal of irrigation water and the loss of cropland, hay or pasture species. Residual nitrogen and phosphorus from prior fertilizer applications favors fast-growing, early-successional non-native invasive species which dominate the site.

Slow variables: Long-term increase in non-native annual species and their associated seed bank. Native seed banks are depleted. Soil redistribution is significant.

Threshold: Reduced cover of seeded, cropland, hay or pasture plant species due to the removal of irrigation and farming practices facilitates invasion of non-native annual species. Changes in plant community composition and spatial variability of vegetation due to the loss of crop, hay or pasture species truncates energy capture spatially and temporally thus impacting nutrient cycling and distribution. Soil compaction, soil surface degradation and redistribution lead to decreased infiltration, increased flow path length, crusting, salt accumulation on the soil surface and altered soil biology.

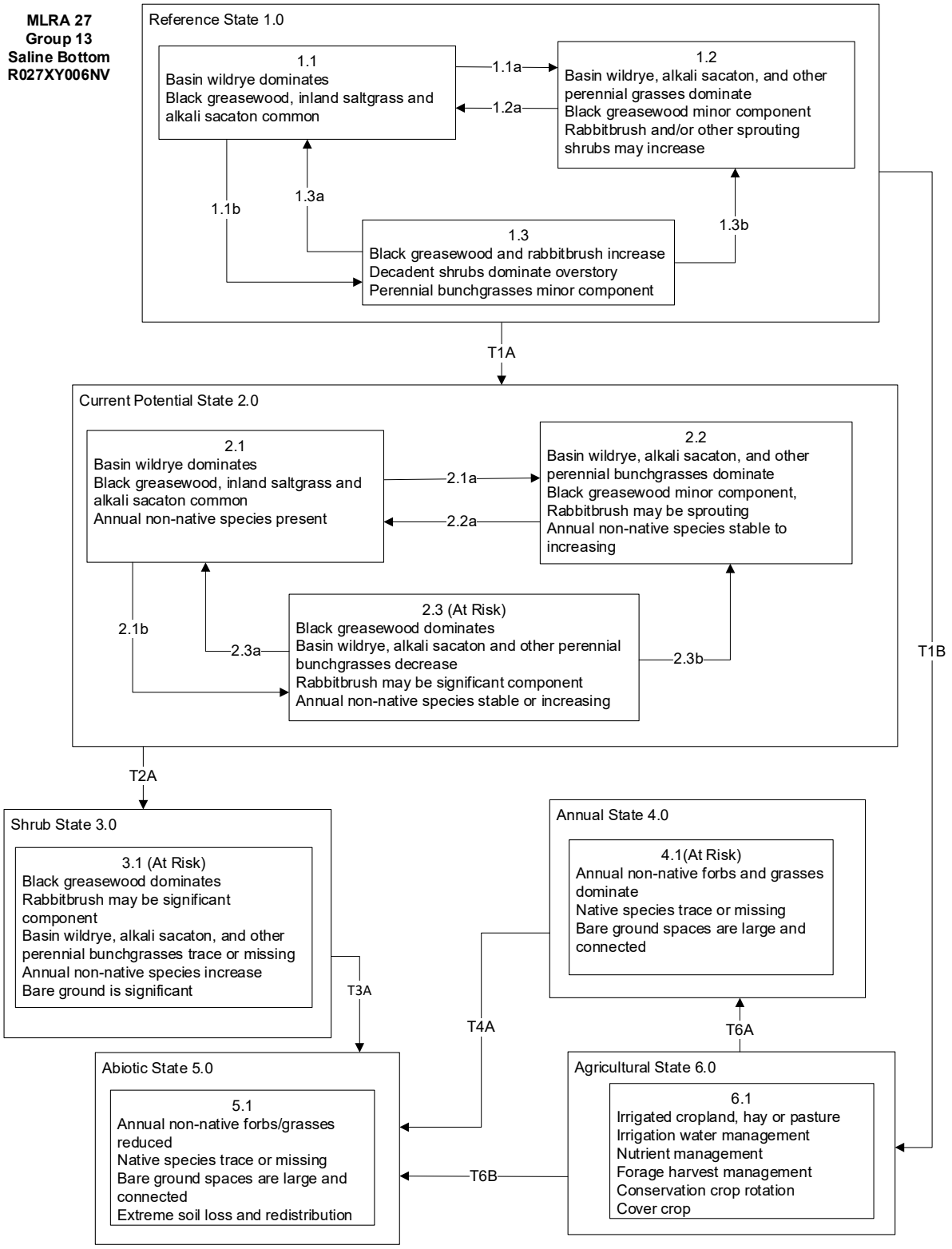
T6B: Transition from Agricultural State 6.0 to Abiotic State 5.0:

Trigger**:** Cessation of farming practices including the removal of irrigation water and the loss of cropland, hay or pasture plant species. Invasion by non-native annual species is reduced under long-term drought conditions increasing bare ground and soil erosion. Significant soil loss and redistribution is occurring. Soil compaction (plow pan) reduces infiltration and effective rooting depth. Soil surface is crusted.

Slow variables: Soil redistribution is significant and on-going. Reduction in soil organic matter inputs contributes to soil surface crusting and reduced infiltration. Reduced infiltration leads to reduced soil water promoting a continued reduction in vegetation.

Threshold: Soil compaction and soil surface changes due to long-term farming practices combined with removal of farming practices and irrigation leads to significant soil redistribution, soil temperature increases, organic matter loss, soil surface ponding, and reduced infiltration.

Modal State and Transition Model for Group 13 in MLRA 27



MLRA 27
Group 13
Saline Bottom
R027XY006NV
KEY

Reference State 1.0 Community Pathways
1.1a: Long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge, or low severity fire would reduce black greasewood and allow for the understory perennial bunchgrasses to increase. High severity fire would greatly reduce black greasewood.
1.1b: Time and lack of disturbance such as fire, long-term spring/summer drought 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: Long-term reduction in winter snow accumulation may lead to reduced groundwater recharge, or low severity fire would reduce black greasewood and allow for the perennial bunchgrasses to dominate the site.
1.3b: High severity fire, due to shrub dominance, significantly reduces shrub cover and increases perennial bunchgrasses and sprouting shrubs.

Transition T1A: Introduction of non-native annual plants.

Transition T1B: Settlement of the area and beginning of agriculture.

Current Potential State 2.0 Community Pathways:
2.1a: Long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge, or low severity fire would reduce black greasewood and allow for the understory perennial bunchgrasses to increase. High severity fire would greatly reduce black greasewood. Non-native annual species are likely to increase after fire.
2.1b: Time and lack of disturbance such as fire, long-term spring/summer 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 grazing management that favors the establishment and growth of black greasewood allows the shrub component to recover.
2.3a: Heavy late fall/winter grazing causing mechanical damage to shrubs, low severity fire, and/or reduced groundwater recharge due to a long-term reduction in winter snow accumulation.
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.

Transition T4A: Cessation of farming practices including the removal of irrigation water and loss of cropland, hay or pasture species. Dominance of non-native annual species is reduced under long-term drought conditions increasing bare ground and soil erosion.

Transition T6A: Cessation of farming practices including the removal of irrigation water and loss of cropland, hay or pasture species. Invasion by non-native annual species in average to above-average precipitation years leads to dominance of those species.

Transition T6B: Cessation of farming practices including the removal of irrigation water and loss of cropland, hay or pasture species. Invasion by non-native annual species is reduced under long-term drought conditions increasing bare ground and soil erosion.

References

Abbott, M. L., L. Fraley Jr., and T. D. Reynolds. 1991. Root profiles of selected cold desert shrubs and grasses in disturbed and undisturbed soils. Environmental and Experimental Botany **31**:165-178.

Allen, E. B., and M. F. Allen. 1988. Facilitation of succession by the nonmycotrophic colonizer *Salsola kali* (Chenopodiaceae) on a harsh site: effects of mycorrhizal fungi. American Journal of Botany **75**:257-266.

Alpert, P. 1990. Water sharing among ramets in a desert population of *Distichlis spicata* (Poaceae). American Journal of Botany **77**:1648-1651.

Anderson, M. D. 2004. *Sarcobatus vermiculatus*. In: Fire Effects Information System. U.S. Department of Agriculture, Forest Service,, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory.

Archer, W. M. 1984. Soil Survey of Lyon County Area, Nevada. U.S.D.A. Soil Conservation Service, Washington D.C.

Bates, J. D., T. Svejcar, R. F. Miller, and R. A. Angell. 2006. The effects of precipitation timing on sagebrush steppe vegetation. Journal of Arid Environments **64**:670-697.

Beatley, J. C. 1975. Climates and vegetation pattern across the Mojave/Great Basin Desert transition of southern Nevada. The American Midland Naturalist **93**:53-70.

Benson, B., S. Green, D. Ogle, D. Tilley, and L. St. John. 2011. Plant guide for black greasewood (*Sarcobatus vermiculatus*). U.S. Department of Agriculture, Natural Resource Conservation Service, Boise, ID.

Benson, B., D. Ogle, D. Tilley, and L. St. John. 2007. Technical Note: managing black greasewood sites. TN Plant Materials No. 15, U.S. Department of Agriculture - Natural Resources Conservation Service, Boise, ID - Salt Lake City, UT.

Blaisdell, J. P., and R. C. Holmgren. 1984. Managing intermountain rangelands - salt-desert shrub ranges. General Technical Report INT-163, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Blauer, A. C., A. P. Plummer, E. D. McArthur, R. Stevens, and B. C. Giunta. 1976. Characteristics and hybridization of important intermountain shrubs. II. Chenopod family. Research Paper INT-177, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Bock, C. E., and J. H. Bock. 1978. Response of birds, small mammals, and vegetation to burning sacaton grasslands in southeastern Arizona. Journal of Range Management **31**:296-300.

Boerboom, C. 1993. Russian thistle (*Salsola iberica* Sennen & Pau).

Brakie, M. 2007. Plant guide for alkali sacaton (*Sporobolus airoides*). U.S. Department of Agriculture, Natural Resources Conservation Service, East Texas Plant Materials, Nacogdoches, TX.

Branson, F. A., R. F. Miller, and I. S. McQueen. 1976. Moisture relationships in twelve northern desert shrub communities near Grand Junction, Colorado. Ecology **57**:1104-1124.

Brehm, J. R. 2019. Cheatgrass die-off in the Great Basin: a comparison of remote sensing detecting methods and identification of environments favorable to die-off. M.S. Thesis. University of Nevada, Reno, NV.

Brown, R. W. 1971. Distribution of plant communities in southeastern Montana badlands. American Midland Naturalist **85**:458-477.

Casey, P. A. 2014. Plant guide for kochia (Bassian scoparia). Kansas Plant Materials Center, Manhattan, KS.

Caudle, D., J. DiBenedetto, M. Karl, H. Sanchez, and C. Talbot. 2013. Interagency ecological site handbook for rangelands. U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.

Chambers, J. C., B. A. Bradley, C. S. Brown, C. D'Antonio, M. J. Germino, J. B. Grace, S. P. Hardegree, R. F. Miller, and D. A. Pyke. 2013. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of western North America. Ecosystems **17**:360-375.

Comstock, J. P., and J. R. Ehleringer. 1992. Plant adaptation in the Great Basin and Colorado Plateau. The Great Basin Naturalist **52**:195-215.

Cronquist, A., A. H. Holmgren, N. H. Holmgren, J. L. Reveal, and P. K. Holmgren. 1977. Intermountain flora: Vascular plants of the Intermountain West, U.S.A. Volume six. The Monocotyledons. Columbia University Press, New York, NY.

Davison, A. W. 1977. The Ecology of Hordeum Murinum L. : III Some Effects of Adverse Climate. Journal of Ecology **65**:523-530.

Dobrowolski, J. P., M. M. Caldwell, and J. H. Richards. 1990. Chapter 7: Basin hydrology and plant root systems. Pages 243-292 *in* C. B. Osmond, L. F. Pitelka, and G. M. Hidy, editors. Plant Biology of the Basin and Range. Springer-Verlag, New York City, NY.

Eckert Jr, R. E., A. D. Bruner, and G. J. Klomp. 1973. Productivity of tall wheatgrass and Great Basin wildrye under irrigation on a greasewood-rabbitbrush range site. Journal of Range Management **26**:286-288.

Eddleman, L. E. 2002. Restoration ecology of native plant species in Oregon's western juniper zone. Revised Project CSRS ORE00367, Oregon State University, Corvallis, OR.

Eddleman, L. E. 2008. *Sarcobatus vermiculatus* (Hook.) Torr. - black greasewood. Pages 1022-1024 *in* F. T. Bonner and R. P. Karrfalt, editors. The Woody Plant Seed Manual. Agriculture Handbook 727. U.S. Department of Agriculture, Forest Service, Washington, D.C.

Everett, R. L., P. T. Tueller, J. B. Davis, and A. D. Brunner. 1980. Plant phenology in galleta-shadscale and galleta-sagebrush associations. Rangeland Ecology & Management/Journal of Range Management Archives **33**:446-450.

Foster, S., B. Schultz, and L. Singletary. 2011. Needs Assessment for Noxious Weeds in Pershing County: Part 1 of 5–Problem Weeds and Approaches and Methods of Control.

Francis, J. K. 2004b. Wildland shrubs of the United States and its territories: Thamnic descriptions: Volume 1. General Technical Report IITF-GTR-26, U.S. Department of Agriculture, Forest Service, International Institute of Tropical Forestry, San Juan, PR and Rocky Mountain Research Station, Fort Collins, CO.

Friesen, L. F., Beckie, H.J., Warwick, S.I, Van Acker, R.C. 2009. The biology of Canadican weeds. 138. Kochia scoparia (L.) Schrad. Canadian Journal of Botany **89**:141-167.

Ganskopp, D., L. Aguilera, and M. Vavra. 2007. Livestock forage conditioning among six northern Great Basin grasses. Rangeland Ecology & Management **60**:71-78.

Ganskopp, D. C. 1986a. Tolerances of sagebrush, rabbitbrush, and greasewood to elevated water tables. Journal of Range Management **39**:334-337.

Graham, J., and W. Johnson. 2004. Managing russian knapweed. University of Nevada Coop. Ext. Fact Sheet:04-37.

Groeneveld, D. P. 1990. Shrub rooting and water acquisition on threatened shallow groundwater habitats in the Owens Valley, California. Pages 221-237 *in* Proceedings—Symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; Las Vegas, NV; April 5-7, 1989. General Technical Report INT-276. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Groeneveld, D. P., and D. E. Crowley. 1988b. Root system response to flooding in three desert shrub species. Functional Ecology **2**:491-497.

Harr, R. D., and K. R. Price. 1972. Evapotranspiration from a greasewood-cheatgrass community. Water Resources Research **8**:1199-1203.

Headley, F. B., and C. Venstrom. 1930. Economic History of the Newlands Irrigation Project. University of Nevada.

Hickey, W. C., Jr., and H. W. Springfield. 1966. Alkali sacaton: Its merits for forage and cover. Journal of Range Management **19**:71-74.

Hickman, J. C. 1993. The Jepson Manual: Higher Plants of California. University of California Press, Los Angeles, CA, USA.

Holmgren, A. H., and N. H. Holmgren. 1977. Poaceae. Pages 175-464 *in* A. Cronquist, A. H. Holmgren, N. H. Holmgren, J. L. Reveal, and P. K. Holmgren, editors. Intermountain Flora. New York Botanical Garden, Bronx, NY.

Holmgren, N. H., P. K. Holmgren, and A. Cronquist. 2005. Intermountain flora: Vascular plants of the Intermountain West, U.S.A. Volume two, part B. Subclass Dilleniidae. The New York Botanical Garden Press, Bronx, NY.

Jacobs, J. 2007. Ecology and management of whitetop (Cardaria Draba (L.) Desv.). US Department of Agriculture, Natural Resources Conservation Service.

Johnson, N. C. 1998. Responses of *Salsola kali* and *Panicum virgatum* to mycorrhizal fungi, phosphorus and soil organic matter: implications for reclamation. Journal of Applied Ecology **35**:86-94.

Klepper, E. L., K. A. Gano, and L. L. Cadwell. 1985. Rooting depth and distribution of deep-rooted plants in the 200 Area Control Zone of the Hanford Site.

Krall, J. L., J. R. Stroh, C. S. Cooper, and S. R. Chapman. 1971. Effect of time and extent of harvesting basin wildrye. Journal of Range Management **24**:414-418.

Lee, C. A., and W. K. Lauenroth. 1994. Spatial distributions of grass and shrub root systems in the shortgrass steppe. American Midland Naturalist **132**:117-123.

Majerus, M. E. 1992. High-stature grasses for winter grazing. Journal of Soil and Water Conservation **47**:224-225.

Marcum, K. B., and D. M. Kopec. 1997. Salinity tolerance of turfgrasses and alternative species in the subfamily Chloridoideae (Poaceae). International Turfgrass Society Research Journal **8**:735-742.

Mathie, A. M., T. L. Welborn, D. D. Susong, and M. L. Tumbusch. 2011. Phreatophytic land-cover map of the northern and central Great Basin ecoregion: California, Idaho, Nevada, Utah,

Oregon, and Wyoming. Pamphlet to accompany Scientific Investigations Map 3169, U.S. Department of the Interior, U.S. Geological Survey, Reston, VA.

Meinzer, O. E. 1927. Plants as indicators of ground water. Water-Supply Paper 577, U.S. Department of the Interior, U.S. Geological Survey, Washington, D.C.

Miller, R. F., J. C. Chambers, D. A. Pyke, F. B. Pierson, and C. J. Williams. 2013. A review of fire effects on vegetation and soils in the Great Basin Region: Response and ecological site characteristics. General Technical Report RMRS-GTR-308, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Miller, R. F., S. T. Knick, D. A. Pyke, C. W. Meinke, S. E. Hanser, M. J. Wisdom, and A. L. Hild. 2008a. Characteristics of sagebrush habitats and limitations to long-term conservation. Administrative Report, U.S. Department of the Interior; U.S. Geological Survey, Reston, VA.

Miller, T. W. 1991. Hoary cress and related whitetops (Cardaria draba, C. pubescens and C. chalapensis).

Monsen, S. B., R. Stevens, and N. L. Shaw. 2004a. Grasses. Pages 295-424 *in* S. B. Monsen, R. Stevens, and N. L. Shaw, editors. Restoring western ranges and wildlands, vol. 2. Gen. Tech. Rep. RMRS-GTR-136-vol-2. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Mozingo, H. N. 1987b. Shrubs of the Great Basin: A natural history. University of Nevada Press, Reno, NV.

Naumburg, E., R. Mata-Gonzalez, R. G. Hunter, T. McLendon, and D. W. Martin. 2005. Phreatophytic vegetation and groundwater fluctuations: A review of current research and application of ecosystem response modeling with an emphasis on Great Basin vegetation. Environmental Management **35**:726-740.

Newman, S. D., and M. Gates. 2000. Plant guide for saltgrass (*Distichlis spicata*). U.S. Department of Agriculture, Natural Resource Conservation Service, Alexandria, LA.

NRCS. 2022. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. Handbook 296, U.S. Department of Agriculture, Natural Resources Conservation Service.

Paysen, T. E., R. J. Ansley, J. K. Brown, G. J. Gottfried, S. M. Haase, M. G. Harrington, M. G. Narog, S. S. Sackett, and R. C. Wilson. 2000. Chapter 6: Fire in western shrubland, woodland, and grassland ecosystems. Pages 121-159 *in* J. K. Brown and J. K. Smith, editors. Wildland fire in ecosystems: Effects of fire on flora. General Technical Report RMRS-GTR-42-Vol. 2. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Peters, E. F., and S. C. Bunting. 1994. Fire conditions pre-and post-occurrence of annual grasses on the Snake River Plain. Pages 31-36 *in* Proceedings—Ecology and management of annual rangelands; September, 1994; Boise, ID. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Pritchett, D. W., and S. J. Manning. 2009. Effects of fire and groundwater extraction on alkali meadow habitat in Owens Valley, California. Madroño **56**:89-98.

Qian, Y. L., J. A. Cosenza, S. J. Wilhelm, and D. Christensen. 2006. Techniques for enhancing saltgrass seed germination and establishment. Crop Science **46**:2613-2616.

Robertson, J. H. 1983. Greasewood (*Sarcobatus vermiculatus* (Hook.) Torr.). Phytologia **54**:309-324.

Robinson, T. W. 1958. Phreatophytes. Geological survey water-supply paper 1423, US Deaprtment of Interior, US Geological Survey, Washington, D.C.

Romo, J. T. 1984. Water relations in *Artemisia tridentata* subsp. *wyomingensis*, *Sarcobatus vermiculatus*, and *Kochia prostrata*. PhD Dissertation. Oregon State University, Corvallis, OR.

Roundy, B. A. 1985. Emergence and establishment of basin wildrye and tall wheatgrass in relation to moisture and salinity. Journal of Range Management **38**:126-131.

Saito, L., S. Byer, K. Badik, K. McGwire, L. Provencher, and B. Minor. 2020. Mapping indicators of groundwater dependent ecosystems in Nevada: Important resources for a water-limited state. Journal of the Nevada Water Resources Association **Winter 2020**:48-72.

Sanderson, S. C., and H. C. Stutz. 1994. Woody chenopods useful for rangeland reclamation in western North America. Pages 374-378 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Skaradek, W., and C. Miller. 2010. Plant fact sheet for saltgrass (*Distichlis spicata*). USDA NRCS Cape May Plant Materials Center, Cape May, NJ.

Smith, M. A., J. D. Rodgers, J. L. Dodd, and Q. D. Skinner. 1992. Habitat selection by cattle along an ephemeral channel. Journal of Range Management **45**:385-390.

Strahorn, A. T. a. C. V. D. 1909. Soil Survey of the Fallon Area, Nevada. USDA-Natural Resources Conservation Service.

Stuart, D. M., G. E. Schuman, and A. S. Dylla. 1971. Chemical characteristics of the coppice dune soils in Paradise Valley, Nevada. Soil Science Society of America Journal. Division S-5 - Soil Genesis, Morphology, and Classification **35**:607-611.

Stubbendieck, J. L., S. L. Hatch, N. M. Bryan, and C. D. Dunn. 2017. North American wildland plants. Third edition. University of Nebraska Press, Lincoln, NE.

Tilley, D., D. Ogle, and L. St. John. 2008. Plant guide for halogeton (*Halogeton glomeratus*). USDA NRCS, USDA NRCS Idaho State Office, Boise, ID.

Trent, J. D., R. R. Blank, and J. A. Young. 1997. Ecophysiology of the temperate desert halophytes: *Allenrolfea occidentalis* and *Sarcobatus vermiculatus*. Great Basin Naturalist **57**:57-65.

Tueller, P. E., and E. D. Payne. 1987. The ecology and management of the genus *Chrysothamnus*. Pages 1–8 *in* Proceedings, 4th Utah shrub ecology workshop: The genus Chrysothamnus. Utah State University, College of Natural Resources, Cedar City, Utah.

USFS. 1988a. Range plant handbook. Reprint of 1937 edition. Dover Publications, New York, NY.

Wallace, A., W. Rhods, and E. Frolich. 1968. Germination behavior of *Salsola* as influenced by temperature, moisture, depth of planting, and gamma irradiation. Agronomy Journal **60**:76-78.

West, N. E. 1994. Effects of fire on salt-desert shrub rangelands. Pages 71-74 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313.

U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, ID.

Wright, H. A. 1971. Why squirreltail is more tolerant to burning than needle-and-thread. Journal of Range Management **24**:277-284.

Young, F., R. Veseth, D. Thill, W. Schillinger, and D. Ball. 1995. Managing Russian thistle under conservation tillage in crop-fallow rotations.

Young, J. A., R. A. Evans, and P. T. Tueller. 1976. Great Basin plant communities - pristine and grazed. Pages 186-215 *in* R. Elston, editor. Holocene Environmental Change in the Great Basin. Nevada Archeological Survey, University of Nevada, Reno, NV.

Young, R. P. 1983. Fire as a vegetation management tool in rangelands of the intermountain region. Pages 18-31 *in* Managing Intermountain rangelands—Improvement of range and wildlife habitats. Proceedings of Symposia: September 15-17, 1981, Twin Falls, Idaho June 22·24, 1982, Elko, Nevada. General Technical Report INT-GTR-157. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Zschaechner, G. A. 1985. Studying rangeland fire effects: A case study in Nevada. Pages 66-84 *in* Rangeland fire effects: a symposium; Boise, ID; November 27-29, 1984. U.S. Department of the Interior, Bureau of Land Management, Idaho State Office, Boise, ID.

MLRA 27 Group 14: Loamy soils with Bailey's greasewood, shadscale and Indian ricegrass

Description of MLRA 27 Disturbance Response Group 14

Disturbance Response Group (DRG) 14 consists of 11 ecological sites. These sites occur on fan skirts, lake terraces, fan piedmonts, and sideslopes of low hills and mountains. The precipitation ranges from 3 to 8 in. with slopes ranging from 0 to 75%, depending on landform. Elevations range from 3,400 to 6,000 ft. Soils are typically formed in alluvium from mixed sources and are typically alkaline, calcareous, or carbonatic. The soils are typically shallow to a soil layer restrictive to root development. Soil textures are variable but soil profiles are skeletal and gravels or stones are common on the surface. The soil temperature regime is mesic and the soil moisture regime is typic aridic. The reference plant communities are typically dominated by shadscale (*Atriplex confertifolia*) and/or Bailey's greasewood (*Sarcobatus baileyi*). Bud sagebrush (*Picrothamnus desertorum*), winterfat (*Krascheninnikovia lanata*), spiny hopsage (*Grayia spinosa*), and Nevada jointfir (*Ephedra nevadensis*) are other important shrubs. The understory is dominated primarily by Indian ricegrass (*Achnatherum hymenoides*) and/or desert needlegrass (*Achnatherum speciosum*). Galleta (*Pleuraphis jamesii*), Sandberg bluegrass (*Poa secunda*) and squirreltail (*Elymus elymoides*) are also common grasses on these sites. Total annual air-dry production ranges from 50 to 600 lb/ac.

Disturbance Response Group 14 Ecological Sites:

Gravelly Loam 4-8" P.Z. – Modal	R027XY018NV
Loamy 4-8" P.Z.	R027XY013NV
Stony Loam 4-8" P.Z.	R027XY015NV
South Slope 4-8" P.Z.	R027XY017NV
Stony Slope 4-8" P.Z.	R027XY019NV
Barren Gravelly Slope	R027XY027NV
Loamy Slope 5-8" P.Z.	R027XY037NV
Coarse Gravelly Loam 3-5" P.Z.	R027XY043NV
Coarse Gravelly Loam 5-8" P.Z.	R027XY050NV
Gravelly Sodic Terrace	R027XY076NV
Stony Terrace 4-8" P.Z.	R027XY093NV

Modal Site:

The Gravelly Loam 4-8" P.Z. ecological site (R027XY018NV) is the modal site that represents this DRG, as it has the most acres mapped. This site occurs on piedmont slopes and low hills on all exposures. Precipitation ranges from 4 to 8 in. Slopes range from 2 to 30%, but slope gradients of 2–15% are most typical. Elevation ranges from 3,400 to 5,000 ft. The soils of this site are typically shallow to a soil layer restrictive to root development. The soils are well drained and

available water capacity is very low. Surface runoff is medium to high. The soil surface is gravelly or cobbly and moderately coarse-textured. Desert pavement is common in some areas. The soil temperature regime is mesic and the soil moisture regime is typic aridic. The reference plant community is dominated by shadscale, Bailey's greasewood, and Indian ricegrass. Other common species include bud sagebrush, spiny hopsage, Nevada jointfir, winterfat, and squirreltail, Sandberg bluegrass, and galleta.

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 27 (MLRA 27 Fallon-Lovelock Area) is almost entirely in Nevada with < 1% in California. The entire area occurs in the rain shadow of the Sierra Nevada mountains and is influenced by Pleistocene Lake Lahontan. Extensive playas occur throughout the area and are a result of the drying of ancient Lake Lahontan. To the west, MLRA 27 has a gradual boundary with MLRA 26 (Carson Basin and Mountains) and to the east has a very gradual boundary with MLRA 24 (Humboldt Basin and Range Area). From west to east the soil temperature increases and the soil moisture decreases, resulting in vast areas dominated by salt-desert shrub communities. Isolated mountain ranges trending north to south are separated by broad desert plains and valleys. Elevations range from 3,300 to 5,900 ft with some mountain peaks over 7,800 ft. The average annual precipitation ranges from 4 to 11 in. and as much as 20 in. at the highest elevations. The majority of annual precipitation is received during late fall and winter occurring mainly as snow. High-intensity, convective thunderstorms also contribute significantly to annual precipitation (NRCS 2022). 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 salt-desert shrub 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 8–32 in. and widths of 12–68 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, 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 (31.5–43.3 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. 1990). Interestingly, periods of above normal springtime precipitation are also linked to shadscale die-off. Nelson et al (Nelson et al. 1990) 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. 1990). 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).

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).

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 4–10 in. and a spread of 8–12 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 9.8–11.8 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.

Spiny hopsage is a rounded, summer-deciduous shrub standing 0.3–1.2 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 (525–7,000 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 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 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).

Indian ricegrass, the dominant understory species of this group, is a long-lived, cool-season perennial bunchgrass that grows from 4 to 24 in. tall (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, perennial bunchgrass that grows 12–24 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 11–19 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 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 most of the sites in the DRG with an additional Seeded State documented for the Loamy 4-8" P.Z. ecological site (R027XY013NV).

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 species; 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 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 these ecological 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. 1999b). 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).

Russian thistle and halogeton 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.

Russian thistle is a taprooted, C4 photosynthesis (warm-season) annual forb of the goosefoot family (Chenopodiaceae) 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 < 2 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 1998).

Halogeton is a non-native 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 taproot that penetrates 4–5 in. and an extensive root system spanning up to 2 ft in lateral spread and depth (Tisdale and Zappetini 1953). 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 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. 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). 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 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). 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). 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 non-native annual grasses has greatly altered fire regimes in areas of the Intermountain West where shadscale is a major vegetation component. The non-native 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).

Bailey's greasewood is resilient against fire and is able to resprout after damage (Monsen and Kitchen 1994).

Spiny hopsage is generally top-killed by fire, but often sprouts after plants are damaged by fire or mechanical injury (Shaw 1992). Fires in spiny hopsage sites generally occur in late summer when plants are dormant, and sprouting generally does not occur until the following spring (Daubenmire 1970). Spiny hopsage is reported to be least susceptible to fire during summer

dormancy (Rickard and McShane 1984). Plants often survive fires that kill adjacent sagebrush (Blauer et al. 1976).

Nevada jointfir vigorously sprouts after fire from extensive woody crowns (Young and Evans 1978, Koniak 1985b). 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).

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).

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.

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.

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 15–20% 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 2+ 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.

Spiny hopsage is palatable to livestock, especially sheep, during the spring and early summer (Phillips et al. 1996, Simmons and Rickard 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 overgrazing, local populations of spiny hopsage may be lost (Simmons and Rickard 2003).

Nevada jointfir is used as winter forage by wild ungulates and livestock (Jameson 1962, Kufeld et al. 1973a). Keeler (1989) found Nevada jointfir to be toxic to cattle and sheep, but not to calves and lambs. Nevada jointfir is also an important component of bighorn sheep diets in the eastern Sierra Nevada (McCullough and Schneegas 1966).

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.

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 (USFS 1988a). 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 2008a).

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 and spiny hopsage, while shadscale and Bailey's greasewood 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 non-native species. 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 14

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 27 Disturbance Response Group 14.

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:
The reference plant community is dominated by Bailey's greasewood, shadscale and Indian ricegrass. Bud sagebrush, Sandberg bluegrass, and squirreltail are minor components. Potential vegetative composition by air-dry weight is 25% grasses, 5% forbs and 70% shrubs. Approximate ground cover (basal and crown) is approximately 15%. Total annual air-dry production ranges from 100 to 400 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 overstory. 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. Bailey's greasewood, bud sagebrush, winterfat, and other shrubs dominate the overstory while perennial bunchgrasses are reduced in the understory.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
Release from drought, insect infestation or disease will allow shadscale and perennial bunchgrasses to reestablish from seed.

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 Bailey's greasewood, shadscale and Indian ricegrass. Sandberg bluegrass, 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.

Gravelly Loam 4-8" P.Z. (R027XY018NV), Current Potential 2.1, T. Stringham, June 2025

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 (Weber et al. 1990, Schultz and Ostler 1995). 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 bunchgrasses and palatable shrubs.

Community Phase 2.2:
Shadscale has been reduced in the community. Bailey's greasewood, bud sagebrush, Nevada ephedra, winterfat, and other shrubs dominate the overstory while perennial bunchgrasses are reduced in the understory. Annual non-native species are present.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Release from drought will allow shadscale and perennial bunchgrasses 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, Bailey's greasewood, yellow rabbitbrush (*Chrysothamnus viscidiflorus*), and Sandberg bluegrass.

Community Phase 2.3 (At-Risk):

Bailey's greasewood and other unpalatable shrubs such as yellow 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.

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 bunchgrass 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 non-native annual species leading to their dominance within the community. Wildfires may occur following a wet spring that produced a flush of growth of the non-native annual species.

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

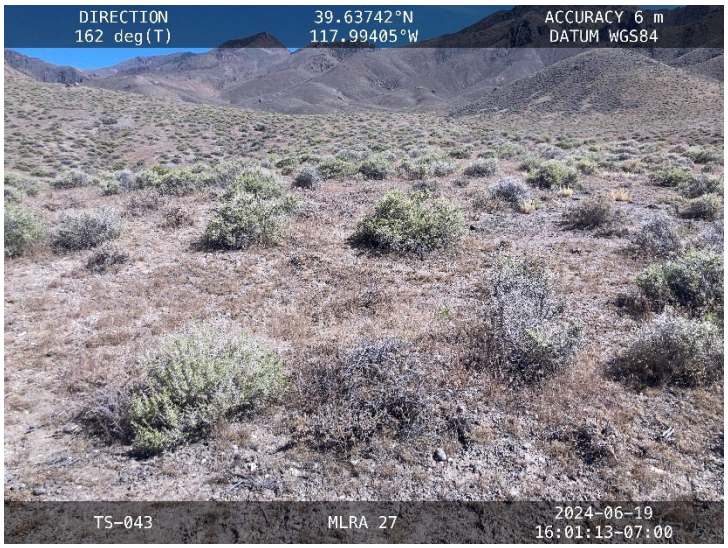
Threshold: Loss of deep-rooted perennial bunchgrasses and shrubs truncates, spatially and temporally, nutrient capture and cycling within the community.

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, Bailey's greasewood, bud sagebrush and Nevada ephedra dominate the overstory. Deep-rooted perennial bunchgrasses may be present in trace amounts or absent from the community, however, Sandberg bluegrass or galleta may be the dominant understory grass species. Annual non-native species have increased and bare ground is significant in low precipitation years.



Gravelly Loam 4-8" P.Z., (R027XY018NV), Shrub State 3.1, T. Stringham, June 2024

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:
Inappropriate or excessive grazing, including wild horse and burros, reduces bud sagebrush and/or winterfat cover and allows for non-palatable 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):
Shadscale or Bailey's greasewood dominates the overstory. Annual non-native species may be increasing and bare ground is significant in dry years. Deep-rooted perennial bunchgrasses such as Indian ricegrass may be present in trace amounts. Non-native annual species will increase in wet years. This community phase is at risk of transitioning to an Annual State 4.0 or an Abiotic State 5.0.

Coarse Gravelly Loam 4-8" P.Z. (R027XY050NV), Shrub State 3.2, T. Stringham, May 2024

Community Phase Pathway 3.2a, from Phase 3.2 to 3.1:
Time, favorable precipitation, and lack of disturbance and/or grazing, including wild horse and burro management that favors the reestablishment and growth of spiny hopsage, winterfat and/or other palatable 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. Wildfires may occur following a wet spring that produced a flush of growth of the non-native annual species.

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, flash flooding, 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, tall tumblemustard (*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. Cheatgrass most commonly invades these sites. Trace amounts of Bailey's greasewood, yellow rabbitbrush, shadscale, winterfat, bud sagebrush, and Nevada jointfir may be present, but are not contributing to overall site function. Bare ground may be significant, especially during low precipitation years.

Gravelly Loam 4-8" P.Z. (R027XY018NV), Annual State 4.1, T. Stringham, June 2024

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 shrubs 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.

Gravelly Loam 4-8" P.Z. (R027XY018NV), Abiotic State 5.1, T. Stringham, September 2025

Potential Resilience Differences with Other Ecological Sites in this Group

Loamy 4-8" P.Z. (R027XY013NV):

This site occurs on piedmont slopes, and alluvial plains and flats on slopes from 2 to 30%. Elevations range from 4,000 to over 5,000 ft. The reference plant community is dominated by shadscale, bud sagebrush and Indian ricegrass. Potential vegetative composition is about 35% grasses, 5% forbs and 60% shrubs. Total annual air-dry production ranges from 250 to 600 lb/ac. This site is slightly more resilient than the modal with higher production and more perennial bunchgrasses. A Seeded State exists for this site – the Pokerbrow Fire in August 1999 was seeded with forage kochia (*Bassia prostrata*) in January 2000.

Loamy 4-8" P.Z. (R027XY013NV), Seeded State 6.1, T. Stringham, May 2025

Stony Loam 4-8" P.Z. (R027XY015NV):

This site occurs on summits and sideslopes of low hills and upper piedmont slopes with slopes ranging from 4 to 50%. Elevations range from 4,200 to 5,500 ft. The reference plant community is dominated by Bailey's greasewood, shadscale and Indian ricegrass. Potential vegetative composition is about 45% grasses, 5% forbs and 50% shrubs. Total annual air-dry production ranges from 200 to 500 lb/ac. This site is slightly more resilient than the modal with higher production and more perennial bunchgrasses. This site would not have an Abiotic State because high amounts of rock fragments protect the soil surface.

Stony Loam 4-8" P.Z. (R027XY015NV), Shrub State 3.1, T. Stringham, June 2025

South Slope 4-8" P.Z. (R027XY017NV):

This site occurs on sideslopes of hills and lower elevation mountains on slopes from 30 to 75%. Elevations range from 4,500 to 5,500 ft. The reference plant community is dominated by desert needlegrass and shadscale. Potential vegetative composition is about 55% grasses, 5% forbs and 40% shrubs. Total annual air-dry production ranges from 100 to 400 lb/ac. This site is slightly more resilient than the modal because of the amount of perennial bunchgrasses and a slightly higher elevation range. This site would not have an Abiotic State because high amounts of rock fragments protect the soil surface.

South Slope 4-8" P.Z. (R027XY017NV), Shrub State 3.2, T. Stringham, May 2025

Stony Slope 4-8" P.Z. (R027XY019NV):

This site occurs on lower mountains, hills and piedmont slopes on slopes ranging from 8 to 75%. Elevations range from 3,400 to 5,000 ft. The reference plant community is dominated by Bailey's greasewood, shadscale and Indian ricegrass. Potential vegetative composition is about 25% grasses, 5% forbs and 70% shrubs. Total annual-air dry production ranges from 50 to 300 lb/ac. This site has similar resilience as the modal but would not have an Abiotic State because high amounts of rock fragments protect the soil surface.

Stony Slope 4-8" P.Z. (R027XY019NV), Annual State 4.1, T. Stringham, May 2025

Barren Gravelly Slope (R027XY027NV):

This site occurs on sideslopes of lower mountains, hills and fan remnants on slopes of 30–50%. Elevations range from 4,000 to 5,500 ft. The reference plant community is dominated by shadscale and Indian ricegrass. Potential vegetative composition is about 25% grasses, 5% forbs and 70% shrubs. Total annual air-dry production ranges from 50 to 200 lb/ac. This site has similar resilience as the modal but would not have an Abiotic State because high amounts of rock fragments protect the soil surface.

Barren Gravelly Slope (R027XY027NV), Shrub State at risk of Annual State, T. Stringham, May 2025

Loamy Slope 5-8" P.Z. (R027XY037NV):

This site occurs on sideslopes of hills and lower mountains on slopes ranging from 15 to 75%. Elevations range from 4,500 to 6,000 ft. At upper elevations this site is usually restricted to southerly exposures. The reference plant community is dominated by shadscale, bud sagebrush and Indian ricegrass. Potential vegetative composition is about 35% grasses, 5% forbs and 60% shrubs. Total annual air-dry production ranges from 150 to 450 lb/ac. This site is slightly more resilient than the modal because of more perennial bunchgrasses and higher elevations. This site would not have an Abiotic State because high amounts of rock fragments protect the soil surface.

Coarse Gravelly Loam 3-5" P.Z. (R027XY043NV):

This site occurs on lower piedmont slopes, fan skirts, inset fans and fan terraces on slopes ranging from 0 to 30%. Elevations range from 3,400 to 4,300 ft. The reference plant community is dominated by Indian ricegrass, shadscale, Shockley's desert-thorn (*Lycium shockleyi*) and Bailey's greasewood. Potential vegetative composition is about 20% grasses, 5% forbs and 75% shrubs. Total annual air-dry production ranges from 200 to 450 lb/ac. This site has similar resilience as the modal and would have the same states.

Coarse Gravelly Loam 5-8" P.Z. (R027XY050NV):

This site occurs on erosional fan piedmonts on slopes from 2 to 15%. Elevations range from 3,500 to 5,000 ft. The reference plant community is dominated by Bailey's greasewood and Indian ricegrass. Shadscale, bud sagebrush and winterfat are important shrub species associated with this plant community. Potential vegetative composition is about 50% grasses,

5% forbs and 45% shrubs. Total annual air-dry production ranges from 200 to 600 lb/ac. This site is slightly more resilient than the modal because of an increase in production and perennial bunchgrass cover.

Coarse Gravelly Loam 5-8" P.Z. (R027XY050NV), Shrub State 3.2, T. Stringham, May 2024

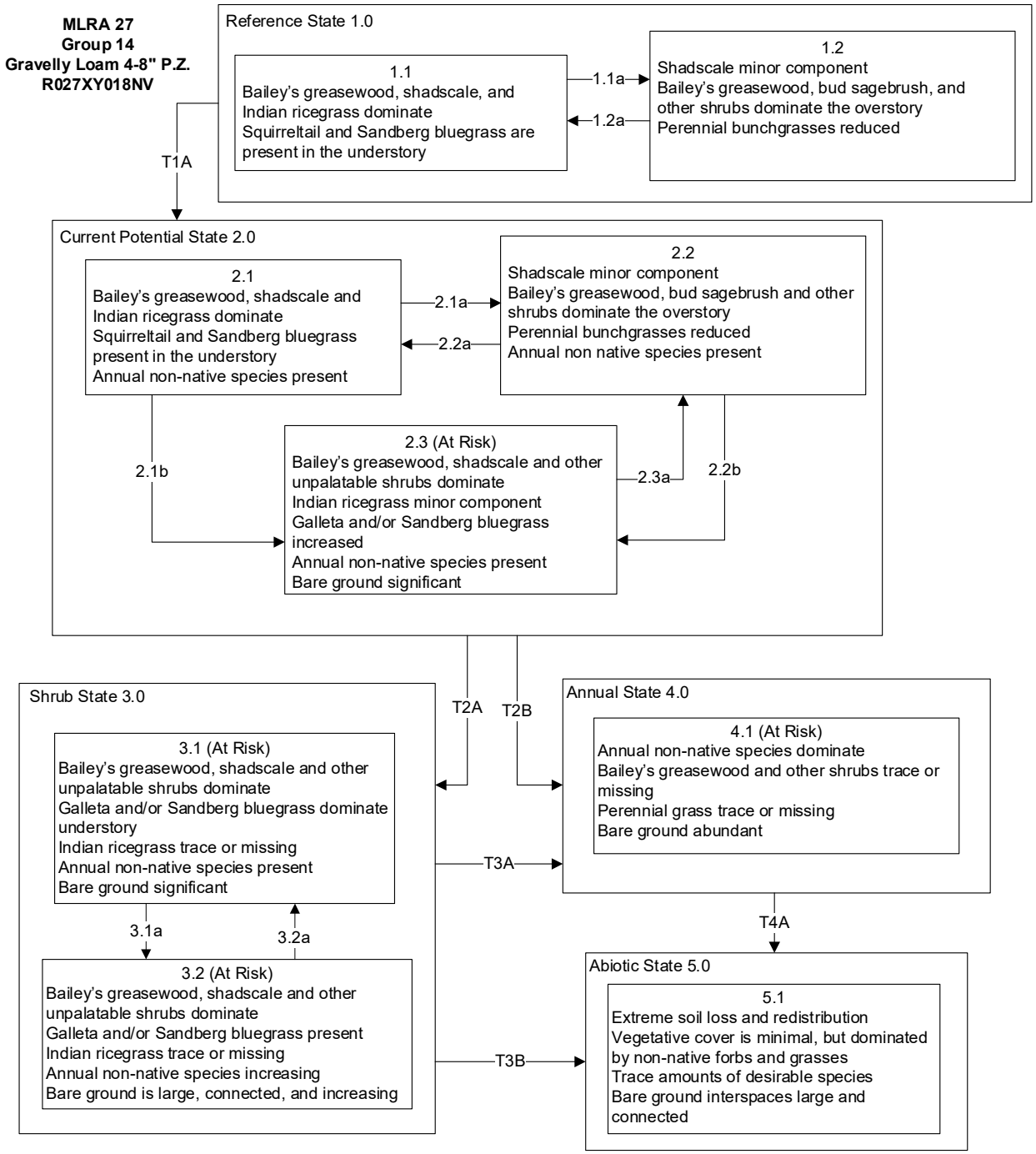
Gravelly Sodic Terrace (R027XY076NV):

This site occurs on beach terraces. Slope gradients of 2–4% are typical. Elevations range from 4,000 to 4,300 ft. The reference plant community is dominated by shadscale. Bailey's greasewood, Mojave seablite (*Suaeda moquinii*) and bud sagebrush are other important shrubs associated with this site. Desert pavement is common and the surface rock fragments trap sodic aeolian dust from the surrounding playas. Potential vegetative composition is about 10% grasses, 5% forbs and 85% shrubs. Total annual air-dry production ranges from 50 to 250 lb/ac. This site has similar resilience as the modal but would not have an Abiotic State because the surface rock fragments protect the surface soil.

Stony Terrace 4-8" P.Z. (R027XY093NV):

This site occurs on lake terraces associated with Lake Lahontan and other Pleistocene lakes. Slopes range from 4 to 15% and elevations range from 4,100 to 4,400 ft. The reference plant community is dominated by Nevada jointfir and desert needlegrass. Potential vegetative composition is about 45% grasses, 10% forbs and 45% shrubs. Total annual air-dry production ranges from 100 to 350 lb/ac. This site has similar resilience as the modal but would not have an Abiotic State because the surface rock fragments protect the surface soil.

Modal State and Transition Model for Group 14 in MLRA 27



MLRA 27
Group 14
Gravelly Loam 4-8" P.Z.
R027XY018NV

Reference State 1.0 Community Phase Pathways
1.1a: Prolonged drought reduces perennial bunchgrass component 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 reduces bunchgrass component 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 and palatable shrubs.
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 which may lead to wildfires the following summer.

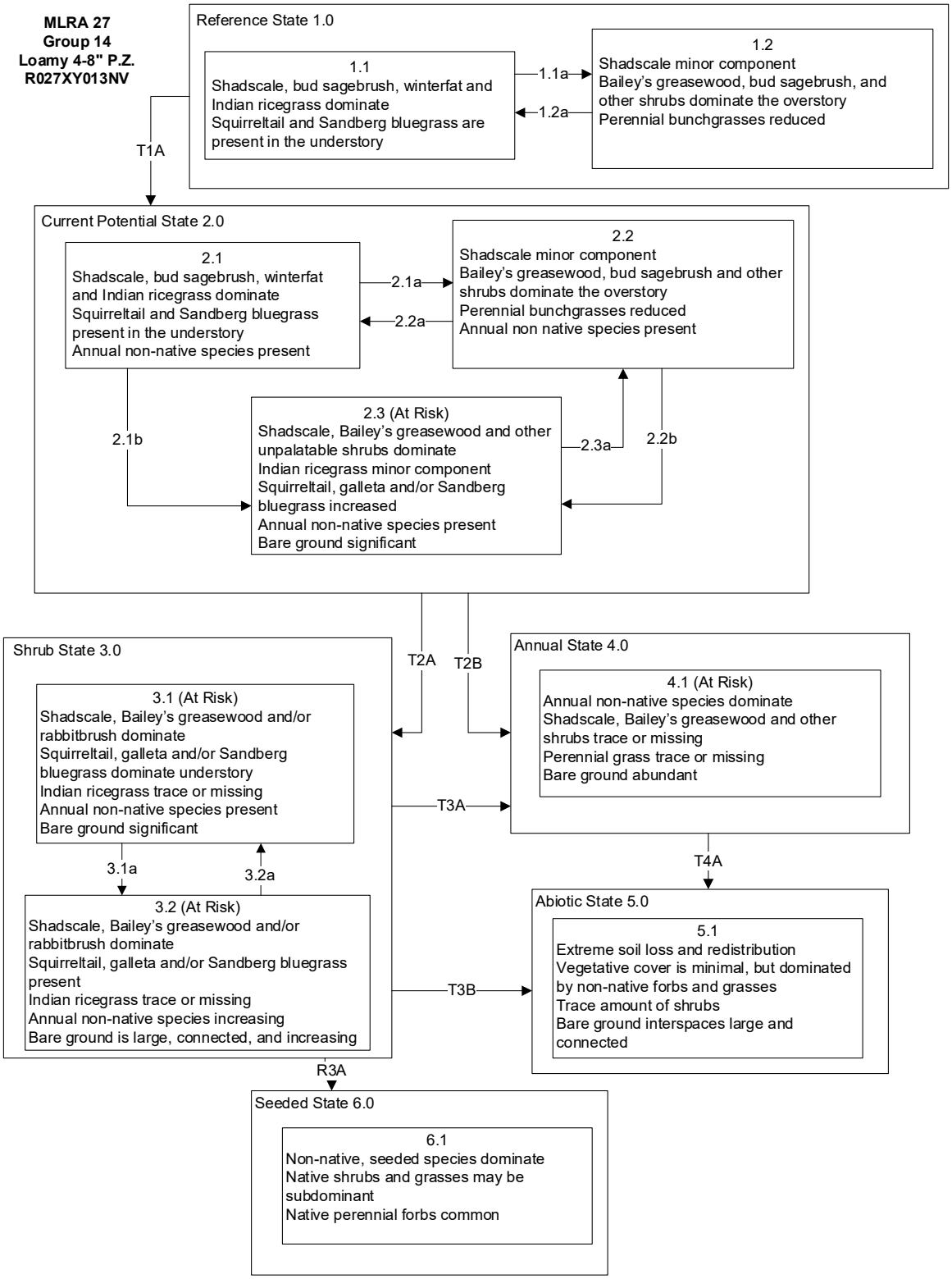
Shrub State 3.0 Community Phase Pathways
3.1a: Long-term inappropriate grazing, soil disturbance, or other disturbance reduces the palatable and/or nonpalatable shrub community.
3.2a: Time and lack of disturbance that allows for shrub reestablishment.

Transition T3A: Long-term inappropriate grazing management, long-term, chronic drought, flash flooding, or an unusually wet spring that may promote wildfires the following summer or combinations.

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 activities combined with significant soil loss and redistribution.

Additional State and Transition Models for Group 14 in MLRA 27



MLRA 27
Group 14
Loamy 4-8" P.Z.
R027XY013NV

Reference State 1.0 Community Phase Pathways
1.1a: Prolonged drought reduces perennial bunchgrasses 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 reduces perennial bunchgrasses 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 and palatable shrubs.
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 may promote wildfires the following summer.

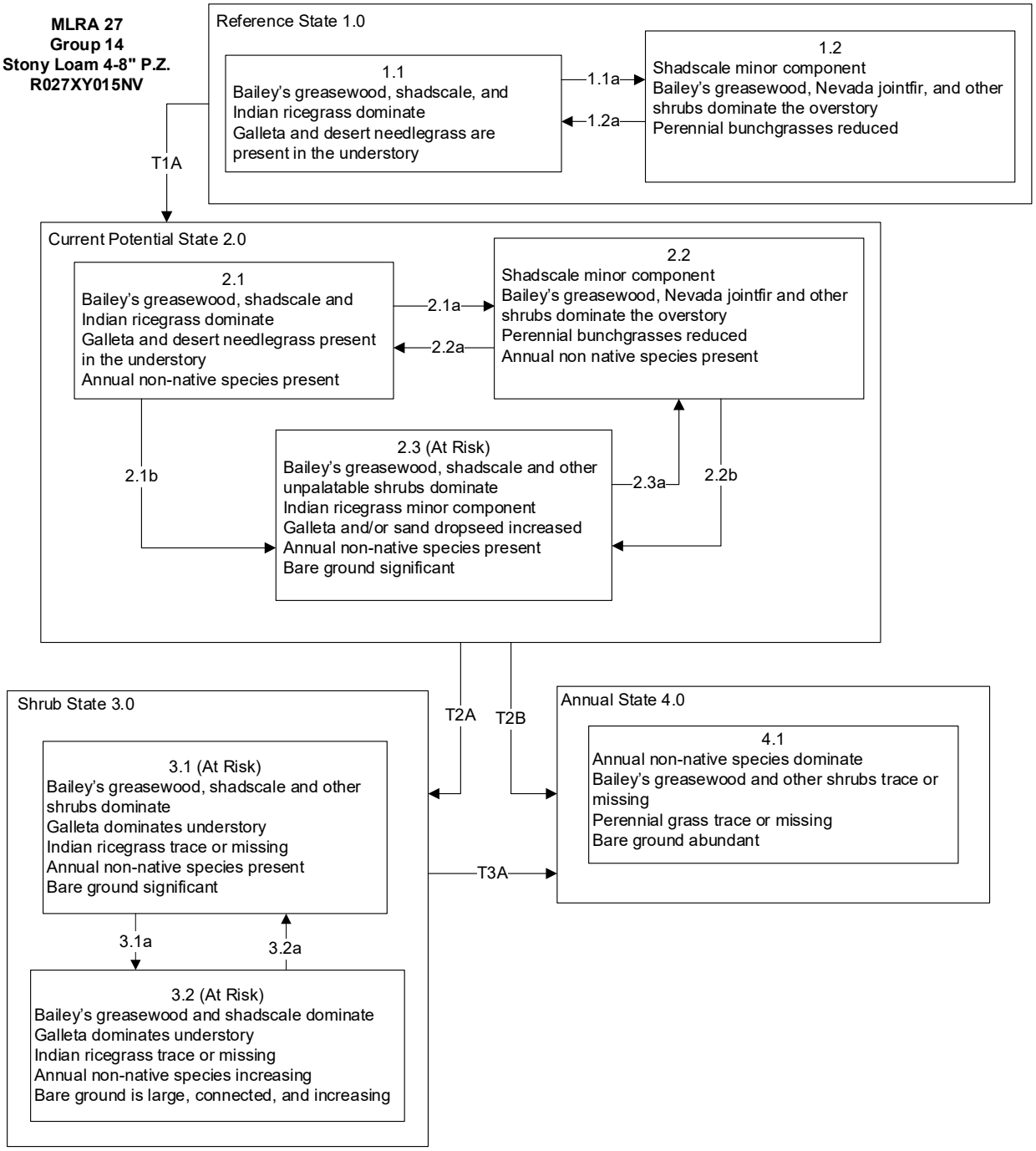
Shrub State 3.0 Community Phase Pathways
3.1a: Long-term inappropriate grazing, soil disturbance, or other disturbance reduces the palatable and/or nonpalatable shrub community.
3.2a: Time and lack of disturbance that allows for shrub reestablishment.

Transition T3A: Long-term inappropriate grazing management, long-term, chronic drought, or an unusually wet spring that may promote wildfires the following summer.

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.

Restoration R3A: Aerial or ground seeding after a wildfire. Success most likely at the higher end of the precipitation zone of this site.

TransitionT4A: Long-term, inappropriate grazing management, and/or severe drought, and/or unsuccessful soil disturbing activities combined with significant soil loss and redistribution.


MLRA 27
Group 14
Stony Loam 4-8" P.Z.
R027XY015NV
Reference State 1.0
1.1
Bailey's greasewood, shadscale, and Indian ricegrass dominate
Galleta and desert needlegrass are present in the understory
1.1a
1.2a
1.2
Shadscale minor component
Bailey's greasewood, Nevada jointfir, and other shrubs dominate the overstory
Perennial bunchgrasses reduced
T1A
Current Potential State 2.0
2.1
Bailey's greasewood, shadscale and Indian ricegrass dominate
Galleta and desert needlegrass present in the understory
Annual non-native species present
2.1a
2.2a
2.2
Shadscale minor component
Bailey's greasewood, Nevada jointfir and other shrubs dominate the overstory
Perennial bunchgrasses reduced
Annual non native species present
2.1b
2.3 (At Risk)
Bailey's greasewood, shadscale and 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, shadscale and other shrubs dominate
Galleta dominates understory
Indian ricegrass trace or missing
Annual non-native species present
Bare ground significant
3.1a
3.2a
3.2 (At Risk)
Bailey's greasewood and shadscale dominate
Galleta dominates understory
Indian ricegrass trace or missing
Annual non-native species increasing
Bare ground is large, connected, and increasing
T3A
Annual State 4.0
4.1
Annual non-native species dominate
Bailey's greasewood and other shrubs trace or missing
Perennial grass trace or missing
Bare ground abundant

MLRA 27
Group 14
Stony Loam 4-8" P.Z.
R027XY015NV

Reference State 1.0 Community Phase Pathways
1.1a: Prolonged drought reduces perennial bunchgrasses 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.

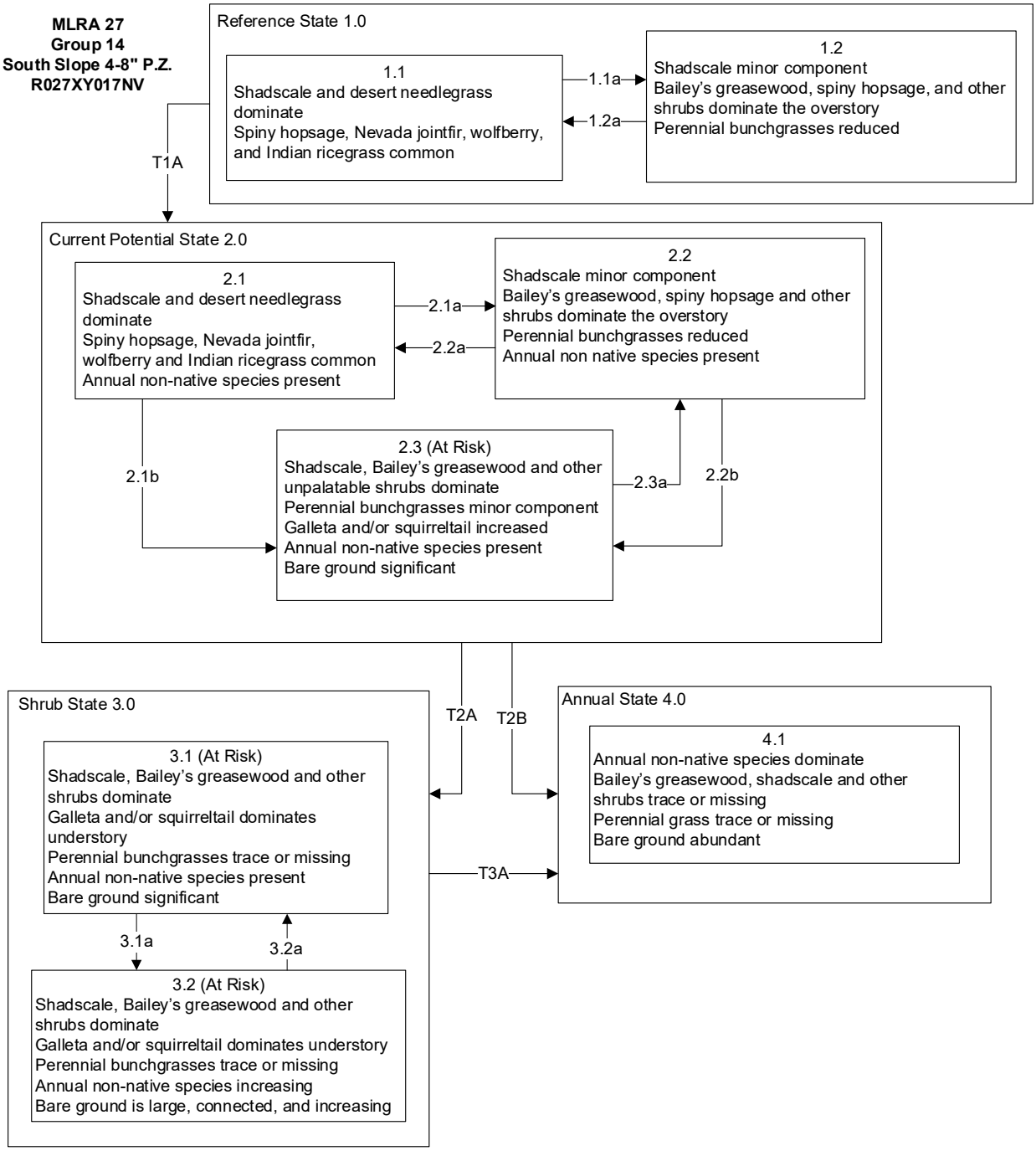
Current Potential State 2.0 Community Phase Pathways
2.1a: Prolonged drought reduces perennial bunchgrasses or an unusually wet spring makes shadscale more susceptible to insects and disease, reducing the shadscale component. Bailey's greasewood and other drought tolerant shrubs may increase.
2.1b: Inappropriate grazing management reduces deep-rooted perennial bunchgrass and palatable shrubs.
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 which may lead to wildfires the following summer.

Shrub State 3.0 Community Phase Pathways
3.1a: Long-term inappropriate grazing, soil disturbance, or other disturbance reduces the palatable and/or nonpalatable 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 that may promote wildfires the following summer.


MLRA 27
Group 14
South Slope 4-8" P.Z.
R027XY017NV
Reference State 1.0
1.1
Shadscale and desert needlegrass dominate
Spiny hopsage, Nevada jointfir, wolfberry, and Indian ricegrass common
1.1a
1.2a
1.2
Shadscale minor component
Bailey's greasewood, spiny hopsage, and other shrubs dominate the overstory
Perennial bunchgrasses reduced
T1A
Current Potential State 2.0
2.1
Shadscale and desert needlegrass dominate
Spiny hopsage, Nevada jointfir, wolfberry and Indian ricegrass common
Annual non-native species present
2.1a
2.2a
2.2
Shadscale minor component
Bailey's greasewood, spiny hopsage and other shrubs dominate the overstory
Perennial bunchgrasses reduced
Annual non native species present
2.1b
2.3 (At Risk)
Shadscale, Bailey's greasewood and other unpalatable shrubs dominate
Perennial bunchgrasses minor component
Galleta and/or squirreltail increased
Annual non-native species present
Bare ground significant
2.3a
2.2b
T2A
T2B
Shrub State 3.0
3.1 (At Risk)
Shadscale, Bailey's greasewood and other shrubs dominate
Galleta and/or squirreltail dominates understory
Perennial bunchgrasses trace or missing
Annual non-native species present
Bare ground significant
3.1a
3.2a
3.2 (At Risk)
Shadscale, Bailey's greasewood and other shrubs dominate
Galleta and/or squirreltail dominates understory
Perennial bunchgrasses trace or missing
Annual non-native species increasing
Bare ground is large, connected, and increasing
T3A
Annual State 4.0
4.1
Annual non-native species dominate
Bailey's greasewood, shadscale and other shrubs trace or missing
Perennial grass trace or missing
Bare ground abundant

MLRA 27
Group 14
South Slope 4-8" P.Z.
R027XY017NV

Reference State 1.0 Community Phase Pathways
1.1a: Prolonged drought or unusually wet spring reduces the shadscale and perennial bunchgrass 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.

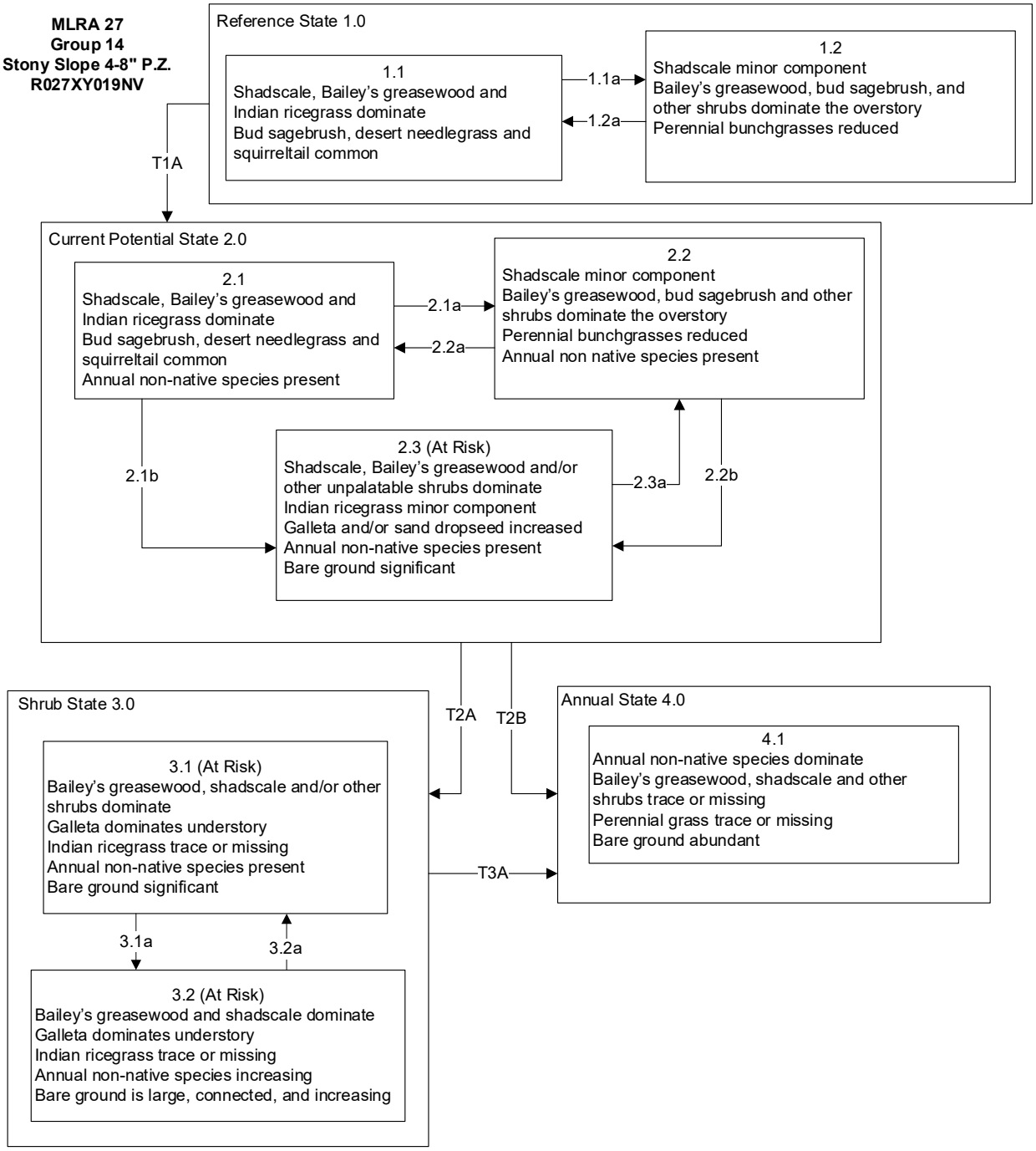
Current Potential State 2.0 Community Phase Pathways
2.1a: Prolonged drought or an unusually wet spring makes shadscale more susceptible to insects and disease, reducing the shadscale component and perennial bunchgrasses component. Bailey's greasewood and other drought tolerant shrubs may increase.
2.1b: Inappropriate grazing management reduces deep-rooted perennial bunchgrass and palatable shrubs.
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 which may lead to wildfires the following summer.

Shrub State 3.0 Community Phase Pathways
3.1a: Long-term inappropriate grazing, soil disturbance, or other disturbance reduces the palatable and/or nonpalatable 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 that may promote wildfires the following summer.


MLRA 27
Group 14
Stony Slope 4-8" P.Z.
R027XY019NV
Reference State 1.0
1.1
Shadscale, Bailey's greasewood and Indian ricegrass dominate
Bud sagebrush, desert needlegrass and squirreltail common
1.1a
1.2a
1.2
Shadscale minor component
Bailey's greasewood, bud sagebrush, and other shrubs dominate the overstory
Perennial bunchgrasses reduced
T1A
Current Potential State 2.0
2.1
Shadscale, Bailey's greasewood and Indian ricegrass dominate
Bud sagebrush, desert needlegrass and squirreltail common
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
Perennial bunchgrasses reduced
Annual non native species present
2.1b
2.3 (At Risk)
Shadscale, 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, shadscale and/or other shrubs dominate
Galleta dominates understory
Indian ricegrass trace or missing
Annual non-native species present
Bare ground significant
3.1a
3.2a
3.2 (At Risk)
Bailey's greasewood and shadscale dominate
Galleta dominates understory
Indian ricegrass trace or missing
Annual non-native species increasing
Bare ground is large, connected, and increasing
T3A
Annual State 4.0
4.1
Annual non-native species dominate
Bailey's greasewood, shadscale and other shrubs trace or missing
Perennial grass trace or missing
Bare ground abundant

MLRA 27
Group 14
Stony Slope 4-8" P.Z.
R027XY019NV

Reference State 1.0 Community Phase Pathways
1.1a: Prolonged drought reduces perennial bunchgrasses 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.

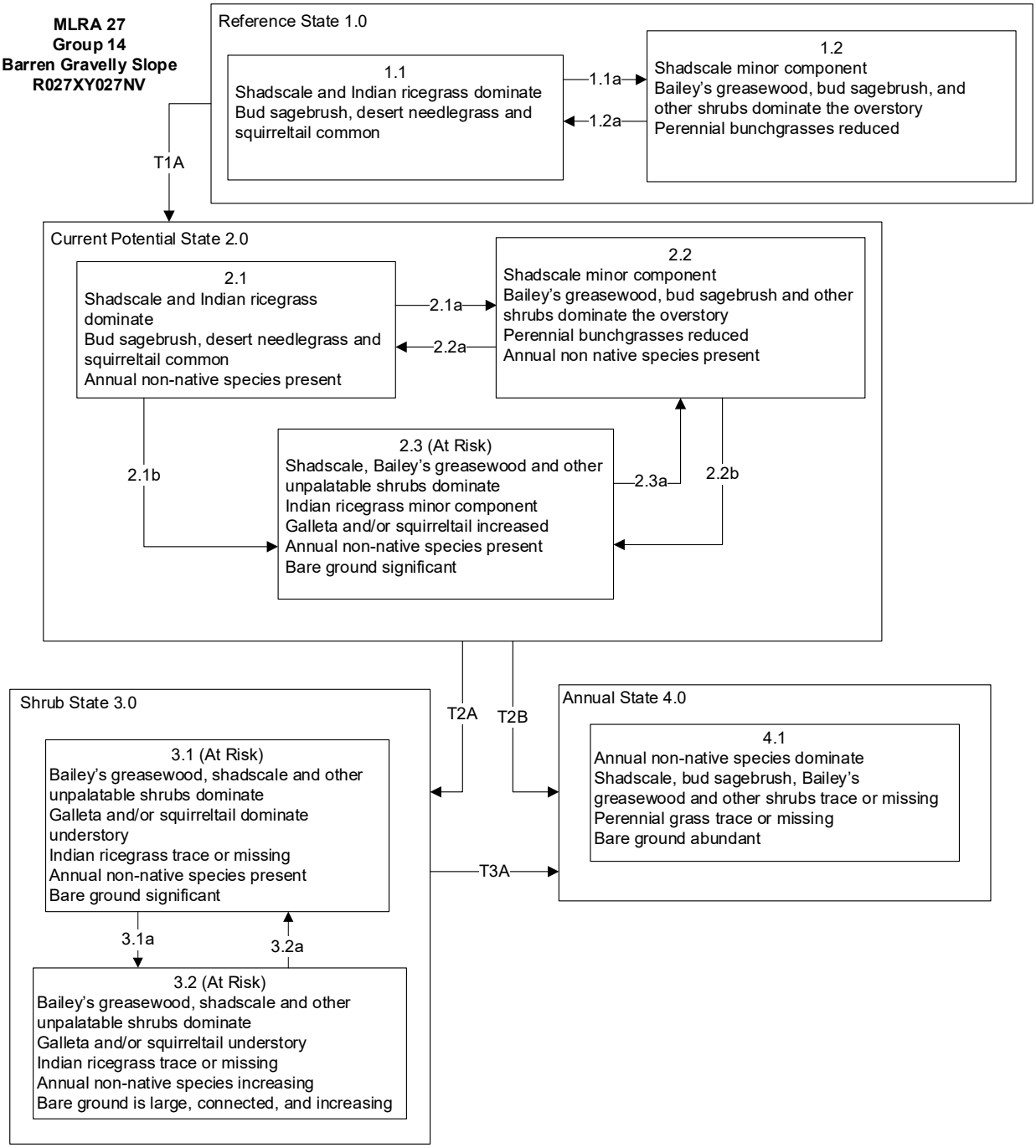
Current Potential State 2.0 Community Phase Pathways
2.1a: Prolonged drought reduces perennial bunchgrasses or an unusually wet spring makes shadscale more susceptible to insects and disease, reducing the shadscale component. Bailey's greasewood and other drought tolerant shrubs may increase.
2.1b: Inappropriate grazing management reduces deep-rooted perennial bunchgrass and palatable shrubs.
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 which may lead to wildfires the following summer.

Shrub State 3.0 Community Phase Pathways
3.1a: Long-term inappropriate grazing, soil disturbance, or other disturbance reduces the palatable and/or nonpalatable 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 that may promote wildfires the following summer.


MLRA 27
Group 14
Barren Gravelly Slope
R027XY027NV
Reference State 1.0
1.1
Shadscale and Indian ricegrass dominate
Bud sagebrush, desert needlegrass and squirreltail common
1.1a
1.2a
1.2
Shadscale minor component
Bailey's greasewood, bud sagebrush, and other shrubs dominate the overstory
Perennial bunchgrasses reduced
T1A
Current Potential State 2.0
2.1
Shadscale and Indian ricegrass dominate
Bud sagebrush, desert needlegrass and squirreltail common
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
Perennial bunchgrasses reduced
Annual non native species present
2.1b
2.3 (At Risk)
Shadscale, Bailey's greasewood and other unpalatable shrubs dominate
Indian ricegrass minor component
Galleta and/or squirreltail 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, shadscale and other unpalatable shrubs dominate
Galleta and/or squirreltail dominate understory
Indian ricegrass trace or missing
Annual non-native species present
Bare ground significant
3.1a
3.2a
3.2 (At Risk)
Bailey's greasewood, shadscale and other unpalatable shrubs dominate
Galleta and/or squirreltail understory
Indian ricegrass trace or missing
Annual non-native species increasing
Bare ground is large, connected, and increasing
T3A
Annual State 4.0
4.1
Annual non-native species dominate
Shadscale, bud sagebrush, Bailey's greasewood and other shrubs trace or missing
Perennial grass trace or missing
Bare ground abundant

MLRA 27
Group 14
Barren Gravelly Slope
R027XY027NV

Reference State 1.0 Community Phase Pathways
1.1a: Prolonged drought reduces perennial bunchgrasses 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.

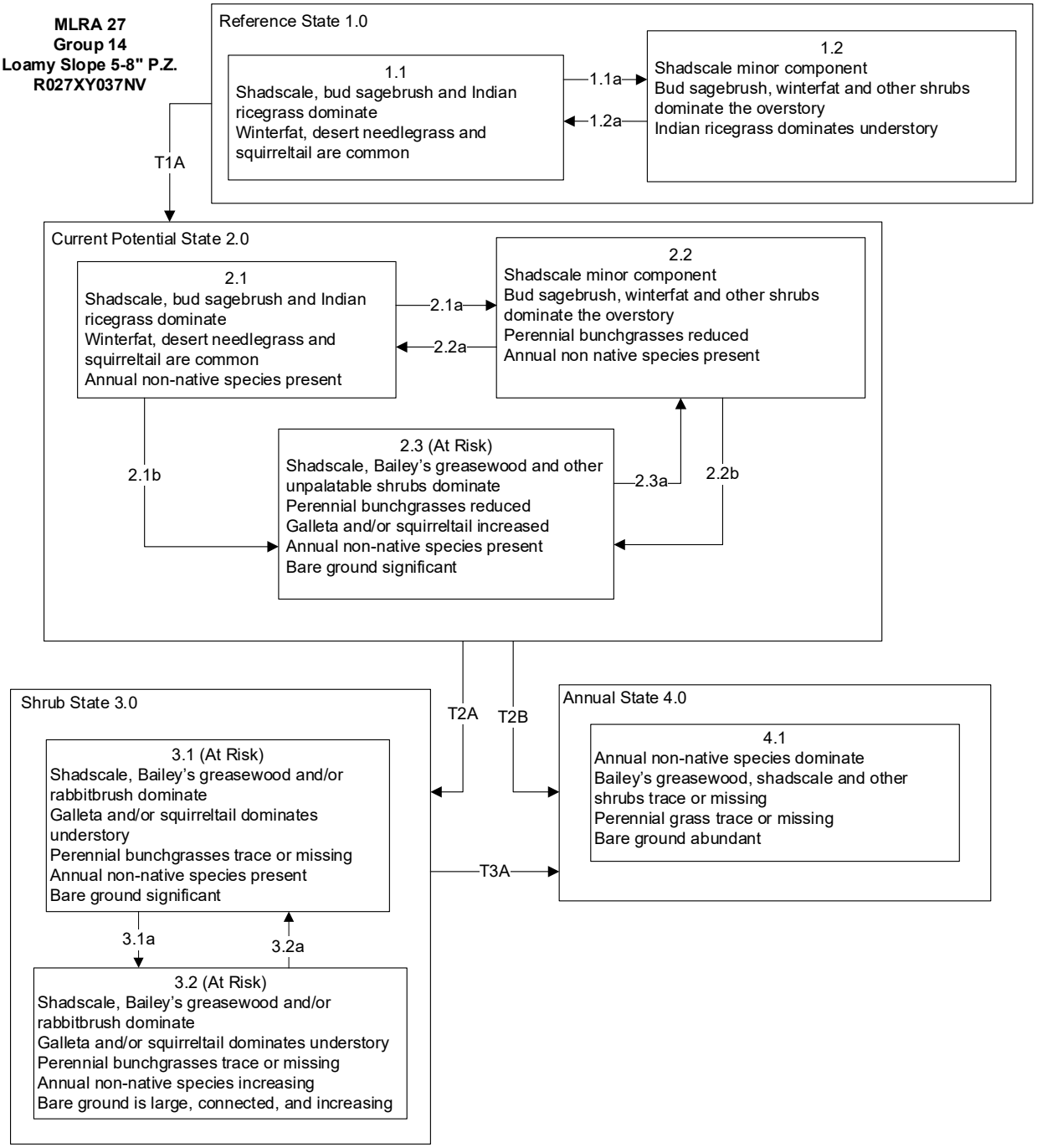
Current Potential State 2.0 Community Phase Pathways
2.1a: Prolonged drought reduces perennial bunchgrasses or an unusually wet spring makes shadscale more susceptible to insects and disease, reducing the shadscale component. Bailey's greasewood and other drought tolerant shrubs may increase.
2.1b: Inappropriate grazing management reduces deep-rooted perennial bunchgrass and palatable shrubs.
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 which may lead to wildfires the following summer.

Shrub State 3.0 Community Phase Pathways
3.1a: Long-term inappropriate grazing, soil disturbance, or other disturbance reduces the palatable and/or nonpalatable 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 that may promote wildfires the following summer.


MLRA 27
Group 14
Loamy Slope 5-8" P.Z.
R027XY037NV
Reference State 1.0
1.1
Shadscale, bud sagebrush and Indian ricegrass dominate
Winterfat, desert needlegrass and squirreltail are common
1.1a
1.2a
1.2
Shadscale minor component
Bud sagebrush, winterfat and other shrubs dominate the overstory
Indian ricegrass dominates understory
T1A
Current Potential State 2.0
2.1
Shadscale, bud sagebrush and Indian ricegrass dominate
Winterfat, desert needlegrass and squirreltail are common
Annual non-native species present
2.1a
2.2a
2.2
Shadscale minor component
Bud sagebrush, winterfat and other shrubs dominate the overstory
Perennial bunchgrasses reduced
Annual non native species present
2.1b
2.3 (At Risk)
Shadscale, Bailey's greasewood and other unpalatable shrubs dominate
Perennial bunchgrasses reduced
Galleta and/or squirreltail increased
Annual non-native species present
Bare ground significant
2.3a
2.2b
T2A
T2B
Shrub State 3.0
3.1 (At Risk)
Shadscale, Bailey's greasewood and/or rabbitbrush dominate
Galleta and/or squirreltail dominates understory
Perennial bunchgrasses trace or missing
Annual non-native species present
Bare ground significant
3.1a
3.2a
3.2 (At Risk)
Shadscale, Bailey's greasewood and/or rabbitbrush dominate
Galleta and/or squirreltail dominates understory
Perennial bunchgrasses trace or missing
Annual non-native species increasing
Bare ground is large, connected, and increasing
T3A
Annual State 4.0
4.1
Annual non-native species dominate
Bailey's greasewood, shadscale and other shrubs trace or missing
Perennial grass trace or missing
Bare ground abundant

MLRA 27
Group 14
Loamy Slope 5-8" P.Z.
R027XY037NV

Reference State 1.0 Community Phase Pathways
1.1a: Prolonged drought reduces perennial bunchgrasses 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.

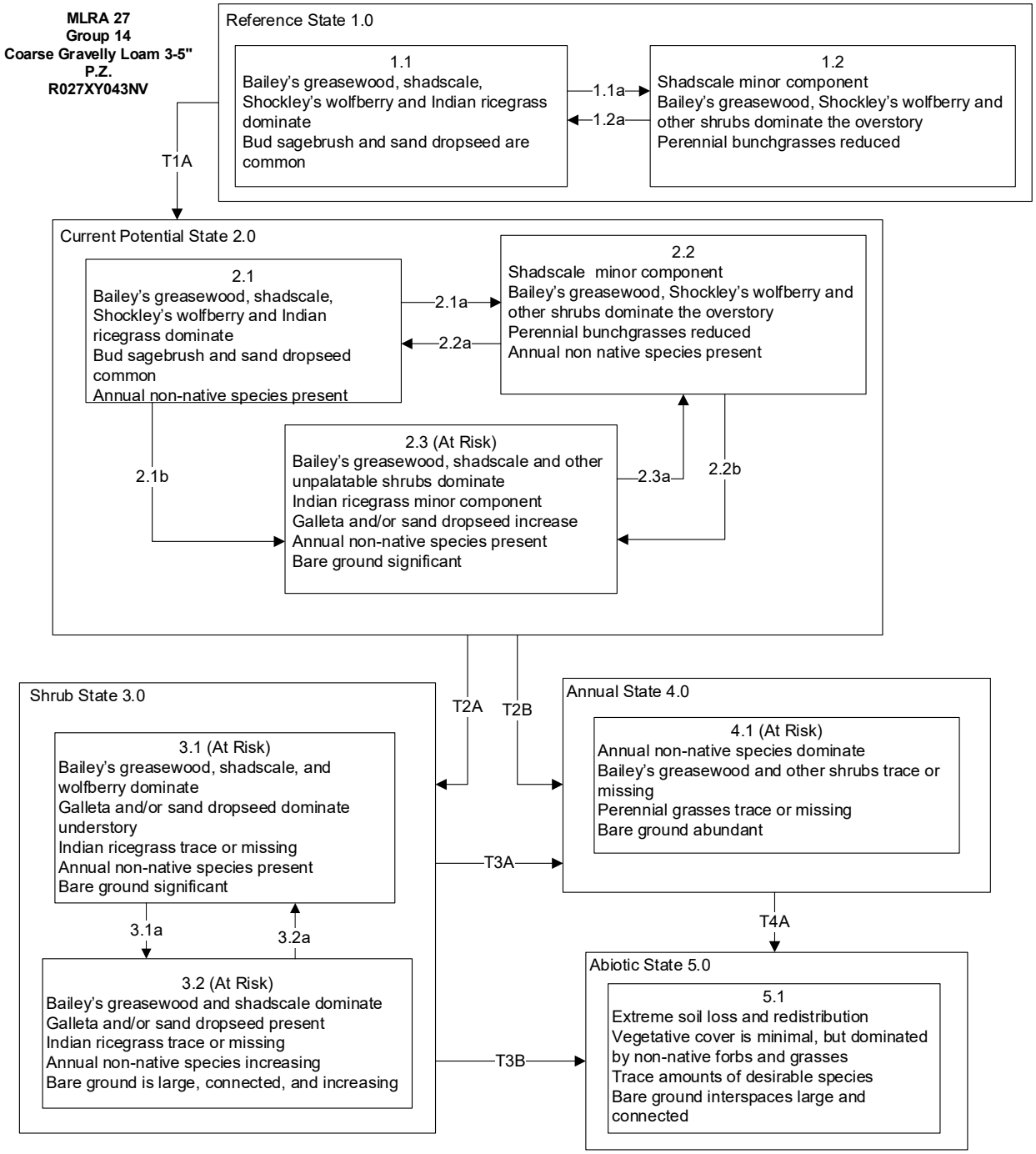
Current Potential State 2.0 Community Phase Pathways
2.1a: Prolonged drought reduces perennial bunchgrasses or an unusually wet spring makes shadscale more susceptible to insects and disease, reducing the shadscale component. Bailey's greasewood and other drought tolerant shrubs may increase.
2.1b: Inappropriate grazing management reduces deep-rooted perennial bunchgrass and palatable shrubs.
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 which may lead to wildfires the following summer.

Shrub State 3.0 Community Phase Pathways
3.1a: Long-term inappropriate grazing, soil disturbance, or other disturbance reduces the palatable and/or nonpalatable 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 that may promote wildfires the following summer.


MLRA 27
Group 14
Coarse Gravelly Loam 3-5"
P.Z.
R027XY043NV
Reference State 1.0
1.1
Bailey's greasewood, shadscale, Shockley's wolfberry and Indian ricegrass dominate
Bud sagebrush and sand dropseed are common
1.1a
1.2a
1.2
Shadscale minor component
Bailey's greasewood, Shockley's wolfberry and other shrubs dominate the overstory
Perennial bunchgrasses reduced
T1A
Current Potential State 2.0
2.1
Bailey's greasewood, shadscale, Shockley's wolfberry and Indian ricegrass dominate
Bud sagebrush and sand dropseed common
Annual non-native species present
2.1a
2.2a
2.2
Shadscale minor component
Bailey's greasewood, Shockley's wolfberry and other shrubs dominate the overstory
Perennial bunchgrasses reduced
Annual non native species present
2.1b
2.3 (At Risk)
Bailey's greasewood, shadscale and other unpalatable shrubs dominate
Indian ricegrass minor component
Galleta and/or sand dropseed increase
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, shadscale, and wolfberry 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)
Bailey's greasewood and shadscale dominate
Galleta and/or sand dropseed present
Indian ricegrass trace or missing
Annual non-native species increasing
Bare ground is large, connected, and increasing
T3A
T3B
Annual State 4.0
4.1 (At Risk)
Annual non-native species dominate
Bailey's greasewood and other shrubs trace or missing
Perennial grasses 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 forbs and grasses
Trace amounts of desirable species
Bare ground interspaces large and connected

MLRA 27
Group 14
Coarse Gravelly Loam 3-5" P.Z.
R027XY043NV

Reference State 1.0 Community Phase Pathways
1.1a: Prolonged drought reduces perennial bunchgrasses 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 reduces perennial bunchgrasses 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 and palatable shrubs.
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.

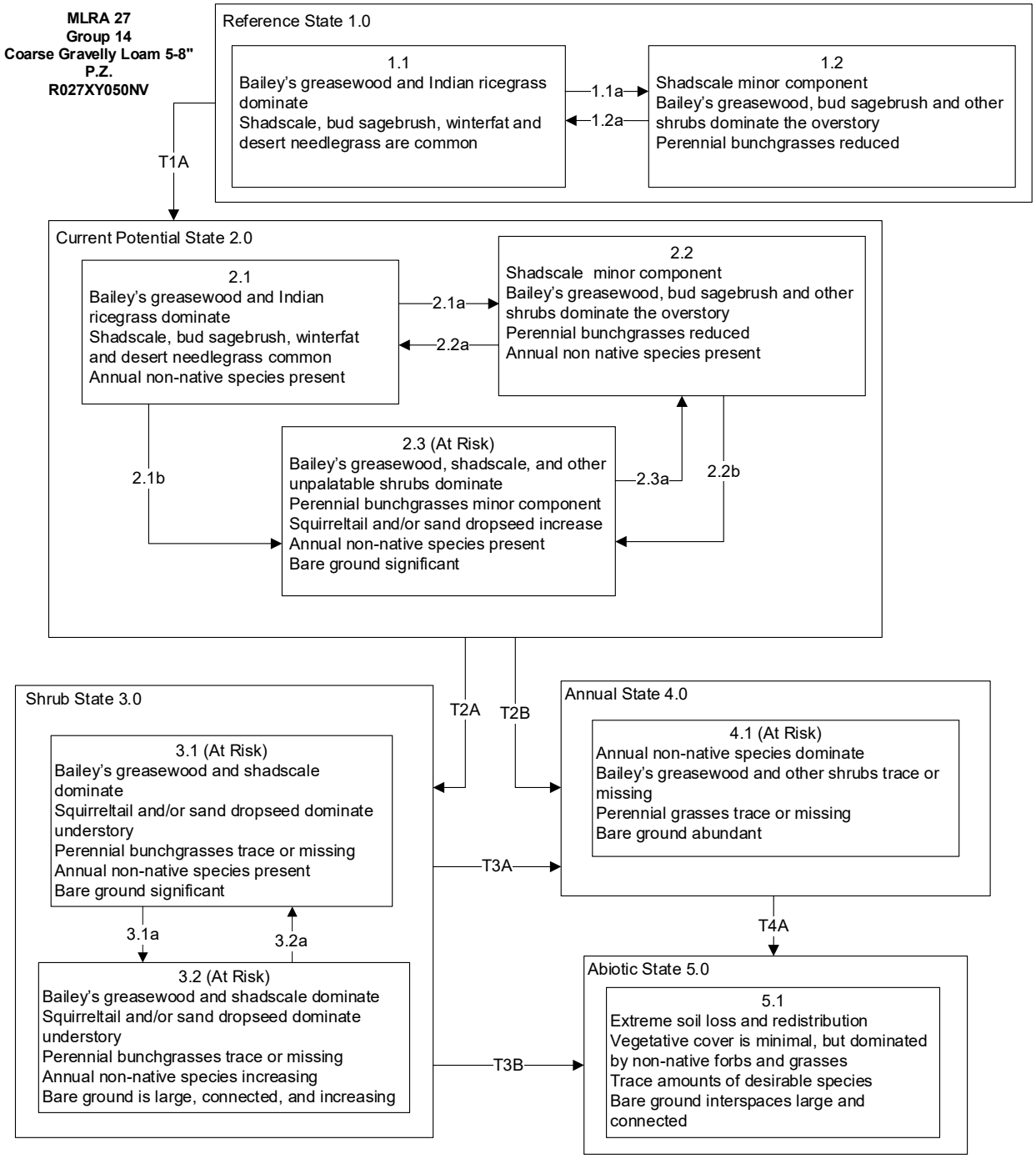
Transition T2B: Long-term inappropriate grazing management and/or an unusually wet spring, increasing germination of invasive annual species which may lead to wildfires the following summer.

Shrub State 3.0 Community Phase Pathways
3.1a: Long-term inappropriate grazing, soil disturbance, or other disturbance reduces the palatable and/or nonpalatable 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, flash flooding, or an unusually wet spring that may promote wildfires the following summer or combinations.

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 activities combined with significant soil loss and redistribution.


MLRA 27
Group 14
Coarse Gravelly Loam 5-8"
P.Z.
R027XY050NV
Reference State 1.0
1.1
Bailey's greasewood and Indian ricegrass dominate
Shadscale, bud sagebrush, winterfat and desert needlegrass are common
1.1a
1.2a
1.2
Shadscale minor component
Bailey's greasewood, bud sagebrush and other shrubs dominate the overstory
Perennial bunchgrasses reduced
T1A
Current Potential State 2.0
2.1
Bailey's greasewood and Indian ricegrass dominate
Shadscale, bud sagebrush, winterfat and desert needlegrass common
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
Perennial bunchgrasses reduced
Annual non native species present
2.1b
2.3 (At Risk)
Bailey's greasewood, shadscale, and other unpalatable shrubs dominate
Perennial bunchgrasses minor component
Squirreltail and/or sand dropseed increase
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 shadscale dominate
Squirreltail and/or sand dropseed dominate understory
Perennial bunchgrasses trace or missing
Annual non-native species present
Bare ground significant
3.1a
3.2a
3.2 (At Risk)
Bailey's greasewood and shadscale dominate
Squirreltail and/or sand dropseed dominate understory
Perennial bunchgrasses trace or missing
Annual non-native species increasing
Bare ground is large, connected, and increasing
T3A
T3B
Annual State 4.0
4.1 (At Risk)
Annual non-native species dominate
Bailey's greasewood and other shrubs trace or missing
Perennial grasses 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 forbs and grasses
Trace amounts of desirable species
Bare ground interspaces large and connected

MLRA 27
Group 14
Coarse Gravelly Loam 5-8" P.Z.
R027XY050NV

Reference State 1.0 Community Phase Pathways
1.1a: Prolonged drought reduces perennial bunchgrasses 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 reduces perennial bunchgrasses 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 and palatable shrubs.
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.

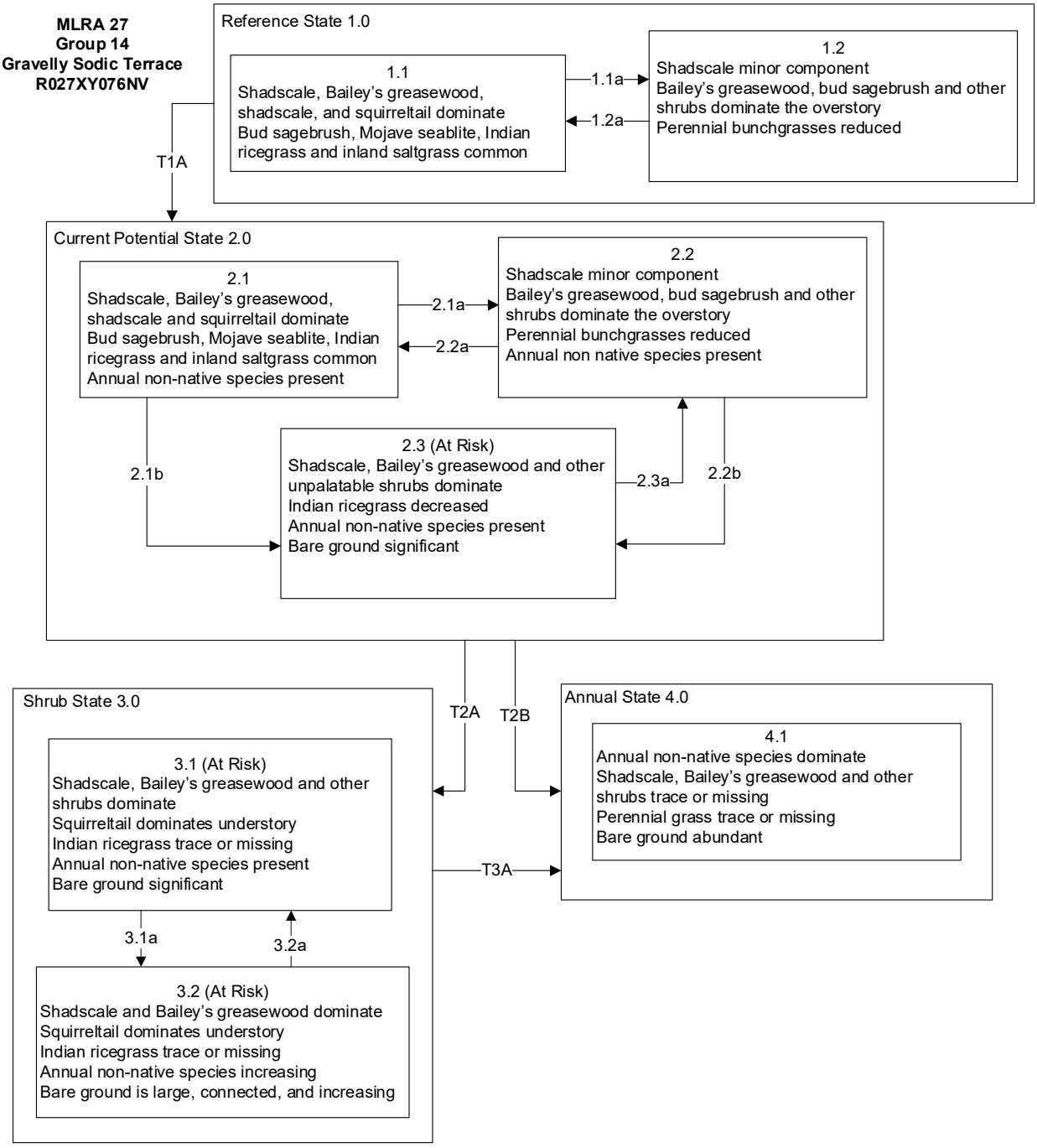
Transition T2B: Long-term inappropriate grazing management and/or an unusually wet spring, increasing germination of invasive annual species which may lead to wildfires the following summer.

Shrub State 3.0 Community Phase Pathways
3.1a: Long-term inappropriate grazing, soil disturbance, or other disturbance reduces the palatable and/or nonpalatable 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, flash flooding, or an unusually wet spring that may promote wildfires the following summer or combinations.

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 activities combined with significant soil loss and redistribution.


MLRA 27
Group 14
Gravelly Sodic Terrace
R027XY076NV
Reference State 1.0
1.1
Shadscale, Bailey's greasewood, shadscale, and squirreltail dominate
Bud sagebrush, Mojave seablite, Indian ricegrass and inland saltgrass common
1.1a
1.2a
1.2
Shadscale minor component
Bailey's greasewood, bud sagebrush and other shrubs dominate the overstory
Perennial bunchgrasses reduced
T1A
Current Potential State 2.0
2.1
Shadscale, Bailey's greasewood, shadscale and squirreltail dominate
Bud sagebrush, Mojave seablite, Indian ricegrass and inland saltgrass common
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
Perennial bunchgrasses reduced
Annual non native species present
2.1b
2.3 (At Risk)
Shadscale, Bailey's greasewood and other unpalatable shrubs dominate
Indian ricegrass decreased
Annual non-native species present
Bare ground significant
2.3a
2.2b
T2A
T2B
Shrub State 3.0
3.1 (At Risk)
Shadscale, Bailey's greasewood and other shrubs dominate
Squirreltail dominates understory
Indian ricegrass trace or missing
Annual non-native species present
Bare ground significant
3.1a
3.2a
3.2 (At Risk)
Shadscale and Bailey's greasewood dominate
Squirreltail dominates understory
Indian ricegrass trace or missing
Annual non-native species increasing
Bare ground is large, connected, and increasing
T3A
Annual State 4.0
4.1
Annual non-native species dominate
Shadscale, Bailey's greasewood and other shrubs trace or missing
Perennial grass trace or missing
Bare ground abundant

MLRA 27
Group 14
Gravelly Sodic Terrace
R027XY076NV

Reference State 1.0 Community Phase Pathways
1.1a: Prolonged drought reduces perennial bunchgrasses 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.

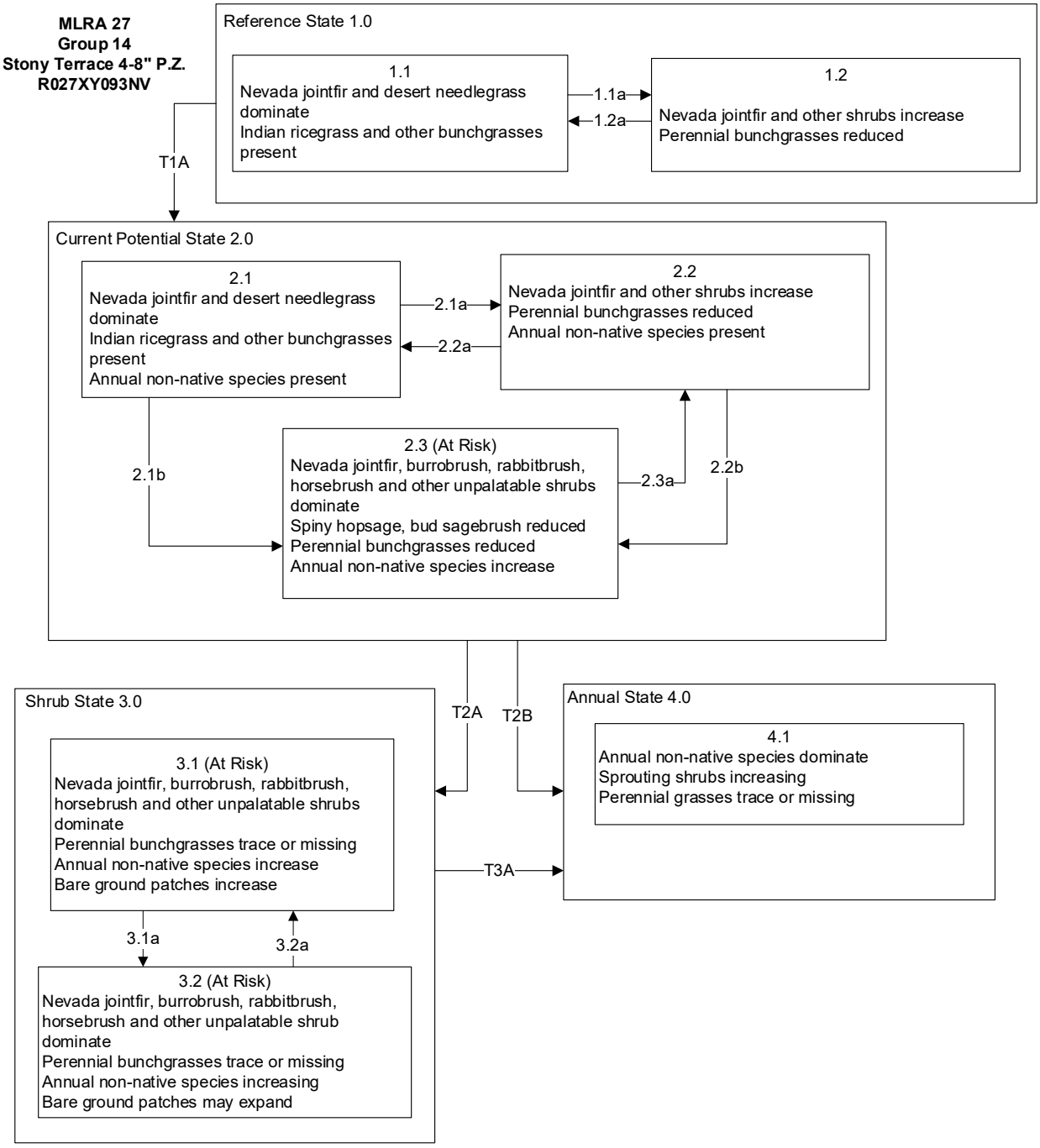
Current Potential State 2.0 Community Phase Pathways
2.1a: Prolonged drought reduces perennial bunchgrasses or an unusually wet spring makes shadscale more susceptible to insects and disease, reducing the shadscale component. Bailey's greasewood and other drought tolerant shrubs may increase.
2.1b: Inappropriate grazing management reduces deep-rooted perennial bunchgrasses and palatable shrubs.
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 which may lead to wildfires the following summer.

Shrub State 3.0 Community Phase Pathways
3.1a: Long-term inappropriate grazing, soil disturbance, or other disturbance reduces the palatable and/or nonpalatable 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 that may promote wildfires the following summer.


MLRA 27
Group 14
Stony Terrace 4-8" P.Z.
R027XY093NV
Reference State 1.0
1.1
Nevada jointfir and desert needlegrass dominate
Indian ricegrass and other bunchgrasses present
1.1a
1.2a
1.2
Nevada jointfir and other shrubs increase
Perennial bunchgrasses reduced
T1A
Current Potential State 2.0
2.1
Nevada jointfir and desert needlegrass dominate
Indian ricegrass and other bunchgrasses present
Annual non-native species present
2.1a
2.2a
2.2
Nevada jointfir and other shrubs increase
Perennial bunchgrasses reduced
Annual non-native species present
2.1b
2.3 (At Risk)
Nevada jointfir, burrobrush, rabbitbrush, horsebrush and other unpalatable shrubs dominate
Spiny hopsage, bud sagebrush reduced
Perennial bunchgrasses reduced
Annual non-native species increase
2.3a
2.2b
T2A
T2B
Shrub State 3.0
3.1 (At Risk)
Nevada jointfir, burrobrush, rabbitbrush, horsebrush and other unpalatable shrubs dominate
Perennial bunchgrasses trace or missing
Annual non-native species increase
Bare ground patches increase
3.1a
3.2a
3.2 (At Risk)
Nevada jointfir, burrobrush, rabbitbrush, horsebrush and other unpalatable shrub dominate
Perennial bunchgrasses trace or missing
Annual non-native species increasing
Bare ground patches may expand
T3A
Annual State 4.0
4.1
Annual non-native species dominate
Sprouting shrubs increasing
Perennial grasses trace or missing

MLRA 27
Group 14
Stony Terrace 4-8" P.Z.
R027XY093NV

Reference State 1.0 Community Phase Pathways
1.1a: Prolonged drought reduces the perennial bunchgrasses favoring shrub growth.
1.2a: Release from drought.

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

Current Potential State 2.0 Community Phase Pathways
2.1a: Prolonged drought reduces perennial bunchgrasses favoring shrub growth.
2.1b: Inappropriate grazing management reduces deep-rooted perennial bunchgrass and palatable shrubs.
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 which may lead to wildfires the following summer.

Shrub State 3.0 Community Phase Pathways
3.1a: Long-term inappropriate grazing, soil disturbance, or other disturbance reduces the palatable and/or nonpalatable 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 that may promote wildfires the following summer.

References

Allen, E. B., and M. F. Allen. 1988. Facilitation of succession by the nonmycotrophic colonizer *Salsola kali* (Chenopodiaceae) on a harsh site: effects of mycorrhizal fungi. American Journal of Botany **75**:257-266.

Banner, R., M. S. Pratt, and J. Bowns. 2011. Grasses and Grasslike Plants of Utah: A Field Guide. Utah State University Extension, Logan, UT.

Banner, R. E. 1992. Vegetation types of Utah. Rangelands **14**:109-114.

Bates, J. D., T. Svejcar, R. F. Miller, and R. A. Angell. 2006. The effects of precipitation timing on sagebrush steppe vegetation. Journal of Arid Environments **64**:670-697.

Baughman, O. W., R. Burton, M. Williams, P. J. Weisberg, T. E. Dilts, and E. A. Leger. 2017. Cheatgrass die-offs: a unique restoration opportunity in northern Nevada. Rangelands **39**:165-173.

Baughman, O. W., S. E. Meyer, Z. T. Aanderud, and E. A. Leger. 2016. Cheatgrass die-offs as an opportunity for restoration in the Great Basin, USA: will local or commercial native plants succeed where exotic invaders fail? Journal of Arid Environments **124**:193-204.

Beatley, J. C. 1975. Climates and vegetation pattern across the Mojave/Great Basin Desert transition of southern Nevada. The American Midland Naturalist **93**:53-70.

Bertiller, M. B., A. M. Beeskow, and F. Coronato. 1991. Seasonal environmental variation and plant phenology in arid Patagonia (Argentina). Journal of Arid Environments **21**:1-11.

Bich, B. S., J. L. Butler, and C. A. Schmidt. 1995. Effects of differential livestock use on key plant species and rodent populations within selected *Oryzopsis hymenoides*/*Hilaria jamesii* communities of Glen Canyon National Recreation Area. The Southwestern Naturalist **40**:281-287.

Blaisdell, J. P., and R. C. Holmgren. 1984. Managing intermountain rangelands - salt-desert shrub ranges. General Technical Report INT-163, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Blauer, A. C., A. P. Plummer, E. D. McArthur, R. Stevens, and B. C. Giunta. 1976. Characteristics and hybridization of important intermountain shrubs. II. Chenopod family. Research Paper INT-177, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Bleak, A., and R. Frischknecht. 1965. Problems in artificial and natural revegetation of the arid shadscale vegetation zone of Utah and Nevada. Rangeland Ecology & Management/Journal of Range Management Archives **18**:59-65.

Boerboom, C. 1993. Russian thistle (*Salsola iberica* Sennen & Pau).

Booth, D. T., C. G. Howard, and C. E. Mowry. 1980. 'Nezpar' Indian ricegrass: description, justification for release, and recommendations for use. Rangelands **2**:53-54.

Boyd, C. S., K. W. Davies, and A. Hulet. 2015. Predicting fire-based perennial bunchgrass mortality in big sagebrush plant communities. International Journal of Wildland Fire **24**:527-533.

Bradley, B. A., C. A. Curtis, E. J. Fusco, J. T. Abatzoglou, J. K. Balch, S. Dadashi, and M.-N. Tuanmu. 2018. Cheatgrass (*Bromus tectorum*) distribution in the intermountain Western

United States and its relationship to fire frequency, seasonality, and ignitions. Biological Invasions **20**:1493-1506.

Brehm, J. R. 2019. Cheatgrass die-off in the Great Basin: a comparison of remote sensing detecting methods and identification of environments favorable to die-off. M.S. Thesis. University of Nevada, Reno, NV.

Carlson, J. R. 1984. *Atriplex* cultivar development. Pages 176-182 *in* Proceedings—Symposium on the biology of *Atriplex* and related chenopods; May 2-6, 1983; Provo, UT. General Technical Report INT-172. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station.

Caudle, D., J. DiBenedetto, M. Karl, H. Sanchez, and C. Talbot. 2013. Interagency ecological site handbook for rangelands. U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.

Chambers, J. C., B. A. Bradley, C. S. Brown, C. D'Antonio, M. J. Germino, J. B. Grace, S. P. Hardegree, R. F. Miller, and D. A. Pyke. 2013. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of western North America. Ecosystems **17**:360-375.

Chambers, J. C., and B. E. Norton. 1993. Effects of grazing and drought on population dynamics of salt desert shrub species on the Desert Experimental Range, Utah. Journal of Arid Environments **24**:261-275.

Cibils, A. F., S. M. David, and D. E. McArthur. 1998. Plant-herbivore interactions in *Atriplex*: current state of knowledge. General Technical Report RMRS-GTR-14, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Comstock, J. P., and J. R. Ehleringer. 1992. Plant adaptation in the Great Basin and Colorado Plateau. The Great Basin Naturalist **52**:195-215.

Cook, C. W. 1962. An evaluation of some common factors affecting utilization of desert range species. Journal of Range Management **15**:333-338.

Cook, C. W., and R. D. Child. 1971. Recovery of desert plants in various states of vigor. Rangeland Ecology & Management/Journal of Range Management Archives **24**:339-343.

Crofts, K. A., and G. V. Epps. 1975. The usefulness of shadscale in the revegetation of disturbed sites in the salt desert shrub type. Pages 151-152 *in* Proceedings: Symposium and workshop: Wildland shrubs. U.S. Department of Agriculture, Forest Service, Shrub Sciences Laboratory, Provo, UT.

Cronin, E. H. 1965. Ecological and physiological factors influencing chemical control of *Halogeton glomeratus*. US Department of Agriculture.

Daubenmire, R. 1970. Steppe vegetation of Washington. Technical Report 62, Washington State University, Washington Agricultural Experiment Station, Pullman, WA.

Everett, R. L., P. T. Tueller, J. B. Davis, and A. D. Brunner. 1980. Plant phenology in galleta-shadscale and galleta-sagebrush associations. Rangeland Ecology & Management/Journal of Range Management Archives **33**:446-450.

Evert, R. F. 2006. Esau's plant anatomy: Meristems, cells, and tissues of the plant body - Their structure, function, and development. Third Edition edition. John Wiley & Sons, Inc., Hoboken, New Jersey.

Fernandez, O. A., and M. M. Caldwell. 1975. Phenology and dynamics of root growth of three cool semi-desert shrubs under field conditions. Journal of Ecology **63**:703-714.

Furbush, P. 1953. Control of medusa-head on California ranges. Journal of Forestry **51**:118-121.

Gardner, W. R. 1960. Dynamic aspects of water availability to plants. Soil Science **89**:63-73.

Green, L. R., L. A. Sharp, C. W. Cook, and L. E. Harris. 1951. Utilization of winter range forage by sheep. Journal of Range Management **4**:233-241.

Harper, K. T., F. J. Wagstaff, and W. P. Clary. 1990. Shrub mortality over a 54-year period in shadscale desert, west-central Utah. Pages 119-126 *in* Proceedings—Symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; Las Vegas, NV, April 5-7, 1989; General Technical Report INT-276. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Harrington, H. D. 1954. Manual of the plants of Colorado: For the identification of the ferns and flowering plants of the state. Sage Books, Denver, CO.

Harrison, B. J., Thatcher, A.P. 1970. Winter sheep grazing and forage preference in southwestern Wyoming. Journal of Range Management **23**:109-111.

Haubensak, K., C. D'Antonio, and D. Wixon. 2009. Effects of fire and environmental variables on plant structure and composition in grazed salt desert shrublands of the Great Basin (USA). Journal of Arid Environments **73**:643-650.

Humphrey, L. D. 1984. Patterns and mechanisms of plant succession after fire on *Artemisia*-grass sites in southeastern Idaho. Vegetatio **57**:91-101.

Hunter, R., A. Wallace, and E. M. Romney. 1978. Persistent atrazine toxicity in Mohave Desert shrub communities. Journal of Range Management **31**:199-203.

Jameson, D. A. 1962. Effects of burning on a galleta-black grama range invaded by juniper. Ecology **43**:760-763.

Johnson, K. L. 1978. Wyoming shrublands: Proceedings of the 7th Wyoming shrub ecology workshop; Rock Springs, WY; May 31 - June 1, 1978. University of Wyoming, Range Management Division, Wyoming Shrub Ecology Workshop.

Johnson, N. C. 1998. Responses of *Salsola kali* and *Panicum virgatum* to mycorrhizal fungi, phosphorus and soil organic matter: implications for reclamation. Journal of Applied Ecology **35**:86-94.

Jones, T. A. 1990. A viewpoint on Indian ricegrass research: its present status and future prospects. Journal of Range Management **43**:416-420.

Kearney, T. H., R. H. Peebles, J. T. Howell, and E. McClintock. 1960. Arizona flora. Second edition. University of California Press, Berkeley, CA.

Keeler, R. F. 1989. Investigation of maternal and embryo-fetal toxicity of *Ephedra viridis* and *Ephedra nevadensis* in sheep and cattle. Journal of Range Management **42**:31-35.

Klemmedson, J. O., and J. G. Smith. 1964. Cheatgrass (*Bromus tectorum* L.). The Botanical Review **30**:226-262.

Knapp, P. A. 1998. Spatio-temporal patterns of large grassland fires in the Intermountain West, U.S.A. Global Ecology and Biogeography Letters **7**:259-272.

Koniak, S. 1985b. Succession in pinyon-juniper woodlands following wildfire in the Great Basin. The Great Basin Naturalist **45**:556-566.

Kufeld, R. C., O. C. Wallmo, and C. Feddema. 1973a. Foods of the Rocky Mountain mule deer. Rocky Mountain Forest and Range Experiment Station, Forest Service, US Department of Agriculture.

Lauenroth, W., and J. Bradford. 2006. Ecohydrology and the partitioning AET between transpiration and evaporation in a semiarid steppe. Ecosystems **9**:756-767.

Mack, R. N., and D. A. Pyke. 1983. The demography of *Bromus tectorum*: Variation in time and space. Journal of Ecology **71**:69-93.

McCullough, D. R., and E. R. Schneegas. 1966. Winter observations on the Sierra Nevada bighorn sheep. California Fish and Game **52**:68-84.

Meyer, S. E., S. L. Carlson, and S. C. Garvin. 1998. Seed germination regulation and field seed bank carryover in shadscale (*Atriplex confertifolia*: Chenopodiaceae). Journal of Arid Environments **38**:255-267.

Miller, R. F., S. T. Knick, D. A. Pyke, C. W. Meinke, S. E. Hanser, M. J. Wisdom, and A. L. Hild. 2008a. Characteristics of sagebrush habitats and limitations to long-term conservation. Administrative Report, U.S. Department of the Interior; U.S. Geological Survey, Reston, VA.

Miller, R. F., R. J. Tausch, and W. Waichler. 1999b. Old-growth juniper and pinyon woodlands. Pages 375-384 *in* Proceedings: ecology and management of pinyon-juniper communities within the interior west; September 15-18, 1997. Proceedings RMRS-P-9. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Brigham Young University Conference Center, Provo, UT.

Monsen, S. B., and S. G. Kitchen. 1994. Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Monsen, S. B., R. Stevens, and N. L. Shaw. 2004a. Grasses. Pages 295-424 *in* S. B. Monsen, R. Stevens, and N. L. Shaw, editors. Restoring western ranges and wildlands, vol. 2. Gen. Tech. Rep. RMRS-GTR-136-vol-2. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Nelson, C. R., B. A. Haws, and D. L. Nelson. 1990. Mealybugs and related homoptera of shadscale: possible agents in the dieoff problem in the Intermountain West. Pages 152-165 *in* Symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management. General Technical Report INT-276. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Las Vegas, Nevada, USA.

NRCS. 2022. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. Handbook 296, U.S. Department of Agriculture, Natural Resources Conservation Service.

Pearson, L. C. 1964. Effect of harvest date on recovery of range grasses and shrubs. Agronomy Journal **56**:80-82.

Pearson, L. C. 1965. Primary production in grazed and ungrazed desert communities of eastern Idaho. Ecology **46**:278-285.

Perkins, S. 2008a. Plant fact sheet for desert needlegrass (*Achnatherum speciosum*). USDA NRCS Great Basin Plant Materials Center, Fallon, Nevada.

Peters, E. F., and S. C. Bunting. 1994. Fire conditions pre-and post-occurrence of annual grasses on the Snake River Plain. Pages 31-36 *in* Proceedings—Ecology and management of annual rangelands; September, 1994; Boise, ID. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Phillips, R. L., N. K. McDougald, and J. Sullins. 1996. Plant preference of sheep grazing the Mojave desert. Rangelands **18**:141-144.

Pratt, M. S., G. A. Rasmussen, and R. E. Banner. 2002. Range judging in Utah. NR 505, Utah State University Extension, Logan, UT.

Quinones, F. A. 1981. Indian ricegrass evaluation and breeding. Bulletin 681, New Mexico State University, Agricultural Experiment Station, Las Cruces, NM.

Rice, B., and M. Westoby. 1978. Vegetative responses of some Great Basin shrub communities protected against jackrabbits or domestic stock. Journal of Range Management **31**:28-34.

Rickard, W. H., and M. C. McShane. 1984. Demise of spiny hopsage shrubs following summer wildfire: An authentic record. Northwest Science **58**:282-285.

Robocker, W. C., M. C. Williams, R. A. Evans, and P. J. Torell. 1969. Effects of age, burial, and region on germination and viability of halogeton seed. Weed Science **17**:63-65.

Sampson, A. W., A. Chase, and D. W. Hedrick. 1951. California grasslands and range forage grasses. Bulletin 724, University of California, the College of Agriculture, California Agricultural Experiment Station, Berkeley, CA.

Sanderson, S. C., and H. C. Stutz. 1994. Woody chenopods useful for rangeland reclamation in western North America. Pages 374-378 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Sanderson, S. C., H. C. Stutz, and E. D. McArthur. 1990. Geographic differentiation in *Atriplex confertifolia*. American Journal of Botany **77**:490-498.

Schultz, B. W., and W. K. Ostler. 1995. Effects of prolonged drought on vegetation associations on the northern Mojave Desert. Pages 228-235 *in* Proceedings: wildland shrub and arid land restoration symposium; Las Vegas, NV; October 19-21, 1993. General Technical Report INT-GTR-315. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Sharp, L. A., K. Sanders, and N. Rimbey. 1990. Forty years of change in a shadscale stand in Idaho. Rangelands **12**:313-328.

Shaw, N. L. 1992. Germination and seedling establishment of spiny hopsage (*Grayia spinosa* [Hook.] Moq.). PhD Dissertation. Oregon State University, Corvallis, OR.

Shaw, N. L., M. R. Haferkamp, and E. G. Hurd. 2008. *Grayia spinosa* (Hook.) Moq: spiny hopsage. Pages 567-572 The Woody Plant Seed Manual Agric. Handbook No. 727. US Department of Agriculture, Forest Service, Washington DC.

Simmons, S. A., and W. H. Rickard. 2003. Fire effects on spiny hopsage in south central Washington. Western North American Naturalist **63**:524-528.

Smith, J. T., B. W. Allred, C. S. Boyd, K. W. Davies, M. O. Jones, A. R. Kleinhesselink, J. D. Maestas, S. L. Morford, and D. E. Naugle. 2022. The elevational ascent and spread of

exotic annual grass dominance in the Great Basin, USA. Diversity and Distributions **28**:83-96.

Smith, S. D., and P. S. Nobel. 1986. Photosynthesis in contrasting environments. Elsevier Science Publishers, Amsterdam, New York.

Stanton, F. 1973. Wildlife guidelines for range fire rehabilitation. Technical Note 237, U.S. Department of the Interior, Bureau of Land Management, Denver, CO.

Stubbendieck, J. L., S. L. Hatch, N. M. Bryan, and C. D. Dunn. 2017. North American wildland plants. Third edition. University of Nebraska Press, Lincoln, NE.

Stubbendieck, J. L., S. L. Hatch, and C. H. Butterfield. 1992. North American range plants. Fourth edition. University of Nebraska Press, Lincoln, NE.

Stubbendieck, J. L., S. L. Hatch, and L. M. Landholt. 2003. North American wildland plants. University of Nebraska Press, Lincoln, NE.

Tisdale, E. W., and G. Zappetini. 1953. Halogeton studies on Idaho ranges. Journal of Range Management **6**:225-236.

USFS. 1988a. Range plant handbook. Reprint of 1937 edition. Dover Publications, New York, NY.

Vallentine, J. F. 1989. Range development and improvements. Academic Press, Inc., San Diego, CA.

Wallace, A., W. Rhods, and E. Frolich. 1968. Germination behavior of *Salsola* as influenced by temperature, moisture, depth of planting, and gamma irradiation. Agronomy Journal **60**:76-78.

Weber, D. J., D. L. Nelson, W. M. Hess, and R. B. Bhat. 1990. Salinity and moisture stress in relation to dieoff of wildland shrubs. Pages 91-102 *in* Proceedings - symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; Las Vegas, NV; April 5-7, 1989. General Technical Report INT-276. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Weisberg, P. J., T. E. Dilts, O. W. Baughman, S. E. Meyer, E. A. Leger, K. J. V. Gunst, and L. Cleeves. 2017. Development of remote sensing indicators for mapping episodic die-off of an invasive annual grass (*Bromus tectorum*) from the Landsat archive. Ecological Indicators **79**:173-181.

Welsh, S. L., N. D. Atwood, S. Goodrich, and L. C. Higgins. 1987. A Utah flora. Great Basin Naturalist Memoir No. 9 edition. Brigham Young University, Provo, Utah.

West, N. E. 1994. Effects of fire on salt-desert shrub rangelands. Pages 71-74 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, ID.

Wood, B. W., and J. D. Brotherson. 1986. Ecological adaptation and grazing response of budsage (*Artemisia spinescens*). Pages 75-92 *in* Symposium on the biology of *Artemisia* and *Chrysothamnus*; Provo, UT; July 9-13, 1984; General Technical Report INT-200. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Wright, H. A. 1971. Why squirreltail is more tolerant to burning than needle-and-thread. Journal of Range Management **24**:277-284.

Wright, H. A. 1985. Effects of fire on grasses and forbs in sagebrush-grass communities. Pages 12-21 *in* Rangeland fire effects: A symposium; Boise, ID; November 27-29, 1984. U.S. Department of the Interior, Bureau of Land Management, Boise, ID.

Young, F., R. Veseth, D. Thill, W. Schillinger, and D. Ball. 1995. Managing Russian thistle under conservation tillage in crop-fallow rotations.

Young, J. A. 2002. Halogeton grazing management: Historical perspective. Journal of Range Management **55**:309.

Young, J. A., and C. D. Clements. 2006. Nevada rangelands. Rangelands **28**:10-15.

Young, J. A., and R. A. Evans. 1978. Population dynamics after wildfires in sagebrush grasslands. Journal of Range Management **31**:283-289.

Young, J. A., and F. Tipton. 1990. Invasion of cheatgrass into arid environments of the Lahontan Basin. Pages 37-40 *in* Proceedings—Symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; Las Vegas, NV; April 5-7, 1989; General Technical Report INT-276. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Young, R. P. 1983. Fire as a vegetation management tool in rangelands of the intermountain region. Pages 18-31 *in* Managing Intermountain rangelands—Improvement of range and wildlife habitats. Proceedings of Symposia: September 15-17, 1981, Twin Falls, Idaho June 22·24, 1982, Elko, Nevada. General Technical Report INT-GTR-157. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Zielinski, M. J. 1994. Controlling erosion on lands administered by the Bureau of Land Management, Winnemucca District, Nevada. Pages 143-146 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

MLRA 27 Group 15: Silty soils with winterfat and Indian ricegrass

Description of MLRA 27 Disturbance Response Group 15

Disturbance Response Group (DRG) 15 consists of one ecological site, Coarse Silty 4-8" P.Z. (R027XY014NV). This site occurs on lower fan piedmonts, alluvial flats and inset fans. The precipitation ranges from 4 to 8 in. Slopes range from 2 to 15%, but slope gradients of 2–8% are typical. Elevations range from 4,000 to about 5,000 ft. The soils are typically deep to very deep and are well to somewhat excessively drained. The soils have coarse surface textures that provide rapid water infiltration, which enhances the effective moisture supply; however, available water capacity is low. Subsoil textures are silt loams, loams and sandy loams. The soils have moderately rapid permeability and slow runoff. The reference plant community is dominated by winterfat (*Krascheninnikovia lanata*) and/or Indian ricegrass (*Achnatherum hymenoides*), with sub-dominant components of bud sagebrush (*Artemisia spinescens*), needle-and-thread (*Hesperostipa comata*), and squirreltail (*Elymus elymoides*). Other common plants include Sandberg bluegrass (*Poa secunda*), galleta (*Pleuraphis jamesii*), sand dropseed (*Sporobolus cryptandrus*), shadscale (*Atriplex confertifolia*), Bailey's greasewood (*Sarcobatus baileyi*), spiny hopsage (*Grayia spinosa*), Nevada jointfir (*Ephedra nevadensis*) and fourwing saltbush (*Atriplex canescens*). Total annual air-dry production ranges from 350 to 700 lb/ac with 500 lb/ac in a normal year.

Disturbance Response Group 15 Ecological Sites:

Coarse Silty 4-8" P.Z. – Modal	R027XY014NV

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 27 (MLRA 27 Fallon-Lovelock Area) is almost entirely in Nevada with < 1% in California. The entire area occurs in the rain shadow of the Sierra Nevada mountains and is influenced by Pleistocene Lake Lahontan. Extensive playas occur throughout the area and are a result of the drying of ancient Lake Lahontan. To the west, MLRA 27 has a gradual

boundary with MLRA 26 (Carson Basin and Mountains) and to the east has a very gradual boundary with MLRA 24 (Humboldt Basin and Range Area). From west to east the soil temperature increases and the soil moisture decreases, resulting in vast areas dominated by salt-desert shrub communities. Isolated mountain ranges trending north to south are separated by broad desert plains and valleys. Elevations range from 3,300 to 5,900 ft with some mountain peaks over 7,800 ft. The average annual precipitation ranges from 4 to 11 in. and as much as 20 in. at the highest elevations. The majority of annual precipitation is received during late fall and winter occurring mainly as snow. High-intensity, convective thunderstorms also contribute significantly to annual precipitation (NRCS 2022). 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, with drought duration and severity increasing throughout the 20th century in much of the Intermountain West (Miller et al. 2008b). 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 site in this DRG is 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 (1.64 ft) 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 cool-season, long-lived and drought tolerant species (Mozingo 1987b). 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. tall), 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 to 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 4–10 in. and a spread of 8–12 in. (Stubbendieck et al. 2017). Bud sagebrush roots are more branched and deeper 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 sagebrush 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 (4–24 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).

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).

Squirreltail is a short, cool-season bunchgrass that grows between 10 to 45 cm (4–18 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) (Welsh et al. 1987). 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 (Welsh et al. 1987).

This ecological site often exhibits 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 biocrusts exhibited higher runoff and more sediment loss than the trampled or scraped crusts. Furthermore, the authors report the trampled dark colored

biocrusts shed slightly more water, after 30 min of intense rainfall (9 in./hr) than the intact comparison. Other authors report a reduction in biotic crust integrity with inappropriate grazing management, wildland fire and cheatgrass (*Bromus tectorum*) invasion (Belnap 2006, Ponzetti et al. 2007).

The ecological site in this DRG has low to moderate resilience to disturbance and resistance to invasion. Drought and/or inappropriate grazing will initially favor shrubs but prolonged drought can cause a decrease in the winterfat and other shrubs while bare ground increases. Squirreltail may maintain or also decline within the community. Repeated spring and early summer grazing will have an especially detrimental effect on winterfat. Cheatgrass and other non-native annual species increase with excessive grazing. Abusive grazing during the winter may lead to soil compaction and reduced infiltration. Prolonged abusive grazing during any season leads to abundant bare ground, desert pavement and active wind and water erosion. Repeated, frequent fire will promote cheatgrass dominance and elimination of the native plant community. These sites frequently attract recreational use, primarily by off highway vehicles (OHV). Annual non-native species increase where surface soils have been disturbed. Five stable states have been identified for this site.

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 (*Bromus tectorum*), red brome (*Bromus rubens*), halogeton (*Halogeton glomeratus*), Russian thistle (*Salsola tragus*) and weedy mustard species (Brassicacae 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 this ecological site.

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).

Methods to control cheatgrass include herbicide application, prescribed burning, targeted grazing, and rangeland seeding. The majority of research on cheatgrass control has focused on

Wyoming big sagebrush (*Artemisia tridentata sp. 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. 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 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.

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.

Bud sagebrush is fire intolerant and must reestablish from seed (Banner 1992, 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 et al. 1983). Boyd et al. (2015) found soil color and depth of burn to be accurate predictors of bunchgrass mortality in post fire landscape. 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, which is likely due to its low culm density and below-ground plant crowns (Wright 1985). Vallentine cites 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 seeds 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 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.

Squirreltail is considered more fire tolerant than Indian ricegrass due to its small size, coarse stems, broad leaves and generally sparse leafy material (Wright 1971, Britton et al. 1990). Post-fire regeneration occurs from surviving root crowns and from on-and off-site seed sources. 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).

Livestock/Wildlife Grazing Interpretations:

Salt-desert shrub communities are characterized by low herbage yields and grazing capacities. The salt-desert is mainly used as winter range for the maintenance of breeding or gestating livestock, thus nutritional requirements are relatively low (Blaisdell and Holmgren 1984).

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 5–16 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*), pronghorn (*Antilocapra americana*), and other wildlife species (Stevens et al. 1977, Ogle et al. 2001). Winterfat and perennial grasses average 80% of jackrabbits' (*Lepus* ssp.) 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 (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.

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).

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 et al. 1987). Squirreltail is more tolerant of grazing than Indian ricegrass but all bunchgrasses are sensitive to over utilization within the growing season.

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 gives a competitive advantage to shrub species including black sagebrush (Eckert et al. 1972). Reduced bunchgrass vigor or

density provides an opportunity for Sandberg bluegrass expansion and/or cheatgrass and other invasive species such as halogeton to occupy interspaces. 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 Sandberg bluegrass or cheatgrass may become the dominant understory with inappropriate grazing management.

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 MLRA 27 Disturbance Response Group 15.

Five possible states have been identified for this DRG including a Reference State, Current Potential State, Shrub State, Annual State and an Abiotic State.

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 abusive grazing. 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 winterfat and Indian ricegrass. Bud sagebrush, needle-and-thread and squirreltail are also common on this site. Potential vegetative composition by air-dry weight is approximately 55% grasses, 5% forbs and 40% shrubs. Approximate ground cover (basal and crown) is 10–20%. Total annual air-dry production ranges from 350 to 700 lb/ac. Community phase changes are primarily a function of chronic drought. Fire is infrequent and patchy due to low fuel loads.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
Prolonged drought and/or excessive herbivory reduces deep-rooted perennial grasses 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 and needle-and-thread are 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, annual 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. 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. Bud sagebrush, needle-and-thread, and squirreltail are also common on this site. Non-native annual species are present.

Coarse Silty 4-8" P.Z. (R027XY014NV), Current Potential State 2.1, T. Stringham, June 2025

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 cattle and/or horse grazing will favor unpalatable shrubs such as Bailey's greasewood and cause a decline in Indian ricegrass, needle-and-thread, winterfat, spiny hopsage and fourwing saltbush.

Community Phase 2.2 (At-Risk):
Indian ricegrass, needle-and-thread, winterfat and bud sagebrush are reduced, however, Sandberg bluegrass, galleta, and sand dropseed may increase. Annual non-native species may be stable to increasing, and bare ground is increasing. This community phase is At Risk of crossing a threshold to either a Shrub State 3.0 (inappropriate grazing and no fire) or an Annual State 4.0 (fire).

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Release from long-term drought and/or appropriate grazing management and/or control of horse grazing pressure 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 perennial bunchgrasses during the growing season and/or long-term drought will favor shrub establishment 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 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: Severe fire/multiple fires and/or long-term inappropriate grazing.

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, a non-sprouting shrub phase and a sprouting shrub phase. 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 like Indian ricegrass are significantly reduced or missing, and the site is dominated by winterfat and bud sagebrush. Perennial forbs are of minor extent. Annual non-native species are present and bare ground has increased.

Coarse Silty 4-8" P.Z. (R027XY014NV), Shrub State 3.1, T. Stringham, May 2024

Community Phase Pathway 3.1a from Phase 3.1 to 3.2:
Long-term inappropriate grazing and/or brush treatments with minimal soil disturbance reduces winterfat, fourwing saltbush and/or bud sagebrush cover and allows for the increase in unpalatable shrubs.

Community Phase 3.2 (At-Risk):
Yellow rabbitbrush (*Chrysothamnus viscidiflorus*) 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.

Community Phase Pathway 3.2a from Phase 3.2 to 3.1:
Time and lack of disturbance and/or grazing management that favors the reestablishment and growth of winterfat and/or other palatable shrubs.

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

Trigger: Long-term inappropriate grazing, flooding, severe drought, and/or unsuccessful soil disturbing treatments such as drill seeding or roller chopping, etc. and/or long-term, chronic drought, and/or fire.

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, and/or severe drought 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 non-native annual species. Halogeton, Russian thistle, and/or cheatgrass dominate the plant community. Bare ground may be abundant and native vegetation is trace or missing.

Community Phase 4.1:
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.

Coarse Silty 4-8" P.Z. (R027XY014NV), Annual State 4.1, T. Stringham, May 2024

Community Phase Pathway 4.1a, from Phase 4.1 to 4.2:
Time and lack of disturbance allows for sprouting shrubs to become co-dominant with the annual non-native species. Probability of winterfat reestablishment is extremely low.

Community Phase 4.2:
Winterfat is co-dominant with annual non-native species in this phase. Perennial bunchgrasses are a trace component or are missing. Bare ground may be abundant, especially during low precipitation years.

Community Phase Pathway 4.2a, from Phase 4.2 to 4.1:
Fire, soil disturbance, and/or inappropriate grazing management eliminates shrub component and allows for annual non-native species to dominate the site.

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

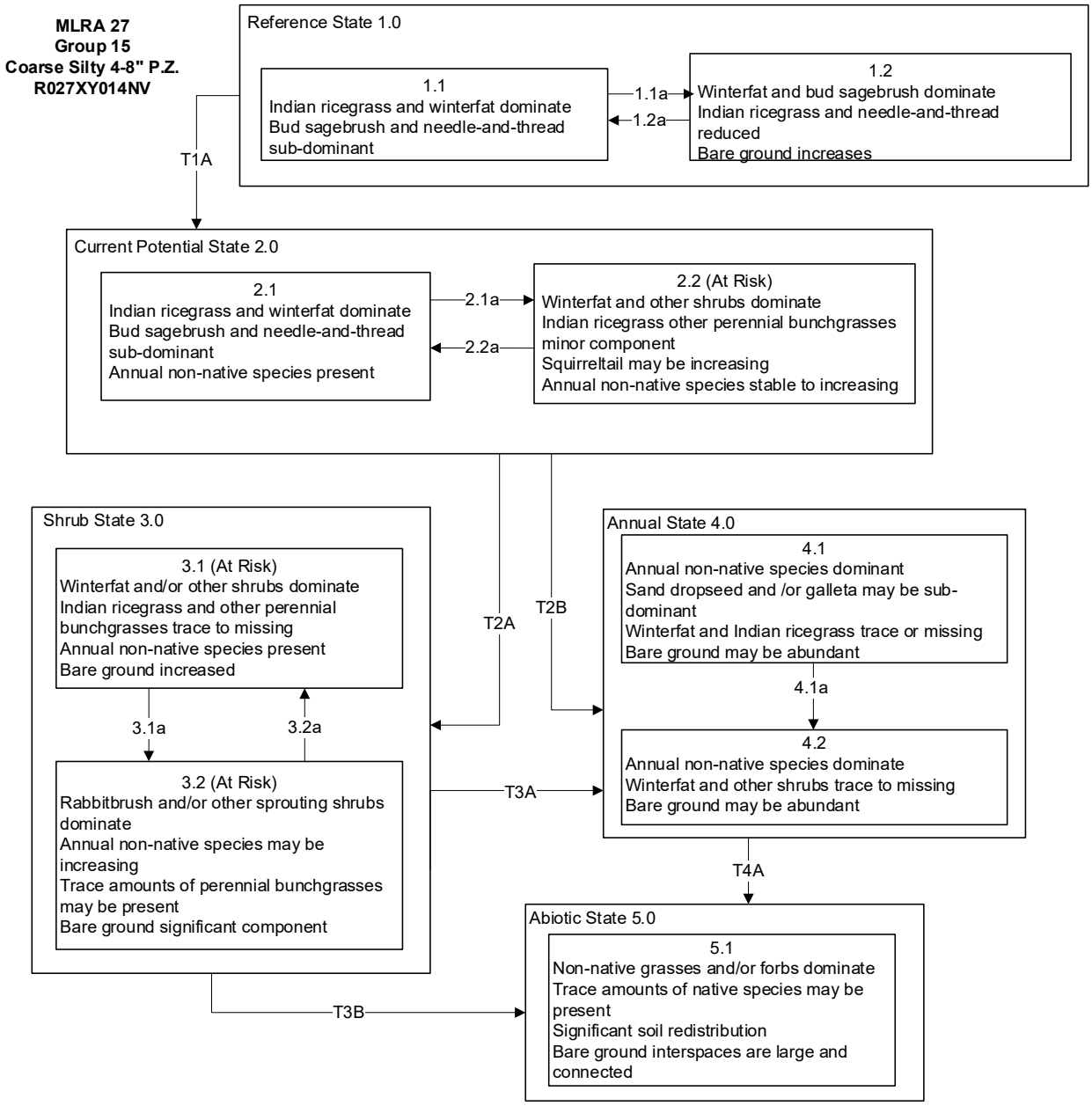
the redistribution and loss of the soil surface. Feedbacks contributing to the stability of this state include soil loss, nutrient loss, soil surface degradation and increased bare ground, soil redistribution and connectivity between patches of bare soil.

Community Phase 5.1:
This community is the result of extreme soil loss and redistribution. The vegetative cover is minimal, and is dominated by introduced non-native grasses and/or forbs. Trace amounts of native 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 4-8" P.Z. (R027XY014NV), Abiotic State. 5.1, P. Novak-Echenique, March 2026

Coarse Silty 4-8" P.Z. (R027XY014NV), Abiotic State 5.1, P. Novak-Echenique, March 2026

Modal State and Transition Model for Group 15 MLRA 27



MLRA 27
Group 15
Coarse Silty 4-8" P.Z.
R027XY014NV

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 reduces winterfat, bud sagebrush and Indian ricegrass. Less palatable shrubs and grasses may increase. Drought will favor shrubs or grasses but a prolonged drought will reduce all vegetation regardless of functional group.
2.2a: Release from long-term drought and/or appropriate grazing management and/or control of 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 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 will reduce winterfat, fourwing saltbush, and/or bud sagebrush cover and allow increase in unpalatable shrubs.
3.2a: Grazing and/or horse and burro management that favors the reestablishment and growth of winterfat, fourwing saltbush and bud sagebrush and/or other palatable 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, 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, 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.

References

Akinsoji, A. 1988. Postfire vegetation dynamics in a sagebrush steppe in southeastern Idaho, USA. Vegetatio **78**:151-155.

Banner, R. E. 1992. Vegetation types of Utah. Rangelands **14**:109-114.

Bates, J. D., T. Svejcar, R. F. Miller, and R. A. Angell. 2006. The effects of precipitation timing on sagebrush steppe vegetation. Journal of Arid Environments **64**:670-697.

Beatley, J. C. 1975. Climates and vegetation pattern across the Mojave/Great Basin Desert transition of southern Nevada. The American Midland Naturalist **93**:53-70.

Belnap, J. 2006. The potential roles of biological soil crusts in dryland hydrologic cycles. Hydrological Processes **20**:3159-3178.

Bich, B. S., J. L. Butler, and C. A. Schmidt. 1995. Effects of differential livestock use on key plant species and rodent populations within selected *Oryzopsis hymenoides*/*Hilaria jamesii* communities of Glen Canyon National Recreation Area. The Southwestern Naturalist **40**:281-287.

Blaisdell, J. P., and R. C. Holmgren. 1984. Managing intermountain rangelands - salt-desert shrub ranges. General Technical Report INT-163, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Booth, D. T., C. G. Howard, and C. E. Mowry. 1980. 'Nezpar' Indian ricegrass: description, justification for release, and recommendations for use. Rangelands **2**:53-54.

Booth, T. D. 1989. Seedbed ecology of winterfat: cations in diaspore bracts and their effect on germination and early plant growth. Journal of Range Management **42**:178-182.

Boyd, C. S., K. W. Davies, and A. Hulet. 2015. Predicting fire-based perennial bunchgrass mortality in big sagebrush plant communities. International Journal of Wildland Fire **24**:527-533.

Bradley, A. F., N. V. Noste, and W. C. Fischer. 1992. Fire ecology of forests and woodlands in Utah. General Technical Report INT-287, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Bradley, B. A., C. A. Curtis, E. J. Fusco, J. T. Abatzoglou, J. K. Balch, S. Dadashi, and M.-N. Tuanmu. 2018. Cheatgrass (*Bromus tectorum*) distribution in the intermountain Western United States and its relationship to fire frequency, seasonality, and ignitions. Biological Invasions **20**:1493-1506.

Britton, C. M., G. R. McPherson, and F. A. Sneva. 1990. Effects of burning and clipping on five bunchgrasses in eastern Oregon. The Great Basin Naturalist **50**:115-120.

Caudle, D., J. DiBenedetto, M. Karl, H. Sanchez, and C. Talbot. 2013. Interagency ecological site handbook for rangelands. U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.

Chambers, J. C., B. A. Bradley, C. S. Brown, C. D'Antonio, M. J. Germino, J. B. Grace, S. P. Hardegree, R. F. Miller, and D. A. Pyke. 2013. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of western North America. Ecosystems **17**:360-375.

Chambers, J. C., and B. E. Norton. 1993. Effects of grazing and drought on population dynamics of salt desert shrub species on the Desert Experimental Range, Utah. Journal of Arid Environments **24**:261-275.

Clark, S. L., D. J. Sebastian, S. J. Nissen, and J. R. Sebastian. 2019. Effect of indaziflam on native species in natural areas and rangeland. Invasive Plant Science and Management **12**:60-67.

Clements, C. D., J. A. Young, D. N. Harmon, and G. McCuin. 2010. Revegetation of degraded winterfat communities. Rangelands **32**:37-40.

Comstock, J. P., and J. R. Ehleringer. 1992. Plant adaptation in the Great Basin and Colorado Plateau. The Great Basin Naturalist **52**:195-215.

Cook, C. W. 1962. An evaluation of some common factors affecting utilization of desert range species. Journal of Range Management **15**:333-338.

Cook, C. W., and R. D. Child. 1971. Recovery of desert plants in various states of vigor. Rangeland Ecology & Management/Journal of Range Management Archives **24**:339-343.

Courkamp, J. S., P. J. Meiman, and M. W. Paschke. 2022. Indaziflam reduces seed bank richness and density but not sagebrush-grassland plant diversity. Rangeland Ecology & Management **84**:31-44.

Davies, K. W., C. S. Boyd, J. D. Bates, and A. Hulet. 2015a. Dormant season grazing may decrease wildfire probability by increasing fuel moisture and reducing fuel amount and continuity. International Journal of Wildland Fire **24**:849-856.

Davies, K. W., A. M. Nafus, C. S. Boyd, A. Hulet, and J. D. Bates. 2016. Effects of using winter grazing as a fuel treatment on Wyoming big sagebrush plant communities. Rangeland Ecology & Management **69**:179-184.

Dobrowolski, J. P., M. M. Caldwell, and J. H. Richards. 1990. Chapter 7: Basin hydrology and plant root systems. Pages 243-292 *in* C. B. Osmond, L. F. Pitelka, and G. M. Hidy, editors. Plant Biology of the Basin and Range. Springer-Verlag, New York City, NY.

Dwyer, D. D., and R. D. Pieper. 1967. Fire effects on blue grama-pinyon-juniper rangeland in New Mexico. Rangeland Ecology & Management/Journal of Range Management Archives **20**:359-362.

Eckert, R. E., Jr. 1954. A study of competition between whitesage and halogeton in Nevada. Journal of Range Management **7**:223-225.

Eckert, R. E., Jr., A. D. Bruner, and G. J. Klomp. 1972. Response of understory species following herbicidal control of low sagebrush. Journal of Range Management **25**:280-285.

Eckert, R. E., Jr., F. F. Peterson, and F. L. Emmerich. 1987. A study of factors influencing secondary succession in the sagebrush [*Artemisia* spp. L.] type. Pages 149-168 *in* Proceedings: Seed and seedbed ecology of rangeland plants; April 21-23, 1987; Tucson, AZ. U. S. Department of Agriculture, Agricultural Research Service, Tucson, A.Z.

Everett, R. L., P. T. Tueller, J. B. Davis, and A. D. Brunner. 1980. Plant phenology in galleta-shadscale and galleta-sagebrush associations. Rangeland Ecology & Management/Journal of Range Management Archives **33**:446-450.

Faist, A. M., J. E. Herrick, J. Belnap, J. W. V. Zee, and N. N. Barger. 2017. Biological soil crust and disturbance controls on surface hydrology in a semi-arid ecosystem. Ecosphere **8**:1-13.

Freeman, D. C., and M. J. Emlen. 1995. Assessment of interspecific interactions in plant communities: an illustration from the cold desert saltbush grasslands of North America. Journal of Arid Environments **31**:179-198.

Furbush, P. 1953. Control of medusa-head on California ranges. Journal of Forestry **51**:118-121.

Harper, K. T., F. J. Wagstaff, and W. P. Clary. 1990. Shrub mortality over a 54-year period in shadscale desert, west-central Utah. Pages 119-126 *in* Proceedings—Symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; Las Vegas, NV, April 5-7, 1989; General Technical Report INT-276. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Hild, A. L., J. M. Muscha, and N. L. Shaw. 2007. Emergence and growth of four winterfat accessions in the presence of the exotic annual cheatgrass. Pages 147-152 *in* Proceedings: Shrubland dynamics - fire and water; Lubbock, TX; August 10-12, 2004; RMRS-P-47. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Hilton, J. W. 1941. Effects of certain micro-ecological factors on the germinability and early development of *Eurotia lanata*. Northwest Science **15**:89-92.

Hironaka, M., and E. W. Tisdale. 1973. Growth and development of *Sitanion hystrix* and *Poa sandbergii*. Research Memorandum RM 73-16, U.S. International Biological Program, Desert Biome, Logan, UT.

Hutchings, S. S., and G. Stewart. 1953. Increasing forage yields and sheep production on intermountain winter ranges. Circular No. 925, U.S. Department of Agriculture, Washington, D.C.

Jameson, D. A. 1962. Effects of burning on a galleta-black grama range invaded by juniper. Ecology **43**:760-763.

Johnson, K. L. 1978. Wyoming shrublands: Proceedings of the 7th Wyoming shrub ecology workshop; Rock Springs, WY; May 31 - June 1, 1978. University of Wyoming, Range Management Division, Wyoming Shrub Ecology Workshop.

Johnson, K. M. 1979. Foods of primary consumers on cold desert shrub-steppe of Southcentral Idaho. Journal of Range Management **32**:365.

Johnson, R. D., and J. E. Anderson. 1984. Diets of black-tailed jack rabbits in relation to population density and vegetation. Journal of Range Management **37**:79-83.

Jones, T. A. 1990. A viewpoint on Indian ricegrass research: its present status and future prospects. Journal of Range Management **43**:416-420.

Kaapro, J., and J. Hall. 2012. Indaziflam - a new herbicide for pre-emergent control of weeds in turf, forestry, industrial vegetation and ornamentals. Pages 224-227 *in* 23rd Asian-Pacific Weed Science Society Conference: Conference Proceedings Volume 1; Queensland, Australia; September 26-29 2011. Asian-Pacific Weed Science Society.

Klemmedson, J. O., and J. G. Smith. 1964. Cheatgrass (*Bromus tectorum* L.). The Botanical Review **30**:226-262.

Mack, R. N., and D. A. Pyke. 1983. The demography of *Bromus tectorum*: Variation in time and space. Journal of Ecology **71**:69-93.

Majerus, M. E. 2003. Production and conditioning of winterfat seeds (*Krascheninnikovia lanata*). Native Plants Journal **4**:10-15.

Miller, R. F., J. C. Chambers, D. A. Pyke, F. B. Pierson, and C. J. Williams. 2013. A review of fire effects on vegetation and soils in the Great Basin Region: Response and ecological site characteristics. General Technical Report RMRS-GTR-308, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Miller, R. F., and J. A. Rose. 1999. Fire history and western juniper encroachment in sagebrush steppe. Journal of Range Management **52**:550-559.

Miller, R. F., R. J. Tausch, E. D. McArthur, D. D. Johnson, and S. C. Sanderson. 2008b. Age structure and expansion of piñon-juniper woodlands: A regional perspective in the Intermountain West. Research Paper Report RMRS-RP-69, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Mozingo, H. N. 1987b. Shrubs of the Great Basin: A natural history. University of Nevada Press, Reno, NV.

NRCS. 2022. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. Handbook 296, U.S. Department of Agriculture, Natural Resources Conservation Service.

Ogle, D. G., L. St. John, and L. Holzworth. 2001. Plant guide for management and use of winterfat. U.S. Department of Agriculture, Natural Resource Conservation Service, Boise, ID.

Pearson, L. C. 1964. Effect of harvest date on recovery of range grasses and shrubs. Agronomy Journal **56**:80-82.

Pearson, L. C. 1965. Primary production in grazed and ungrazed desert communities of eastern Idaho. Ecology **46**:278-285.

Pellant, M., and L. Reichert. 1984. Management and rehabilitation of a burned winterfat community in southwestern Idaho. Pages 281-285 *in* Proceedings—Symposium on the biology of *Atriplex* and related chenopods; Provo, UT; May 2-6, 1983; General Technical Report INT-172. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Perryman, B. L., B. W. Schultz, M. Burrows, T. Shenkoru, and J. Wilker. 2020. Fall-grazing and grazing-exclusion effects on cheatgrass (*Bromus tectorum*) seed bank assays in Nevada, United States. Rangeland Ecology & Management **73**:343-347.

Peters, E. F., and S. C. Bunting. 1994. Fire conditions pre-and post-occurrence of annual grasses on the Snake River Plain. Pages 31-36 *in* Proceedings—Ecology and management of annual rangelands; September, 1994; Boise, ID. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Ponzetti, J. M., B. McCune, and D. A. Pyke. 2007. Biotic Soil crusts in relation to topography, cheatgrass and fire in the Columbia Basin, Washington. The American Bryological and Lichenological Society.

Quinones, F. A. 1981. Indian ricegrass evaluation and breeding. Bulletin 681, New Mexico State University, Agricultural Experiment Station, Las Cruces, NM.

Rasmussen, L. L., and J. D. Brotherson. 1986. Response of winterfat (*Ceratoides lanata*) communities to release from grazing pressure. Great Basin Naturalist **46**:148-156.

Rice, B., and M. Westoby. 1978. Vegetative responses of some Great Basin shrub communities protected against jackrabbits or domestic stock. Journal of Range Management **31**:28-34.

Robocker, W. C., M. C. Williams, R. A. Evans, and P. J. Torell. 1969. Effects of age, burial, and region on germination and viability of halogeton seed. Weed Science **17**:63-65.

Romo, J. T., R. E. Redmann, B. L. Kowalenko, and A. R. Nicholson. 1995. Growth of winterfat following defoliation in northern mixed prairie of Saskatchewan. Journal of Range Management **48**:240-245.

Sebastian, D. J., M. B. Fleming, E. L. Patterson, J. R. Sebastian, and S. J. Nissen. 2017a. Indaziflam: A new cellulose-biosynthesis-inhibiting herbicide provides long-term control of invasive winter annual grasses. Pest Management Science **73**:2149-2162.

Sheley, R. L., E. A. Vasquez, A.-M. Chamberlain, and B. S. Smith. 2012. Landscape-scale rehabilitation of medusahead (*Taeniatherum caput-medusae*)-dominated sagebrush steppe. Invasive Plant Science and Management **5**:436-442.

Smith, J. T., B. W. Allred, C. S. Boyd, K. W. Davies, M. O. Jones, A. R. Kleinhesselink, J. D. Maestas, S. L. Morford, and D. E. Naugle. 2022. The elevational ascent and spread of exotic annual grass dominance in the Great Basin, USA. Diversity and Distributions **28**:83-96.

Smoliak, S., J. F. Dormaar, and A. Johnston. 1972. Long-term grazing effects on *Stipa-bouteloua* prairie soils. Journal of Range Management **25**:246-250.

Statler, G. D. 1967. *Eurotia lanata* establishment trials. Journal of Range Management **20**:253-255.

Stevens, R., B. C. Giunta, K. Jorgensen, and A. P. Plummer. 1977. Winterfat (*Ceratoides lanata*). Federal Aid Project W-82-R, Utah State Division of Wildlife Resources, Salt Lake City, UT.

Stubbendieck, J. L., S. L. Hatch, N. M. Bryan, and C. D. Dunn. 2017. North American wildland plants. Third edition. University of Nebraska Press, Lincoln, NE.

Stubbendieck, J. L., S. L. Hatch, and C. H. Butterfield. 1992. North American range plants. Fourth edition. University of Nebraska Press, Lincoln, NE.

Stubbendieck, J. L., S. L. Hatch, and L. M. Landholt. 2003. North American wildland plants. University of Nebraska Press, Lincoln, NE.

Tisdale, E. W., and M. Hironaka. 1981. The sagebrush - grass region: A review of the ecological literature. Forest, Wildlife and Range Experiment Station, University of Idaho **209**.

Tisdale, E. W., and G. Zappetini. 1953. Halogeton studies on Idaho ranges. Journal of Range Management **6**:225-236.

Tueller, P. T., and W. H. Blackburn. 1974. Condition and trend of the big sagebrush/needleandthread habitat type in Nevada. Journal of Range Management **27**:36-40.

Vallentine, J. F. 1989. Range development and improvements. Academic Press, Inc., San Diego, CA.

Weaver, J. E. 1958. Summary and interpretation of underground development in natural grassland communities. Ecological Monographs **28**:55-78.

Welsh, S. L., N. D. Atwood, S. Goodrich, and L. C. Higgins. 1987. A Utah flora. Great Basin Naturalist Memoir No. 9 edition. Brigham Young University, Provo, Utah.

West, N. E. 1994. Effects of fire on salt-desert shrub rangelands. Pages 71-74 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, ID.

West, N. E., and J. Gasto. 1978. Phenology of the aerial portions of shadscale and winterfat in Curlew Valley, Utah. Journal of Range Management **31**:43-45.

Wood, B. W., and J. D. Brotherson. 1986. Ecological adaptation and grazing response of budsage (*Artemisia spinescens*). Pages 75-92 *in* Symposium on the biology of *Artemisia* and *Chrysothamnus*; Provo, UT; July 9-13, 1984; General Technical Report INT-200. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Wright, H. A. 1971. Why squirreltail is more tolerant to burning than needle-and-thread. Journal of Range Management **24**:277-284.

Wright, H. A. 1985. Effects of fire on grasses and forbs in sagebrush-grass communities. Pages 12-21 *in* Rangeland fire effects: A symposium; Boise, ID; November 27-29, 1984. U.S. Department of the Interior, Bureau of Land Management, Boise, ID.

Wright, H. A., and J. O. Klemmedson. 1965. Effect of fire on bunchgrasses of the sagebrush-grass region in Southern Idaho. Ecology **46**:680-688.

Young, J. A. 2002. Halogeton grazing management: Historical perspective. Journal of Range Management **55**:309.

Young, J. A., and R. A. Evans. 1977. Squirreltail seed germination. Journal of Range Management **30**:33-36.

Young, J. A., R. A. Evans, and B. A. Roundy. 1983. Quantity and germinability of *Oryzopsis hymenoides* seed in Lahontan sands. Journal of Range Management **36**:82-86.

MLRA 27 Group 16: Salt-affected soils with iodinebush and warm-season grasses

Description of MLRA 27 Disturbance Response Group 16

Disturbance Response Group (DRG) 16 consists of one ecological site, Moist Saline Flat (R027XY077NV). This site is found primarily on lake plains, usually adjacent to playas. Slopes range from 0 to 2%. Elevations range from 3,500 to about 4,000 ft. Precipitation ranges from approximately 4 to 8 in. The soils are very deep, somewhat poorly drained, fine-textured and salt-affected. 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 aquic. A water table occurs near the surface for short periods in the early spring that usually stabilizes at depths below 60 in. during the early summer. Plant growth is attenuated by water table fluctuation, soil pH, and natural ponding and crusting of the soil surface. Seasonal flooding is common. The reference plant communities are dominated by iodinebush (*Allenrolfea occidentalis*) and inland saltgrass (*Distichlis spicata*). Other important species include alkali sacaton (*Sporobolus airoides*), basin wildrye (*Leymus cinereus*), black greasewood (*Sarcobatus vermiculatus),* Torrey's saltbush (*Atriplex torreyi*), and rubber rabbitbrush (*Ericameria nauseosa*). Total annual air-dry production ranges from 50 to 100 lb/ac, with 75 lb/ac for a normal year.

Disturbance Response Group 16 Ecological Site:

Moist Saline Flat – Modal	R027XY077NV

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 27 (MLRA 27 Fallon-Lovelock Area) is almost entirely in Nevada with < 1% in California. The entire area occurs in the rain shadow of the Sierra Nevada mountains

and is influenced by Pleistocene Lake Lahontan. Extensive playas occur throughout the area and are a result of the drying of ancient Lake Lahontan. To the west, MLRA 27 has a gradual boundary with MLRA 26 (Carson Basin and Mountains) and to the east has a very gradual boundary with MLRA 24 (Humboldt Basin and Range Area). From west to east the soil temperature increases and the soil moisture decreases, resulting in vast areas dominated by salt-desert shrub communities. Isolated mountain ranges trending north to south are separated by broad desert plains and valleys. Elevations range from 3,300 to 5,900 ft with some mountain peaks over 7,800 ft. The average annual precipitation ranges from 4 to 11 in. and as much as 20 in. at the highest elevations. The majority of annual precipitation is received during late fall and winter occurring mainly as snow. High-intensity, convective thunderstorms also contribute significantly to annual precipitation (NRCS 2022). 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:

Iodinebush, the dominant shrub on the Moist Saline Flat 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).

Black greasewood, an important but minor component of this site, 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 1987b, Trent et al. 1997, Naumburg et al. 2005). Black greasewood covers roughly 2 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 (1986a) reported that water tables within 9.8–11.8 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 1988b, 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.

The dominant grass species in this group is inland saltgrass, while alkali sacaton is an important but minor component. Both species are warm-season grasses, which 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).

Inland saltgrass is a warm-season, rhizomatous species that grows 10–60 cm (4–24 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 8–12 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, and other species in the absence of drought.

Alkali sacaton, a hardy, warm-season species, is a densely tufted, native perennial bunchgrass that grows from 20–60 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).

The ecological site in this DRG has moderate resilience to disturbance and resistance to invasion. Primary disturbances on these sites include extended drought, flooding, lowering of the water table, and conversion to agricultural land and urban development. Two 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, salt-desert shrub communities were free of exotic invaders; however, excessive grazing pressure and groundwater lowering during settlement and into the 20th century has increased the overall presence of halogeton (*Halogeton glomeratus*) and

Russian thistle (*Salsola* spp.) (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 this ecological site is halogeton. 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.

Fire Ecology:

Natural fire return intervals are estimated to vary between less than 35 years up to 100 years in salt-desert shrub ecosystems (Paysen et al. 2000), however with annual production between 50 and 100 lb/ac the likelihood of fire is extremely rare and undocumented.

The impact of fire on iodinebush is unknown, however 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.

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:

Salt-desert shrub communities are characterized by low herbage yields and grazing capacities. The salt-desert is mainly used as winter range for the maintenance of breeding or gestating livestock, thus nutritional requirements are relatively low (Blaisdell and Holmgren 1984).

Iodinebush is assumed to have low palatability for all kinds of livestock and wildlife because of the high salt content. Kovalev and Krylova (1992) found that iodinebush is a possible feed for animals if mixed with other forage plants. Iodinebush provides cover for small mammals, birds and small reptiles.

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).

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).

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 16

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 perennial 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, shallow groundwater recharge, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by periodic long-term drought.

Community Phase 1.1:

The reference plant community is dominated by iodinebush and inland saltgrass. Alkali sacaton and other perennial grasses, grass-likes, and shrubs make up minor components. Potential vegetative composition by air-dry weight is approximately 30% grasses, 5% forbs and 65% shrubs. Approximate ground cover (basal and canopy) is 5–15%. Total annual air-dry production ranges from 50 to 100 lb/ac.

Moist Saline Flat (R027XY077NV), Reference State 1.1, P. Novak-Echenique, March 2026

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 iodinebush and black greasewood.

Community Phase 1.2:
This community phase is characteristic of an early-seral community phase. Inland saltgrass and other perennial grasses dominate the community. Iodinebush, black greasewood are minor components. Other drought tolerant shrubs such as rubber rabbitbrush may be increasing.

Moist Saline Flat (R027XY077NV), Reference State 1.2, P. Novak-Echenique, March 2026

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
Release from chronic winter drought will allow recovery of iodinebush. Black greasewood, a minor component, may also increase.

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 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-native species 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 phase is similar to the Reference State Community Phase 1.1. Iodinebush dominates the overstory while 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 iodinebush and black greasewood. Annual non-native species are likely to increase.

Community Phase 2.2:
This community phase is characteristic of an early-seral community phase. Inland saltgrass and other perennial grasses dominate the community. Iodinebush is reduced and black greasewood is a minor component. Other drought tolerant shrubs such as rubber rabbitbrush may be increasing. Annual non-native species are stable to increasing in the community.

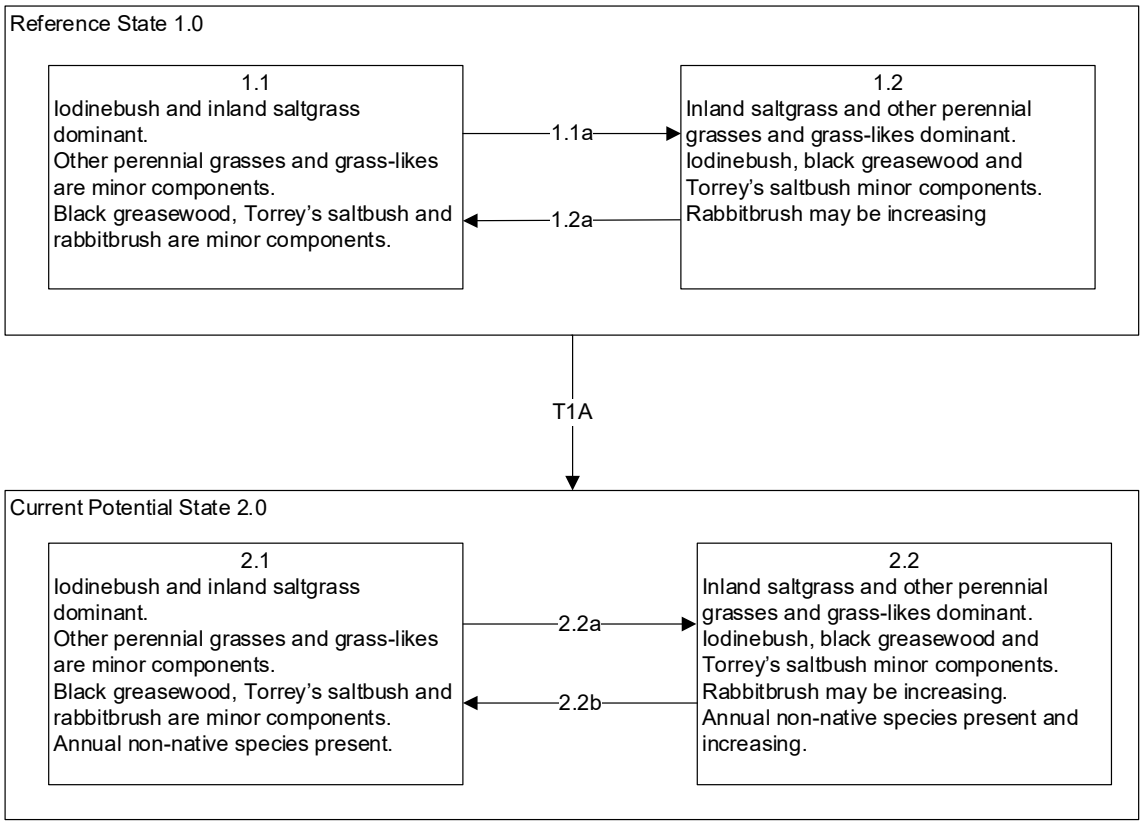
Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Release from chronic winter drought will allow recovery of iodinebush. Black greasewood, a minor component, may also increase.

Additional Potential States:

Although, a Shrub State and Annual Invasive State were not observed in MLRA 27, a similar site in MLRA 29 exhibited both of these altered States (Stringham et al. 2026).

Modal State and Transition Model for Group 16 in MLRA 27

MLRA 27
Group 16
Moist Saline Flat
R027XY077NV



MLRA 27
Group 16
Moist Saline Flat
R027XY077NV

Reference State 1.0 Community Phase Pathways
1.1a: Long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge resulting in a reduction of iodinebush, black greasewood and Torrey's saltbush.
1.2a: Release from chronic winter drought will allow recovery of iodinebush. Black greasewood and other shrubs may increase..

Transition T1A: Introduction of non-native annual species.

Current Potential 2.0 Community Phase Pathways
2.1a: Long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge resulting in a reduction in iodinebush, black greasewood and Torrey's saltbush. Annual non-native species are likely to increase..
2.2a: Release from chronic winter drought will allow recovery of iodinebush. Black greasewood and other shrubs may increase.

References

Alpert, P. 1990. Water sharing among ramets in a desert population of *Distichlis spicata* (Poaceae). American Journal of Botany **77**:1648-1651.

Bates, J. D., T. Svejcar, R. F. Miller, and R. A. Angell. 2006. The effects of precipitation timing on sagebrush steppe vegetation. Journal of Arid Environments **64**:670-697.

Beatley, J. C. 1975. Climates and vegetation pattern across the Mojave/Great Basin Desert transition of southern Nevada. The American Midland Naturalist **93**:53-70.

Benson, B., D. Ogle, D. Tilley, and L. St. John. 2007. Technical Note: managing black greasewood sites. TN Plant Materials No. 15, U.S. Department of Agriculture - Natural Resources Conservation Service, Boise, ID - Salt Lake City, UT.

Blaisdell, J. P., and R. C. Holmgren. 1984. Managing intermountain rangelands - salt-desert shrub ranges. General Technical Report INT-163, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Blank, R. R., J. A. Young, J. D. Trent, and D. E. Palmquist. 1998. Natural history of a saline mound ecosystem. Great Basin Naturalist **58**:217-230.

Blauer, A. C., A. P. Plummer, E. D. McArthur, R. Stevens, and B. C. Giunta. 1976. Characteristics and hybridization of important intermountain shrubs. II. Chenopod family. Research Paper INT-177, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Bock, C. E., and J. H. Bock. 1978. Response of birds, small mammals, and vegetation to burning sacaton grasslands in southeastern Arizona. Journal of Range Management **31**:296-300.

Bowers, J. E. 1993. Shrubs and trees of the Southwest deserts. Southwest Parks and Monuments Association, Tucson, AZ.

Brakie, M. 2007. Plant guide for alkali sacaton (*Sporobolus airoides*). U.S. Department of Agriculture, Natural Resources Conservation Service, East Texas Plant Materials, Nacogdoches, TX.

Branson, F. A., R. F. Miller, and I. S. McQueen. 1976. Moisture relationships in twelve northern desert shrub communities near Grand Junction, Colorado. Ecology **57**:1104-1124.

Caudle, D., J. DiBenedetto, M. Karl, H. Sanchez, and C. Talbot. 2013. Interagency ecological site handbook for rangelands. U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.

Chambers, J. C., B. A. Bradley, C. S. Brown, C. D'Antonio, M. J. Germino, J. B. Grace, S. P. Hardegree, R. F. Miller, and D. A. Pyke. 2013. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of western North America. Ecosystems **17**:360-375.

Comstock, J. P., and J. R. Ehleringer. 1992. Plant adaptation in the Great Basin and Colorado Plateau. The Great Basin Naturalist **52**:195-215.

Cook, C. W., L. A. Stoddart, and L. E. Harris. 1954. The nutritive value of winter range plants in the Great Basin as determined with digestion trials with sheep. Bulletin No. 372, Utah State Agricultural College, Agricultural Experiment Station, Logan, UT.

Devitt, D. A., and B. Bird. 2016. Changes in groundwater oscillations, soil water content and evapotranspiration as the water table declined in an area with deep rooted phreatophytes. Ecohydrology **9**:1082-1093.

Eddleman, L. E. 2008. *Sarcobatus vermiculatus* (Hook.) Torr. - black greasewood. Pages 1022-1024 *in* F. T. Bonner and R. P. Karrfalt, editors. The Woody Plant Seed Manual. Agriculture Handbook 727. U.S. Department of Agriculture, Forest Service, Washington, D.C.

Elmore, A. J., J. F. Mustard, S. P. Hamburg, and S. J. Manning. 2006. Agricultural legacies in the Great Basin alter vegetation cover, composition, and response to precipitation. Ecosystems **9**:1231-1241.

Everett, R. L., P. T. Tueller, J. B. Davis, and A. D. Brunner. 1980. Plant phenology in galleta-shadscale and galleta-sagebrush associations. Rangeland Ecology & Management/Journal of Range Management Archives **33**:446-450.

Ganskopp, D. C. 1986a. Tolerances of sagebrush, rabbitbrush, and greasewood to elevated water tables. Journal of Range Management **39**:334-337.

Groeneveld, D. P. 1990. Shrub rooting and water acquisition on threatened shallow groundwater habitats in the Owens Valley, California. Pages 221-237 *in* Proceedings—Symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; Las Vegas, NV; April 5-7, 1989. General Technical Report INT-276. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Groeneveld, D. P., and D. E. Crowley. 1988b. Root system response to flooding in three desert shrub species. Functional Ecology **2**:491-497.

Gul, B., and D. J. Weber. 1999. Effect of salinity, light, and temperature on germination in *Allenrolfea occidentalis*. Canadian Journal of Botany **77**:240-246.

Gul, B., and D. J. Weber. 2001. Seed bank dynamics in a Great Basin salt playa. Journal of Arid Environments **49**:785-794.

Harr, R. D., and K. R. Price. 1972. Evapotranspiration from a greasewood-cheatgrass community. Water Resources Research **8**:1199-1203.

Hickey, W. C., Jr., and H. W. Springfield. 1966. Alkali sacaton: Its merits for forage and cover. Journal of Range Management **19**:71-74.

Howery, L. D., J. E. Sprinkle, and J. E. Bowns. 2016. A summary of livestock grazing systems used on rangelands in the western United States and Canada. AZ1184, University of Arizona, College of Agriculture and Life Sciences, Cooperative Extension, Tucson, AZ.

Huntington, J., K. McGwire, C. Morton, K. Snyder, S. Peterson, T. Erickson, R. Niswonger, R. Carroll, G. Smith, and R. Allen. 2016. Assessing the role of climate and resource management on groundwater dependent ecoystem changes in arid environements with the Landsat archive. Remote Sensing of Environment **185**:186-197.

Kovalev, V. M., and N. P. Krylova. 1992. Use of halophytes to improve arid pastures. Sel'skokhozyaistvennaya Biologiya **4**:135-141.

Marcum, K. B., and D. M. Kopec. 1997. Salinity tolerance of turfgrasses and alternative species in the subfamily Chloridoideae (Poaceae). International Turfgrass Society Research Journal **8**:735-742.

Meinzer, O. E. 1927. Plants as indicators of ground water. Water-Supply Paper 577, U.S. Department of the Interior, U.S. Geological Survey, Washington, D.C.

Miller, R. F., S. T. Knick, D. A. Pyke, C. W. Meinke, S. E. Hanser, M. J. Wisdom, and A. L. Hild. 2008a. Characteristics of sagebrush habitats and limitations to long-term conservation. Administrative Report, U.S. Department of the Interior; U.S. Geological Survey, Reston, VA.

Monsen, S. B., R. Stevens, and N. L. Shaw. 2004a. Grasses. Pages 295-424 *in* S. B. Monsen, R. Stevens, and N. L. Shaw, editors. Restoring western ranges and wildlands, vol. 2. Gen. Tech. Rep. RMRS-GTR-136-vol-2. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Mozingo, H. N. 1987b. Shrubs of the Great Basin: A natural history. University of Nevada Press, Reno, NV.

Naumburg, E., R. Mata-Gonzalez, R. G. Hunter, T. McLendon, and D. W. Martin. 2005. Phreatophytic vegetation and groundwater fluctuations: A review of current research and application of ecosystem response modeling with an emphasis on Great Basin vegetation. Environmental Management **35**:726-740.

Newman, S. D., and M. Gates. 2000. Plant guide for saltgrass (*Distichlis spicata*). U.S. Department of Agriculture, Natural Resource Conservation Service, Alexandria, LA.

NRCS. 2022. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. Handbook 296, U.S. Department of Agriculture, Natural Resources Conservation Service.

Paysen, T. E., R. J. Ansley, J. K. Brown, G. J. Gottfried, S. M. Haase, M. G. Harrington, M. G. Narog, S. S. Sackett, and R. C. Wilson. 2000. Chapter 6: Fire in western shrubland, woodland, and grassland ecosystems. Pages 121-159 *in* J. K. Brown and J. K. Smith, editors. Wildland fire in ecosystems: Effects of fire on flora. General Technical Report RMRS-GTR-42-Vol. 2. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Pessarakli, M. 2017. Growth responses of sacaton grass (*Sporobolus airoides* Torr.) and Seashore paspalum (*Paspalum vaginatum* Swartz) under prolonged drought stress condition. Advances in Plants & Agriculture Research **7**:320-326.

Peters, E. F., and S. C. Bunting. 1994. Fire conditions pre-and post-occurrence of annual grasses on the Snake River Plain. Pages 31-36 *in* Proceedings—Ecology and management of annual rangelands; September, 1994; Boise, ID. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Pritchett, D. W., and S. J. Manning. 2009. Effects of fire and groundwater extraction on alkali meadow habitat in Owens Valley, California. Madroño **56**:89-98.

Provencher, L., L. Saito, K. Badik, and S. Byer. 2020. All systems are equal: In defense of undervalued ecosystems. Rangelands **42**:159-167.

Qian, Y. L., J. A. Cosenza, S. J. Wilhelm, and D. Christensen. 2006. Techniques for enhancing saltgrass seed germination and establishment. Crop Science **46**:2613-2616.

Robertson, J. H. 1983. Greasewood (*Sarcobatus vermiculatus* (Hook.) Torr.). Phytologia **54**:309-324.

Robocker, W. C., M. C. Williams, R. A. Evans, and P. J. Torell. 1969. Effects of age, burial, and region on germination and viability of halogeton seed. Weed Science **17**:63-65.

Roundy, B. A. 1985. Emergence and establishment of basin wildrye and tall wheatgrass in relation to moisture and salinity. Journal of Range Management **38**:126-131.

Saito, L., S. Byer, K. Badik, K. McGwire, L. Provencher, and B. Minor. 2020. Mapping indicators of groundwater dependent ecosystems in Nevada: Important resources for a water-limited state. Journal of the Nevada Water Resources Association **Winter 2020**:48-72.

Sheeter, G. R. 1968. Secondary succession and range improvements after wildfire in northeastern Nevada. Thesis. University of Nevada, Reno, NV.

Skaradek, W., and C. Miller. 2010. Plant fact sheet for saltgrass (*Distichlis spicata*). USDA NRCS Cape May Plant Materials Center, Cape May, NJ.

Smith, M. A., J. D. Rodgers, J. L. Dodd, and Q. D. Skinner. 1992. Habitat selection by cattle along an ephemeral channel. Journal of Range Management **45**:385-390.

Stringham, T. K., W. C. P. Richardson, Lucas, W. Lieurance, D. K. Snyder, and P. Novak-Echenique. 2026. Great Basin ecological site development project: State-and-transition models for Major Land Resource Area 29, Nevada. Nevada Agricultural Experiment Station Research Report NAES-TR-26-01, University of Nevada Reno, USA.

Taylor, S. H., S. P. Hulme, M. Rees, B. S. Ripley, F. I. Woodward, and C. P. Osborne. 2010. Ecophysiological traits in C3 and C4 grasses: a phylogenetically controlled screening experiment. New Physiologist **185**:780-791.

Tisdale, E. W., and G. Zappetini. 1953. Halogeton studies on Idaho ranges. Journal of Range Management **6**:225-236.

Trent, J. D., R. R. Blank, and J. A. Young. 1997. Ecophysiology of the temperate desert halophytes: *Allenrolfea occidentalis* and *Sarcobatus vermiculatus*. Great Basin Naturalist **57**:57-65.

USFS. 1937. Range plant handbook. U.S. Department of Agriculture, Forest Service, Washington, D.C.

Wasser, C. H., P. L. Dittberner, and D. R. Dietz. 1986. Alkali sacaton (*Sporobolus airoides*): Section 7.1.4, US Army Corps of Engneers wildlife resouces management manual. Technical Report EL-86-37, Department of the ARMY US Army Corps of Engineers, Washington, DC.

Weber, D. J., B. Gul, and M. A. Khan. 2002. Halophytic characteristics and potential uses of *Allenrolfea occidentalis*. Pages 333-352 *in* R. Ahmad and K. A. Malik, editors. Prospects for saline agriculture. Kluwer Academic Publishers, Alphen aan den Rijn, Netherlands.

West, N. E. 1994. Effects of fire on salt-desert shrub rangelands. Pages 71-74 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, ID.

Witwicki, D. L., S. M. Munson, and D. P. Thoma. 2016. Effects of climate and water balance across grasslands of varying C3 and C4 grass cover. Ecosphere **7**:1-19.

Young, J. A. 2002. Halogeton grazing management: Historical perspective. Journal of Range Management **55**:309.

Young, J. A., R. A. Evans, and P. T. Tueller. 1976. Great Basin plant communities - pristine and grazed. Pages 186-215 *in* R. Elston, editor. Holocene Environmental Change in the Great Basin. Nevada Archeological Survey, University of Nevada, Reno, NV.

MLRA 27 Group 17: Sandy soils dominated by black greasewood and Indian ricegrass

Description of MLRA 27 Disturbance Response Group 17

Disturbance Response Group (DRG) 17 consists of two ecological sites. These sites occur on partially stabilized sand dunes, sand sheets, lake plain terraces, and fan skirts. Slopes range from 0 to 30% and elevations range from approximately 3,800 to 5,900 ft. Precipitation ranges from 4 to 8 in. The soils are very deep, and somewhat excessively drained to excessively drained. The soils formed in alluvium and water-reworked eolian sand derived from mixed rocks. The soil temperature regime is mesic and the soil moisture regime is typic aridic. These soils are extremely susceptible to wind erosion. Groundwater occurs within the rooting depth of black greasewood *(Sarcobatus vermiculatus)*. Available water holding capacity is low to high and runoff is low to very low. The reference plant communities are dominated by black greasewood and Indian ricegrass *(Achnatherum hymenoides)*. Other important species are fourwing saltbush (*Atriplex canescens*), winterfat (*Krascheninnikovia lanata*), spiny hopsage (*Grayia spinosa*), needle-and-thread *(Hesperostipa comata)* and inland saltgrass (*Distichlis spicata*). Total annual air-dry production ranges from 150 to 600 lb/ac.

Disturbance Response Group 17 Ecological Sites:

Sodic Dune – Modal	R027XY016NV
Sodic Sands	R027XY012NV

Modal Site:

The Sodic Dune ecological site (R027XY016NV) is the modal site for this group as it has the most acres mapped. It occurs on partially stabilized sand sheets. Elevation ranges from 3,400 to about 5,500 ft. Slopes range from 0 to 50%, but slope gradients of 8–30% are typical. Soils correlated to this site are deep to very deep and excessively drained. They are formed in alluvium and aeolian sands from mixed rock sources. Soil temperature regime is mesic, and the soil moisture regime is typic aridic. Runoff is low and water infiltration is high. A seasonal water table occurs at greater than 60 in. The potential for rill and sheet erosion is slight but wind erosion potential is high. This site is dominated by black greasewood and Indian ricegrass. Other important species are fourwing saltbush, winterfat, spiny hopsage, needle-and-thread and basin wildrye (*Leymus cinereus*). Total annual air-dry production ranges from 150 to 500 lb/ac with 300 lb/ac in a normal year.

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 27 (MLRA 27 Fallon-Lovelock Area) is almost entirely in Nevada with < 1% in California. The entire area occurs in the rain shadow of the Sierra Nevada mountains and is influenced by Pleistocene Lake Lahontan. Extensive playas occur throughout the area and are a result of the drying of ancient Lake Lahontan. To the west, MLRA 27 has a gradual boundary with MLRA 26 (Carson Basin and Mountains) and to the east has a very gradual boundary with MLRA 24 (Humboldt Basin and Range Area). From west to east the soil temperature increases and the soil moisture decreases, resulting in vast areas dominated by salt-desert shrub communities. Isolated mountain ranges trending north to south are separated by broad desert plains and valleys. Elevations range from 3,300 to 5,900 ft with some mountain peaks over 7,800 ft. The average annual precipitation ranges from 4 to 11 in. and as much as 20 in. at the highest elevations. The majority of annual precipitation is received during late fall and winter occurring mainly as snow. High-intensity, convective thunderstorms also contribute significantly to annual precipitation (NRCS 2022). 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).

Aeolian processes, which are presumably the dominant mechanism of soil detachment and transport on these sites, 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 30–60 cm (12–24 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 1987b). 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 (1986a) reported that water tables within 9.8–11.8 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 1988b, 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 is the most widely distributed and abundant saltbush in the southwest (Mozingo 1987b). 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 (16–49 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).

Winterfat is a native, long-lived and drought tolerant species (Mozingo 1987b). 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. tall), 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 to 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).

Spiny hopsage is a rounded, summer-deciduous shrub standing 0.3–1.2 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 (525–7,000 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.

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 4–24 inches in height (Blaisdell and Holmgren 1984).

The dominant grass on these sites is Indian ricegrass, a hardy, cool-season, densely tufted, long-lived perennial bunchgrass that grows from 4–24 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 27, 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).

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).

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 minor component on these sites, occurs 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 (*Atriplex confertifolia*), fourwing saltbush, inland saltgrass and other species in the absence of drought.

The ecological sites 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 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. Five stable states have been identified for the Sodic Dune ecological site and six possible stable states have been identified for the Sodic Sands ecological site.

Agricultural History:

The Sodic Sands ecological site (R027XY012NV) has acreage historically and currently farmed in the Fallon-Fernley area. Agricultural development began in the early 1850s when overland stage travel was at its peak (Strahorn 1909). The first permanent settlements were made on the Carson River and the South Branch of the Carson at points where the overland trails crossed the rivers. Later settlements occurred on adjacent lands where it was possible to irrigate from the spring flow of the rivers to grow crops for local consumption. Large scale agricultural development started after the construction of the Newlands Project by the U.S. Reclamation Service (Headley and Venstrom 1930). Irrigation has been removed on some acreage and restoration attempts have been made by USDA-Natural Resources Conservation Service in cooperation with the University of Nevada Cooperative Extension and the Lahontan Conservation District. One notable project on private land is the Swingle Bench Project – Species and Technology for Revegetation of Abandoned Cropland, Technical Note Plant Materials No. 54 (Perkins 2008b).

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 (*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 this site are cheatgrass, halogeton, Russian thistle and tall tumblemustard (*Sisymbrium altissimum*).

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. 1999b). 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). Dobrowolski et al. (1990) cite multiple authors on the extent of the soil profile exploited by 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 1.5–1.7 m (59–67 in.).

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 North Africa grass (*Ventenata dubia*) within residual stands of native bunchgrasses. 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). 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, North Africa grass, 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).

Russian thistle and halogeton 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.

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 < 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 1998).

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 1966a). 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).

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 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 2 years following fire. They also counted 185 shrubs before wildfire and 210 shrubs 2 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 2003).

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). 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.

Spiny hopsage is generally top-killed by fire, but often sprouts after plants are damaged by fire or mechanical injury (Shaw 1992). Fires in spiny hopsage sites generally occur in late summer when plants are dormant, and sprouting generally does not occur until the following spring (Daubenmire 1970). Spiny hopsage is reported to be least susceptible to fire during summer dormancy (Rickard and McShane 1984).

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.

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.

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:

This salt-desert shrub community is typically regarded as a browse-specific plant community. It is characterized by low productivity, which requires substantial acreage for a grazing animal. Within this vegetation type, it is acknowledged that 65–90% of the available forage is browse (Costello 1944).

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.

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 5–16 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.

Spiny hopsage is palatable to livestock, especially sheep, during the spring and early summer (Phillips et al. 1996, Simmons and Rickard 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 and Rickard 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).

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.

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).

Livestock generally avoid inland 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 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 invasive species such as halogeton or Russian thistle to occupy interspaces.

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 1966a). 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 17

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 27 Disturbance Response Group 17.

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 black greasewood and Indian ricegrass. 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 35% grasses, 5% forbs and 65% shrubs. Approximate ground cover (basal and crown) is 10–20%. 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 (*Ericameria nauseosa*) 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. 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 grass and 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 maybe 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.

Sodic Dune (R027XY016NV), Current Potential 2.3, T. Stringham, June 2024

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: 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 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.

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

Trigger: Long-term chronic drought, long-term inappropriate grazing management including wild horse and burro use and/or off-road vehicle use reduces the native shrub and grass understory. An unusually wet spring may also facilitate the increased germination and production of non-native annual species leading to their dominance within the community.

Wildfires may occur following a wet spring that produced a flush of growth of the non-native annual species and reduces the native vegetation.

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

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

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 but may be declining. Deep-rooted perennial bunchgrasses or inland saltgrass may be present in trace amounts or absent from the community. Annual non-native species increase. Bare ground is significant.

Sodic Dune (R027XY016NV), Shrub State 3.1, T. Stringham, May 2024

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

Trigger: Long-term inappropriate grazing, including wild horse and burros, off-road vehicle use, long-term chronic drought, land clearing or combinations. Wildfires may occur following a wet spring that produced a flush of growth of the non-native annual species.

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.

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 non-native annual species. Russian thistle and/or cheatgrass dominate the plant community. Bare ground may be significant and desirable, native vegetation is trace or missing.

Community Phase 4.1:
This community is dominated by annual non-native species. Russian thistle most commonly invades these sites. Black greasewood, fourwing saltbush, and other shrubs may be present in minor amounts but are not contributing to overall site function. Bare ground may be significant.

Sodic Dune (R027XY016NV), Annual State 4.1, T. Stringham, September 2025

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

Trigger: Long-term, inappropriate grazing management, long-term chronic drought, land-clearing, or off-road vehicle use 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 that leads 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 scattered shrubs or introduced non-native forbs and/or grasses. Native annual forbs may be present in wet years. Bare ground interspaces are large and connected. Site function is controlled by soil erosion and soil temperature.

Potential Resilience Differences with Other Ecological Sites in this Group

Sodic Sands (R027XY012NV):

This site occurs on fan skirts, sand sheets and lake plain terraces. Slopes range from 0 to 8% and elevations range from 3,800 to 5,800 ft. The reference plant community is dominated by black greasewood and Indian ricegrass. Winterfat, spiny hopsage, fourwing saltbush, needle-and-thread and basin wildrye are also common on this site. Potential vegetative composition is approximately 65% grasses, 5% forbs and 30% shrubs. Total annual air-dry production ranges from 200 to 600 lb/ac. This site is slightly more resilient than the modal with higher production of deep-rooted perennial bunchgrasses and higher soil water holding capacity. This site has one additional state: an Agricultural State.

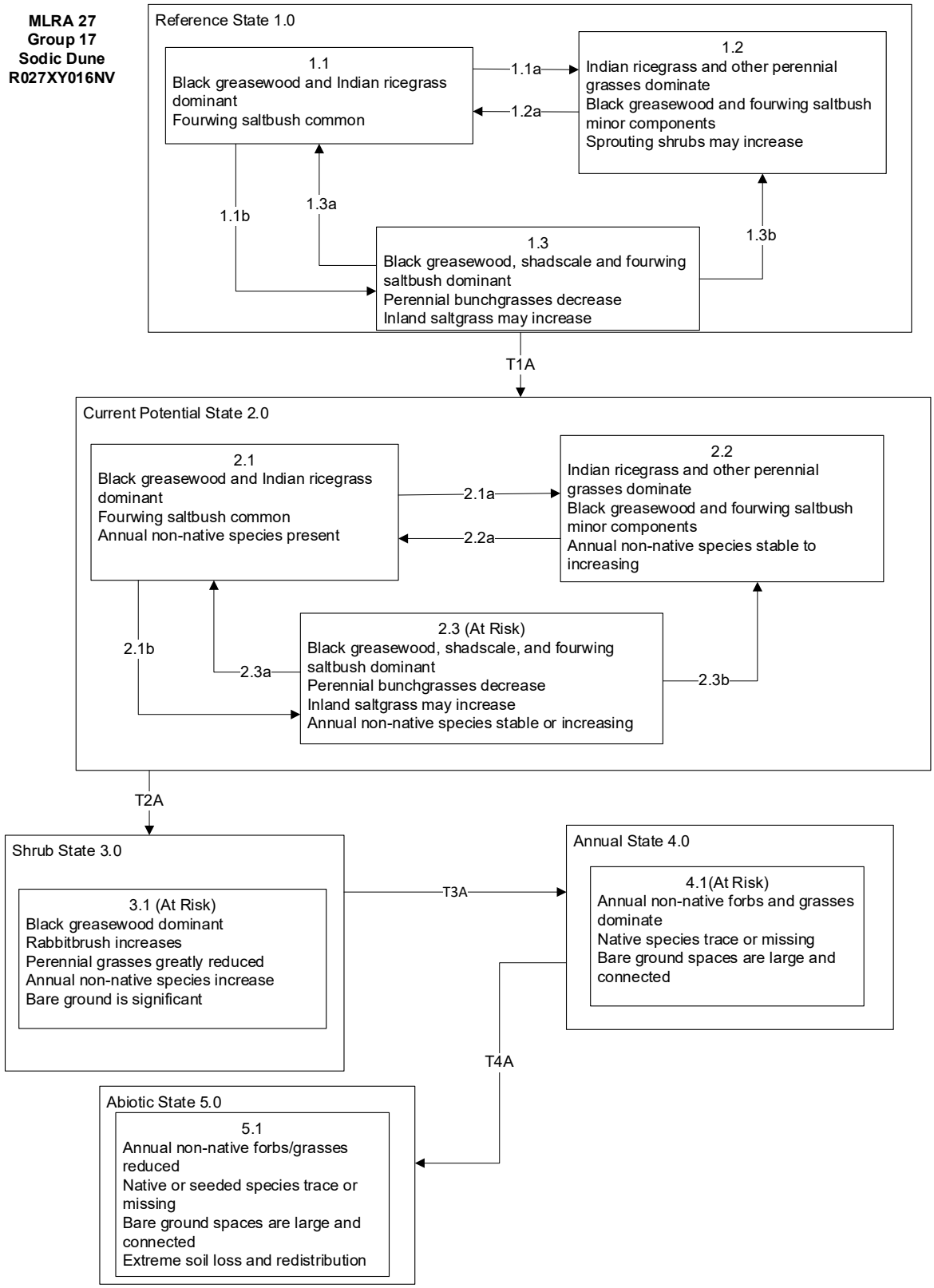
Sodic Sands (R027XY012NV), Current Potential 2.2, T. Stringham, May 2024

Sodic Sands (R027XY012NV), Annual State 4.1, P. Novak-Echenique, May 2026

Sodic Sands (R027XY012NV), Agricultural State 5.1, P. Novak-Echenique, May 2026

Sodic Sands (R027XY012NV), Abiotic State 6.1, P. Novak-Echenique, May 2026

Modal State and Transition Model for Group 17 in MLRA 27



MLRA 27
Group 17
Sodic Dune
R027XY016NV
KEY

Reference State 1.0 Community Pathways
1.1a: Long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge, or low severity fire would reduce black greasewood and winterfat and allow for the understory perennial grasses to increase. High severity fire would greatly reduce black greasewood, winterfat, and shadscale. An unusually wet spring could also reduce the shadscale component due to insects and/or disease.
1.1b: Time and lack of disturbance such as fire, long-term drought, unusually wet periods or combinations of these. Black greasewood, shadscale and inland saltgrass increase.
1.2a: Time and lack of disturbance and/or release from chronic winter drought.
1.3a: Long-term reduction in winter snow accumulation may lead to reduced groundwater recharge, or low severity fire would reduce black greasewood and allow for the perennial grasses to dominate the site.
1.3b: High severity fire, due to shrub dominance, significantly reduces shrub cover and increases perennial bunchgrasses and sprouting shrubs.

Transition T1A: Introduction of non-native annual plants.

Transition T1B: Settlement of the area and beginning of agriculture.

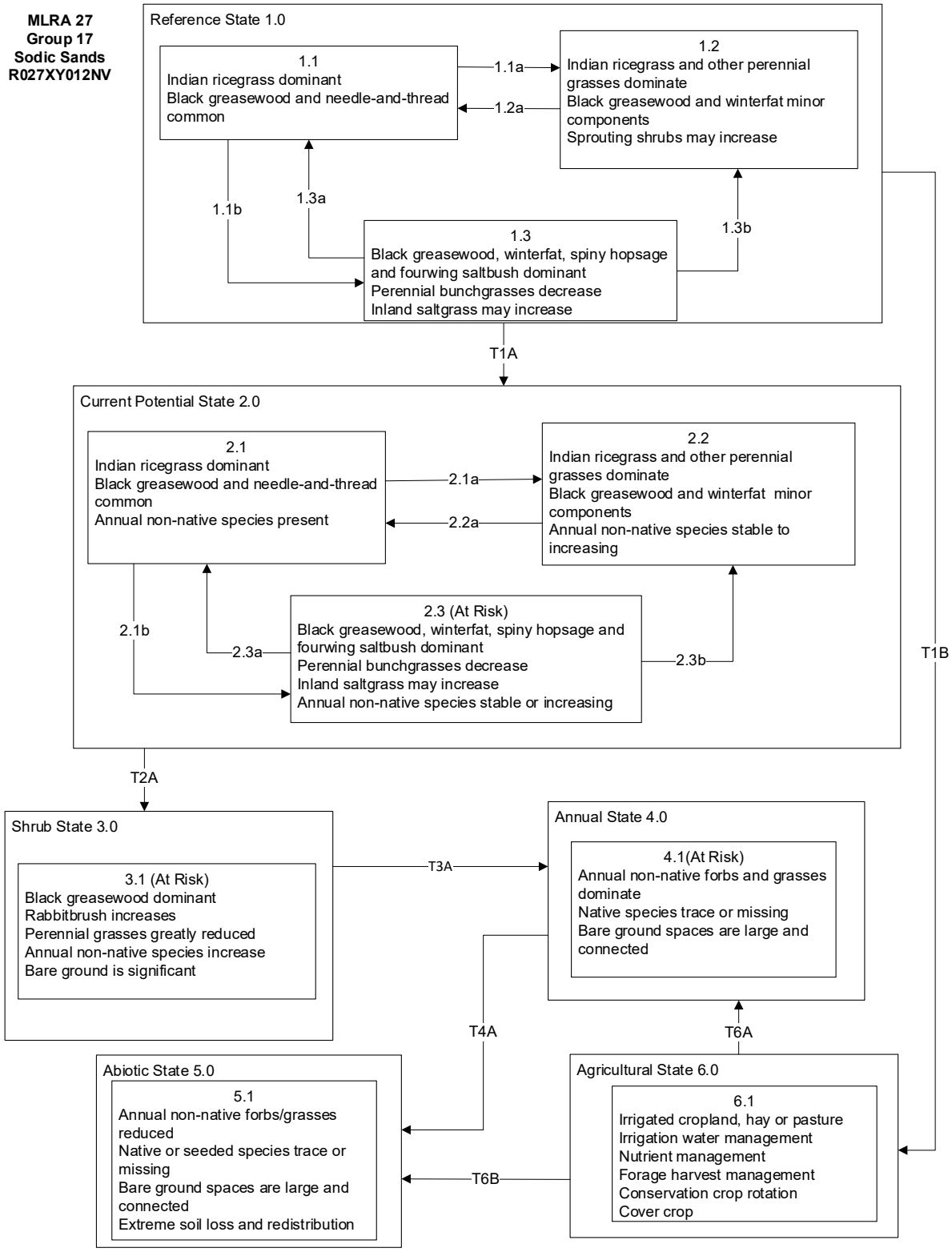
Current Potential State 2.0 Community Pathways:
2.1a: Long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge, or low severity fire would reduce black greasewood and winterfat and allow for the understory perennial grasses to increase. High severity fire would greatly reduce black greasewood, winterfat and shadscale. Non-native annual species are likely to increase after fire. An unusually wet spring could also reduce shadscale due to insects and/or disease.
2.1b: Time and lack of disturbance such as fire, long-term drought, inappropriate grazing management, and unusually wet spring, or combinations of these. Black greasewood, winterfat, spiny hopsage and fourwing saltbush increase.
2.2a: Time, lack of disturbance, release from chronic winter drought, and/or grazing management that favors the establishment and growth of black greasewood allows the shrub component to recover.
2.3a: Heavy late fall/winter grazing causing mechanical damage to shrubs, low severity fire, and/or reduced groundwater recharge due to a long-term reduction in winter snow accumulation.
2.3b: High severity fire, due to shrub dominance, significantly reduces shrub cover and increases perennial grasses.

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

Transition T3A: Long-term, inappropriate grazing management, long-term drought, groundwater pumping, off-road vehicle use, land clearing, or combinations. Significant soil loss and redistribution is occurring.

Transition T4A: Long-term drought, groundwater pumping, off-road vehicle use, land-clearing or combinations. Significant soil loss and redistribution is severe.

Additional State and Transition Models for Group 17 in MLRA 27



MLRA 27
Group 17
Sodic Sands
R027XY012NV
KEY

Reference State 1.0 Community Pathways
1.1a: Long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge, or low severity fire would reduce black greasewood and winterfat and allow for the understory perennial grasses to increase. High severity fire would greatly reduce black greasewood, winterfat, and shadscale. An unusually wet spring could also reduce the shadscale component due to insects and/or disease.
1.1b: Time and lack of disturbance such as fire, long-term drought, unusually wet periods or combinations of these. Black greasewood, shadscale and inland saltgrass increase.
1.2a: Time and lack of disturbance and/or release from chronic winter drought.
1.3a: Long-term reduction in winter snow accumulation may lead to reduced groundwater recharge, or low severity fire would reduce black greasewood and allow for the perennial grasses to dominate the site.
1.3b: High severity fire, due to shrub dominance, significantly reduces shrub cover and increases perennial bunchgrasses and sprouting shrubs.

Transition T1A: Introduction of non-native annual plants.

Transition T1B: Settlement of the area and beginning of agriculture.

Current Potential State 2.0 Community Pathways:
2.1a: Long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge, or low severity fire would reduce black greasewood and winterfat and allow for the understory perennial grasses to increase. High severity fire would greatly reduce black greasewood, winterfat and shadscale. Non-native annual species are likely to increase after fire. An unusually wet spring could also reduce shadscale due to insects and/or disease.
2.1b: Time and lack of disturbance such as fire, long-term drought, inappropriate grazing management, and unusually wet spring, or combinations of these. Black greasewood, winterfat, spiny hopsage and fourwing saltbush increase.
2.2a: Time, lack of disturbance, release from chronic winter drought, and/or grazing management that favors the establishment and growth of black greasewood allows the shrub component to recover.
2.3a: Heavy late fall/winter grazing causing mechanical damage to shrubs, low severity fire, and/or reduced groundwater recharge due to a long-term reduction in winter snow accumulation.
2.3b: High severity fire, due to shrub dominance, significantly reduces shrub cover and increases perennial grasses.

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

Transition T3A: Long-term, inappropriate grazing management, long-term drought, groundwater pumping, off-road vehicle use, land clearing, or combinations. Significant soil loss and redistribution is occurring.

Transition T4A: Cessation of farming practices including the removal of irrigation water and loss of cropland, hay or pasture species. Dominance of non-native species is reduced under long-term drought conditions increasing bare ground and soil erosion.

Transition T6A: Cessation of farming practices including the removal of irrigation water and loss of cropland, hay or pasture species. Invasion by non-native species in average to above-average precipitation years leads to dominance of those species.

Transition T6B: Cessation of farming practices including the removal of irrigation water and loss of cropland, hay or pasture species. Invasion by non-native species is reduced under long-term drought conditions increasing bare ground and soil erosion.

References

Abbott, M. L., L. Fraley Jr., and T. D. Reynolds. 1991. Root profiles of selected cold desert shrubs and grasses in disturbed and undisturbed soils. Environmental and Experimental Botany **31**:165-178.

Akinsoji, A. 1988. Postfire vegetation dynamics in a sagebrush steppe in southeastern Idaho, USA. Vegetatio **78**:151-155.

Allen, E. B., and M. F. Allen. 1988. Facilitation of succession by the nonmycotrophic colonizer *Salsola kali* (Chenopodiaceae) on a harsh site: effects of mycorrhizal fungi. American Journal of Botany **75**:257-266.

Barrow, J. R. 1997. Natural asexual reproduction in fourwing saltbush *Atriplex canescens* (Pursh) Nutt. Journal of Arid Environments **36**:267-270.

Beatley, J. C. 1975. Climates and vegetation pattern across the Mojave/Great Basin Desert transition of southern Nevada. The American Midland Naturalist **93**:53-70.

Benson, B., S. Green, D. Ogle, D. Tilley, and L. St. John. 2011. Plant guide for black greasewood (*Sarcobatus vermiculatus*). U.S. Department of Agriculture, Natural Resource Conservation Service, Boise, ID.

Bentz, B., D. Alston, and T. Evans. 2008. Great Basin insect outbreaks. Pages 45-48 *in* Collaborative management and research in the Great Basin - Examining the issues and developing a framework for action. General Technical Report RMRS-GTR-204. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Bich, B. S., J. L. Butler, and C. A. Schmidt. 1995. Effects of differential livestock use on key plant species and rodent populations within selected *Oryzopsis hymenoides*/*Hilaria jamesii* communities of Glen Canyon National Recreation Area. The Southwestern Naturalist **40**:281-287.

Blaisdell, J. P., and R. C. Holmgren. 1984. Managing intermountain rangelands - salt-desert shrub ranges. General Technical Report INT-163, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Blank, R. R., C. Clements, T. Morgan, D. Harmon, and F. Allen. 2020. Suppression of cheatgrass by perennial bunchgrasses. Rangeland Ecology & Management **73**:766-771.

Blauer, A. C., A. P. Plummer, E. D. McArthur, R. Stevens, and B. C. Giunta. 1976. Characteristics and hybridization of important intermountain shrubs. II. Chenopod family. Research Paper INT-177, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Boerboom, C. 1993. Russian thistle (*Salsola iberica* Sennen & Pau).

Booth, D. T., C. G. Howard, and C. E. Mowry. 1980. 'Nezpar' Indian ricegrass: description, justification for release, and recommendations for use. Rangelands **2**:53-54.

Booth, T. D. 1989. Seedbed ecology of winterfat: cations in diaspore bracts and their effect on germination and early plant growth. Journal of Range Management **42**:178-182.

Bowns, J., A. Rasmussen, and R. Banner. 2025b. Range plants of Utah: Saltgrass. Utah State University Extension, Logan, Utah.

Bradley, A. F., N. V. Noste, and W. C. Fischer. 1992. Fire ecology of forests and woodlands in Utah. General Technical Report INT-287, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Bradley, B. A., C. A. Curtis, E. J. Fusco, J. T. Abatzoglou, J. K. Balch, S. Dadashi, and M.-N. Tuanmu. 2018. Cheatgrass (*Bromus tectorum*) distribution in the intermountain Western United States and its relationship to fire frequency, seasonality, and ignitions. Biological Invasions **20**:1493-1506.

Branson, F. A., R. F. Miller, and I. S. McQueen. 1976. Moisture relationships in twelve northern desert shrub communities near Grand Junction, Colorado. Ecology **57**:1104-1124.

Brown, R. W. 1971. Distribution of plant communities in southeastern Montana badlands. American Midland Naturalist **85**:458-477.

Butler, M., F. Brummer, J. Weber, and R. Simmons. 2011. Restoring Central Oregon rangeland from ventenata and medusahead to a sustainable bunchgrass environment – Warm Springs and Ashwood. COARC 2011, Oregon State University, Central Oregon Agricultural Research and Extension Center, Corvallis, OR.

Catlin, C. N. 1925. Composition of Arizona forages, with comparative data. Bulletin No. 113, University of Arizona, College of Agriculture, Agricultural Experiment Station, Tucson, AZ.

Caudle, D., J. DiBenedetto, M. Karl, H. Sanchez, and C. Talbot. 2013. Interagency ecological site handbook for rangelands. U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.

Chambers, J. C., B. A. Bradley, C. S. Brown, C. D'Antonio, M. J. Germino, J. B. Grace, S. P. Hardegree, R. F. Miller, and D. A. Pyke. 2013. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of western North America. Ecosystems **17**:360-375.

Cibils, A. F., S. M. David, and D. E. McArthur. 1998. Plant-herbivore interactions in *Atriplex*: current state of knowledge. General Technical Report RMRS-GTR-14, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Clark, S. L., D. J. Sebastian, S. J. Nissen, and J. R. Sebastian. 2019. Effect of indaziflam on native species in natural areas and rangeland. Invasive Plant Science and Management **12**:60-67.

Clements, C. D., D. N. Harmon, and R. R. Blank. 2022. Seed mix performance and cheatgrass suppression on arid rangelands. Rangelands **44**:129-135.

Clements, C. D., J. A. Young, D. N. Harmon, and G. McCuin. 2010. Revegetation of degraded winterfat communities. Rangelands **32**:37-40.

Comstock, J. P., and J. R. Ehleringer. 1992. Plant adaptation in the Great Basin and Colorado Plateau. The Great Basin Naturalist **52**:195-215.

Cook, C. W. 1962. An evaluation of some common factors affecting utilization of desert range species. Journal of Range Management **15**:333-338.

Cook, C. W., and R. D. Child. 1971. Recovery of desert plants in various states of vigor. Rangeland Ecology & Management/Journal of Range Management Archives **24**:339-343.

Cook, C. W., and L. A. Stoddart. 1953. Bulletin No. 364 - The halogeton problem in Utah. UAES Bulletins.

Costello, D. F. 1944. Important species of the major forage types in Colorado and Wyoming. Ecological Monographs **14**:107-134.

Courkamp, J. S., P. J. Meiman, and M. W. Paschke. 2022. Indaziflam reduces seed bank richness and density but not sagebrush-grassland plant diversity. Rangeland Ecology & Management **84**:31-44.

Cronin, E. H., and M. C. Williams. 1966a. Principles for managing ranges infested with halogeton.

Daubenmire, R. 1970. Steppe vegetation of Washington. Technical Report 62, Washington State University, Washington Agricultural Experiment Station, Pullman, WA.

Davies, K. W., C. S. Boyd, J. D. Bates, and A. Hulet. 2015a. Dormant season grazing may decrease wildfire probability by increasing fuel moisture and reducing fuel amount and continuity. International Journal of Wildland Fire **24**:849-856.

Davies, K. W., A. M. Nafus, C. S. Boyd, A. Hulet, and J. D. Bates. 2016. Effects of using winter grazing as a fuel treatment on Wyoming big sagebrush plant communities. Rangeland Ecology & Management **69**:179-184.

Dobrowolski, J. P., M. M. Caldwell, and J. H. Richards. 1990. Chapter 7: Basin hydrology and plant root systems. Pages 243-292 *in* C. B. Osmond, L. F. Pitelka, and G. M. Hidy, editors. Plant Biology of the Basin and Range. Springer-Verlag, New York City, NY.

Duda, J. J., D. C. Freeman, J. M. Emlen, J. Belnap, S. G. Kitchen, J. C. Zak, E. Sobek, M. Tracy, and J. Montante. 2003. Differences in native soil ecology associated with invasion of the exotic annual chenopod, *Halogeton glomeratus*. Biology and Fertility of Soils **38**:72-77.

Dwyer, D. D., and R. D. Pieper. 1967. Fire effects on blue grama-pinyon-juniper rangeland in New Mexico. Rangeland Ecology & Management/Journal of Range Management Archives **20**:359-362.

Eckert, R. E., Jr., A. D. Bruner, and G. J. Klomp. 1972. Response of understory species following herbicidal control of low sagebrush. Journal of Range Management **25**:280-285.

Eddleman, L. E. 2008. *Sarcobatus vermiculatus* (Hook.) Torr. - black greasewood. Pages 1022-1024 *in* F. T. Bonner and R. P. Karrfalt, editors. The Woody Plant Seed Manual. Agriculture Handbook 727. U.S. Department of Agriculture, Forest Service, Washington, D.C.

Everett, R. L., P. T. Tueller, J. B. Davis, and A. D. Brunner. 1980. Plant phenology in galleta-shadscale and galleta-sagebrush associations. Rangeland Ecology & Management/Journal of Range Management Archives **33**:446-450.

Freeman, D. C., and M. J. Emlen. 1995. Assessment of interspecific interactions in plant communities: an illustration from the cold desert saltbush grasslands of North America. Journal of Arid Environments **31**:179-198.

Furbush, P. 1953. Control of medusa-head on California ranges. Journal of Forestry **51**:118-121.

Ganskopp, D., L. Aguilera, and M. Vavra. 2007. Livestock forage conditioning among six northern Great Basin grasses. Rangeland Ecology & Management **60**:71-78.

Ganskopp, D. C. 1986a. Tolerances of sagebrush, rabbitbrush, and greasewood to elevated water tables. Journal of Range Management **39**:334-337.

Green, L. R., L. A. Sharp, C. W. Cook, and L. E. Harris. 1951. Utilization of winter range forage by sheep. Journal of Range Management **4**:233-241.

Groeneveld, D. P. 1990. Shrub rooting and water acquisition on threatened shallow groundwater habitats in the Owens Valley, California. Pages 221-237 *in* Proceedings—Symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; Las Vegas, NV; April 5-7, 1989. General Technical Report INT-276. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Groeneveld, D. P., and D. E. Crowley. 1988b. Root system response to flooding in three desert shrub species. Functional Ecology **2**:491-497.

Harper, K. T., F. J. Wagstaff, and W. P. Clary. 1990. Shrub mortality over a 54-year period in shadscale desert, west-central Utah. Pages 119-126 *in* Proceedings—Symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; Las Vegas, NV, April 5-7, 1989; General Technical Report INT-276. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Harr, R. D., and K. R. Price. 1972. Evapotranspiration from a greasewood-cheatgrass community. Water Resources Research **8**:1199-1203.

Harrison, B. J., Thatcher, A.P. 1970. Winter sheep grazing and forage preference in southwestern Wyoming. Journal of Range Management **23**:109-111.

Headley, F. B., and C. Venstrom. 1930. Economic History of the Newlands Irrigation Project. University of Nevada.

Henrickson, J. 1977. Saline habitats and halophytic vegetation of the Chihuahuan Desert region. Pages 289-314 *in* Transactions of the Symposium on the Biological Resources of the Chihuahuan Desert Region: United States and Mexico; Sul Ross State University, Alpine, TX; October 17-18, 1974. NPS Transactions and Proceedings Series No. 3. U.S. Department of the Interior, National Park Service.

Hild, A. L., J. M. Muscha, and N. L. Shaw. 2007. Emergence and growth of four winterfat accessions in the presence of the exotic annual cheatgrass. Pages 147-152 *in* Proceedings: Shrubland dynamics - fire and water; Lubbock, TX; August 10-12, 2004; RMRS-P-47. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Hilton, J. W. 1941. Effects of certain micro-ecological factors on the germinability and early development of *Eurotia lanata*. Northwest Science **15**:89-92.

Hopper, T. H., and L. L. Nesbitt. 1930. The chemical composition of some North Dakota pasture and hay grasses. Agricultural Experiment Station, North Dakota Agricultural College, Fargo, ND.

Howard, J. L. 2003. *Atriplex canescens.in* O. Fire Effects Information System, editor. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory.

James, L. F. 1970. Locomotor disturbance of cattle grazing *Halogeton glomeratus*. Journal of the American Veterinary Medical Association **156**:1310-1312.

Johnson, K. M. 1979. Foods of primary consumers on cold desert shrub-steppe of Southcentral Idaho. Journal of Range Management **32**:365.

Johnson, N. C. 1998. Responses of *Salsola kali* and *Panicum virgatum* to mycorrhizal fungi, phosphorus and soil organic matter: implications for reclamation. Journal of Applied Ecology **35**:86-94.

Kaapro, J., and J. Hall. 2012. Indaziflam - a new herbicide for pre-emergent control of weeds in turf, forestry, industrial vegetation and ornamentals. Pages 224-227 *in* 23rd Asian-Pacific Weed Science Society Conference: Conference Proceedings Volume 1; Queensland, Australia; September 26-29 2011. Asian-Pacific Weed Science Society.

Klemmedson, J. O., and J. G. Smith. 1964. Cheatgrass (*Bromus tectorum* L.). The Botanical Review **30**:226-262.

Krall, J. L., J. R. Stroh, C. S. Cooper, and S. R. Chapman. 1971. Effect of time and extent of harvesting basin wildrye. Journal of Range Management **24**:414-418.

Mack, R. N., and D. A. Pyke. 1983. The demography of *Bromus tectorum*: Variation in time and space. Journal of Ecology **71**:69-93.

Majerus, M. E. 1992. High-stature grasses for winter grazing. Journal of Soil and Water Conservation **47**:224-225.

Majerus, M. E. 2003. Production and conditioning of winterfat seeds (*Krascheninnikovia lanata*). Native Plants Journal **4**:10-15.

Meinzer, O. E. 1927. Plants as indicators of ground water. Water-Supply Paper 577, U.S. Department of the Interior, U.S. Geological Survey, Washington, D.C.

Miller, R. F., J. C. Chambers, D. A. Pyke, F. B. Pierson, and C. J. Williams. 2013. A review of fire effects on vegetation and soils in the Great Basin Region: Response and ecological site characteristics. General Technical Report RMRS-GTR-308, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Miller, R. F., R. J. Tausch, and W. Waichler. 1999b. Old-growth juniper and pinyon woodlands. Pages 375-384 *in* Proceedings: ecology and management of pinyon-juniper communities within the interior west; September 15-18, 1997. Proceedings RMRS-P-9. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Brigham Young University Conference Center, Provo, UT.

Monsen, S. B., R. Stevens, and N. L. Shaw. 2004a. Grasses. Pages 295-424 *in* S. B. Monsen, R. Stevens, and N. L. Shaw, editors. Restoring western ranges and wildlands, vol. 2. Gen. Tech. Rep. RMRS-GTR-136-vol-2. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Mozingo, H. N. 1987b. Shrubs of the Great Basin: A natural history. University of Nevada Press, Reno, NV.

Newton, R. J., and J. R. Goodin. 1989. Moisture stress adaptation in shrubs. Pages 365-383 *in* C. M. McKell, editor. The biology and utilization of shrubs. Academic Press, San Diego, CA.

NRCS. 2022. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. Handbook 296, U.S. Department of Agriculture, Natural Resources Conservation Service.

Ogle, D. G., L. St. John, and L. Holzworth. 2001. Plant guide for management and use of winterfat. U.S. Department of Agriculture, Natural Resource Conservation Service, Boise, ID.

Ogle, D. G., L. St. John, and D. Tilley. 2012a. Plant guide for fourwing saltbush (*Atriplex canescens)*. U.S. Department of Agriculture, Natural Resource Conservation Service, Idaho Plants Material Center, Aberdeen, ID.

Otsyina, R., C. M. McKell, and G. Van Epps. 1982. Use of range shrubs to meet nutrient requirements of sheep grazing on crested wheatgrass during fall and early winter. Journal of Range Management **35**:751-753.

Parmenter, R. R. 2008. Long-term effects of a summer fire on desert grassland plant demographics in New Mexico. Rangeland Ecology & Management **61**:156-168.

Paysen, T. E., R. J. Ansley, J. K. Brown, G. J. Gottfried, S. M. Haase, M. G. Harrington, M. G. Narog, S. S. Sackett, and R. C. Wilson. 2000. Chapter 6: Fire in western shrubland, woodland, and grassland ecosystems. Pages 121-159 *in* J. K. Brown and J. K. Smith, editors. Wildland fire in ecosystems: Effects of fire on flora. General Technical Report RMRS-GTR-42-Vol. 2. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Pearson, L. 1979. Effects of temperature and moisture on phenology and productivity of Indian ricegrass. Rangeland Ecology & Management/Journal of Range Management Archives **32**:127-134.

Pearson, L. C. 1964. Effect of harvest date on recovery of range grasses and shrubs. Agronomy Journal **56**:80-82.

Pearson, L. C. 1965. Primary production in grazed and ungrazed desert communities of eastern Idaho. Ecology **46**:278-285.

Pellant, M., and L. Reichert. 1984. Management and rehabilitation of a burned winterfat community in southwestern Idaho. Pages 281-285 *in* Proceedings—Symposium on the biology of *Atriplex* and related chenopods; Provo, UT; May 2-6, 1983; General Technical Report INT-172. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Pemberton, R. W. 1986. The distribution of halogeton in North America. Journal of Range Management **39**:281-282.

Perkins, S., Davison, J. Lawry, T., Brackley, G. 2008b. Swingle Bench Project - Species and Technology for Revegetation of Abandoned Cropland. USDA Natural Resources Conservation Service, Reno, NV.

Perryman, B. L., B. W. Schultz, M. Burrows, T. Shenkoru, and J. Wilker. 2020. Fall-grazing and grazing-exclusion effects on cheatgrass (*Bromus tectorum*) seed bank assays in Nevada, United States. Rangeland Ecology & Management **73**:343-347.

Peters, E. F., and S. C. Bunting. 1994. Fire conditions pre-and post-occurrence of annual grasses on the Snake River Plain. Pages 31-36 *in* Proceedings—Ecology and management of annual rangelands; September, 1994; Boise, ID. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Phillips, R. L., N. K. McDougald, and J. Sullins. 1996. Plant preference of sheep grazing the Mojave desert. Rangelands **18**:141-144.

Pritchett, D. W., and S. J. Manning. 2009. Effects of fire and groundwater extraction on alkali meadow habitat in Owens Valley, California. Madroño **56**:89-98.

Puigdefábregas, J. 2005. The role of vegetation patterns in structuring runoff and sediment fluxes in drylands. Earth Surface Processes and Landforms **30**:133-147.

Quinones, F. A. 1981. Indian ricegrass evaluation and breeding. Bulletin 681, New Mexico State University, Agricultural Experiment Station, Las Cruces, NM.

Rasmussen, L. L., and J. D. Brotherson. 1986. Response of winterfat (*Ceratoides lanata*) communities to release from grazing pressure. Great Basin Naturalist **46**:148-156.

Rice, B., and M. Westoby. 1978. Vegetative responses of some Great Basin shrub communities protected against jackrabbits or domestic stock. Journal of Range Management **31**:28-34.

Rickard, W. H., and M. C. McShane. 1984. Demise of spiny hopsage shrubs following summer wildfire: An authentic record. Northwest Science **58**:282-285.

Romo, J. T. 1984. Water relations in *Artemisia tridentata* subsp. *wyomingensis*, *Sarcobatus vermiculatus*, and *Kochia prostrata*. PhD Dissertation. Oregon State University, Corvallis, OR.

Romo, J. T., R. E. Redmann, B. L. Kowalenko, and A. R. Nicholson. 1995. Growth of winterfat following defoliation in northern mixed prairie of Saskatchewan. Journal of Range Management **48**:240-245.

Saltz, D., M. Shachak, M. Caldwell, S. T. A. Pickett, J. Dawson, H. Tsoar, Y. Yom-Tov, M. Weltz, and R. Farrow. 1999. The study and management of dryland population systems. Pages 75-96 *in* T. W. Hoekstra and M. Shachak, editors. Arid Lands Management: Towards Ecological Sustainability. International Arid Lands Consortium; University of Illinois Press, Chicago, IL.

Sanderson, S. C., and H. C. Stutz. 1994. Woody chenopods useful for rangeland reclamation in western North America. Pages 374-378 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Schlesinger, W. H., J. F. Reynolds, G. L. Cunningham, L. F. Huenneke, W. M. Jarrell, R. A. Virginia, and W. G. Whitford. 1990. Biological feedbacks in global desertification. Science **247**:1043-1048.

Sebastian, D. J., M. B. Fleming, E. L. Patterson, J. R. Sebastian, and S. J. Nissen. 2017a. Indaziflam: A new cellulose-biosynthesis-inhibiting herbicide provides long-term control of invasive winter annual grasses. Pest Management Science **73**:2149-2162.

Shaw, N. L. 1992. Germination and seedling establishment of spiny hopsage (*Grayia spinosa* [Hook.] Moq.). PhD Dissertation. Oregon State University, Corvallis, OR.

Shaw, N. L., M. R. Haferkamp, and E. G. Hurd. 2008. *Grayia spinosa* (Hook.) Moq: spiny hopsage. Pages 567-572 The Woody Plant Seed Manual Agric. Handbook No. 727. US Department of Agriculture, Forest Service, Washington DC.

Sheley, R. L., E. A. Vasquez, A.-M. Chamberlain, and B. S. Smith. 2012. Landscape-scale rehabilitation of medusahead (*Taeniatherum caput-medusae*)-dominated sagebrush steppe. Invasive Plant Science and Management **5**:436-442.

Simmons, S. A., and W. H. Rickard. 2003. Fire effects on spiny hopsage in south central Washington. Western North American Naturalist **63**:524-528.

Smith, J. T., B. W. Allred, C. S. Boyd, K. W. Davies, M. O. Jones, A. R. Kleinhesselink, J. D. Maestas, S. L. Morford, and D. E. Naugle. 2022. The elevational ascent and spread of

exotic annual grass dominance in the Great Basin, USA. Diversity and Distributions **28**:83-96.

Smith, M. A., J. D. Rodgers, J. L. Dodd, and Q. D. Skinner. 1992. Habitat selection by cattle along an ephemeral channel. Journal of Range Management **45**:385-390.

Smoliak, S., J. F. Dormaar, and A. Johnston. 1972. Long-term grazing effects on *Stipa-bouteloua* prairie soils. Journal of Range Management **25**:246-250.

Statler, G. D. 1967. *Eurotia lanata* establishment trials. Journal of Range Management **20**:253-255.

Stevens, R., B. C. Giunta, K. Jorgensen, and A. P. Plummer. 1977. Winterfat (*Ceratoides lanata*). Federal Aid Project W-82-R, Utah State Division of Wildlife Resources, Salt Lake City, UT.

Stoddart, L. A., and G. Clegg. 1951. The halogeton problem on Utah's ranges. Rangeland Ecology & Management/Journal of Range Management Archives **4**:223-227.

Strahorn, A. T. a. C. V. D. 1909. Soil Survey of the Fallon Area, Nevada. USDA-Natural Resources Conservation Service.

Straub, P. F., D. M. Decker, and J. L. Gallagher. 1989. Tissue culture and regeneration of *Distichlis spicata* (Gramineae). American Journal of Botany **76**:1448-1451.

Stubbendieck, J. L., S. L. Hatch, and L. M. Landholt. 2003. North American wildland plants. University of Nebraska Press, Lincoln, NE.

Stubbendieck, J. L., J. T. Nichols, and K. K. Roberts. 1985. Nebraska range and pasture grasses (including grass-like plants). University of Nebraska, Department of Agriculture, Cooperative Extension Service, Lincoln, NE.

Stutz, H. C. 1979. The meaning of "rare" and "endangered" in the evolution of western shrubs. Pages 119-128 *in* The endangered species: A symposium: Proceedings; Provo, UT; December 7-8, 1978. Great Basin Naturalist Memoirs No. 3. Brigham Young University, Provo, UT.

Tueller, P. T., and W. H. Blackburn. 1974. Condition and trend of the big sagebrush/needleandthread habitat type in Nevada. Journal of Range Management **27**:36-40.

USFS. 1937. Range plant handbook. U.S. Department of Agriculture, Forest Service, Washington, D.C.

Vallentine, J. F. 1989. Range development and improvements. Academic Press, Inc., San Diego, CA.

Van Dersal, W. R. 1938. Native woody plants of the United States: Their erosion-control and wildlife values. U.S. Government Printing Office, Washington, D.C.

Van Epps, G. A. 1975. Winter injury to fourwing saltbush. Journal of Range Management Archives **28**:157-159.

Wallace, A., S. A. Bamberg, and J. W. Cha. 1974. Quantitative studies of roots of perennial plants in the Mojave Desert. Ecology **55**:1160-1162.

Wallace, A., W. Rhods, and E. Frolich. 1968. Germination behavior of *Salsola* as influenced by temperature, moisture, depth of planting, and gamma irradiation. Agronomy Journal **60**:76-78.

Wasser, C. H. 1982. Ecology and culture of selected species useful in revegetating disturbed lands in the West. FWS/OBS-82/56, U.S. Department of the Interior, Fish & Wildlife Service, Fort Collins, CO.

Weaver, J. E. 1958. Summary and interpretation of underground development in natural grassland communities. Ecological Monographs **28**:55-78.

Welsh, S. L., N. D. Atwood, S. Goodrich, and L. C. Higgins. 1987. A Utah flora. Great Basin Naturalist Memoir No. 9 edition. Brigham Young University, Provo, Utah.

West, N. E. 1994. Effects of fire on salt-desert shrub rangelands. Pages 71-74 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, ID.

West, N. E., and J. Gasto. 1978. Phenology of the aerial portions of shadscale and winterfat in Curlew Valley, Utah. Journal of Range Management **31**:43-45.

West, N. E., K. McDaniel, E. L. Smith, P. T. Tueller, and S. Leonard. 1994. Monitoring and interpreting ecological integrity on arid and semi-arid lands of the western United States. Report 37, New Mexico State University, College of Agriculture and Home Economics, Cooperative Extension Service, Agricultural Experiment Station, New Mexico Range Improvement Task Force, Las Cruces, NM.

Williams, T. A. 1897. Grasses and forage plants of the Dakotas. US Department of Agriculture, Division of Agrostology, Washington, DC.

Wright, H. A. 1971. Why squirreltail is more tolerant to burning than needle-and-thread. Journal of Range Management **24**:277-284.

Wright, H. A. 1985. Effects of fire on grasses and forbs in sagebrush-grass communities. Pages 12-21 *in* Rangeland fire effects: A symposium; Boise, ID; November 27-29, 1984. U.S. Department of the Interior, Bureau of Land Management, Boise, ID.

Wright, H. A., and J. O. Klemmedson. 1965. Effect of fire on bunchgrasses of the sagebrush-grass region in Southern Idaho. Ecology **46**:680-688.

Young, F., R. Veseth, D. Thill, W. Schillinger, and D. Ball. 1995. Managing Russian thistle under conservation tillage in crop-fallow rotations.

Young, R. P. 1983. Fire as a vegetation management tool in rangelands of the intermountain region. Pages 18-31 *in* Managing Intermountain rangelands—Improvement of range and wildlife habitats. Proceedings of Symposia: September 15-17, 1981, Twin Falls, Idaho June 22·24, 1982, Elko, Nevada. General Technical Report INT-GTR-157. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Zschaechner, G. A. 1985. Studying rangeland fire effects: A case study in Nevada. Pages 66-84 *in* Rangeland fire effects: a symposium; Boise, ID; November 27-29, 1984. U.S. Department of the Interior, Bureau of Land Management, Idaho State Office, Boise, ID.

MLRA 27 Group 18: Salt-affected soils with black greasewood and warm-season grasses

Description of MLRA 27 Disturbance Response Group 18

Disturbance Response Group (DRG) 18 consists of one ecological site, Sodic Flat (R027XY025NV). This site is found primarily on alluvial flats and lake plains, usually adjacent to playas. Slopes range from 0 to 2%. Elevations range from 3,300 to about 4,000 ft. Precipitation ranges from 3 to 7 in. 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. Plant growth is attenuated by water table fluctuation, soil pH, and natural ponding and crusting of the soil surface. Seasonal flooding is common. The reference plant community is dominated by black greasewood (*Sarcobatus vermiculatus)* and inland saltgrass (*Distichlis spicata*). Other important species include shadscale (*Atriplex confertifolia*), Mojave seablite (*Suaeda moquinii*), alkali sacaton (*Sporobolus airoides*), squirreltail (*Elymus elymoides*), Indian ricegrass (*Achnatherum hymenoides*), basin wildrye (*Leymus cinereus*), Torrey's saltbush (*Atriplex torreyi*), rubber rabbitbrush (*Ericameria nauseosa*) and a variety of other salt tolerant shrubs. Total annual air-dry production ranges from 150 to 500 lb/ac, with 350 lb/ac for a normal year.

Disturbance Response Group 18 Ecological Site:

Sodic Flat – Modal	R027XY025NV

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 27 (MLRA 27 Fallon-Lovelock Area) is almost entirely in Nevada with < 1% in California. The entire area occurs in the rain shadow of the Sierra Nevada mountains

and is influenced by Pleistocene Lake Lahontan. Extensive playas occur throughout the area and are a result of the drying of ancient Lake Lahontan. To the west, MLRA 27 has a gradual boundary with MLRA 26 (Carson Basin and Mountains) and to the east has a very gradual boundary with MLRA 24 (Humboldt Basin and Range Area). From west to east the soil temperature increases and the soil moisture decreases, resulting in vast areas dominated by salt-desert shrub communities. Isolated mountain ranges trending north to south are separated by broad desert plains and valleys. Elevations range from 3,300 to 5,900 ft with some mountain peaks over 7,800 ft. The average annual precipitation ranges from 4 to 11 in. and as much as 20 in. at the highest elevations. The majority of annual precipitation is received during late fall and winter occurring mainly as snow. High-intensity, convective thunderstorms also contribute significantly to annual precipitation (NRCS 2022). 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 on this site, 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 1987b, Trent et al. 1997, Naumburg et al. 2005). Black greasewood covers roughly 2 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 (1986a) reported that water tables within 9.8–11.8

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 1988b, 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, a C_4 species, the co-dominant shrub on this site, 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 40–60 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 western tansymustard (*Descurainia pinnata*) (Nelson et al. 1989).

The dominant grass species in this group is inland saltgrass, while alkali sacaton is an important but minor component. Both species are 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).

Inland saltgrass is a warm-season, rhizomatous species that grows 10–60 cm (4–24 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 8–12 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, and other species in the absence of drought.

Alkali sacaton, a hardy, warm-season species, is a densely tufted, native perennial bunchgrass that grows from 20–60 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).

Squirreltail is a short, cool-season bunchgrass that grows between 10 to 45 cm (4–19 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) (Cronquist et al. 1977). 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 (Cronquist et al. 1977).

Indian ricegrass is a hardy, cool-season, densely tufted, long-lived perennial bunchgrass that grows from 4–24 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 27, 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).

Basin wildrye is the largest of the native grasses commonly found on western ranges and may occur as a minor component on this ecological site. 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).

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 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 limits cheatgrass invasion. Other annual non-native species such as halogeton, prickly Russian thistle, tall tumblemustard, and smotherweed (*Bassia* spp.) also invade these sites where competition from perennial species is decreased. Native annual forbs like western tansymustard 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 site in this DRG has moderate resilience to disturbance and resistance to invasion. Primary disturbances on this site includes long-term drought, excessive livestock grazing, lowering of the water table, and conversion to agricultural land and urban development. Annual non-native species invade these sites where competition from perennial species is decreased.

Agricultural History:

This ecological site is mapped in the Fallon and Yerington areas where it has been converted to agriculture. Agricultural development began in the early 1850s when overland stage travel was at its peak (Strahorn 1909). The first permanent settlements were made on the Carson River and the South Branch of the Carson at points where the overland trails crossed the rivers. Later settlements occurred on adjacent lands where it was possible to irrigate from the spring flow of the rivers to grow crops for local consumption. Large scale agricultural development started after the construction of the Newlands Project by the U.S. Reclamation Service (Headley and Venstrom 1930).

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 and groundwater lowering during settlement and into the 20th century has increased the overall presence of 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 this ecosystem decreases ecosystem resilience and resistance to disturbance through competition for limited resources. Annual non-native species such as halogeton, Russian thistle, tall tumblemustard (*Sisymbrium altissimum*), and fivehorn smotherweed (*Bassia hyssopifolia*) invade this site where competition from perennial species is decreased.

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 lb 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 < 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 1998).

Tall tumblemustard is a cool-season annual forb, introduced from southern Europe, and found throughout most of North America (Holmgren et al. 2005). It is one of the most invasive species in the Great Basin and is characterized by early germination, rapid growth, production of numerous seeds and an effective dispersal mechanism (Holmgren et al. 2005). Tall tumblemustard has low palatability but is grazed when growth is young by cattle and sheep (USFS 1988a).

Fivehorn smotherweed is a non-native, erect, summer annual forb that is common throughout the western and northern US and is also found throughout Canada (Collins 1979, Friesen 2009). It is native to central and eastern Europe and Asia and is particularly adapted to arid and semi-arid regions. Smotherweed exhibits early germination making it capable of utilizing spring moisture and seeds will continue to germinate throughout the growing season as long as moisture is available (Collins 1979, Friesen 2009). It occurs in most counties in Nevada.

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). This particular ecological site's annual production typically averages 350 lb/ac, thus fire likely was a rare, but important disturbance. Fire suppression and / or historical grazing which facilitated a reduction in bunchgrasses and an increase in the shrub component likely has caused a reduction in fire frequency. Sites with reduced fine fuels and increased shrub dominance 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 lack of continuous fine fuels to carry fires made fire an infrequent disturbance (Young and Tipton 1990), thus it is not surprising that shadscale is 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).

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.

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 2–4 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).

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). 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).

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:

This salt-desert shrub community is typically regarded as a browse-specific plant community. It is characterized by low productivity, which requires substantial acreage for a grazing animal. Within this vegetation type, it is acknowledged that 65–90% of the available forage is browse (Costello 1944).

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 black 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. 2007). Black greasewood also provides good cover for wildlife species (Benson et al. 2007).

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 15–20% 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 2+ years may be 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).

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. Notably, inland saltgrass stays green during drought periods when many other grasses dry out, and due to its stoloniferous growth form it is highly resistant to both grazing and trampling (Skaradek and Miller 2010). It 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).

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.

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 species (Young et al. 1976, Roundy 1985). 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). Spring grazing should be employed on a rest-rotation basis. 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 18

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 27 Disturbance Response Group 18.

Six possible alternative stable states have been identified for this DRG including a shrub dominated state, an annual / perennial invasive state, an abiotically controlled state, and an agricultural 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 two general community phases; a shrub-grass dominant phase and a perennial 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, shallow groundwater recharge, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by periodic drought and/or insect or disease attack and rare fire events.

Community Phase 1.1:
The reference plant community is dominated by black greasewood, shadscale and inland saltgrass. Alkali sacaton, Indian ricegrass, squirreltail and basin wildrye are minor components. A variety of other shrubs make up minor components. Potential vegetative composition by air-dry weight is approximately 80% shrubs, 15% grasses and 5% forbs. Approximate ground cover (basal and crown) is 10–20%. Total annual air-dry production ranges from 150 to 500 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 and shadscale. A low severity fire would temporally decrease the overstory cover of black greasewood and shadscale allowing for the understory perennial grasses to increase. Low severity fires typically create a mosaic pattern of grass and shrubs. A high severity will reduce black greasewood and shadscale cover to trace amounts. Likelihood of fire is very low. An unusually wet spring could also reduce shadscale due to insects and disease.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.3:
Absence of disturbance over time, 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.

Community Phase 1.2:
This community phase is characteristic of a post-disturbance, early-seral, grass dominated community phase. Inland saltgrass dominates the community while Indian ricegrass, squirreltail, and basin wildrye are minor components. Black greasewood is a

minor component but will likely sprout and return to pre-disturbance levels within a few years. Shadscale is greatly reduced to absent.

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 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 grasses to recover.

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.

T1B: Transition from Reference State 1.0 to Agricultural State 6.0:

Trigger: Settlement of the area which included damming of the Carson, Truckee, and Walker rivers, construction of canals, diversion of water for irrigation, plowing and brush removal, land leveling and building furrows for irrigation.

Slow variables: Over time, local drainage improvement effectively lowered the water table. Increase in salt salinity from furrow irrigation. Reduction in soil organic carbon from the conversion of rangeland to cropland.

Threshold: Removal of native vegetation by soil disturbance causes loss of soil structure, soil compaction, reduced infiltration, increased wind and water erosion, loss of organic matter and nutrient-rich topsoil, and reduced moisture retention. These changes make restoration extremely challenging.

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 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 phase is dominated by black greasewood, shadscale and inland saltgrass. Alkali sacaton, Indian ricegrass, squirreltail and basin wildrye are minor components. A variety of other shrubs make up minor components. Non-native annual species such as halogeton and Russian thistle are present.

Sodic Flat (R027XY025NV), Current Potential 2.1, T. Stringham, May 2024

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. A low severity fire would temporally decrease the overstory cover of black greasewood and allow for the understory perennial grasses to increase. Low severity fires typically create a mosaic pattern of grass and shrubs. A high severity will reduce black greasewood cover to trace amounts. Fire is highly unlikely.

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 where annual non-native species are present. Annual non-native species are stable to increasing in the community. Inland saltgrass dominates the community while Indian ricegrass, squirreltail, and basin wildrye are minor components. Black greasewood is a minor component but will likely sprout and return to pre-disturbance levels within a few years. Shadscale is greatly reduced to absent.

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 and shadscale 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.

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

Trigger: 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 inland saltgrass and allow for other shrubs to increase.

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

Threshold: Loss of deep-rooted perennial grasses 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 black greasewood. 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. Inland saltgrass is the dominant understory grass. Deep-rooted perennial bunchgrasses such as basin wildrye, squirreltail and Indian ricegrass have significantly declined. Annual non-native species increase. Bare ground is significant. Formation of black greasewood hummocks may be occurring due to soil displacement caused by water and wind erosion. Invasive forbs likely dominate the understory. Inland saltgrass dominates the understory.

T3A: Transition from Shrub State 3.0 to Abiotic State 5.0:

Trigger**:** Long-term, inappropriate grazing management, flooding, severe drought, groundwater pumping, land clearing 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 hummocks leads to decreased infiltration, increased flow path length, ponding and salt accumulation on interspace soils surface.

Annual / Perennial Invasive State 4.0:

This state consists of one community phase in which invasive species 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 seed bank of invasive species, water table reduction, soil surface degradation, loss, nutrient loss, increased bare ground patch size. Annual species such as halogeton, Russian thistle, fivehorn smotherweed and/or annual wheatgrass (*Eremopyrum triticeum*) dominate the site. Non-native perennial species such as Russian knapweed (*Rhaponticum repens*) and field bindweed (*Convolvulus arvensis*) may also be present.

Community Phase 4.1 (At-Risk):
This community phase is the result of loss of irrigation water and loss of cropland, hay or pasture plant species. Conservation (farming) practices are no longer implemented and the site is allowed to naturally recolonize. The vegetative cover is dominated by non-native annual species. Bare ground is extensive, leaving the field susceptible to wind erosion. Trace amounts of native species may be present and bare ground interspaces are large and connected. Site function is controlled by non-native vegetation. Soil erosion and redistribution is occurring. Site is at-risk of transitioning to an Abiotic State.

Sodic Flat (R027XY025NV), Annual/Perennial Invasive State 4.1, T. Stringham, September 2025

Sodic Flat (R027XY025NV), Annual/Perennial Invasive State 4.1, T. Stringham, September 2025

T4A: Transition from Annual/Perennial Invasive State 4.0 to Abiotic State 5.0:

Trigger**:** Cessation of farming practices including the removal of irrigation water and loss of cropland, hay or pasture species. Long-term drought reduces cover of invasive species resulting in increased bare ground. Significant soil loss and redistribution is occurring. Soil compaction (plow pan) reduces infiltration and effective rooting depth. Soil surface is crusted.

Slow variables: Soil redistribution is significant and on-going. Reduction in soil organic matter inputs contributes to soil surface crusting and reduced infiltration. Reduced infiltration leads to reduced soil water promoting a continued reduction in vegetation.

Threshold: Soil compaction and soil surface changes due to long-term farming practices combined with removal of farming practices and irrigation leads to significant soil redistribution, soil temperature increases, organic matter loss, soil surface ponding, and reduced infiltration.

Abiotic State 5.0:

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, soil compaction, nutrient loss, soil surface degradation, increased bare ground patch size, and increased connectivity between patches of bare soil.

Community Phase 5.1:
This community is the result of significant soil redistribution and loss. Farming practices, including irrigation, are no longer implemented and the site is allowed to naturally recolonize. The vegetative cover is minimal; dominated by introduced non-native forbs. 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.

Sodic Flat (R027XY025NV), Abiotic State 5.1, T. Stringham, September 2025

Agricultural State 6.0:

This state is characterized by an irrigated agriculture phase with either cropland, hay or pasture. Irrigation water is critical to the production of crops in this MLRA because of low precipitation. Once irrigation water is removed the lasting effects on the soil include diminished soil stability, altered soil structure, compaction, reduced infiltration and increased wind and water erosion.

Community Phase 6.1 (Irrigated Agriculture)
This community phase is either cropland, hay or pasture actively maintained by irrigation water during the growing season. Typical crops include alfalfa, corn, oats and wheat. Conservation practices implemented include pasture and hay planting, irrigation water management, nutrient management, forage harvest management, conservation crop rotation, and cover crop.

Sodic Flat (R027XY025NV), Agricultural State 6.1, T. Stringham, September 2025

T6A: Transition from Agricultural State 6.0 to Annual/Perennial Invasive State 4.0:

Trigger**:** Cessation of farming practices including the removal of irrigation water and the loss of cropland, hay or pasture species. Residual nitrogen and phosphorus from prior fertilizer applications favors fast-growing, early-successional non-native invasive species which dominate the site.

Slow variables: Long-term increase in non-native annual or perennial invasive species and their associated seed banks. Native seed banks are depleted. Soil redistribution is significant.

Threshold: Reduced cover of seeded, cropland, hay or pasture species due to the removal of irrigation and farming practices facilitates invasion of non-native annual species. Changes in plant community composition and spatial variability of vegetation due to the loss of crop, hay or pasture species truncates energy capture spatially and temporally thus impacting nutrient cycling and distribution. Soil compaction, soil surface degradation and redistribution lead to decreased infiltration, increased flow path length, crusting, salt accumulation on the soil surface and altered soil biology.

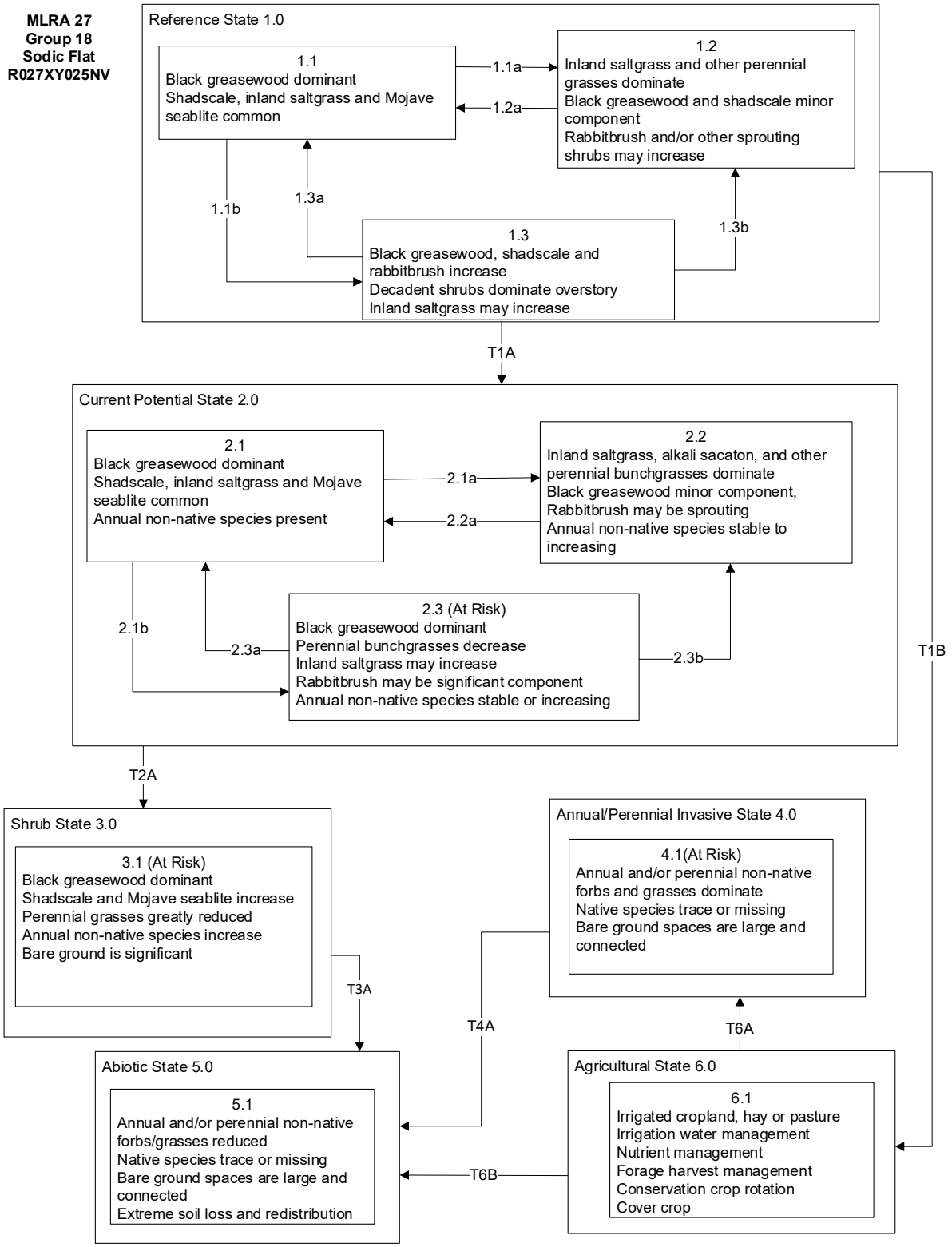
T6B: Transition from Agricultural State 6.0 to Abiotic State 5.0:

Trigger**:** Cessation of farming practices including the removal of irrigation water and the loss of cropland, hay or pasture species. Invasion by non-native annual or perennial invasive species is reduced under long-term drought conditions increasing bare ground and soil erosion. Significant soil loss and redistribution is occurring. Soil compaction (plow pan) reduces infiltration and effective rooting depth. Soil surface is crusted.

Slow variables: Soil redistribution is significant and on-going. Reduction in soil organic matter inputs contributes to soil surface crusting and reduced infiltration. Reduced infiltration leads to reduced soil water promoting a continued reduction in vegetation.

Threshold: Soil compaction and soil surface changes due to long-term farming practices combined with removal of farming practices and irrigation leads to significant soil redistribution, soil temperature increases, organic matter loss, soil surface ponding, and reduced infiltration.

Modal State and Transition Model for Group 18 in MLRA 27



MLRA 27
Group 18
Sodic Flat
R027XY025NV
KEY

Reference State 1.0 Community Pathways
1.1a: Long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge, or low severity fire would reduce black greasewood and shadscale and allow for the understory perennial bunchgrasses to increase. High severity fire would greatly reduce black greasewood and shadscale. An unusually wet spring would reduce the shadscale component due to insects and/or disease.
1.1b: Time and lack of disturbance such as fire, long-term spring/summer drought, unusually wet periods or combinations of these. Black greasewood, shadscale and inland saltgrass increase.
1.2a: Time and lack of disturbance and/or release from chronic winter drought.
1.3a: Long-term reduction in winter snow accumulation may lead to reduced groundwater recharge, or low severity fire would reduce black greasewood and allow for the perennial bunchgrasses to dominate the site.
1.3b: High severity fire, due to shrub dominance, significantly reduces shrub cover and increases perennial bunchgrasses and sprouting shrubs.

Transition T1A: Introduction of non-native annual plants.

Transition T1B: Settlement of the area and beginning of agriculture.

Current Potential State 2.0 Community Pathways:
2.1a: Long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge, or low severity fire would reduce black greasewood and shadscale and allow for the understory perennial bunchgrasses to increase. High severity fire would greatly reduce black greasewood. Non-native annual species are likely to increase after fire. An unusually wet spring could reduce shadscale due to insects and/or disease.
2.1b: Time and lack of disturbance such as fire, long-term spring/summer drought, inappropriate grazing management, and unusually wet spring, or combinations of these. Black greasewood, shadscale and inland saltgrass increase.
2.2a: Time, lack of disturbance, release from chronic winter drought, and/or grazing management that favors the establishment and growth of black greasewood allows the shrub component to recover.
2.3a: Heavy late fall/winter grazing causing mechanical damage to shrubs, low severity fire, and/or reduced groundwater recharge due to a long-term reduction in winter snow accumulation.
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.

Transition T4A: Cessation of farming practices including the removal of irrigation water and loss of cropland, hay or pasture species. Dominance of non-native species is reduced under long-term drought conditions increasing bare ground and soil erosion.

Transition T6A: Cessation of farming practices including the removal of irrigation water and loss of cropland, hay or pasture species. Invasion by non-native species in average to above-average precipitation years leads to dominance of those species.

Transition T6B: Cessation of farming practices including the removal of irrigation water and loss of cropland, hay or pasture species. Invasion by non-native species is reduced under long-term drought conditions increasing bare ground and soil erosion.

References

Abbott, M. L., L. Fraley Jr., and T. D. Reynolds. 1991. Root profiles of selected cold desert shrubs and grasses in disturbed and undisturbed soils. Environmental and Experimental Botany **31**:165-178.

Allen, E. B., and M. F. Allen. 1988. Facilitation of succession by the nonmycotrophic colonizer *Salsola kali* (Chenopodiaceae) on a harsh site: effects of mycorrhizal fungi. American Journal of Botany **75**:257-266.

Alpert, P. 1990. Water sharing among ramets in a desert population of *Distichlis spicata* (Poaceae). American Journal of Botany **77**:1648-1651.

Anderson, D. C., K. T. Harper, and S. R. Rushforth. 1982. Recovery of cryptogamic soil crusts from grazing on Utah winter ranges. Journal of Range Management **35**:355-359.

Anderson, M. D. 2004. *Sarcobatus vermiculatus*. In: Fire Effects Information System. U.S. Department of Agriculture, Forest Service,, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory.

Banner, R. E. 1992. Vegetation types of Utah. Rangelands **14**:109-114.

Bates, J. D., T. Svejcar, R. F. Miller, and R. A. Angell. 2006. The effects of precipitation timing on sagebrush steppe vegetation. Journal of Arid Environments **64**:670-697.

Beatley, J. C. 1975. Climates and vegetation pattern across the Mojave/Great Basin Desert transition of southern Nevada. The American Midland Naturalist **93**:53-70.

Benson, B., D. Ogle, D. Tilley, and L. St. John. 2007. Technical Note: managing black greasewood sites. TN Plant Materials No. 15, U.S. Department of Agriculture - Natural Resources Conservation Service, Boise, ID - Salt Lake City, UT.

Bich, B. S., J. L. Butler, and C. A. Schmidt. 1995. Effects of differential livestock use on key plant species and rodent populations within selected *Oryzopsis hymenoides*/*Hilaria jamesii* communities of Glen Canyon National Recreation Area. The Southwestern Naturalist **40**:281-287.

Blaisdell, J. P., and R. C. Holmgren. 1984. Managing intermountain rangelands - salt-desert shrub ranges. General Technical Report INT-163, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Blauer, A. C., A. P. Plummer, E. D. McArthur, R. Stevens, and B. C. Giunta. 1976. Characteristics and hybridization of important intermountain shrubs. II. Chenopod family. Research Paper INT-177, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Bock, C. E., and J. H. Bock. 1978. Response of birds, small mammals, and vegetation to burning sacaton grasslands in southeastern Arizona. Journal of Range Management **31**:296-300.

Boerboom, C. 1993. Russian thistle (*Salsola iberica* Sennen & Pau).

Booth, D. T., C. G. Howard, and C. E. Mowry. 1980. 'Nezpar' Indian ricegrass: description, justification for release, and recommendations for use. Rangelands **2**:53-54.

Booth, E. G., J. F. Mount, and J. H. Viers. 2006. Hydrologic variability of the Cosumnes River floodplain. San Francisco Estuary and Watershed Science **4**:Article 2.

Bradley, A. F., N. V. Noste, and W. C. Fischer. 1992. Fire ecology of forests and woodlands in Utah. General Technical Report INT-287, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Brakie, M. 2007. Plant guide for alkali sacaton (*Sporobolus airoides*). U.S. Department of Agriculture, Natural Resources Conservation Service, East Texas Plant Materials, Nacogdoches, TX.

Branson, F. A., R. F. Miller, and I. S. McQueen. 1976. Moisture relationships in twelve northern desert shrub communities near Grand Junction, Colorado. Ecology **57**:1104-1124.

Britton, C. M., G. R. McPherson, and F. A. Sneva. 1990. Effects of burning and clipping on five bunchgrasses in eastern Oregon. The Great Basin Naturalist **50**:115-120.

Buwai, M., and M. Trlica. 1977. Multiple defoliation effects on herbage yield, vigor, and total nonstructural carbohydrates of five range species. Rangeland Ecology & Management/Journal of Range Management Archives **30**:164-171.

Carlson, J. R. 1984. *Atriplex* cultivar development. Pages 176-182 *in* Proceedings—Symposium on the biology of *Atriplex* and related chenopods; May 2-6, 1983; Provo, UT. General Technical Report INT-172. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station.

Caudle, D., J. DiBenedetto, M. Karl, H. Sanchez, and C. Talbot. 2013. Interagency ecological site handbook for rangelands. U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.

Chambers, J. C., B. A. Bradley, C. S. Brown, C. D'Antonio, M. J. Germino, J. B. Grace, S. P. Hardegree, R. F. Miller, and D. A. Pyke. 2013. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of western North America. Ecosystems **17**:360-375.

Chambers, J. C., and B. E. Norton. 1993. Effects of grazing and drought on population dynamics of salt desert shrub species on the Desert Experimental Range, Utah. Journal of Arid Environments **24**:261-275.

Cibils, A. F., S. M. David, and D. E. McArthur. 1998. Plant-herbivore interactions in *Atriplex*: current state of knowledge. General Technical Report RMRS-GTR-14, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Collins, S. L. a. W. H. B. 1979. Bassia (Chenopodiaceae) in North America. SIDA, Contributions to Botany **8**:57-64.

Comstock, J. P., and J. R. Ehleringer. 1992. Plant adaptation in the Great Basin and Colorado Plateau. The Great Basin Naturalist **52**:195-215.

Cook, C. W. 1962. An evaluation of some common factors affecting utilization of desert range species. Journal of Range Management **15**:333-338.

Cook, C. W., and R. D. Child. 1971. Recovery of desert plants in various states of vigor. Rangeland Ecology & Management/Journal of Range Management Archives **24**:339-343.

Cook, C. W., L. A. Stoddart, and L. E. Harris. 1954. The nutritive value of winter range plants in the Great Basin as determined with digestion trials with sheep. Bulletin No. 372, Utah State Agricultural College, Agricultural Experiment Station, Logan, UT.

Costello, D. F. 1944. Important species of the major forage types in Colorado and Wyoming. Ecological Monographs **14**:107-134.

Crofts, K. A., and G. V. Epps. 1975. The usefulness of shadscale in the revegetation of disturbed sites in the salt desert shrub type. Pages 151-152 *in* Proceedings: Symposium and workshop: Wildland shrubs. U.S. Department of Agriculture, Forest Service, Shrub Sciences Laboratory, Provo, UT.

Cronquist, A., A. H. Holmgren, N. H. Holmgren, J. L. Reveal, and P. K. Holmgren. 1977. Intermountain flora: Vascular plants of the Intermountain West, U.S.A. Volume six. The Monocotyledons. Columbia University Press, New York, NY.

Devitt, D. A., and B. Bird. 2016. Changes in groundwater oscillations, soil water content and evapotranspiration as the water table declined in an area with deep rooted phreatophytes. Ecohydrology **9**:1082-1093.

Eckert, R. E., Jr., and J. S. Spencer. 1987. Growth and reproduction of grasses heavily grazed under rest-rotation management. Journal of Range Management **40**:156-159.

Eddleman, L. E. 2008. *Sarcobatus vermiculatus* (Hook.) Torr. - black greasewood. Pages 1022-1024 *in* F. T. Bonner and R. P. Karrfalt, editors. The Woody Plant Seed Manual. Agriculture Handbook 727. U.S. Department of Agriculture, Forest Service, Washington, D.C.

Elmore, A. J., J. F. Mustard, S. P. Hamburg, and S. J. Manning. 2006. Agricultural legacies in the Great Basin alter vegetation cover, composition, and response to precipitation. Ecosystems **9**:1231-1241.

Everett, R. L., P. T. Tueller, J. B. Davis, and A. D. Brunner. 1980. Plant phenology in galleta-shadscale and galleta-sagebrush associations. Rangeland Ecology & Management/Journal of Range Management Archives **33**:446-450.

Ewing, K., and J. P. Dobrowolski. 1992. Dynamics of shrub die-off in a salt desert plant community. Rangeland Ecology & Management/Journal of Range Management Archives **45**:194-199.

Fletcher, J. E., and W. P. Martin. 1948. Some effects of algae and molds in the rain-crust of desert soils. Ecology **29**:95-100.

Friesen, L. F., Beckie, H.J., Warwick, S.I, Van Acker, R.C. 2009. The biology of Canadican weeds. 138. Kochia scoparia (L.) Schrad. Canadian Journal of Botany **89**:141-167.

Ganskopp, D., L. Aguilera, and M. Vavra. 2007. Livestock forage conditioning among six northern Great Basin grasses. Rangeland Ecology & Management **60**:71-78.

Ganskopp, D. C. 1986a. Tolerances of sagebrush, rabbitbrush, and greasewood to elevated water tables. Journal of Range Management **39**:334-337.

Groeneveld, D. P. 1990. Shrub rooting and water acquisition on threatened shallow groundwater habitats in the Owens Valley, California. Pages 221-237 *in* Proceedings—Symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; Las Vegas, NV; April 5-7, 1989. General Technical Report INT-276. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Groeneveld, D. P., and D. E. Crowley. 1988b. Root system response to flooding in three desert shrub species. Functional Ecology **2**:491-497.

Gutierrez, J. R., and W. G. Whitford. 1987. Chihuahuan Desert annuals: Importance of water and nitrogen. Ecology **68**:2032-2045.

Hansen, D. J., P. Dayanandan, P. B. Kaufman, and J. D. Brotherson. 1976. Ecological adaptations of salt marsh grass, *Distichlis spicata* (Gramineae), and environmental factors affecting its growth and distribution. American Journal of Botany **63**:635-650.

Harr, R. D., and K. R. Price. 1972. Evapotranspiration from a greasewood-cheatgrass community. Water Resources Research **8**:1199-1203.

Headley, F. B., and C. Venstrom. 1930. Economic History of the Newlands Irrigation Project. University of Nevada.

Hickey, W. C., Jr., and H. W. Springfield. 1966. Alkali sacaton: Its merits for forage and cover. Journal of Range Management **19**:71-74.

Hironaka, M. 1994. Medusahead: Natural successor to the cheatgrass type in the northern Great Basin. Pages 89-91 *in* Proceedings—Ecology and management of annual rangelands; September 1994; Boise, ID. General Technical Report INT-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Hironaka, M., and E. Tisdale. 1963. Secondary succession in annual vegetation in southern Idaho. Ecology **44**:810-812.

Hironaka, M., and E. W. Tisdale. 1973. Growth and development of *Sitanion hystrix* and *Poa sandbergii*. Research Memorandum RM 73-16, U.S. International Biological Program, Desert Biome, Logan, UT.

Holmgren, N. H., P. K. Holmgren, and A. Cronquist. 2005. Intermountain flora: Vascular plants of the Intermountain West, U.S.A. Volume two, part B. Subclass Dilleniidae. The New York Botanical Garden Press, Bronx, NY.

Howery, L. D., J. E. Sprinkle, and J. E. Bowns. 2016. A summary of livestock grazing systems used on rangelands in the western United States and Canada. AZ1184, University of Arizona, College of Agriculture and Life Sciences, Cooperative Extension, Tucson, AZ.

Huntington, J., K. McGwire, C. Morton, K. Snyder, S. Peterson, T. Erickson, R. Niswonger, R. Carroll, G. Smith, and R. Allen. 2016. Assessing the role of climate and resource management on groundwater dependent ecoystem changes in arid environements with the Landsat archive. Remote Sensing of Environment **185**:186-197.

Hutchings, S. S., and G. Stewart. 1953. Increasing forage yields and sheep production on intermountain winter ranges. Circular No. 925, U.S. Department of Agriculture, Washington, D.C.

Johnson, N. C. 1998. Responses of *Salsola kali* and *Panicum virgatum* to mycorrhizal fungi, phosphorus and soil organic matter: implications for reclamation. Journal of Applied Ecology **35**:86-94.

Krall, J. L., J. R. Stroh, C. S. Cooper, and S. R. Chapman. 1971. Effect of time and extent of harvesting basin wildrye. Journal of Range Management **24**:414-418.

Kulpa, S. M., and E. A. Leger. 2013. Strong natural selection during plant restoration favors an unexpected suite of plant traits. Evolutionary Applications **6**:510-523.

Majerus, M. E. 1992. High-stature grasses for winter grazing. Journal of Soil and Water Conservation **47**:224-225.

Marcum, K. B., and D. M. Kopec. 1997. Salinity tolerance of turfgrasses and alternative species in the subfamily Chloridoideae (Poaceae). International Turfgrass Society Research Journal **8**:735-742.

Marlette, G. M., and J. E. Anderson. 1986. Seed banks and propagule dispersal in crested-wheatgrass stands. Journal of Applied Ecology **23**:161-175.

Medin, D. E. 1990. Birds of a shadscale (*Atriplex confertifolia*) habitat in east central Nevada. The Great Basin Naturalist **50**:295-298.

Meinzer, O. E. 1927. Plants as indicators of ground water. Water-Supply Paper 577, U.S. Department of the Interior, U.S. Geological Survey, Washington, D.C.

Miller, R. F., J. C. Chambers, D. A. Pyke, F. B. Pierson, and C. J. Williams. 2013. A review of fire effects on vegetation and soils in the Great Basin Region: Response and ecological site characteristics. General Technical Report RMRS-GTR-308, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Miller, R. F., S. T. Knick, D. A. Pyke, C. W. Meinke, S. E. Hanser, M. J. Wisdom, and A. L. Hild. 2008a. Characteristics of sagebrush habitats and limitations to long-term conservation. Administrative Report, U.S. Department of the Interior; U.S. Geological Survey, Reston, VA.

Mohebby, A., M. Jafari, A. Tavili, S. A. Javadi, E. Zandi Esfahan, and M. Ramezani. 2012. Effect of livestock grazing on growth characteristics of *Atriplex canescens*. Desert **17**:290-303.

Monsen, S. B., R. Stevens, and N. L. Shaw. 2004a. Grasses. Pages 295-424 *in* S. B. Monsen, R. Stevens, and N. L. Shaw, editors. Restoring western ranges and wildlands, vol. 2. Gen. Tech. Rep. RMRS-GTR-136-vol-2. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Mozingo, H. N. 1987b. Shrubs of the Great Basin: A natural history. University of Nevada Press, Reno, NV.

Naumburg, E., R. Mata-Gonzalez, R. G. Hunter, T. McLendon, and D. W. Martin. 2005. Phreatophytic vegetation and groundwater fluctuations: A review of current research and application of ecosystem response modeling with an emphasis on Great Basin vegetation. Environmental Management **35**:726-740.

Nelson, D. L., K. T. Harper, K. C. Boyer, D. J. Weber, B. A. Haws, and J. R. Marble. 1989. Wildland shrub dieoffs in Utah: An approach to understanding the cause. Pages 119-135 *in* Proceedings—Symposium on shrub ecophysiology and biotechnology; General Technical Report INT-256. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Logan, UT.

Newman, S. D., and M. Gates. 2000. Plant guide for saltgrass (*Distichlis spicata*). U.S. Department of Agriculture, Natural Resource Conservation Service, Alexandria, LA.

NRCS. 2022. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. Handbook 296, U.S. Department of Agriculture, Natural Resources Conservation Service.

Parker, K. G. 1975. Some important Utah range plants. Extension Service Bulletin EC-383, Utah State University, Logan, UT.

Paysen, T. E., R. J. Ansley, J. K. Brown, G. J. Gottfried, S. M. Haase, M. G. Harrington, M. G. Narog, S. S. Sackett, and R. C. Wilson. 2000. Chapter 6: Fire in western shrubland, woodland, and grassland ecosystems. Pages 121-159 *in* J. K. Brown and J. K. Smith, editors. Wildland fire in ecosystems: Effects of fire on flora. General Technical Report

RMRS-GTR-42-Vol. 2. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Pearson, L. 1979. Effects of temperature and moisture on phenology and productivity of Indian ricegrass. Rangeland Ecology & Management/Journal of Range Management Archives **32**:127-134.

Pearson, L. C. 1964. Effect of harvest date on recovery of range grasses and shrubs. Agronomy Journal **56**:80-82.

Pearson, L. C. 1965. Primary production in grazed and ungrazed desert communities of eastern Idaho. Ecology **46**:278-285.

Pessarakli, M. 2017. Growth responses of sacaton grass (*Sporobolus airoides* Torr.) and Seashore paspalum (*Paspalum vaginatum* Swartz) under prolonged drought stress condition. Advances in Plants & Agriculture Research **7**:320-326.

Peters, E. F., and S. C. Bunting. 1994. Fire conditions pre-and post-occurrence of annual grasses on the Snake River Plain. Pages 31-36 *in* Proceedings—Ecology and management of annual rangelands; September, 1994; Boise, ID. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Ponzetti, J. M., B. McCune, and D. A. Pyke. 2007. Biotic Soil crusts in relation to topography, cheatgrass and fire in the Columbia Basin, Washington. The American Bryological and Lichenological Society.

Pritchett, D. W., and S. J. Manning. 2009. Effects of fire and groundwater extraction on alkali meadow habitat in Owens Valley, California. Madroño **56**:89-98.

Provencher, L., L. Saito, K. Badik, and S. Byer. 2020. All systems are equal: In defense of undervalued ecosystems. Rangelands **42**:159-167.

Qian, Y. L., J. A. Cosenza, S. J. Wilhelm, and D. Christensen. 2006. Techniques for enhancing saltgrass seed germination and establishment. Crop Science **46**:2613-2616.

Quinones, F. A. 1981. Indian ricegrass evaluation and breeding. Bulletin 681, New Mexico State University, Agricultural Experiment Station, Las Cruces, NM.

Reynolds, T. D., and L. Fraley, Jr. 1989. Root profiles of some native and exotic plant species in southeastern Idaho. Environmental and Experimental Botany **29**:241-248.

Robertson, J. H. 1983. Greasewood (*Sarcobatus vermiculatus* (Hook.) Torr.). Phytologia **54**:309-324.

Roundy, B. A. 1985. Emergence and establishment of basin wildrye and tall wheatgrass in relation to moisture and salinity. Journal of Range Management **38**:126-131.

Saito, L., S. Byer, K. Badik, K. McGwire, L. Provencher, and B. Minor. 2020. Mapping indicators of groundwater dependent ecosystems in Nevada: Important resources for a water-limited state. Journal of the Nevada Water Resources Association **Winter 2020**:48-72.

Sanderson, S. C., and H. C. Stutz. 1994. Woody chenopods useful for rangeland reclamation in western North America. Pages 374-378 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Sanderson, S. C., H. C. Stutz, and E. D. McArthur. 1990. Geographic differentiation in *Atriplex confertifolia*. American Journal of Botany **77**:490-498.

Skaradek, W., and C. Miller. 2010. Plant fact sheet for saltgrass (*Distichlis spicata*). USDA NRCS Cape May Plant Materials Center, Cape May, NJ.

Smith, M. A., J. D. Rodgers, J. L. Dodd, and Q. D. Skinner. 1992. Habitat selection by cattle along an ephemeral channel. Journal of Range Management **45**:385-390.

Smith, S. D., and P. S. Nobel. 1986. Photosynthesis in contrasting environments. Elsevier Science Publishers, Amsterdam, New York.

Strahorn, A. T. a. C. V. D. 1909. Soil Survey of the Fallon Area, Nevada. USDA-Natural Resources Conservation Service.

Stubbendieck, J. L., J. T. Nichols, and K. K. Roberts. 1985. Nebraska range and pasture grasses (including grass-like plants). University of Nebraska, Department of Agriculture, Cooperative Extension Service, Lincoln, NE.

Taylor, S. H., S. P. Hulme, M. Rees, B. S. Ripley, F. I. Woodward, and C. P. Osborne. 2010. Ecophysiological traits in C3 and C4 grasses: a phylogenetically controlled screening experiment. New Physiologist **185**:780-791.

Tilley, D., D. Ogle, and L. St. John. 2008. Plant guide for halogeton (*Halogeton glomeratus*). USDA NRCS, USDA NRCS Idaho State Office, Boise, ID.

Trent, J. D., R. R. Blank, and J. A. Young. 1997. Ecophysiology of the temperate desert halophytes: *Allenrolfea occidentalis* and *Sarcobatus vermiculatus*. Great Basin Naturalist **57**:57-65.

USFS. 1937. Range plant handbook. U.S. Department of Agriculture, Forest Service, Washington, D.C.

USFS. 1988a. Range plant handbook. Reprint of 1937 edition. Dover Publications, New York, NY.

Vallentine, J. F. 1989. Range development and improvements. Academic Press, Inc., San Diego, CA.

Wallace, A., W. Rhods, and E. Frolich. 1968. Germination behavior of *Salsola* as influenced by temperature, moisture, depth of planting, and gamma irradiation. Agronomy Journal **60**:76-78.

Wasser, C. H., P. L. Dittberner, and D. R. Dietz. 1986. Alkali sacaton (*Sporobolus airoides*): Section 7.1.4, US Army Corps of Engneers wildlife resouces management manual. Technical Report EL-86-37, Department of the ARMY US Army Corps of Engineers, Washington, DC.

West, N. E. 1994. Effects of fire on salt-desert shrub rangelands. Pages 71-74 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, ID.

Williams, J. D. 1993. Influence of microphytic crusts on selected soil physical and hydrologic properties in the Hartnet Draw, Capital Reef National Park, Utah. Ph.D Dissertation. Utah State University, Logan, UT.

Witwicki, D. L., S. M. Munson, and D. P. Thoma. 2016. Effects of climate and water balance across grasslands of varying C3 and C4 grass cover. Ecosphere **7**:1-19.

Wood, M. K., B. A. Buchanan, and W. Skeet. 1995. Shrub preference and utilization by big game on New Mexico reclaimed mine land. Journal of Range Management **48**:431-437.

Wright, H. A. 1971. Why squirreltail is more tolerant to burning than needle-and-thread. Journal of Range Management **24**:277-284.

Wright, H. A. 1985. Effects of fire on grasses and forbs in sagebrush-grass communities. Pages 12-21 *in* Rangeland fire effects: A symposium; Boise, ID; November 27-29, 1984. U.S. Department of the Interior, Bureau of Land Management, Boise, ID.

Wright, H. A., and J. O. Klemmedson. 1965. Effect of fire on bunchgrasses of the sagebrush-grass region in Southern Idaho. Ecology **46**:680-688.

Young, F., R. Veseth, D. Thill, W. Schillinger, and D. Ball. 1995. Managing Russian thistle under conservation tillage in crop-fallow rotations.

Young, J. A., and R. A. Evans. 1977. Squirreltail seed germination. Journal of Range Management **30**:33-36.

Young, J. A., R. A. Evans, and P. T. Tueller. 1976. Great Basin plant communities - pristine and grazed. Pages 186-215 *in* R. Elston, editor. Holocene Environmental Change in the Great Basin. Nevada Archeological Survey, University of Nevada, Reno, NV.

Young, J. A., and F. Tipton. 1990. Invasion of cheatgrass into arid environments of the Lahontan Basin. Pages 37-40 *in* Proceedings—Symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; Las Vegas, NV; April 5-7, 1989; General Technical Report INT-276. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Young, R. P. 1983. Fire as a vegetation management tool in rangelands of the intermountain region. Pages 18-31 *in* Managing Intermountain rangelands—Improvement of range and wildlife habitats. Proceedings of Symposia: September 15-17, 1981, Twin Falls, Idaho June 22·24, 1982, Elko, Nevada. General Technical Report INT-GTR-157. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Zielinski, M. J. 1994. Controlling erosion on lands administered by the Bureau of Land Management, Winnemucca District, Nevada. Pages 143-146 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Zschaechner, G. A. 1985. Studying rangeland fire effects: A case study in Nevada. Pages 66-84 *in* Rangeland fire effects: a symposium; Boise, ID; November 27-29, 1984. U.S. Department of the Interior, Bureau of Land Management, Idaho State Office, Boise, ID.

MLRA 27 Group 19: Sandy soils dominated by fourwing saltbush

Description of MLRA 27 Disturbance Response Group 19

Disturbance Response Group (DRG) 19 consists of two ecological sites. These sites occur on partially stabilized sand dunes. Slopes range from 0 to 50% and elevations range from approximately 3,400 to 6,500 ft. Precipitation ranges from 4 to 10 in. The soils are very deep, somewhat excessively drained to excessively drained. The soils formed in alluvium and water-reworked eolian sand derived from mixed rocks. The soil temperature regime is mesic and the soil moisture regime is typic aridic. These soils are extremely susceptible to wind erosion. Available water holding capacity is low to high and runoff is low to very low. The reference plant communities are dominated by fourwing saltbush (*Atriplex canescens*), fourpart horsebrush (*Tetradymia tetrameres*) and Indian ricegrass *(Achnatherum hymenoides)*. Other important species are Nevada dalea (*Psorothamnus polydenius*), big sagebrush (*Artemisia tridentata*), and needle-and-thread *(Hesperostipa comata)*. Total annual air-dry production ranges from 300 to 700 lb/ac.

Disturbance Response Group 19 Ecological Sites:

Dunes 4-8" P.Z. – Modal	R027XY023NV
Dunes 8-10" P.Z.	R027XY053NV

Modal Site:

The Dunes 4-8" P.Z. ecological site (R027XY023NV) is the modal site for this group as it has the most acres mapped. It occurs on partially stabilized sand dunes. Elevation ranges from 3,400 to about 5,000 ft. Slopes range from 0 to 50%, but slope gradients of 8–30% are typical. Soils correlated to this site are very deep and excessively drained. They are formed in alluvium and aeolian sands from mixed rock sources. Soil temperature regime is mesic, and the soil moisture regime is typic aridic. Runoff is low and water infiltration is high. The potential for rill and sheet erosion is slight but wind erosion potential is high. This site is dominated by fourpart horsebrush, fourwing saltbush, Indian ricegrass and needle-and-thread. Total annual air-dry production ranges from 300 to 700 lb/ac with 500 lb/ac in a normal year.

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 27 (MLRA 27 Fallon-Lovelock Area) is almost entirely in Nevada with < 1% in California. The entire area occurs in the rain shadow of the Sierra Nevada mountains and is influenced by Pleistocene Lake Lahontan. Extensive playas occur throughout the area and are a result of the drying of ancient Lake Lahontan. To the west, MLRA 27 has a gradual boundary with MLRA 26 (Carson Basin and Mountains) and to the east has a very gradual boundary with MLRA 24 (Humboldt Basin and Range Area). From west to east the soil temperature increases and the soil moisture decreases, resulting in vast areas dominated by salt-desert shrub communities. Isolated mountain ranges trending north to south are separated by broad desert plains and valleys. Elevations range from 3,300 to 5,900 ft with some mountain peaks over 7,800 ft. The average annual precipitation ranges from 4 to 11 in. and as much as 20 in. at the highest elevations. The majority of annual precipitation is received during late fall and winter occurring mainly as snow. High-intensity, convective thunderstorms also contribute significantly to annual precipitation (NRCS 2022). 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).

Aeolian processes, which are presumably the dominant mechanism of soil detachment and transport on these sites, 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. Precipitation rapidly percolates deep into the sands where it is not evaporated but is available for uptake by plants. Moisture retention occurs below the upper 30–60 cm (12–24 in.) (Saltz et al. 1999).

Fourwing saltbush, a dominant shrub on these sites, is the most widely distributed and abundant saltbush in the southwest (Mozingo 1987b). 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 (16–49 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).

Nevada dalea is a native, short-lived, drought-deciduous shrub 0.5–2.5 m tall (1.6–8.2 ft). It mostly occurs on sandy soils of the Mojave and sagebrush deserts in eastern California, western to southern Nevada and southern Utah (Benson and Darrow 1981b). It occurs on sand sheets, partially stabilized sand dunes, alluvial flats and inset fans with intermittent water courses (Perryman 2014a). This shrub has the capability of breaking dormancy with summer rains, producing new leaves and flowers (Mozingo 1987b). Nevada dalea develops a deep taproot (up to 5 ft) and several lateral roots in order to access water in the sandy soils where it occurs (Ting 1961).

Fourpart horsebrush is a native, long-lived, drought-deciduous shrub up to 2 m tall (6.5 ft) (Mozingo 1987b). It occurs on deep sands in western Nevada and adjacent Inyo and Mono counties, California (Perryman 2014a). Fourpart horsebrush is a creeping root-stock species and vegetatively reproduces from rhizomes as well as from seed (Mozingo 1987b).

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 4–24 inches in height (Blaisdell and Holmgren 1984).

The dominant grass on these sites is Indian ricegrass, a hardy, cool-season, densely tufted, long-lived perennial bunchgrass that grows 4–24 in. tall (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 (*Atriplex confertifolia*), and winterfat and in elevations up to 10,000 ft. It can be found throughout MLRA 27, 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).

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).

The ecological sites within this DRG may experience high wind erosion, especially with a decrease in vegetative cover. This can be caused by inappropriate grazing practices, drought, off-road vehicle use, and/or fire. As ecological condition declines the dunes become mobile and recruitment and establishment of perennial grasses is reduced. This can facilitate an increase in sprouting shrubs such as rabbitbrush (*Chrysothamnus* spp.) and horsebrush (*Tetradymia* spp.) which are more adapted to disturbed sites. Annual non-native species such as cheatgrass (*Bromus tectorum*), Russian thistle *(Salsola tragus*), halogeton (*Halogeton glomeratus)*, and tall tumblemustard (*Sisymbrium altissimum*) invade these sites where competition from perennial species is decreased. 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 stable states have been identified for the ecological sites in 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, 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 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 this site are cheatgrass, halogeton, Russian thistle and tumblemustard.

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. 1999b). 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). Dobrowolski et al. (1990) cite multiple authors on the extent of the soil profile exploited by 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 1.5–1.7 m (59–67 in.).

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 North Africa grass (*Ventenata dubia*) within residual stands of native bunchgrasses. 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). 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, North Africa grass 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).

Russian thistle and halogeton 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.

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 < 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 1998).

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 1966a). 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).

Tall tumblemustard is a cool-season annual forb, introduced from southern Europe, and found throughout most of North America (Holmgren et al. 2005). It is one of the most invasive species in the Great Basin and is characterized by early germination, rapid growth, production of numerous seeds and an effective dispersal mechanism (Holmgren et al. 2005). Tall

tumblemustard has low palatability but is grazed when growth is young by cattle and sheep (USFS 1988a).

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).

Fire rarely kills horsebrush species, however the top-growth is removed. Sprouting occurs from the root crown and rhizomes after fire. Horsebrush also establishes from seed after fire (Neuenschwander 1978).

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 2003).

Psorothamnus species (Nevada dalea) are generally weakly sprouting shrubs that are commonly top-killed by fire. Resprouting from the root crown or base may occur after low-intensity burns but experience high mortality from hotter fires. Reestablishment primarily occurs from off-site seed sources (Society 2009).

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:

This 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 animal. Within this vegetation type, it is acknowledged that 65–90% of the available forage is browse (Costello 1944).

Horsebrush species are rarely grazed and are considered unpalatable or some species are toxic. Sheep may consume young shoots and buds early in the spring which may cause photosensitization and liver damage except early in the spring when animals may consume young shoots and buds (Johnson 1987).

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 1988a). The palatability rates from fairly good to 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.

Dalea species are thought to be poisonous to livestock, however Native Americans utilize the roots and stems for various treatments including gastrointestinal issues, toothaches and influenza (Society 2009).

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.

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 invasive species such as halogeton or Russian thistle to occupy interspaces.

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 1966a). 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 19

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the modal site in MLRA 27 Disturbance Response Group 19.

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 fourpart horsebrush, fourwing saltbush and Indian ricegrass. Nevada dalea and needle-and-thread are also common. Perennial forbs are present but not abundant. Potential vegetative composition by air-dry weight is approximately 25% grasses, 5% forbs and 75% shrubs. Approximate ground cover (basal and crown) is 10–25%. Total annual air-dry production ranges from 300 to 700 lb/ac.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
Drought or a low severity fire would temporarily decrease the overstory of fourpart horsebrush 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, long-term spring/summer drought, herbivory by native wildlife, or combinations of these would allow the shrub overstory to increase and dominate the site. This will generally cause a reduction in perennial bunchgrasses.

Community Phase 1.2:
This community phase is characteristic of a post-disturbance, early-seral community phase. Indian ricegrass and perennial forbs dominate. Sprouting shrubs such as fourpart horsebrush, fourwing saltbush, and yellow rabbitbrush (*Chrysothamnus viscidiflorus*) and will likely sprout and return to pre-disturbance levels within a few years.

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

Community Phase 1.3 (At-Risk):
Fourpart horsebrush, fourwing saltbush, and other shrubs increase in the absence of disturbance. Perennial bunchgrasses are reduced from competition with shrubs and/or from herbivory. 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:
A low severity fire, herbivory by native wildlife, or combinations would reduce the fourwing saltbush and other palatable shrubs providing a competitive advantage to the perennial grasses and forbs.

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

Trigger: Introduction of non-native annual plants, such as cheatgrass, 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 and has three general community phases, a shrub-grass dominated phase, a grass dominated phase and a shrub dominated phase. Ecological function has not changed from the Reference State; 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:
The plant community is dominated by fourpart horsebrush, fourwing saltbush and Indian ricegrass. Nevada dalea and needle-and-thread are also common. Perennial forbs are present but not abundant. Perennial forbs are present but not abundant. Non-native annual grass and forb species are present.

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
Inappropriate grazing during the late summer to early spring period reduces fourwing saltbush, Indian ricegrass and needle-and-thread. Fire would reduce the shrub cover and allow perennial grasses to increase.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.3:
Absence of disturbance over time, long-term drought, inappropriate grazing management, off-road vehicle use, or combinations of these would allow the shrub overstory to increase and dominate the site. Inappropriate grazing will cause a decrease in perennial bunchgrasses and fourwing saltbush facilitating an increase in horsebrush, Nevada dalea and other unpalatable shrubs.

Community Phase 2.2:
This community phase is characteristic of a post-disturbance, early-seral community phase. Indian ricegrass and other perennial bunchgrasses dominate. Fourwing saltbush may sprout after fire depending on ecotype. Other sprouting shrubs will increase. 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 palatable shrubs and allows the shrub component to recover.

Community Phase 2.3 (At-Risk):
Fourpart horsebrush, 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. Annual non-native species are stable or increasing. This community is at-risk of transitioning to a Shrub State 3.0.

Community Phase Pathway 2.3a, from Phase 2.3 to 2.1:
Late summer through winter grazing that reduces shrub cover facilitates an increase in perennial grasses and a decrease in palatable shrubs. Low severity fire, while not a primary driver of change in this community, would create a shrub-grass mosaic. Brush treatments with minimal soil disturbance (aerial herbicide application) would also create a shrub-grass mosaic.

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 fourwing saltbush (grazing) while facilitating fourpart horsebrush and other non-palatable shrubs. Off-road vehicle use could also reduce the understory grasses.

Slow variables: Long-term increase in shrubs along with a decrease in deep-rooted perennial bunchgrasses.

Threshold: Loss of deep-rooted perennial grasses changes nutrient cycling, nutrient redistribution, and reduces soil organic matter. Increase in shrubs changes the temporal and spatial distribution of energy and nutrient cycling.

Shrub State 3.0:

This state consists of two community phases, one is dominated by shrubs with a sparse understory of perennial grasses. 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. 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 (At-Risk):
Perennial bunchgrasses like Indian ricegrass are reduced and the site is dominated by horsebrush species (*Tetradymia* spp.), fourwing saltbush, and Nevada dalea. Other shrubs like spiny hopsage (*Grayia spinosa*), yellow rabbitbrush, rubber rabbitbrush (*Ericameria nauseosa*) and Bailey's greasewood (*Sarcobatus baileyi*) may be present. Indian ricegrass, needle-and-thread, sand dropseed and thickspike wheatgrass may be present in minor amounts. Bare ground is increasing, with interspaces that are large and connected. Annual non-native species are present. This phase is at-risk of transitioning to an Annual State.

Dunes 4-8" P.Z. (R027XY023NV), Shrub State 3.1, P. Novak-Echenique, May 2026

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:
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 and spiny hopsage. Off-road vehicle use may also reduce the remaining understory grasses. A fire would reduce non-sprouting shrubs and sprouting shrubs would increase.

Community Phase 3.2 (At-Risk)
Sprouting shrubs such as rubber rabbitbrush, yellow rabbitbrush, and horsebrush species dominate the community. Perennial bunchgrasses are trace to missing. Bare

ground has increased and interspaces are large and connected. Wind erosion may be significant and lead to soil redistribution under shrubs. Trace amounts of fourwing saltbush may be present. Annual non-native species are present and increasing. This phase is at-risk of transitioning to an Annual State.

Dunes 4-8" P.Z. (R027XY023NV), Shrub State 3.2, T. Stringham (May 2024)

Community Phase Pathway 3.2a, from Phase 3.2 to 3.1:
Time and lack of disturbance may allow for regeneration of non-sprouting shrubs.

States Not Observed in Group 19:

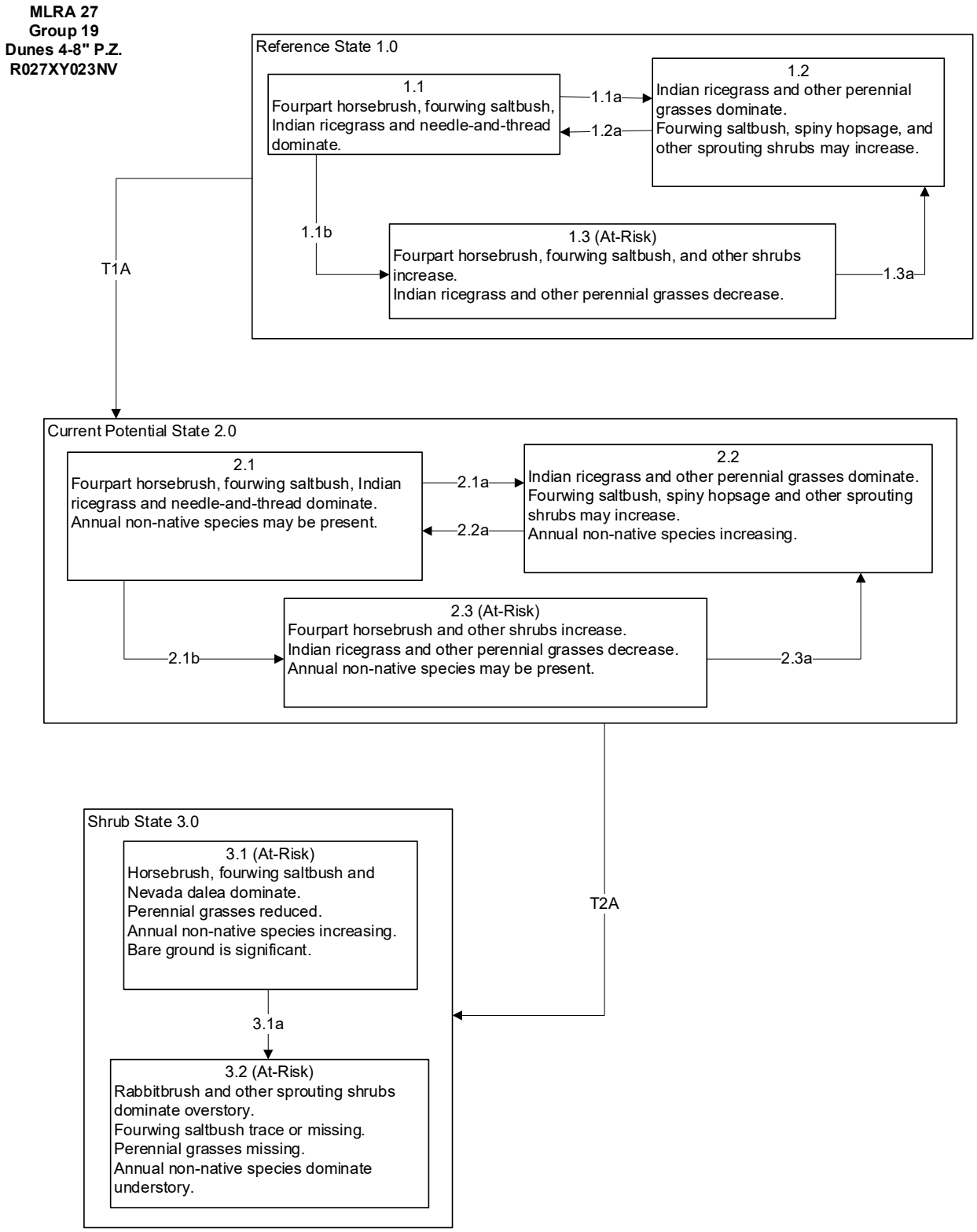
Annual State: An Annual State was not observed during field work for this project. An Annual State could occur after a wildfire, a rare occurrence for this DRG. Extensive off-road vehicle use that eliminated the native vegetation could also transition these sites to an Annual State.

Potential Resilience Differences with Other Ecological Sites in this Group

Dunes 8-10" P.Z. (R027XY053NV):

This site occurs on sand dunes situated within mountain valleys. Slopes range from 8 to over 30% and elevations range from 4,800 to 6,500 ft. The reference plant community is dominated by fourwing saltbush, Nevada jointfir (*Ephedra nevadensis*), and Indian ricegrass. Nevada dalea, big sagebrush (*Artemisia tridentata*) and needle-and-thread are common. Potential vegetative composition is approximately 40% grasses, 10% forbs and 50% shrubs. Total annual air-dry production ranges from 300 to 600 lb/ac. This site is slightly more resilient than the modal because it occurs at higher elevations with more precipitation and higher production in deep-rooted perennial bunchgrasses.

Modal State and Transition Model for Group 19 in MLRA 27



MLRA 27
Group 19
Dunes 4-8" P.Z.
R027XY023NV

Reference State 1.0 Community Phase Pathways
1.1a: Drought or low severity fire increase perennial grass understory.
1.1b: Time and lack of disturbance such as fire, long-term spring/summer drought, herbivory by native wildlife, or combinations would allow the shrub overstory to increase.
1.2a: Time and lack of disturbance and/or release from chronic drought allows for shrub regeneration.
1.3a: Low severity fire or herbivory by native wildlife, or combinations resulting in a mosaic pattern.

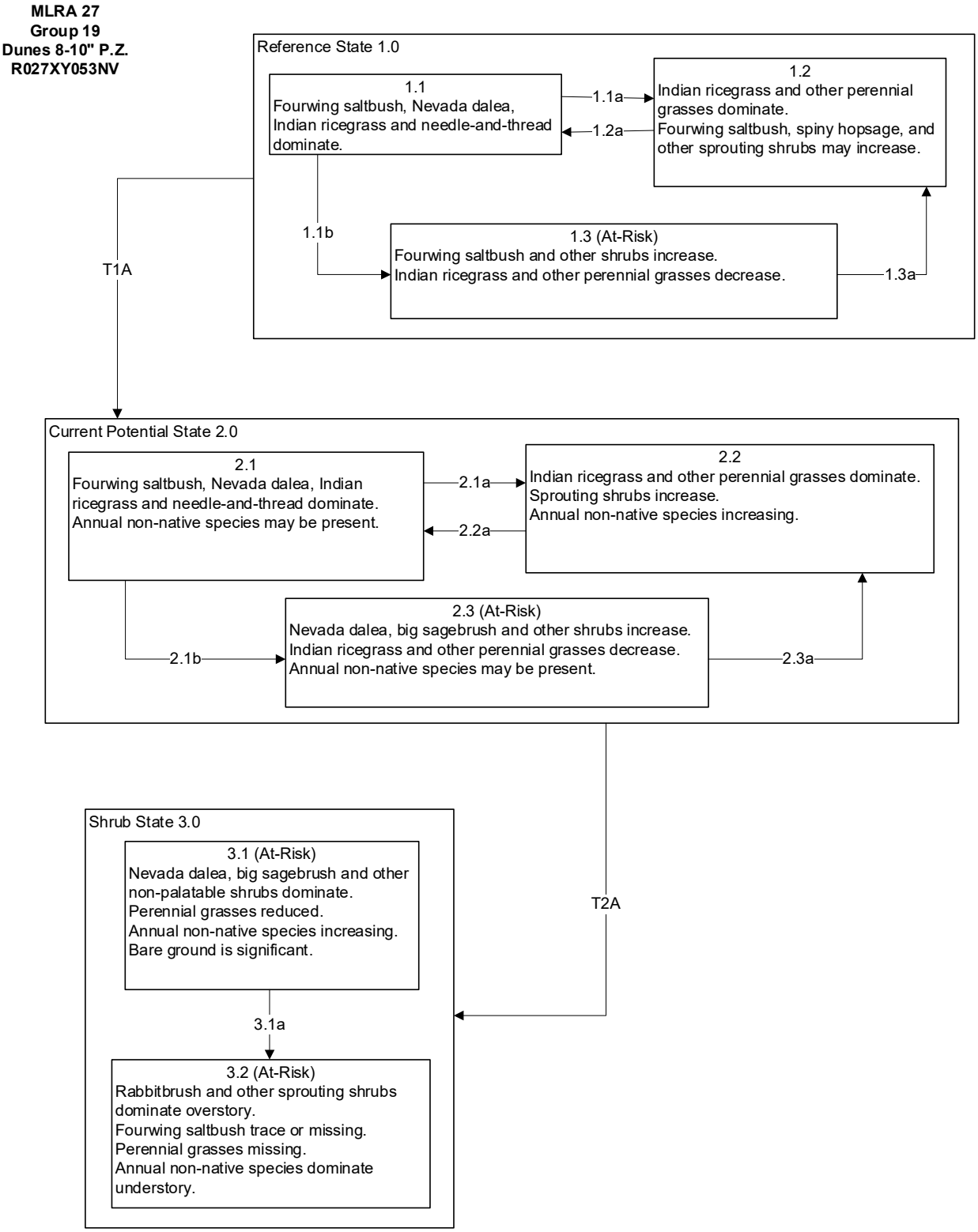
Transition T1A: Introduction of non-native species such as halogeton, cheatgrass, Russian thistle and mustards.

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire or inappropriate grazing during the late summer to early spring reduces fourwing saltbush, Indian ricegrass and needle-and-thread. Non-native annual species present.
2.1b: Time and lack of disturbance such as fire, spring/summer drought, inappropriate grazing management or combinations reduce perennial grasl understory.
2.2a: Time and lack of disturbance allows for shrub regeneration
2.3a: Low severity fire creates shrub/grass mosaic. Brush management with minimal soil disturbance(aerial herbicide application); late-fall/ winter grazing causing mechanical damage to shrubs

Transition T2A: Inappropriate grazing management favoring shrub dominance and reducing perennial bunchgrasses and/or drought.

Shrub State 3.0
3.1a: Inappropriate grazing management in the presence of annual non-native species

Additional State and Transition Models for Group 19 in MLRA 27



MLRA 27
Group 19
Dunes 8-10" P.Z.
R027XY053NV

Reference State 1.0 Community Phase Pathways
1.1a: Drought or low severity fire increase perennial grass understory.
1.1b: Time and lack of disturbance such as fire, long-term spring/summer drought, herbivory by native wildlife, or combinations would allow the shrub overstory to increase.
1.2a: Time and lack of disturbance and/or release from chronic drought allows for shrub regeneration.
1.3a: Low severity fire or herbivory by native wildlife, or combinations resulting in a mosaic pattern.

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

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire or inappropriate grazing during the late summer to early spring reduces fourwing saltbush, Indian ricegrass and needle-and-thread. Non-native annual species present.
2.1b: Time and lack of disturbance such as fire, long-term drought, inappropriate grazing management or combinations reduce perennial grass understory.
2.2a: Time and lack of disturbance, release from chronic winter drought, and or grazing management that favors the establishment and growth of palatable shrubs allows the shrub component to recover.
2.3a: Late summer through winter grazing that reduces palatable shrub cover facilitates an increase in perennial grasses. Low severity fire creates shrub/grass mosaic. Brush management with minimal soil disturbance (aerial herbicide application).

Transition T2A: Long-term inappropriate grazing management or long-term drought favors non-palatable shrub dominance and reduces perennial grasses.

Shrub State 3.0
3.1a: Inappropriate grazing in the late summer to early spring would decrease or eliminate the overstory of palatable shrubs and remaining understory grasses. A fire would reduce the non-sprouting shrubs and sprouting shrubs would increase. Off-road vehicle use would reduce the remaining understory grasses and sprouting shrubs would increase.
3.2a: Time and lack of disturbance may allow for regeneration of non-sprouting shrubs.

References

Akinsoji, A. 1988. Postfire vegetation dynamics in a sagebrush steppe in southeastern Idaho, USA. Vegetatio **78**:151-155.

Allen, E. B., and M. F. Allen. 1988. Facilitation of succession by the nonmycotrophic colonizer *Salsola kali* (Chenopodiaceae) on a harsh site: effects of mycorrhizal fungi. American Journal of Botany **75**:257-266.

Barrow, J. R. 1997. Natural asexual reproduction in fourwing saltbush *Atriplex canescens* (Pursh) Nutt. Journal of Arid Environments **36**:267-270.

Beatley, J. C. 1975. Climates and vegetation pattern across the Mojave/Great Basin Desert transition of southern Nevada. The American Midland Naturalist **93**:53-70.

Benson, L., and R. A. Darrow. 1981b. Trees and shrubs of the southwestern deserts.

Bich, B. S., J. L. Butler, and C. A. Schmidt. 1995. Effects of differential livestock use on key plant species and rodent populations within selected *Oryzopsis hymenoides*/*Hilaria jamesii* communities of Glen Canyon National Recreation Area. The Southwestern Naturalist **40**:281-287.

Blaisdell, J. P., and R. C. Holmgren. 1984. Managing intermountain rangelands - salt-desert shrub ranges. General Technical Report INT-163, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Blank, R. R., C. Clements, T. Morgan, D. Harmon, and F. Allen. 2020. Suppression of cheatgrass by perennial bunchgrasses. Rangeland Ecology & Management **73**:766-771.

Boerboom, C. 1993. Russian thistle (*Salsola iberica* Sennen & Pau).

Booth, D. T., C. G. Howard, and C. E. Mowry. 1980. 'Nezpar' Indian ricegrass: description, justification for release, and recommendations for use. Rangelands **2**:53-54.

Bradley, A. F., N. V. Noste, and W. C. Fischer. 1992. Fire ecology of forests and woodlands in Utah. General Technical Report INT-287, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Bradley, B. A., C. A. Curtis, E. J. Fusco, J. T. Abatzoglou, J. K. Balch, S. Dadashi, and M.-N. Tuanmu. 2018. Cheatgrass (*Bromus tectorum*) distribution in the intermountain Western United States and its relationship to fire frequency, seasonality, and ignitions. Biological Invasions **20**:1493-1506.

Butler, M., F. Brummer, J. Weber, and R. Simmons. 2011. Restoring Central Oregon rangeland from ventenata and medusahead to a sustainable bunchgrass environment – Warm Springs and Ashwood. COARC 2011, Oregon State University, Central Oregon Agricultural Research and Extension Center, Corvallis, OR.

Catlin, C. N. 1925. Composition of Arizona forages, with comparative data. Bulletin No. 113, University of Arizona, College of Agriculture, Agricultural Experiment Station, Tucson, AZ.

Caudle, D., J. DiBenedetto, M. Karl, H. Sanchez, and C. Talbot. 2013. Interagency ecological site handbook for rangelands. U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.

Chambers, J. C., B. A. Bradley, C. S. Brown, C. D'Antonio, M. J. Germino, J. B. Grace, S. P. Hardegree, R. F. Miller, and D. A. Pyke. 2013. Resilience to stress and disturbance, and

resistance to *Bromus tectorum* L. invasion in cold desert shrublands of western North America. Ecosystems **17**:360-375.
Cibils, A. F., S. M. David, and D. E. McArthur. 1998. Plant-herbivore interactions in *Atriplex*: current state of knowledge. General Technical Report RMRS-GTR-14, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.
Clark, S. L., D. J. Sebastian, S. J. Nissen, and J. R. Sebastian. 2019. Effect of indaziflam on native species in natural areas and rangeland. Invasive Plant Science and Management **12**:60-67.
Clements, C. D., D. N. Harmon, and R. R. Blank. 2022. Seed mix performance and cheatgrass suppression on arid rangelands. Rangelands **44**:129-135.
Comstock, J. P., and J. R. Ehleringer. 1992. Plant adaptation in the Great Basin and Colorado Plateau. The Great Basin Naturalist **52**:195-215.
Cook, C. W. 1962. An evaluation of some common factors affecting utilization of desert range species. Journal of Range Management **15**:333-338.
Cook, C. W., and R. D. Child. 1971. Recovery of desert plants in various states of vigor. Rangeland Ecology & Management/Journal of Range Management Archives **24**:339-343.
Cook, C. W., and L. A. Stoddart. 1953. Bulletin No. 364 - The halogeton problem in Utah. UAES Bulletins.
Costello, D. F. 1944. Important species of the major forage types in Colorado and Wyoming. Ecological Monographs **14**:107-134.
Courkamp, J. S., P. J. Meiman, and M. W. Paschke. 2022. Indaziflam reduces seed bank richness and density but not sagebrush-grassland plant diversity. Rangeland Ecology & Management **84**:31-44.
Cronin, E. H., and M. C. Williams. 1966a. Principles for managing ranges infested with halogeton.
Davies, K. W., C. S. Boyd, J. D. Bates, and A. Hulet. 2015a. Dormant season grazing may decrease wildfire probability by increasing fuel moisture and reducing fuel amount and continuity. International Journal of Wildland Fire **24**:849-856.
Davies, K. W., A. M. Nafus, C. S. Boyd, A. Hulet, and J. D. Bates. 2016. Effects of using winter grazing as a fuel treatment on Wyoming big sagebrush plant communities. Rangeland Ecology & Management **69**:179-184.
Dobrowolski, J. P., M. M. Caldwell, and J. H. Richards. 1990. Chapter 7: Basin hydrology and plant root systems. Pages 243-292 *in* C. B. Osmond, L. F. Pitelka, and G. M. Hidy, editors. Plant Biology of the Basin and Range. Springer-Verlag, New York City, NY.
Duda, J. J., D. C. Freeman, J. M. Emlen, J. Belnap, S. G. Kitchen, J. C. Zak, E. Sobek, M. Tracy, and J. Montante. 2003. Differences in native soil ecology associated with invasion of the exotic annual chenopod, *Halogeton glomeratus*. Biology and Fertility of Soils **38**:72-77.
Eckert, R. E., Jr., A. D. Bruner, and G. J. Klomp. 1972. Response of understory species following herbicidal control of low sagebrush. Journal of Range Management **25**:280-285.
Everett, R. L., P. T. Tueller, J. B. Davis, and A. D. Brunner. 1980. Plant phenology in galleta-shadscale and galleta-sagebrush associations. Rangeland Ecology & Management/Journal of Range Management Archives **33**:446-450.
Furbush, P. 1953. Control of medusa-head on California ranges. Journal of Forestry **51**:118-121.

Henrickson, J. 1977. Saline habitats and halophytic vegetation of the Chihuahuan Desert region. Pages 289-314 *in* Transactions of the Symposium on the Biological Resources of the Chihuahuan Desert Region: United States and Mexico; Sul Ross State University, Alpine, TX; October 17-18, 1974. NPS Transactions and Proceedings Series No. 3. U.S. Department of the Interior, National Park Service.

Holmgren, N. H., P. K. Holmgren, and A. Cronquist. 2005. Intermountain flora: Vascular plants of the Intermountain West, U.S.A. Volume two, part B. Subclass Dilleniidae. The New York Botanical Garden Press, Bronx, NY.

Howard, J. L. 2003. *Atriplex canescens*.*in* O. Fire Effects Information System, editor. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory.

James, L. F. 1970. Locomotor disturbance of cattle grazing *Halogeton glomeratus*. Journal of the American Veterinary Medical Association **156**:1310-1312.

Johnson, A. E. 1987. The relationship of Tetradymia species and Artemisia nova to photosensitization in sheep. Page 113 *in* Proceedings-Symposium on Plant-Herbivore Interactions.

Johnson, N. C. 1998. Responses of *Salsola kali* and *Panicum virgatum* to mycorrhizal fungi, phosphorus and soil organic matter: implications for reclamation. Journal of Applied Ecology **35**:86-94.

Kaapro, J., and J. Hall. 2012. Indaziflam - a new herbicide for pre-emergent control of weeds in turf, forestry, industrial vegetation and ornamentals. Pages 224-227 *in* 23rd Asian-Pacific Weed Science Society Conference: Conference Proceedings Volume 1; Queensland, Australia; September 26-29 2011. Asian-Pacific Weed Science Society.

Klemmedson, J. O., and J. G. Smith. 1964. Cheatgrass (*Bromus tectorum* L.). The Botanical Review **30**:226-262.

Mack, R. N., and D. A. Pyke. 1983. The demography of *Bromus tectorum*: Variation in time and space. Journal of Ecology **71**:69-93.

Meinzer, O. E. 1927. Plants as indicators of ground water. Water-Supply Paper 577, U.S. Department of the Interior, U.S. Geological Survey, Washington, D.C.

Miller, R. F., J. C. Chambers, D. A. Pyke, F. B. Pierson, and C. J. Williams. 2013. A review of fire effects on vegetation and soils in the Great Basin Region: Response and ecological site characteristics. General Technical Report RMRS-GTR-308, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Miller, R. F., R. J. Tausch, and W. Waichler. 1999b. Old-growth juniper and pinyon woodlands. Pages 375-384 *in* Proceedings: ecology and management of pinyon-juniper communities within the interior west; September 15-18, 1997. Proceedings RMRS-P-9. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Brigham Young University Conference Center, Provo, UT.

Mozingo, H. N. 1987b. Shrubs of the Great Basin: A natural history. University of Nevada Press, Reno, NV.

Neuenschwander, L. F. 1978. The fire induced autecology of selected shrubs of the cold desert and surrounding forests: a-state-of-the-art review. Unpublished manuscript, U.S.

Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, Missoula, MT.
Newton, R. J., and J. R. Goodin. 1989. Moisture stress adaptation in shrubs. Pages 365-383 *in* C. M. McKell, editor. The biology and utilization of shrubs. Academic Press, San Diego, CA.
NRCS. 2022. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. Handbook 296, U.S. Department of Agriculture, Natural Resources Conservation Service.
Ogle, D. G., L. St. John, and D. Tilley. 2012a. Plant guide for fourwing saltbush (*Atriplex canescens)*. U.S. Department of Agriculture, Natural Resource Conservation Service, Idaho Plants Material Center, Aberdeen, ID.
Otsyina, R., C. M. McKell, and G. Van Epps. 1982. Use of range shrubs to meet nutrient requirements of sheep grazing on crested wheatgrass during fall and early winter. Journal of Range Management **35**:751-753.
Parmenter, R. R. 2008. Long-term effects of a summer fire on desert grassland plant demographics in New Mexico. Rangeland Ecology & Management **61**:156-168.
Paysen, T. E., R. J. Ansley, J. K. Brown, G. J. Gottfried, S. M. Haase, M. G. Harrington, M. G. Narog, S. S. Sackett, and R. C. Wilson. 2000. Chapter 6: Fire in western shrubland, woodland, and grassland ecosystems. Pages 121-159 *in* J. K. Brown and J. K. Smith, editors. Wildland fire in ecosystems: Effects of fire on flora. General Technical Report RMRS-GTR-42-Vol. 2. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.
Pearson, L. 1979. Effects of temperature and moisture on phenology and productivity of Indian ricegrass. Rangeland Ecology & Management/Journal of Range Management Archives **32**:127-134.
Pearson, L. C. 1964. Effect of harvest date on recovery of range grasses and shrubs. Agronomy Journal **56**:80-82.
Pearson, L. C. 1965. Primary production in grazed and ungrazed desert communities of eastern Idaho. Ecology **46**:278-285.
Pemberton, R. W. 1986. The distribution of halogeton in North America. Journal of Range Management **39**:281-282.
Perryman, B. L. 2014a. A field guide to Nevada shrubs. Indigenous Rangeland Management Press, Lander, WY.
Perryman, B. L., B. W. Schultz, M. Burrows, T. Shenkoru, and J. Wilker. 2020. Fall-grazing and grazing-exclusion effects on cheatgrass (*Bromus tectorum*) seed bank assays in Nevada, United States. Rangeland Ecology & Management **73**:343-347.
Peters, E. F., and S. C. Bunting. 1994. Fire conditions pre-and post-occurrence of annual grasses on the Snake River Plain. Pages 31-36 *in* Proceedings—Ecology and management of annual rangelands; September, 1994; Boise, ID. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.
Puigdefábregas, J. 2005. The role of vegetation patterns in structuring runoff and sediment fluxes in drylands. Earth Surface Processes and Landforms **30**:133-147.

Quinones, F. A. 1981. Indian ricegrass evaluation and breeding. Bulletin 681, New Mexico State University, Agricultural Experiment Station, Las Cruces, NM.

Saltz, D., M. Shachak, M. Caldwell, S. T. A. Pickett, J. Dawson, H. Tsoar, Y. Yom-Tov, M. Weltz, and R. Farrow. 1999. The study and management of dryland population systems. Pages 75-96 *in* T. W. Hoekstra and M. Shachak, editors. Arid Lands Management: Towards Ecological Sustainability. International Arid Lands Consortium; University of Illinois Press, Chicago, IL.

Schlesinger, W. H., J. F. Reynolds, G. L. Cunningham, L. F. Huenneke, W. M. Jarrell, R. A. Virginia, and W. G. Whitford. 1990. Biological feedbacks in global desertification. Science **247**:1043-1048.

Sebastian, D. J., M. B. Fleming, E. L. Patterson, J. R. Sebastian, and S. J. Nissen. 2017a. Indaziflam: A new cellulose-biosynthesis-inhibiting herbicide provides long-term control of invasive winter annual grasses. Pest Management Science **73**:2149-2162.

Sheley, R. L., E. A. Vasquez, A.-M. Chamberlain, and B. S. Smith. 2012. Landscape-scale rehabilitation of medusahead (*Taeniatherum caput-medusae*)-dominated sagebrush steppe. Invasive Plant Science and Management **5**:436-442.

Smith, J. T., B. W. Allred, C. S. Boyd, K. W. Davies, M. O. Jones, A. R. Kleinhesselink, J. D. Maestas, S. L. Morford, and D. E. Naugle. 2022. The elevational ascent and spread of exotic annual grass dominance in the Great Basin, USA. Diversity and Distributions **28**:83-96.

Smoliak, S., J. F. Dormaar, and A. Johnston. 1972. Long-term grazing effects on *Stipa-bouteloua* prairie soils. Journal of Range Management **25**:246-250.

Society, C. N. P. 2009. A Manual of California Vegetation Online. California Native Plant Society.

Stoddart, L. A., and G. Clegg. 1951. The halogeton problem on Utah's ranges. Rangeland Ecology & Management/Journal of Range Management Archives **4**:223-227.

Stubbendieck, J. L., S. L. Hatch, and L. M. Landholt. 2003. North American wildland plants. University of Nebraska Press, Lincoln, NE.

Stubbendieck, J. L., J. T. Nichols, and K. K. Roberts. 1985. Nebraska range and pasture grasses (including grass-like plants). University of Nebraska, Department of Agriculture, Cooperative Extension Service, Lincoln, NE.

Stutz, H. C. 1979. The meaning of "rare" and "endangered" in the evolution of western shrubs. Pages 119-128 *in* The endangered species: A symposium: Proceedings; Provo, UT; December 7-8, 1978. Great Basin Naturalist Memoirs No. 3. Brigham Young University, Provo, UT.

Ting, I. P. 1961. An ecological study of "Dalea Polyadenia" Torr. [publisher not identified], Place of publication not identified.

Tueller, P. T., and W. H. Blackburn. 1974. Condition and trend of the big sagebrush/needleandthread habitat type in Nevada. Journal of Range Management **27**:36-40.

USFS. 1937. Range plant handbook. U.S. Department of Agriculture, Forest Service, Washington, D.C.

USFS. 1988a. Range plant handbook. Reprint of 1937 edition. Dover Publications, New York, NY.

Vallentine, J. F. 1989. Range development and improvements. Academic Press, Inc., San Diego, CA.

Van Dersal, W. R. 1938. Native woody plants of the United States: Their erosion-control and wildlife values. U.S. Government Printing Office, Washington, D.C.

Wallace, A., S. A. Bamberg, and J. W. Cha. 1974. Quantitative studies of roots of perennial plants in the Mojave Desert. Ecology **55**:1160-1162.

Wallace, A., W. Rhods, and E. Frolich. 1968. Germination behavior of *Salsola* as influenced by temperature, moisture, depth of planting, and gamma irradiation. Agronomy Journal **60**:76-78.

Wasser, C. H. 1982. Ecology and culture of selected species useful in revegetating disturbed lands in the West. FWS/OBS-82/56, U.S. Department of the Interior, Fish & Wildlife Service, Fort Collins, CO.

Weaver, J. E. 1958. Summary and interpretation of underground development in natural grassland communities. Ecological Monographs **28**:55-78.

West, N. E. 1994. Effects of fire on salt-desert shrub rangelands. Pages 71-74 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, ID.

West, N. E., K. McDaniel, E. L. Smith, P. T. Tueller, and S. Leonard. 1994. Monitoring and interpreting ecological integrity on arid and semi-arid lands of the western United States. Report 37, New Mexico State University, College of Agriculture and Home Economics, Cooperative Extension Service, Agricultural Experiment Station, New Mexico Range Improvement Task Force, Las Cruces, NM.

Wright, H. A. 1971. Why squirreltail is more tolerant to burning than needle-and-thread. Journal of Range Management **24**:277-284.

Wright, H. A. 1985. Effects of fire on grasses and forbs in sagebrush-grass communities. Pages 12-21 *in* Rangeland fire effects: A symposium; Boise, ID; November 27-29, 1984. U.S. Department of the Interior, Bureau of Land Management, Boise, ID.

Wright, H. A., and J. O. Klemmedson. 1965. Effect of fire on bunchgrasses of the sagebrush-grass region in Southern Idaho. Ecology **46**:680-688.

Young, F., R. Veseth, D. Thill, W. Schillinger, and D. Ball. 1995. Managing Russian thistle under conservation tillage in crop-fallow rotations.

Young, R. P. 1983. Fire as a vegetation management tool in rangelands of the intermountain region. Pages 18-31 *in* Managing Intermountain rangelands—Improvement of range and wildlife habitats. Proceedings of Symposia: September 15-17, 1981, Twin Falls, Idaho June 22·24, 1982, Elko, Nevada. General Technical Report INT-GTR-157. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

MLRA 27 Group 20: Pinyon and/or juniper woodland with Wyoming big sagebrush understory

Description of MLRA 27 Disturbance Response Group 20

Disturbance Response Group (DRG) 20 consists of two ecological sites. The sites occur on sideslopes of hills and mountains. The precipitation ranges from 10 to 14 in. Slopes range from 15 to 75%. Elevations range from 5,000 to 8,000 ft. The soils are formed in residuum and colluvium from sedimentary or volcanic rocks. They range from very shallow to shallow and are well drained. They are typically skeletal and have 15 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 an overstory of singleleaf pinyon *(Pinus monophylla*) and/or Utah juniper *(Juniperus osteosperma)*. Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) is the dominant understory shrub species. Other shrub species include ephedra (*Ephedra* spp.), mountain snowberry (*Symphoricarpos oreophilus*), Stansbury cliffrose (*Purshia stansburiana*), yellow rabbitbrush (*Chrysothamnus viscidiflorus*) and currant (*Ribes* spp.). The perennial grass component is dominated by Thurber's needlegrass (*Achnatherum thurberianum*) and Sandberg bluegrass (*Poa secunda*). Other grass species important to these sites include Indian ricegrass *(Achnatherum hymenoides)*, muttongrass (*Poa fendleriana*), and squirreltail (*Elymus elymoides*). Understory production ranges from 200 to 500 lb/acre with canopy cover of 21–35%. These sites have low to very low site quality for tree production.

Disturbance Response Group 20 Ecological Sites:

Shallow Rocky Loam (PIMO-JUOS/ARTRW8/ACTH7) – Modal	F027XY081NV
Shallow Rocky Slope (JUOS/ARTRW8/ACTH7)	F027XY075NV

Modal Site:

The Shallow Rocky Loam ecological site (F027XY081NV) is the modal for this DRG as it has the most acres mapped. This woodland site occurs on mountain sideslopes and is limited to southerly exposures at lower elevations. Slopes range from 30 to over 50%. Elevations are approximately 6,000–8,000 ft. This site is limited to southerly exposures at higher elevations. Average annual precipitation is 10 to about 14 in. Soils are shallow to very shallow. These soils are typically skeletal with 15–50% gravels, paragravels or cobbles 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 Utah juniper and singleleaf pinyon. Overstory tree canopy composition is about 50–70% Utah juniper and 30–50% singleleaf pinyon. An overstory canopy of 20–35% is assumed to be representative of tree dominance on this site in the pristine environment. However, current research indicates a canopy cover of 10–20% 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 Thurber's needlegrass and Sandberg bluegrass are the prominent understory grasses. Mountain snowberry, currant and Mormon tea (*Ephedra viridis*) 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 50% grasses, 10% forbs and 40% shrubs and young trees in a mature woodland averaging 20–35% canopy cover. Average understory production ranges from 200 to 500 lb/ac with 300 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. This site has low site quality for tree production. Site index ranges from 35–50.

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 27 (MLRA 27 Fallon-Lovelock Area) is almost entirely in Nevada with < 1% in California. The entire area occurs in the rain shadow of the Sierra Nevada mountains and is influenced by Pleistocene Lake Lahontan. Extensive playas occur throughout the area and are a result of the drying of ancient Lake Lahontan. To the west, MLRA 27 has a gradual boundary with MLRA 26 (Carson Basin and Mountains) and to the east has a very gradual boundary with MLRA 24 (Humboldt Basin and Range Area). From west to east the soil temperature increases and the soil moisture decreases, resulting in vast areas dominated by salt-desert shrub communities. Isolated mountain ranges trending north to south are separated by broad desert plains and valleys. Elevations range from 3,300 to 5,900 ft with some mountain peaks over 7,800 ft. The average annual precipitation ranges from 4 to 11 in. and as much as 20 in. at the highest elevations. The majority of annual precipitation is received during late fall and winter occurring mainly as snow. High-intensity, convective thunderstorms also contribute significantly to annual precipitation (NRCS 2022). 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 (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 ha (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 CO2 levels favoring woody plant establishment (Bunting 1994, Tausch 1999). Miller et al. (2008b) found pre-settlement tree densities averaged 2–11 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 10–20% 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 < 2% of the stands sampled in Nevada, Oregon, and Utah (Miller et al. 1999b, 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 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 non-native annual species 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.

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 10–15 years after infection. Seedlings and saplings are most susceptible to the parasite (Christopherson 2014). Other diseases affecting juniper are: witches' broom

(*Gymnosporangium* sp.) that may girdle and kill branches; leaf rust (*Gymnosporangium* sp.) on leaves and young branches; and juniper blight (*Phomopsis* sp.). Flat-head borers (*Chrysobothris* sp.) 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 ssp.)*, 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 one 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 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 1.0 to over 3.0 m (3–10 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).

Mormon tea 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). Mormon tea does not compete well with cheatgrass, and may exhibit reduced shoot growth when growing in areas dominated by cheatgrass (Pendleton et al. 2007).

The primary perennial bunchgrasses that are found on these sites include Thurber's needlegrass, Sandberg bluegrass, Indian ricegrass, and 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.

Thurber's needlegrass is a native, cool-season grass common to the semiarid regions of the Intermountain West and is an important component of many sagebrush communities (Johnson et al. 2017). It is a deep-rooted perennial bunchgrass, 1–2 ft tall with fine, narrow in rolled leaves about 6–10 in. long (Perryman and Skinner 2007). It is very drought and cold tolerant and prefers well drained, fine sandy loam to silt loam soils. It is not tolerant of shade and saline or sodic soil conditions (Ogle 2006).

Sandberg bluegrass is a low-growing, cool-season perennial bunchgrass that grows from 3–6.1 dm (12–24 in.) tall (Perryman and Skinner 2007). It is notable for its early growth and short season of vegetative activity (Tisdale and Hironaka 1981). It is one of the most drought resistant of the bluegrasses because of the mass of coarse fibrous roots, and its ability to make growth, produce flowers and mature its seeds early in the season while soil moisture is still available (USFS 1988a). Sandberg bluegrass is widely distributed and an important species in most of the West growing from 1,000 ft to as high as 12,000 ft elevation (USFS 1988a).

Indian ricegrass is a long-lived, cool-season perennial bunchgrass that grows 4–24 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-lived 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).

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.

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 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 1.5–1.7 m (5–5.5 ft).

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 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, able to germinate in the autumn or spring, tolerant of grazing and increases with frequent fire (Klemmedson and Smith 1964, Miller et al. 1999b). 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.

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 (*Poa secunda*) 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. 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 one 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 cheatgrass is very flammable and fire can be used to remove the thatch layer, consume standing vegetation, and even reduce seed levels.

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 (*Purshia tridentata*), and multiple sagebrush species to three rates of imazapic and the same rates with methylated seed oil as a surfactant. They found 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 15–20 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 (100–600 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/ac, 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 2–3 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 50–120 or more years (Baker 2006).

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 3–5 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).

Ephedra vigorously sprouts after fire from extensive woody crowns (Young and Evans 1978, Koniak 1985b). Sprouting after fire may vary by season of burn and fire severity, however. Spiny hopsage is a sprouting shrub (Daubenmire 1970) 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). 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).

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.

Burning has been found to decrease the vegetative and reproductive vigor of Thurber's needlegrass (Uresk et al. 1976b). 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). Thurber's needlegrass often survives fire and will continue growth or regenerate from tillers when conditions are favorable (Koniak 1985b, Britton et al. 1990). Thurber's needlegrass was shown to decrease in density following a spring fire, but it produced more reproductive culms the year after a fall fire (Ellsworth and Kauffman 2010). Reestablishment on burned sites has been found to be relatively slow due to low germination and competitive ability (Koniak 1985b). Cheatgrass has been found to be a highly successful competitor with seedlings of this needlegrass and may preclude reestablishment (Young and Evans 1978).

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 bunchgrasses. 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).

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). 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). 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, 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).

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 ssp.)*. The trees provide important cover for mule deer (*Odocoileus heminous*), 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. 1973b). 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 1–2% 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 sheep, cattle, goats, and horses. 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.

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).

Sandberg bluegrass increases under grazing pressure (Tisdale and Hironaka 1981) and is capable of co-existing with cheatgrass. Excessive 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 20

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 27 Disturbance Response 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:
The reference plant community is characterized by widely dispersed mature Utah juniper and singleleaf pinyon with an understory of big sagebrush and perennial bunchgrasses. The visual aspect is dominated by old growth Utah juniper and singleleaf pinyon which make up 15% or more of the canopy cover. Total tree canopy cover ranges from 20 to 35%. Understory production ranges from 200 to 500 lb/ac. 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. Thurber's needlegrass is the most prevalent grass. Mormon tea and currant are common understory shrubs. Forbs such as buckwheat (*Eriogonum* spp.), lupine (*Lupinus* 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 will eliminate or reduce the Utah juniper and singleleaf pinyon 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 Utah juniper and singleleaf pinyon.

Community Phase 1.2:
This community phase is characterized by a post-fire shrub and herbaceous community. Sandberg bluegrass and other perennial bunchgrasses dominate. Forbs may increase after a fire but will likely return to pre-burn levels within a few years. Juniper and pinyon seedlings and saplings 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. Tree canopy cover is less than 10%. Understory production ranges from 400 to 800 lb/ac.

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 Utah juniper and singleleaf pinyon component. Trees and shrubs reestablish.

Community Phase 1.3:
This community phase is characterized as an immature woodland with juniper and pinyon trees averaging over 4.5 ft in height. Juniper and pinyon 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. Understory production ranges from 300 to 700 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 Utah juniper and singleleaf pinyon. 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 Utah juniper and singleleaf pinyon. The stand exhibits mixed age classes and canopy cover may be greater than 35% and is commonly greater than 50%. Upper crowns are typically irregularly flat-topped or rounded. The density and vigor of the big sagebrush and perennial bunchgrass understory is decreased because of tree competition, overstory shading and duff accumulation. Bare ground areas are likely to increase. Mat-forming forbs may increase. This community is at risk of crossing a threshold to an Infilled Tree State (3.0). Understory production ranges from 75 to 250 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 old-growth 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 45%. 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 Utah juniper and singleleaf pinyon of 15% or more of the canopy cover. Total 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 inches in diameter at one-foot stump height. Thurber's needlegrass is the most prevalent grass in the understory, found primarily under tree canopies. Mormon tea and currant are common understory shrubs. Mat-forming forbs are present. Overall, the understory is sparse. Non-native, annual species such as cheatgrass are sparse.

Shallow Rocky Loam (F027XY081NV), Mature Woodland 2.1, T. Stringham, June 2024

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
A high-severity crown fire will eliminate or reduce the Utah juniper and singleleaf pinyon 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 Utah juniper and singleleaf pinyon.

Community Phase 2.2:
This community phase is characterized by a post-fire shrub and herbaceous community. Sandberg bluegrass and other perennial grasses dominate. Forbs may increase post-fire but will likely return to pre-burn levels within a few years. Juniper and pinyon seedlings and saplings 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. Shrubs reestablish. 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. 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 Utah juniper and singleleaf pinyon. 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 to dominate the site.

Community Phase 2.4 (At-Risk):
This phase is dominated by Utah juniper and singleleaf. The stand exhibits mixed age classes and canopy cover and is over 35% and commonly 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. 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, 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 shrub 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 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 45%. 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 singleleaf pinyon and Utah juniper 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:**
> Utah juniper and singleleaf pinyon 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 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 Utah juniper. Infilling by younger trees continues.
>
> **Community Phase 3.2:**
> Utah juniper and singleleaf pinyon dominate the aspect. Tree canopy cover exceeds 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.

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 20:

Annual State: 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.

R4A Restoration from Annual State 4.0 to Current Potential State 2.0:

Herbicide treatment of non-natives with a follow-up seeding of native shrubs, trees, and native or non-native forbs and perennial grasses. Highest success likely from community phase 4.2.

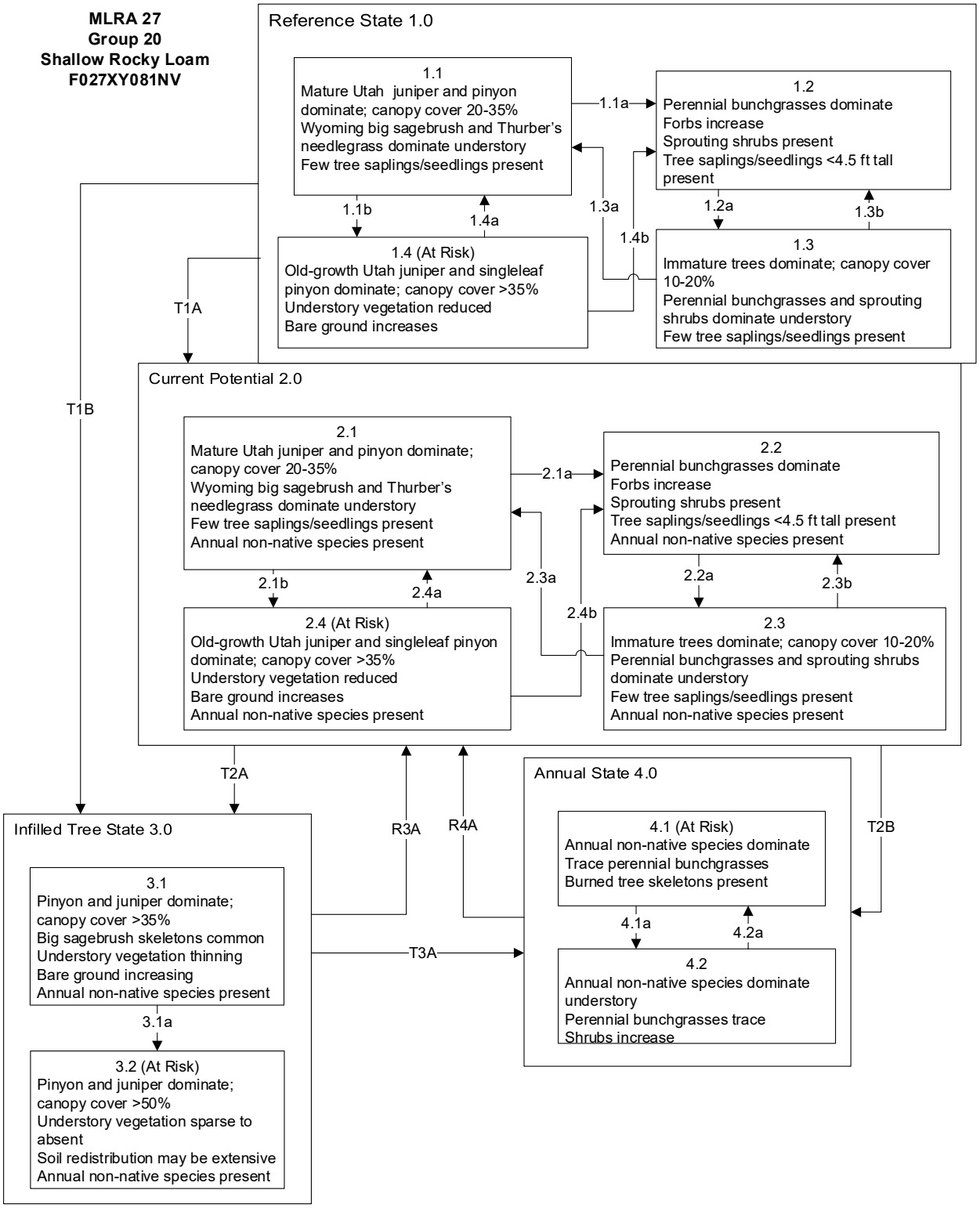
Potential Resilience Differences with other Ecological Sites in this Group

Shallow Rocky Slope - JUOS/ARTRW8/ACTH7 (F027XY075NV):

This woodland site occurs on summits and sideslopes of upper fan piedmonts, hills and lower mountains on all exposures. Slopes range are typically 15–50%. Elevations are 6,000–7,500 ft and precipitation ranges from 10 to 12 in. The soils are very shallow and well drained. Available water capacity is low. Overstory tree composition is 100% Utah juniper. Understory vegetative

composition is approximately 40% grasses, 10% forbs and 50% shrubs. Wyoming big sagebrush and/or mountain big sagebrush, Mormon tea, and currant (*Ribes* spp.) are the primary understory shrubs. Thurber's needlegrass, muttongrass, Sandberg bluegrass, Indian ricegrass, and squirreltail are the primary understory grasses. Total annual understory production under a medium canopy (21–35%) ranges from 200 to 500 lb/ac. The site has a lower tree site index as the modal. Resilience is similar to the modal and this site will have the same ecological states as the modal site.

Modal State and Transition Model for Group 20 MLRA 27



MLRA 27
Group 20
Shallow Rocky Loam
F027XY081NV

Reference State 1.0 Community Phase Pathways
1.1a: High severity crown fire or disease 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. Wyoming 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. Wyoming 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 or disease 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. Wyoming 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. Wyoming 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.

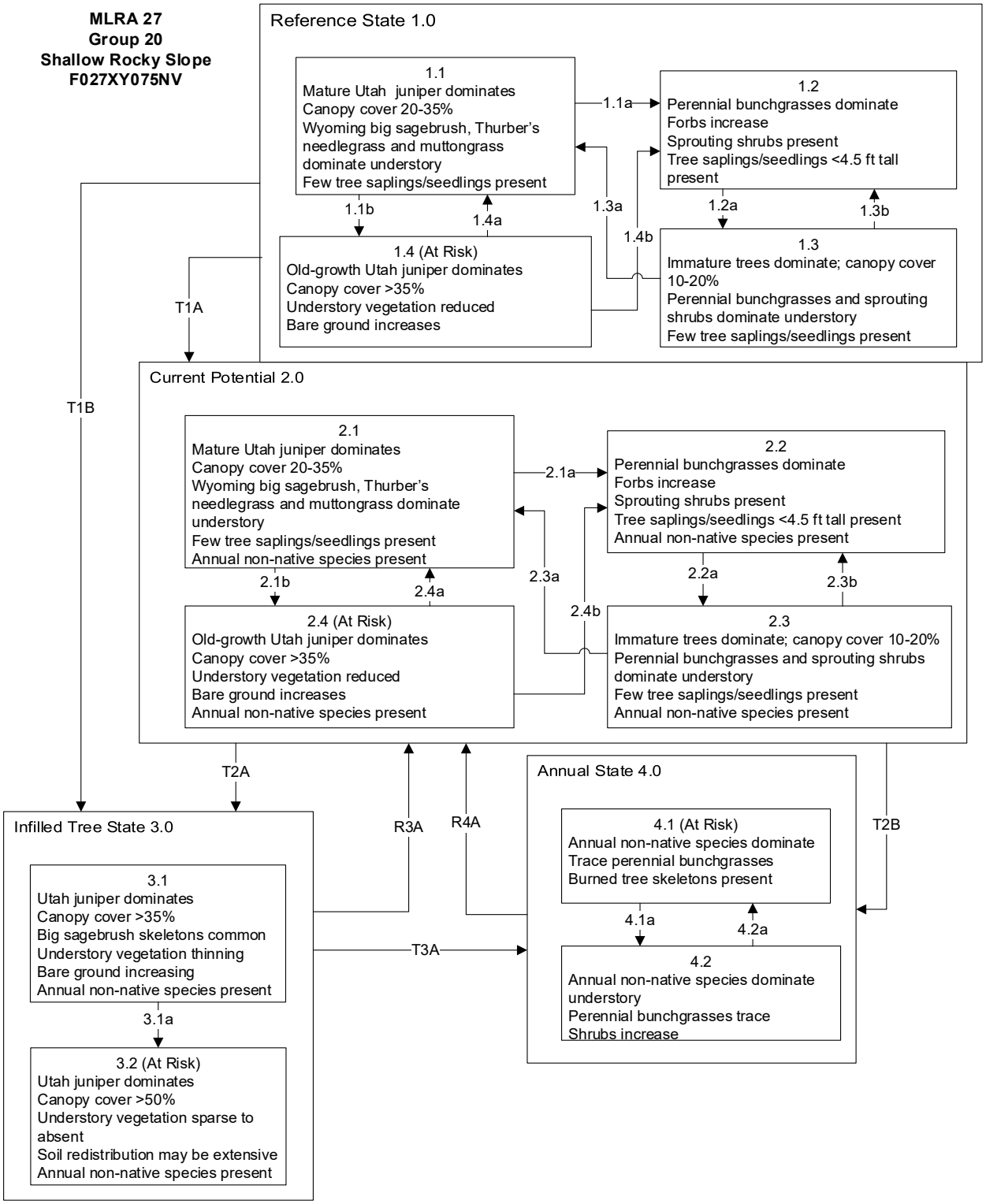
Transition T3B: Stand-replacing fire reduces pinyon and juniper overstory, allows sprouting shrubs in the understory to dominate the site.

Restoration R3A: Manual or mechanical thinning of trees coupled with seeding. Recovery of understory species.

Annual State 4.0 Community Phase Pathways
4.1a. Time allows for sprouting shrubs to recover.
4.2a Frequent wildfires.

Restoration R4A: Herbicide treatment and seeding of native grass, shrub, and tree species. Highest success likely from phase 4.2.

Additional State and Transition Models for Group 20 MLRA 27



MLRA 27
Group 20
Shallow Rocky Slope
F027XY075NV

Reference State 1.0 Community Phase Pathways
1.1a: High severity crown fire or disease will eliminate/reduce Utah juniper overstory, allowing sprouting shrubs and perennial bunchgrasses to dominate.
1.1b: Time, lack of disturbance allows for infilling of Utah juniper.
1.2a: Time, lack of disturbance allows for maturation of trees. Wyoming big sagebrush reestablishes.
1.3a: Time, lack of disturbance allows for maturation of 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. Wyoming big sagebrush and perennial bunchgrass community increases.
1.4b: High severity crown fire will reduce or eliminate 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 or disease will eliminate or reduce 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 Utah juniper.
2.2a: Time, lack of disturbance allows maturation of trees. Wyoming big sagebrush reestablishes.
2.3a: Time, lack of disturbance allows for maturation of 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. Wyoming big sagebrush and perennial bunchgrasses increase.
2.4b: High-severity crown fire eliminates/reduces 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 Utah juniper.

Transition T3A: Frequent wildfires reduce Utah juniper overstory, allows non-native species in the understory to dominate the site.

Transition T3B: Stand-replacing fire reduces Utah 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.

Annual State 4.0 Community Phase Pathways
4.1a. Time allows for sprouting shrubs to recover.
4.2a Frequent wildfires.

Restoration R4A: Herbicide treatment and seeding of native grass, shrub, and tree species. Highest success likely from phase 4.2.

References

Baker, W. L. 2006. Fire and restoration of sagebrush ecosystems. Wildlife Society Bulletin **34**:177-185.

Balda, R. P., and N. Masters. 1980. Avian communities in the pinyon-juniper woodland: a descriptive analysis. Pages 146-169 *in* Workshop proceedings: Management of western forests and grasslands for nongame birds. February 11-14, 1980, Salt Lake City, UT. General Technical Report INT-86. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Rocky Mountain Forest and Range Experiment Station, and Intermountain Region, Ogden, UT.

Bates, J. D., T. Svejcar, R. F. Miller, and R. A. Angell. 2006. The effects of precipitation timing on sagebrush steppe vegetation. Journal of Arid Environments **64**:670-697.

Beatley, J. C. 1975. Climates and vegetation pattern across the Mojave/Great Basin Desert transition of southern Nevada. The American Midland Naturalist **93**:53-70.

Bich, B. S., J. L. Butler, and C. A. Schmidt. 1995. Effects of differential livestock use on key plant species and rodent populations within selected *Oryzopsis hymenoides*/*Hilaria jamesii* communities of Glen Canyon National Recreation Area. The Southwestern Naturalist **40**:281-287.

Blaisdell, J. P. 1953. Ecological effects of planned burning of sagebrush-grass range on the upper Snake River plains. Technical Bulletin No. 1075, U.S. Department of Agriculture, Washington, D.C.

Blaisdell, J. P., and R. C. Holmgren. 1984. Managing intermountain rangelands - salt-desert shrub ranges. General Technical Report INT-163, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Booth, D. T., C. G. Howard, and C. E. Mowry. 1980. 'Nezpar' Indian ricegrass: description, justification for release, and recommendations for use. Rangelands **2**:53-54.

Bradford, J. B., and W. K. Lauenroth. 2006. Controls over invasion of *Bromus tectorum*: the importance of climate, soil, disturbance and seed availability. Journal of Vegetation Science **17**:693-704.

Bradley, A. F., N. V. Noste, and W. C. Fischer. 1992. Fire ecology of forests and woodlands in Utah. General Technical Report INT-287, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Britton, C. M., G. R. McPherson, and F. A. Sneva. 1990. Effects of burning and clipping on five bunchgrasses in eastern Oregon. The Great Basin Naturalist **50**:115-120.

Bunting, S. C. 1994. Effects of fire on juniper woodland ecosystems in the Great Basin. Pages 53-55 *in* Proceedings: Ecology and Management of Annual Rangelands. Gen. Tech. Rep. INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, ID.

Bunting, S. C., B. M. Kilgore, and C. L. Bushey. 1987. Guidelines for prescribed burning sagebrush-grass rangelands in the Northern Great Basin. General Technical Report INT-231, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Butler, M., F. Brummer, J. Weber, and R. Simmons. 2011. Restoring Central Oregon rangeland from ventenata and medusahead to a sustainable bunchgrass environment – Warm Springs and Ashwood. COARC 2011, Oregon State University, Central Oregon Agricultural Research and Extension Center, Corvallis, OR.

Caudle, D., J. DiBenedetto, M. Karl, H. Sanchez, and C. Talbot. 2013. Interagency ecological site handbook for rangelands. U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.

Chambers, J. C., B. A. Bradley, C. S. Brown, C. D'Antonio, M. J. Germino, J. B. Grace, S. P. Hardegree, R. F. Miller, and D. A. Pyke. 2013. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of western North America. Ecosystems **17**:360-375.

Chambers, J. C., E. W. Schupp, and S. B. V. Wall. 1999. Seed dispersal and seedling establishment of piñon and juniper species within the piñon-juniper woodland. Pages 29-34 *in* Proceedings: Ecology and management of pinyon-juniper communities within the Interior West; Provo, UT; September 15-18, 1997. Proceedings RMRS-P-9. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Christopherson, J. 2014. Dwarf mistletoe (*Arceuthobium* spp.). Nevada Division of Forestry, Carson City, NV.

Coates, K. P., and S. D. Schemnitz. 1994. Habitat use and behavior of male mountain sheep in foraging associations with wild horses. The Great Basin Naturalist **54**:86-90.

Comstock, J. P., and J. R. Ehleringer. 1992. Plant adaptation in the Great Basin and Colorado Plateau. The Great Basin Naturalist **52**:195-215.

Cook, C. W. 1962. An evaluation of some common factors affecting utilization of desert range species. Journal of Range Management **15**:333-338.

Cook, C. W., and R. D. Child. 1971. Recovery of desert plants in various states of vigor. Rangeland Ecology & Management/Journal of Range Management Archives **24**:339-343.

Daubenmire, R. 1970. Steppe vegetation of Washington. Technical Report 62, Washington State University, Washington Agricultural Experiment Station, Pullman, WA.

Daubenmire, R. 1975. Plant succession on abandoned fields, and fire influences in a steppe area in southeastern Washington. Northwest Science **49**:36-48.

Davies, K. W., C. S. Boyd, D. D. Johnson, A. M. Nafus, and M. D. Madsen. 2015b. Success of seeding native compared with introduced perennial vegetation for revegetating medusahead-invaded sagebrush rangeland. Rangeland Ecology & Management **68**:224-230.

Dobkin, D. S., and J. D. Sauder. 2004. Shrubsteppe landscapes in jeopardy: Distributions, abundances, and the uncertain future of birds and small mammals in the Intermountain West. High Desert Ecological Research Institute, Bend, OR.

Dobrowolski, J. P., M. M. Caldwell, and J. H. Richards. 1990. Chapter 7: Basin hydrology and plant root systems. Pages 243-292 *in* C. B. Osmond, L. F. Pitelka, and G. M. Hidy, editors. Plant Biology of the Basin and Range. Springer-Verlag, New York City, NY.

Durham, G. 2014. Juniper pocket rot (*Pyrofomes demidoffii*). Nevada Division of Forestry, Carson City, NV.

Eckert, R. E., Jr., and J. S. Spencer. 1987. Growth and reproduction of grasses heavily grazed under rest-rotation management. Journal of Range Management **40**:156-159.

Eddleman, L. E., P. M. Miller, R. F. Miller, and P. L. Dysart. 1994. Western juniper woodlands (of the Pacific Northwest): Science assessment. Department of Rangeland Resources, Oregon State University.

Ellsworth, L. M., and J. B. Kauffman. 2010. Native bunchgrass response to prescribed fire in ungrazed mountain big sagebrush ecosystems. Fire Ecology **6**:86-96.

Emerson, F. W. 1932. The tension zone between the grama grass and piñon-juniper associations in northeastern New Mexico. Ecology **13**:347-358.

Evans, R. A. 1988. Management of pinyon-juniper woodlands. General Technical Report INT-249, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Everett, R. L., P. T. Tueller, J. B. Davis, and A. D. Brunner. 1980. Plant phenology in galleta-shadscale and galleta-sagebrush associations. Rangeland Ecology & Management/Journal of Range Management Archives **33**:446-450.

Freeman, C. D., G. L. Klikoff, and T. K. Harper. 1976. Differential resource utilization by the sexes of dioecious plants. Science **193**:597-599.

Frischknecht, N. C. 1975. Native faunal relationships within the pinyon-juniper ecosystem. Pages 55-65 *in* Proceedings of the pinyon-juniper ecosystem: A symposium; May 1975. Utah State University, Logan, UT.

Furbush, P. 1953. Control of medusa-head on California ranges. Journal of Forestry **51**:118-121.

Ganskopp, D. L. 1988. Defoliation of Thurber needlegrass: herbage and root responses. Journal of Range Management **41**:472-476.

Gese, E. M., O. J. Rongstad, and W. R. Mytton. 1988. Home range and habitat use of coyotes in southeastern Colorado. Journal of Wildlife Management **52**:640-646.

Gottfried, G. J., P. F. Folliott, and M. B. Baker Jr. 2000. Measurement of historical inventory locations to assess changes in forest and woodlands in Arizona. Pages 51-52 *in* First biennial North American forest ecology workshop; June 24-26, 1997, North Carolina State University, Raleigh, NC.

Gottfried, G. J., and K. E. Severson. 1994. Managing pinyon-juniper woodlands. Rangelands **16**:234-236.

Gruell, G. E. 1999. Historical and modern roles of fire in pinyon-juniper. Pages 24-28 *in* Ecology and management of pinyon-juniper communities within the Interior West. Proceeding RMRS-P-9. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Provo, UT.

Hepting, G. H. 1971. Diseases of forest and shade trees of the United States. Handbook Number 386, U.S. Department of Agriculture, Forest Service, Washington, D.C.

Heyerdahl, E. K., R. F. Miller, and R. A. Parsons. 2006. History of fire and Douglas-fir establishment in a savanna and sagebrush-grassland mosaic, southwestern Montana, USA. Forest Ecology and Management **230**:107-118.

Hironaka, M., and E. Tisdale. 1963. Secondary succession in annual vegetation in southern Idaho. Ecology **44**:810-812.

Hoffmeister, D. F. 1981. *Peromyscus truei*. Mammalian Species **No. 161**:1-5.

Holechek, J. L. 1981. Brush control impacts on rangeland wildlife. Journal of Soil and Water Conservation **36**:265-269.

Holmes, R. L., R. K. Adams, and H. C. Fritts. 1986. Tree-ring chronologies of western North America: California, eastern Oregon and northern Great Basin with procedures used in the chronology development work including users manuals for computer programs COFECHA and ARSTAN. Chronology Series VI, University of Arizona, Laboratory of Tree-Ring Research, Tucson, AZ.

Hurst, W. D. 1975. Management of strategies within the pinyon-juniper ecosystem. Pages 187-192 *in* Proceedings of the pinyon-juniper ecosystem: A symposium. Utah State University, Logan, UT.

Jameson, D. A. 1970. Degradation and accumulation of inhibitory substances from *Juniperus osteosperma* (Torr.) Little. Plant and Soil **33**:213-224.

Johnson, R., E. Leger, and K. Vance-Borland. 2017. Genecology of Thurber's Needlegrass (Achnatherum thurberianum [Piper] Barkworth) in the Western United States. Rangeland Ecology & Management **70**:509-517.

Jones, T. A. 1990. A viewpoint on Indian ricegrass research: its present status and future prospects. Journal of Range Management **43**:416-420.

Kitchen, A. M., E. M. Gese, and E. R. Schauster. 2000. Changes in coyote activity patterns due to reduced exposure to human persecution. Canadian Journal of Zoology **78**:853-857.

Klemmedson, J. O., and J. G. Smith. 1964. Cheatgrass (*Bromus tectorum* L.). The Botanical Review **30**:226-262.

Koniak, S. 1985b. Succession in pinyon-juniper woodlands following wildfire in the Great Basin. The Great Basin Naturalist **45**:556-566.

Kufeld, R. C., O. C. Wallmo, and C. Feddema. 1973b. Foods of the Rocky Mountain mule deer. Research Paper RM-11, U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Kulpa, S. M., and E. A. Leger. 2013. Strong natural selection during plant restoration favors an unexpected suite of plant traits. Evolutionary Applications **6**:510-523.

Lanner, R. M. 1981. The piñon pine - A natural and cultural history. University of Nevada Press, Reno, NV.

Ligon, J. D. 1974. Green cones of the piñon pine stimulate late summer breeding in the piñon jay. Nature **250**:80-82.

Logan, K. A., and L. Irwin. 1985. Mountain lion habitats in the Big Horn Mountains, Wyoming. Wildlife Society Bulletin **13**:257-262.

Mack, R. N., and D. A. Pyke. 1983. The demography of *Bromus tectorum*: Variation in time and space. Journal of Ecology **71**:69-93.

Marlette, G. M., and J. E. Anderson. 1986. Seed banks and propagule dispersal in crested-wheatgrass stands. Journal of Applied Ecology **23**:161-175.

Meeuwig, R. O., and R. L. Basset. 1983. Pinyon - juniper. Pages 84-86 *in* Silvicultural systems for the major forest types of the United States; Agriculture Handbook No. 445. U.S. Department of Agriculture, Forest Service, Washington, D.C.

Miller, R. F., J. C. Chambers, L. Evers, C. J. Williams, K. A. Snyder, B. A. Roundy, and F. B. Pierson. 2019. The ecology, history, ecohydrology, and management of pinyon and juniper

woodlands in the Great Basin and northern Colorado Plateau of the western United States. General Technical Report RMRS-GTR-403, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Miller, R. F., and E. K. Heyerdahl. 2008. Fine-scale variation of historical fire regimes in sagebrush-steppe and juniper woodland: An example from California, USA. International Journal of Wildland Fire **17**:245-254.

Miller, R. F., S. T. Knick, D. A. Pyke, C. W. Meinke, S. E. Hanser, M. J. Wisdom, and A. L. Hild. 2008a. Characteristics of sagebrush habitats and limitations to long-term conservation. Administrative Report, U.S. Department of the Interior; U.S. Geological Survey, Reston, VA.

Miller, R. F., and J. A. Rose. 1995. Historic expansion of *Juniperus occidentalis* (western juniper) in southeastern Oregon. The Great Basin Naturalist **55**:37-45.

Miller, R. F., and R. J. Tausch. 2001. The role of fire in juniper and pinyon woodlands: A descriptive analysis. Pages 15-30 *in* Fire conference 2000: the first national congress on fire ecology, prevention, and management; San Diego, CA. Misc. Pub. No. 11. Tall Timbers Research Station, Tallahassee, FL.

Miller, R. F., R. J. Tausch, E. D. McArthur, D. D. Johnson, and S. C. Sanderson. 2008b. Age structure and expansion of piñon-juniper woodlands: A regional perspective in the Intermountain West. Research Paper Report RMRS-RP-69, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Miller, R. F., R. J. Tausch, and W. Waichler. 1999b. Old-growth juniper and pinyon woodlands. Pages 375-384 *in* Proceedings: ecology and management of pinyon-juniper communities within the interior west; September 15-18, 1997. Proceedings RMRS-P-9. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Brigham Young University Conference Center, Provo, UT.

Monsen, S. B., R. Stevens, and N. L. Shaw. 2004b. Restoring western ranges and wildlands: Volume 2. General Technical Report RMRS-GTR-136-vol. 2, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Morrison, M. L., and L. S. Hall. 1999. Habitat characteristics of reptiles in pinyon-juniper woodland. The Great Basin Naturalist **59**:288-291.

Neuenschwander, L. F. 1980. Broadcast burning of sagebrush in the winter. Journal of Range Management **33**:233-236.

Noy-Meir, I. 1973. Desert ecosystems: Environment and producers. Annual Review of Ecology and Systematics **4**:25-51.

NRCS. 2022. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. Handbook 296, U.S. Department of Agriculture, Natural Resources Conservation Service.

Ogle, D., St. John, L, Tilley, D, Jones, T. 2006. Plant Guide for Thurber's Needlegrass. USDA NRCS, USDA NRCS Idaho State Office.

Pearson, L. C. 1964. Effect of harvest date on recovery of range grasses and shrubs. Agronomy Journal **56**:80-82.

Pearson, L. C. 1965. Primary production in grazed and ungrazed desert communities of eastern Idaho. Ecology **46**:278-285.

Pellant, M., and C. Hall. 1994. Distribution of two exotic grasses in intermountain rangelands: Status in 1992. Pages 109-112 *in* S. B. Monsen and S. G. Kitchen, editors. Proceedings—Ecology and management of annual rangelands; General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Pendleton, R. L., B. K. Pendleton, S. D. Warren, J. R. Johansen, and L. L. S. Clair. 2007. Shrub establishment in the presence of cheatgrass: The effect of soil microorganisms.*in* Sosebee, Ronald E.; Wester, David B.; Britton, Carlton M.; McArthur, E. Durant; Kitchen, Stanley G., comps. Proceedings: Shrubland dynamics -- fire and water; RMRS-P-47. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Lubbock, TX.

Perryman, B. L., and Q. D. Skinner. 2007. A Field Guide to Nevada Grasses. Indigenous Rangeland Management Press, Lander, WY.

Peters, E. F., and S. C. Bunting. 1994. Fire conditions pre-and post-occurrence of annual grasses on the Snake River Plain. Pages 31-36 *in* Proceedings—Ecology and management of annual rangelands; September, 1994; Boise, ID. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Phillips, F. J. 1909. A study of piñon pine. Botanical Gazette **48**:216-223.

Phillips, G., and D. Reboletti. 2014. 2013 forest pest conditions in Nevada. R4-OFO-TR-05-00, Nevada Division of Forestry, Carson City, NV.

Quinones, F. A. 1981. Indian ricegrass evaluation and breeding. Bulletin 681, New Mexico State University, Agricultural Experiment Station, Las Cruces, NM.

Reynolds, T. D., and L. Fraley, Jr. 1989. Root profiles of some native and exotic plant species in southeastern Idaho. Environmental and Experimental Botany **29**:241-248.

Richards, J. H., and M. M. Caldwell. 1987. Hydraulic lift: substantial nocturnal water transport between soil layers by *Artemisia tridentata* roots. Oecologia **73**:486-489.

Rickard, W. H., and M. C. McShane. 1984. Demise of spiny hopsage shrubs following summer wildfire: An authentic record. Northwest Science **58**:282-285.

Schupp, E. W., J. C. Chambers, S. B. Vander Wall, J. M. Gómez, and M. Fuentes. 1999. Piñon and juniper seed dispersal and seedling recruitment at woodland ecotones. Pages 66-70 *in* Proceedings: Shrubland ecotones; August 12-14, 1998; Ephraim, UT. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Shaw, N. L. 1992. Germination and seedling establishment of spiny hopsage (*Grayia spinosa* [Hook.] Moq.). PhD Dissertation. Oregon State University, Corvallis, OR.

Sheley, R. L., E. A. Vasquez, A.-M. Chamberlain, and B. S. Smith. 2012. Landscape-scale rehabilitation of medusahead (*Taeniatherum caput-medusae*)-dominated sagebrush steppe. Invasive Plant Science and Management **5**:436-442.

Short, H. L., and C. Y. McCulloch. 1977. Managing pinyon-juniper ranges for wildlife. General Technical Report RM-47, U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Stubbendieck, J. L., J. T. Nichols, and K. K. Roberts. 1985. Nebraska range and pasture grasses (including grass-like plants). University of Nebraska, Department of Agriculture, Cooperative Extension Service, Lincoln, NE.

Tausch, R. J. 1999. Historic pinyon and juniper woodland development. Pages 12-19 *in* Proceedings: Ecology and management of pinyon-juniper communities within the Interior West; September 15-18, 1997; Provo, UT; Proceedings RMRS-P-9. US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Provo, UT.

Tausch, R. J., N. E. West, and A. A. Nabi. 1981. Tree age and dominance patterns in Great Basin pinyon-juniper woodlands. Journal of Range Management **34**:259-264.

Tisdale, E. W., and M. Hironaka. 1981. The sagebrush - grass region: A review of the ecological literature. Forest, Wildlife and Range Experiment Station, University of Idaho **209**.

Tueller, P. T., and J. E. Clark. 1975. Autecology of pinyon-juniper species of the Great Basin and Colorado Plateau. Pages 27-40 *in* Proceedings of the pinyon-juniper ecosystem: A symposium. Utah State University, Logan, UT.

Turkowski, F. J., and R. K. Watkins. 1976. White-throated woodrat (*Neotoma albigula*) habitat relations in modified pinyon-juniper woodland of southwestern New Mexico. Journal of Mammalogy **57**:586-591.

Uresk, D. W., J. F. Cline, and W. H. Rickard. 1976b. Impact of wildfire on three perennial grasses in south-central Washington. Journal of Range Management **29**:309-310.

USFS. 1937. Range plant handbook. U.S. Department of Agriculture, Forest Service, Washington, D.C.

USFS. 1988a. Range plant handbook. Reprint of 1937 edition. Dover Publications, New York, NY.

Vallentine, J. F. 1989. Range development and improvements. Academic Press, Inc., San Diego, CA.

Vollmer, J. L., and J. G. Vollmer. 2008. Controlling cheatgrass in winter range to restore habitat and endemic fire. Pages 57-60 *in* Proceedings—Shrublands under fire: Disturbance and recovery in a changing world. RMRS-P-52. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Cedar City, UT.

Weisberg, P. J., and D. W. Ko. 2012. Old tree morphology in singleleaf pinyon pine (*Pinus monophylla*). Forest Ecology and Management **263**:67-73.

Welsh, S. L., N. D. Atwood, S. Goodrich, and L. C. Higgins. 1987. A Utah flora. Great Basin Naturalist Memoir No. 9 edition. Brigham Young University, Provo, Utah.

West, N. E. 1994. Effects of fire on salt-desert shrub rangelands. Pages 71-74 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, ID.

West, N. E., K. H. Rea, and R. J. Tausch. 1975. Basic synecological relationships in juniper-pinyon woodlands. Pages 41-53 *in* The pinyon-juniper ecosystem: A symposium. Utah State University Agricultural Experiment Station, Logan, UT.

West, N. E., R. J. Tausch, and P. T. Tueller. 1998. A management-oriented classification of pinyon-juniper woodlands of the Great Basin. General Technical Report RMRS-GTR-12, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Wildlife Action Plan Team. 2012. Nevada wildlife action plan. Nevada Department of Wildlife, Reno, NV.

Wright, H. A. 1971. Why squirreltail is more tolerant to burning than needle-and-thread. Journal of Range Management **24**:277-284.

Wright, H. A. 1985. Effects of fire on grasses and forbs in sagebrush-grass communities. Pages 12-21 *in* Rangeland fire effects: A symposium; Boise, ID; November 27-29, 1984. U.S. Department of the Interior, Bureau of Land Management, Boise, ID.

Wright, H. A., and J. O. Klemmedson. 1965. Effect of fire on bunchgrasses of the sagebrush-grass region in Southern Idaho. Ecology **46**:680-688.

Young, J. A., and R. A. Evans. 1977. Squirreltail seed germination. Journal of Range Management **30**:33-36.

Young, J. A., and R. A. Evans. 1978. Population dynamics after wildfires in sagebrush grasslands. Journal of Range Management **31**:283-289.

Young, R. P. 1983. Fire as a vegetation management tool in rangelands of the intermountain region. Pages 18-31 *in* Managing Intermountain rangelands—Improvement of range and wildlife habitats. Proceedings of Symposia: September 15-17, 1981, Twin Falls, Idaho June 22·24, 1982, Elko, Nevada. General Technical Report INT-GTR-157. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Ziegenhagen, L. L. 2003. Shrub reestablishment following fire in the mountain big sagebrush (*Artemisia tridentata* Nutt. ssp. *vaseyana* (Rydb.) Beetle) alliance. M.S. Thesis. Oregon State University, Corvallis, OR.

MLRA 27 Group 21: Pinyon and juniper woodland with mountain big sagebrush understory

Description of MLRA 27 Disturbance Response Group 21

Disturbance Response Group (DRG) 21 consists of one ecological site, Very Steep Shallow Loam (F027XY082NV). This site occurs on mountain sideslopes on all aspects. Precipitation ranges from approximately 12 to 16 in. Slopes range from 30 to 50%. Elevations range from approximately 7,000 to 8,500 ft. The soils are range from very shallow to shallow and are well drained. They are typically skeletal and up to 60% 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 xeric bordering on aridic. The reference plant community is an overstory of singleleaf pinyon (*Pinus monophylla)* and Utah juniper (*Juniperus osteosperma)*. Mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*) is the dominant understory shrub species. Other shrub species include antelope bitterbrush (*Purshia tridentata*), mountain snowberry (*Symphoricarpos oreophilus*), Utah serviceberry (*Amelanchier utahensis*), currant (*Ribes* spp.), yellow rabbitbrush (*Chrysothamnus viscidiflorus*) and ephedra (*Ephedra* spp.). The perennial grass component is dominated by Thurber's needlegrass (*Achnatherum thurberianum*), and Sandberg bluegrass (Poa secunda). Other common grasses include Indian ricegrass (*Achnatherum hymenoides),* Idaho fescue *(Festuca idahoensis*), muttongrass *(Poa fendleriana*) and squirreltail (*Elymus elymoides*). Understory production ranges from 300 to 700 lb/ac under a medium canopy cover of 21–35%. The site has moderately low site quality for tree production. Site index ranges from 55–80.

Disturbance Response Group 21 Ecological Sites:

Very Steep Shallow Loam (PIMO-JUOS/ARTRV/ACTH7) – Modal F027XY082NV

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 27 (MLRA 27 Fallon-Lovelock Area) is almost entirely in Nevada with < 1% in California. The entire area occurs in the rain shadow of the Sierra Nevada mountains and is influenced by Pleistocene Lake Lahontan. Extensive playas occur throughout the area and are a result of the drying of ancient Lake Lahontan. To the west, MLRA 27 has a gradual boundary with MLRA 26 (Carson Basin and Mountains) and to the east has a very gradual boundary with MLRA 24 (Humboldt Basin and Range Area). From west to east the soil temperature increases and the soil moisture decreases, resulting in vast areas dominated by salt-desert shrub communities. Isolated mountain ranges trending north to south are separated by broad desert plains and valleys. Elevations range from 3,300 to 5,900 ft with some mountain peaks over 7,800 ft. The average annual precipitation ranges from 4 to 11 in. and as much as 20 in. at the highest elevations. The majority of annual precipitation is received during late fall and winter occurring mainly as snow. High-intensity, convective thunderstorms also contribute significantly to annual precipitation (NRCS 2022). 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 (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 2–11 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 10–20% 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. 1999b, 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 10–15 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 one 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 (3–10 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).

Utah serviceberry is a large shrub that grows from 2 to 4 m (6.5–13 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).

Antelope bitterbrush is a slow growing, drought tolerant shrub that provides high quality browse for domestic and wild ungulates (Bishop et al. 2001). It is moderate to very deep-rooted with wide ecotypic variations. It is normally 2–6 ft in height and up to 8 ft in width (Dyer 2007). Antelope bitterbrush is adapted to a wide range of soils with 8–34 in. of annual precipitation and is found at elevation from 4,000 to 11,000 ft. It has good tolerance to drought and cold temperatures (Dyer 2007).

Thurber's needlegrass is a native, cool-season grass common to the semiarid regions of the Intermountain West and is an important component of many sagebrush communities (Johnson

et al. 2017). It is a deep-rooted perennial bunchgrass, 1–2 ft tall with fine, narrow in rolled leaves about 6–10 in. long (Perryman and Skinner 2007). It is very drought and cold tolerant and prefers well drained, fine sandy loam to silt loam soils. It is not tolerant of shade and saline or sodic soil conditions (Ogle 2006).

Sandberg bluegrass is a low-growing, cool-season perennial bunchgrass that grows from 3 to 6.1 dm (12–24 in.) tall (Perryman and Skinner 2007). It is notable for its early growth and short season of vegetative activity (Tisdale and Hironaka 1981). It is one of the most drought resistant of the bluegrasses because of the mass of coarse fibrous roots, and its ability to make growth, produce flowers and mature its seeds early in the season while soil moisture is still available (USFS 1988a). Sandberg bluegrass is widely distributed and an important species in most of the West growing from 1,000 ft to as high as 12,000 ft elevation (USFS 1988a).

Indian ricegrass is a long-lived, cool-season perennial bunchgrass that grows from 4 to 24 in. tall (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).

Idaho fescue is a densely tufted, cool-season perennial bunchgrass 1–3 ft high. It is one of the most common and widely distributed grasses in the West (USFS 1988b). Idaho fescue occupies very diversified habitats typically occurring between 5,000 to 10,000 ft and grows on a wide variety of soils (Ogle 2008). Growth starts in March through April and seed maturity occurs in mid to late summer. With adequate moisture, Idaho fescue will produce a moderate amount of regrowth following seed maturity (Ogle 2008). Idaho fescue has excellent cold tolerance, moderate drought tolerance and moderate shade tolerance (Ogle 2008).

The ecological site in this Disturbance Response Group (DRG) has 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 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 non-native 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 1.5–1.7 m (5–5.5 ft).

The species most likely to invade this site 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. 1999a). 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 (*Agropyron cristatum*) and Sandberg bluegrass 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). 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 (*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 one 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 15–20 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 (100–600 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/ac, 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 2–3 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 3–5 years (Bunting et al. 1987). Mountain big sagebrush may return to pre-burn density and cover within 15–20 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).

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 8–10 years for plants to be fully mature and productive (Noller 2008).

Antelope bitterbrush 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, 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 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 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.

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).

Thurber's needlegrass 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 1985b, Britton et al. 1990). Reestablishment on burned sites has been found to be relatively slow due to low germination and competitive ability (Koniak 1985b). Cheatgrass has been found to be a highly successful competitor with seedlings of this needlegrass and may preclude reestablishment (Evans and Young 1978).

Sandberg bluegrass 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 bunchgrasses. 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).

Idaho fescue is a dense, fine-leaved bunchgrass, which allows fires to burn and smolder in the accumulated leaves at the base of the plant. Idaho fescue's response to fire varies with condition and size of the plant, season and severity of fire, and ecological conditions. This bunchgrass can survive light-severity fires, but can be severely damaged by fire in all seasons

(Wright et al. 1979, Wright 1985). Rapid tillering can occur after fire when root crowns are not killed and soil moisture is favorable (Robberecht and Defossé 1995).

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. 1973a). 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 1–2% 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 latrans*), 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.

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).

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).

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. "Heavy" was not defined in this study. 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). Thurber's needlegrass may increase in crude protein content after grazing (Ganskopp et al. 2007).

Reduced bunchgrass vigor or density may provide an opportunity for squirreltail or Sandberg bluegrass expansion. With further degradation, cheatgrass and other invasive species may occupy interspaces. Sandberg bluegrass increases under grazing pressure (Tisdale and Hironaka 1981) and is capable of co-existing with cheatgrass or other weedy species. Excessive 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, squirreltail, Sandberg bluegrass, or cheatgrass may become the dominant understory with inappropriate grazing management.

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.

Idaho fescue is valuable forage for livestock and wildlife. However, Idaho fescue decreases under heavy grazing by livestock (Eckert and Spencer 1987, Ogle 2008) and wildlife (Gaffney 1941).

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 (*Poa fendleriana*) and Sandberg bluegrass.

State and Transition Model Narrative for 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 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:

The reference plant community 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 35%. Overstory tree canopy composition is about 40–50% Utah juniper and 50–60% singleleaf pinyon. Understory vegetative composition is about 60% grasses, 10% forbs and 30% shrubs and young trees. Average understory production ranges from 300 to 700 lb/ac under a medium tree canopy (20–35%). 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. Mountain big sagebrush is the primary understory shrub. Other common shrubs include Utah serviceberry *(Amelanchier utahensis*), antelope bitterbrush (*Purshia tridentata*) and Mormon tea (*Ephedra viridis*). Thurber's needlegrass is the most prevalent understory grass. Other common grasses include Idaho fescue (*Festuca idahoensis*), Indian ricegrass (*Achnatherum hymenoides*) and Sandberg's bluegrass (*Poa secunda*). Forbs such as arrowleaf balsamroot (*Balsamorhiza sagittat*a), phlox (*Phlox* spp.), and tapertip hawksbeard (*Crepis acuminata*) are minor components.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
A high severity-crown fire or disease 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 will 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. Sandberg bluegrass and other perennial bunchgrasses dominate. Sprouting shrubs such as Utah serviceberry and Mormon tea will be common. 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. Understory production ranges from 600 to 1,200 lb/ac under an open tree canopy of less than 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 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 tree canopy cover (10–20%), understory production ranges from 400 to 900 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 tree canopy cover is commonly over 35%. 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 tree canopy cover (> 35%) ranges from 75 to 250 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 or disease 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 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 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 35%. Overstory tree canopy composition is about 40–50% Utah juniper and 50–60% singleleaf pinyon. Understory vegetative composition is about 60% grasses, 10% forbs and 30% shrubs and young trees. Average understory production ranges from 300 to 700 lb/ac under a medium tree canopy (20–35%). 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. Mountain big sagebrush is the primary understory shrub. Other common shrubs include

Utah serviceberry, antelope bitterbrush and Mormon tea. Thurber's needlegrass is the most prevalent understory grass. Other common perennial grasses include Idaho fescue, Indian ricegrass and Sandberg's bluegrass. Forbs include arrowleaf balsamroot, phlox and tapertip hawksbeard. Non-native annual grasses are present in the understory.

Very Steep Shallow Loam (F027XY082NV), Mature Woodland, 2.1, T. Stringham, June 2024

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
A high-severity crown fire or disease 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. Sandberg bluegrass and other perennial grasses dominate. Sprouting shrubs will increase. 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 600 to 1,200 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 900 lb/ac under a sparse tree 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 tree canopy cover is commonly greater than 50%. The density and vigor of the mountain big sagebrush and perennial bunchgrass understory is decreased. Understory production ranges from 75 to 250 lb/ac under a dense canopy (> 35 %). Annual non-native species are present primarily under tree canopies.

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 or disease 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 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 singleleaf pinyon and Utah juniper 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 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 Utah juniper. Infilling by younger trees continues.

Community Phase 3.2:
Singleleaf pinyon and Utah juniper dominate the aspect. Tree canopy cover exceeds 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.

T3A: Transition from Infilled Tree State 3.0 to Annual State 4.0:

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.

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.

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.

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 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 4.1:
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.

Community Phase Pathway 4.1a, from Phase 4.1 to 4.2:
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 4.2:
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.

Community Phase Pathway 4.2a, from Phase 4.2 to 4.1:
Frequent wildfires reduce shrub overstory. The understory is dominated by annual non-natives.

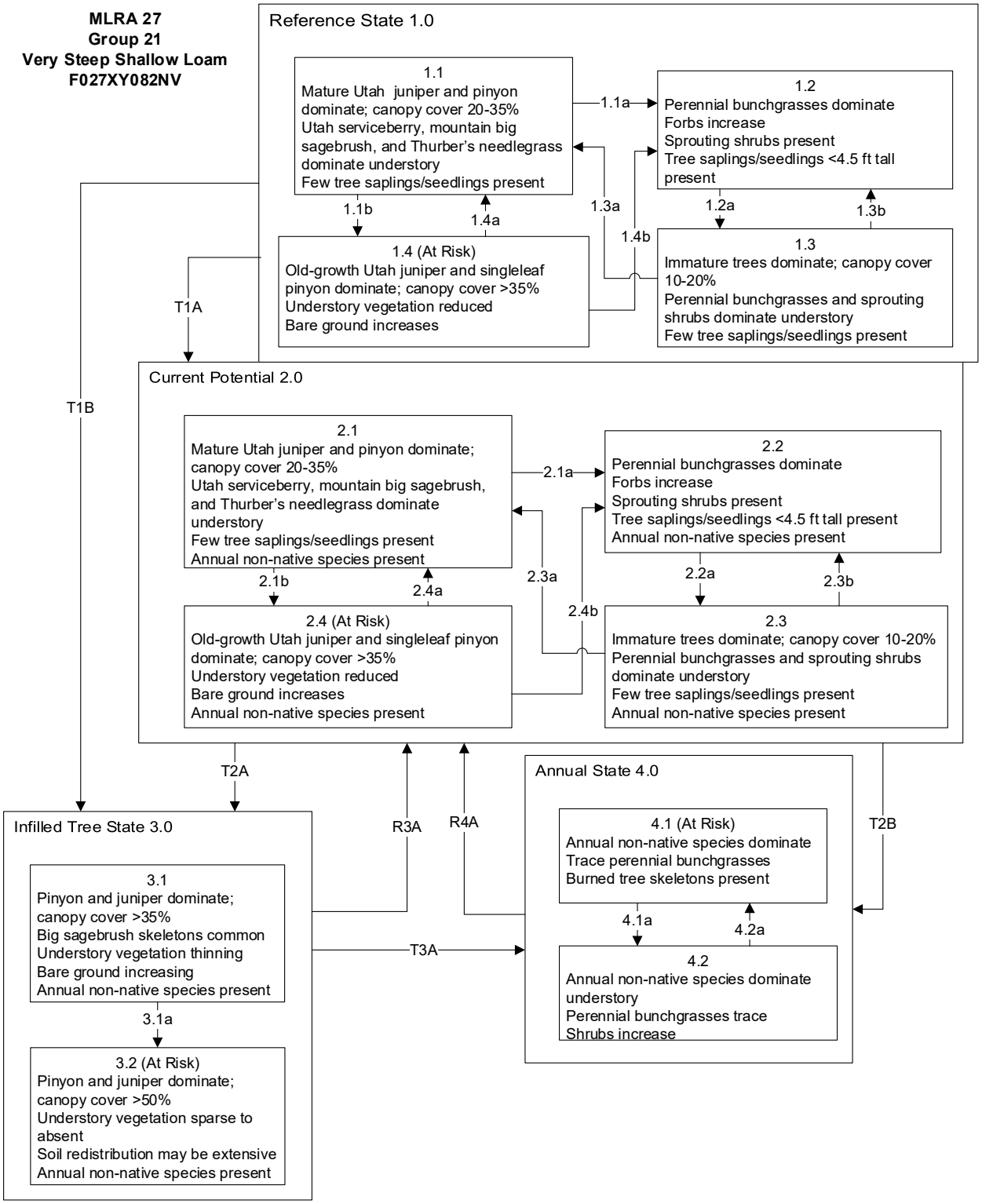
R4A Restoration from Annual State 4.0 to Current Potential State 2.0:

Herbicide treatment of non-natives with a follow-up seeding of native shrubs, trees, and native or non-native forbs and perennial grasses. Highest success likely from community phase 4.2.

States Not Observed in Group 21:

Annual State: An Annual State was not observed during field work for this project, however cheatgrass was observed in the understory of some of the sites. Remote sensing also indicates annual forbs and grasses dominate this site after wildfire.

Modal State and Transition Model for Group 21 in MLRA 27



MLRA 27
Group 21
Very Steep Shallow Loam
F027XY082NV

Reference State 1.0 Community Phase Pathways
1.1a: High severity crown fire or disease 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 or disease 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.

Annual State 4.0 Community Phase Pathways
4.1a. Time allows for sprouting shrubs to recover.
4.2a Frequent wildfires.

Restoration R4A: Herbicide treatment and seeding of native grass, shrub, and tree species. Highest success likely from phase 4.2.

References

Balda, R. P., and N. Masters. 1980. Avian communities in the pinyon-juniper woodland: a descriptive analysis. Pages 146-169 *in* Workshop proceedings: Management of western forests and grasslands for nongame birds. February 11-14, 1980, Salt Lake City, UT. General Technical Report INT-86. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Rocky Mountain Forest and Range Experiment Station, and Intermountain Region, Ogden, UT.

Bates, J. D., T. Svejcar, R. F. Miller, and R. A. Angell. 2006. The effects of precipitation timing on sagebrush steppe vegetation. Journal of Arid Environments **64**:670-697.

Baughman, O. W., R. Burton, M. Williams, P. J. Weisberg, T. E. Dilts, and E. A. Leger. 2017. Cheatgrass die-offs: a unique restoration opportunity in northern Nevada. Rangelands **39**:165-173.

Baughman, O. W., S. E. Meyer, Z. T. Aanderud, and E. A. Leger. 2016. Cheatgrass die-offs as an opportunity for restoration in the Great Basin, USA: will local or commercial native plants succeed where exotic invaders fail? Journal of Arid Environments **124**:193-204.

Beatley, J. C. 1975. Climates and vegetation pattern across the Mojave/Great Basin Desert transition of southern Nevada. The American Midland Naturalist **93**:53-70.

Bich, B. S., J. L. Butler, and C. A. Schmidt. 1995. Effects of differential livestock use on key plant species and rodent populations within selected *Oryzopsis hymenoides*/*Hilaria jamesii* communities of Glen Canyon National Recreation Area. The Southwestern Naturalist **40**:281-287.

Bilbrough, C. J., and J. H. Richards. 1993. Growth of sagebrush and bitterbrush following simulated winter browsing: mechanisms of tolerance. Ecology **74**:481-492.

Bishop, C., E. Garton, and J. Unsworth. 2001. Bitterbrush and cheatgrass quality on 3 southwest Idaho winter ranges. Journal of Range Management:595-602.

Blaisdell, J. P. 1953. Ecological effects of planned burning of sagebrush-grass range on the upper Snake River plains. Technical Bulletin No. 1075, U.S. Department of Agriculture, Washington, D.C.

Blaisdell, J. P., and R. C. Holmgren. 1984. Managing intermountain rangelands - salt-desert shrub ranges. General Technical Report INT-163, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Blaisdell, J. P., and W. F. Mueggler. 1956. Sprouting of bitterbrush (*Purshia tridentata*) following burning or top removal. Ecology **37**:365-370.

Blaisdell, J. P., R. B. Murray, and E. D. McArthur. 1982. Managing intermountain rangelands - sagebrush-grass ranges. General Technical Report INT-134, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Blank, R. R., C. Clements, T. Morgan, D. Harmon, and F. Allen. 2020. Suppression of cheatgrass by perennial bunchgrasses. Rangeland Ecology & Management **73**:766-771.

Booth, D. T., C. G. Howard, and C. E. Mowry. 1980. 'Nezpar' Indian ricegrass: description, justification for release, and recommendations for use. Rangelands **2**:53-54.

Bradford, J. B., and W. K. Lauenroth. 2006. Controls over invasion of *Bromus tectorum*: the importance of climate, soil, disturbance and seed availability. Journal of Vegetation Science **17**:693-704.

Bradley, A. F., N. V. Noste, and W. C. Fischer. 1992. Fire ecology of forests and woodlands in Utah. General Technical Report INT-287, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Brehm, J. R. 2019. Cheatgrass die-off in the Great Basin: a comparison of remote sensing detecting methods and identification of environments favorable to die-off. M.S. Thesis. University of Nevada, Reno, NV.

Britton, C. M., G. R. McPherson, and F. A. Sneva. 1990. Effects of burning and clipping on five bunchgrasses in eastern Oregon. The Great Basin Naturalist **50**:115-120.

Bunting, S. C. 1994. Effects of fire on juniper woodland ecosystems in the Great Basin. Pages 53-55 *in* Proceedings: Ecology and Management of Annual Rangelands. Gen. Tech. Rep. INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, ID.

Bunting, S. C., B. M. Kilgore, and C. L. Bushey. 1987. Guidelines for prescribed burning sagebrush-grass rangelands in the Northern Great Basin. General Technical Report INT-231, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Busse, M. D., S. A. Simon, and G. M. Riegel. 2000. Tree-growth and understory responses to low-severity prescribed burning in thinned *Pinus ponderosa* forests of central Oregon. Forest Science **46**:258-268.

Butler, M., F. Brummer, J. Weber, and R. Simmons. 2011. Restoring Central Oregon rangeland from ventenata and medusahead to a sustainable bunchgrass environment – Warm Springs and Ashwood. COARC 2011, Oregon State University, Central Oregon Agricultural Research and Extension Center, Corvallis, OR.

Caudle, D., J. DiBenedetto, M. Karl, H. Sanchez, and C. Talbot. 2013. Interagency ecological site handbook for rangelands. U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.

Chambers, J. C., B. A. Bradley, C. S. Brown, C. D'Antonio, M. J. Germino, J. B. Grace, S. P. Hardegree, R. F. Miller, and D. A. Pyke. 2013. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of western North America. Ecosystems **17**:360-375.

Chambers, J. C., E. W. Schupp, and S. B. V. Wall. 1999. Seed dispersal and seedling establishment of piñon and juniper species within the piñon-juniper woodland. Pages 29-34 *in* Proceedings: Ecology and management of pinyon-juniper communities within the Interior West; Provo, UT; September 15-18, 1997. Proceedings RMRS-P-9. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Christopherson, J. 2014. Dwarf mistletoe (*Arceuthobium* spp.). Nevada Division of Forestry, Carson City, NV.

Clark, R. G., C. M. Britton, and F. A. Sneva. 1982. Mortality of bitterbrush after burning and clipping in eastern Oregon. Journal of Range Management **35**:711-714.

Clements, C. D., D. N. Harmon, R. R. Blank, and M. Weltz. 2017. Improving seeding success on cheatgrass-infested rangelands in Northern Nevada. Rangelands **39**:174-181.

Clements, C. D., and J. A. Young. 2002. Restoring antelope bitterbrush. Rangelands **24**:3-6.

Coates, K. P., and S. D. Schemnitz. 1994. Habitat use and behavior of male mountain sheep in foraging associations with wild horses. The Great Basin Naturalist **54**:86-90.

Comstock, J. P., and J. R. Ehleringer. 1992. Plant adaptation in the Great Basin and Colorado Plateau. The Great Basin Naturalist **52**:195-215.

Cook, C. W. 1962. An evaluation of some common factors affecting utilization of desert range species. Journal of Range Management **15**:333-338.

Cook, C. W., and R. D. Child. 1971. Recovery of desert plants in various states of vigor. Rangeland Ecology & Management/Journal of Range Management Archives **24**:339-343.

Cook, J. G., T. J. Hershey, and L. L. Irwin. 1994. Vegetative response to burning on Wyoming mountain-shrub big game ranges. Journal of Range Management **47**:296-302.

Daubenmire, R. 1970. Steppe vegetation of Washington. Technical Report 62, Washington State University, Washington Agricultural Experiment Station, Pullman, WA.

Daubenmire, R. 1975. Plant succession on abandoned fields, and fire influences in a steppe area in southeastern Washington. Northwest Science **49**:36-48.

Davies, K. W., C. S. Boyd, D. D. Johnson, A. M. Nafus, and M. D. Madsen. 2015b. Success of seeding native compared with introduced perennial vegetation for revegetating medusahead-invaded sagebrush rangeland. Rangeland Ecology & Management **68**:224-230.

Dobkin, D. S., and J. D. Sauder. 2004. Shrubsteppe landscapes in jeopardy: Distributions, abundances, and the uncertain future of birds and small mammals in the Intermountain West. High Desert Ecological Research Institute, Bend, OR.

Dobrowolski, J. P., M. M. Caldwell, and J. H. Richards. 1990. Chapter 7: Basin hydrology and plant root systems. Pages 243-292 *in* C. B. Osmond, L. F. Pitelka, and G. M. Hidy, editors. Plant Biology of the Basin and Range. Springer-Verlag, New York City, NY.

Durham, G. 2014. Juniper pocket rot (*Pyrofomes demidoffii*). Nevada Division of Forestry, Carson City, NV.

Dyer, D., R. O'Beck, and G.L. Noller. 2007. Plant Guide for Antelope Bitterbrush. USDA Natural Resources Conservation Service.

Eckert, R. E., Jr., and J. S. Spencer. 1987. Growth and reproduction of grasses heavily grazed under rest-rotation management. Journal of Range Management **40**:156-159.

Eddleman, L. E., P. M. Miller, R. F. Miller, and P. L. Dysart. 1994. Western juniper woodlands (of the Pacific Northwest): Science assessment. Department of Rangeland Resources, Oregon State University.

Emerson, F. W. 1932. The tension zone between the grama grass and piñon-juniper associations in northeastern New Mexico. Ecology **13**:347-358.

Evans, R. A. 1988. Management of pinyon-juniper woodlands. General Technical Report INT-249, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Evans, R. A., and J. A. Young. 1978. Effectiveness of rehabilitation practices following wildfire in a degraded big sagebrush-downy brome community. Journal of Range Management **31**:185-188.

Everett, R. L., P. T. Tueller, J. B. Davis, and A. D. Brunner. 1980. Plant phenology in galleta-shadscale and galleta-sagebrush associations. Rangeland Ecology & Management/Journal of Range Management Archives **33**:446-450.

Frischknecht, N. C. 1975. Native faunal relationships within the pinyon-juniper ecosystem. Pages 55-65 *in* Proceedings of the pinyon-juniper ecosystem: A symposium; May 1975. Utah State University, Logan, UT.

Gaffney, W. S. 1941. The effects of winter elk browsing, South Fork of the Flathead River, Montana. The Journal of Wildlife Management **5**:427-453.

Ganskopp, D., L. Aguilera, and M. Vavra. 2007. Livestock forage conditioning among six northern Great Basin grasses. Rangeland Ecology & Management **60**:71-78.

Ganskopp, D. L. 1988. Defoliation of Thurber needlegrass: herbage and root responses. Journal of Range Management **41**:472-476.

Garrison, G. A. 1953. Effects of clipping on some range shrubs. Journal of Range Management **6**:309-317.

Gese, E. M., O. J. Rongstad, and W. R. Mytton. 1988. Home range and habitat use of coyotes in southeastern Colorado. Journal of Wildlife Management **52**:640-646.

Gottfried, G. J., P. F. Folliott, and M. B. Baker Jr. 2000. Measurement of historical inventory locations to assess changes in forest and woodlands in Arizona. Pages 51-52 *in* First biennial North American forest ecology workshop; June 24-26, 1997, North Carolina State University, Raleigh, NC.

Gottfried, G. J., and K. E. Severson. 1994. Managing pinyon-juniper woodlands. Rangelands **16**:234-236.

Gruell, G. E. 1999. Historical and modern roles of fire in pinyon-juniper. Pages 24-28 *in* Ecology and management of pinyon-juniper communities within the Interior West. Proceeding RMRS-P-9. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Provo, UT.

Hammond, E. 2012. Multi-site trial of woody plants: 2006 planting and evaluation of differences in drought tolerance of three *Amelanchier* species. Master's thesis. Colorado State University, Fort Collins, CO.

Hepting, G. H. 1971. Diseases of forest and shade trees of the United States. Handbook Number 386, U.S. Department of Agriculture, Forest Service, Washington, D.C.

Heyerdahl, E. K., R. F. Miller, and R. A. Parsons. 2006. History of fire and Douglas-fir establishment in a savanna and sagebrush-grassland mosaic, southwestern Montana, USA. Forest Ecology and Management **230**:107-118.

Hoffmeister, D. F. 1981. *Peromyscus truei*. Mammalian Species **No. 161**:1-5.

Holechek, J. L. 1981. Brush control impacts on rangeland wildlife. Journal of Soil and Water Conservation **36**:265-269.

Holmes, R. L., R. K. Adams, and H. C. Fritts. 1986. Tree-ring chronologies of western North America: California, eastern Oregon and northern Great Basin with procedures used in the chronology development work including users manuals for computer programs

COFECHA and ARSTAN. Chronology Series VI, University of Arizona, Laboratory of Tree-Ring Research, Tucson, AZ.
Hormay, A. L. 1943. Bitterbrush in California. Research Note No. 34, U.S. Department of Agriculture, Forest Service, California Forest and Range Experiment Station, Berkeley, CA.
Hurst, W. D. 1975. Management of strategies within the pinyon-juniper ecosystem. Pages 187-192 *in* Proceedings of the pinyon-juniper ecosystem: A symposium. Utah State University, Logan, UT.
Jameson, D. A. 1970. Degradation and accumulation of inhibitory substances from *Juniperus osteosperma* (Torr.) Little. Plant and Soil **33**:213-224.
Johnson, R., E. Leger, and K. Vance-Borland. 2017. Genecology of Thurber's Needlegrass (Achnatherum thurberianum [Piper] Barkworth) in the Western United States. Rangeland Ecology & Management **70**:509-517.
Jones, T. A. 1990. A viewpoint on Indian ricegrass research: its present status and future prospects. Journal of Range Management **43**:416-420.
Kerns, B. K., T. W. G., and C. G. and Niwa. 2006. Season and severity of prescribed burn in ponderosa pine forests: Implications for understory native and exotic plants. Ecoscience **13**:44-55.
Kitchen, A. M., E. M. Gese, and E. R. Schauster. 2000. Changes in coyote activity patterns due to reduced exposure to human persecution. Canadian Journal of Zoology **78**:853-857.
Klemmedson, J. O., and J. G. Smith. 1964. Cheatgrass (*Bromus tectorum* L.). The Botanical Review **30**:226-262.
Koniak, S. 1985b. Succession in pinyon-juniper woodlands following wildfire in the Great Basin. The Great Basin Naturalist **45**:556-566.
Kufeld, R. C., O. C. Wallmo, and C. Feddema. 1973a. Foods of the Rocky Mountain mule deer. Rocky Mountain Forest and Range Experiment Station, Forest Service, US Department of Agriculture.
Lanner, R. M. 1981. The piñon pine - A natural and cultural history. University of Nevada Press, Reno, NV.
Ligon, J. D. 1974. Green cones of the piñon pine stimulate late summer breeding in the piñon jay. Nature **250**:80-82.
Logan, K. A., and L. Irwin. 1985. Mountain lion habitats in the Big Horn Mountains, Wyoming. Wildlife Society Bulletin **13**:257-262.
McArthur, E. D., and B. L. Welch. 1982. Growth rate differences among big sagebrush (*Artemisia tridentata*) accessions and subspecies. Journal of Range Management **35**:396-401.
McConnell, B. R., and J. G. Smith. 1977. Influence of grazing on age-yield interactions in bitterbrush. Journal of Range Management **30**:91-93.
McCulloch, C. Y., Jr. 1955. Utilization of winter browse on wilderness big game range. The Journal of Wildlife Management **19**:206-215.
Meeuwig, R. O., and R. L. Basset. 1983. Pinyon - juniper. Pages 84-86 *in* Silvicultural systems for the major forest types of the United States; Agriculture Handbook No. 445. U.S. Department of Agriculture, Forest Service, Washington, D.C.

Miller, H. C., D. Clausnitzer, and M. M. Borman. 1999a. Medusahead. Pages 272-281 *in* R. L. S. a. J. K. Petroff, editor. Biology and Management of Noxious Rangeland Weeds. Oregon State University Press, Oregon State University.

Miller, R. F., J. C. Chambers, L. Evers, C. J. Williams, K. A. Snyder, B. A. Roundy, and F. B. Pierson. 2019. The ecology, history, ecohydrology, and management of pinyon and juniper woodlands in the Great Basin and northern Colorado Plateau of the western United States. General Technical Report RMRS-GTR-403, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Miller, R. F., and E. K. Heyerdahl. 2008. Fine-scale variation of historical fire regimes in sagebrush-steppe and juniper woodland: An example from California, USA. International Journal of Wildland Fire **17**:245-254.

Miller, R. F., S. T. Knick, D. A. Pyke, C. W. Meinke, S. E. Hanser, M. J. Wisdom, and A. L. Hild. 2008a. Characteristics of sagebrush habitats and limitations to long-term conservation. Administrative Report, U.S. Department of the Interior; U.S. Geological Survey, Reston, VA.

Miller, R. F., and J. A. Rose. 1995. Historic expansion of *Juniperus occidentalis* (western juniper) in southeastern Oregon. The Great Basin Naturalist **55**:37-45.

Miller, R. F., and R. J. Tausch. 2001. The role of fire in juniper and pinyon woodlands: A descriptive analysis. Pages 15-30 *in* Fire conference 2000: the first national congress on fire ecology, prevention, and management; San Diego, CA. Misc. Pub. No. 11. Tall Timbers Research Station, Tallahassee, FL.

Miller, R. F., R. J. Tausch, E. D. McArthur, D. D. Johnson, and S. C. Sanderson. 2008b. Age structure and expansion of piñon-juniper woodlands: A regional perspective in the Intermountain West. Research Paper Report RMRS-RP-69, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Miller, R. F., R. J. Tausch, and W. Waichler. 1999b. Old-growth juniper and pinyon woodlands. Pages 375-384 *in* Proceedings: ecology and management of pinyon-juniper communities within the interior west; September 15-18, 1997. Proceedings RMRS-P-9. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Brigham Young University Conference Center, Provo, UT.

Morrison, M. L., and L. S. Hall. 1999. Habitat characteristics of reptiles in pinyon-juniper woodland. The Great Basin Naturalist **59**:288-291.

Murray, R. B. 1983. Response of antelope bitterbrush to burning and spraying in southeastern Idaho. Pages 142-152 *in* Proceedings—Research and management of bitterbrush and cliffrose in western North America; Salt Lake City, UT; April 13-15, 1982. General Technical Report INT-152. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Neuenschwander, L. F. 1980. Broadcast burning of sagebrush in the winter. Journal of Range Management **33**:233-236.

Noller, G. L. 2008. Plant guide for Utah serviceberry (*Amelanchier utahensis*). U.S. Department of Agriculture, Natural Resources Conservation Service.

Noy-Meir, I. 1973. Desert ecosystems: Environment and producers. Annual Review of Ecology and Systematics **4**:25-51.

NRCS. 2022. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. Handbook 296, U.S. Department of Agriculture, Natural Resources Conservation Service.

Ogle, D., J. Henson, M. Stannard. 2008. Plant Guide for Idaho Fescue. USDA-Natural Resources Conservation Service, USDA-NRCS Plant Materials Center, Boise, ID.

Ogle, D., St. John, L, Tilley, D, Jones, T. 2006. Plant Guide for Thurber's Needlegrass. USDA NRCS, USDA NRCS Idaho State Office.

Pearson, L. C. 1964. Effect of harvest date on recovery of range grasses and shrubs. Agronomy Journal **56**:80-82.

Pearson, L. C. 1965. Primary production in grazed and ungrazed desert communities of eastern Idaho. Ecology **46**:278-285.

Pellant, M., and C. Hall. 1994. Distribution of two exotic grasses in intermountain rangelands: Status in 1992. Pages 109-112 *in* S. B. Monsen and S. G. Kitchen, editors. Proceedings—Ecology and management of annual rangelands; General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Perryman, B. L., and Q. D. Skinner. 2007. A Field Guide to Nevada Grasses. Indigenous Rangeland Management Press, Lander, WY.

Peters, E. F., and S. C. Bunting. 1994. Fire conditions pre-and post-occurrence of annual grasses on the Snake River Plain. Pages 31-36 *in* Proceedings—Ecology and management of annual rangelands; September, 1994; Boise, ID. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Phillips, F. J. 1909. A study of piñon pine. Botanical Gazette **48**:216-223.

Phillips, G., and D. Reboletti. 2014. 2013 forest pest conditions in Nevada. R4-OFO-TR-05-00, Nevada Division of Forestry, Carson City, NV.

Quinones, F. A. 1981. Indian ricegrass evaluation and breeding. Bulletin 681, New Mexico State University, Agricultural Experiment Station, Las Cruces, NM.

Richards, J. H., and M. M. Caldwell. 1987. Hydraulic lift: substantial nocturnal water transport between soil layers by *Artemisia tridentata* roots. Oecologia **73**:486-489.

Robberecht, R., and G. Defossé. 1995. The relative sensitivity of two bunchgrass species to fire. International Journal of Wildland Fire **5**:127-134.

Schupp, E. W., J. C. Chambers, S. B. Vander Wall, J. M. Gómez, and M. Fuentes. 1999. Piñon and juniper seed dispersal and seedling recruitment at woodland ecotones. Pages 66-70 *in* Proceedings: Shrubland ecotones; August 12-14, 1998; Ephraim, UT. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Sheley, R. L., E. A. Vasquez, A.-M. Chamberlain, and B. S. Smith. 2012. Landscape-scale rehabilitation of medusahead (*Taeniatherum caput-medusae*)-dominated sagebrush steppe. Invasive Plant Science and Management **5**:436-442.

Short, H. L., and C. Y. McCulloch. 1977. Managing pinyon-juniper ranges for wildlife. General Technical Report RM-47, U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Stubbendieck, J. L., J. T. Nichols, and K. K. Roberts. 1985. Nebraska range and pasture grasses (including grass-like plants). University of Nebraska, Department of Agriculture, Cooperative Extension Service, Lincoln, NE.

Tausch, R. J. 1999. Historic pinyon and juniper woodland development. Pages 12-19 *in* Proceedings: Ecology and management of pinyon-juniper communities within the Interior West; September 15-18, 1997; Provo, UT; Proceedings RMRS-P-9. US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Provo, UT.

Tausch, R. J., N. E. West, and A. A. Nabi. 1981. Tree age and dominance patterns in Great Basin pinyon-juniper woodlands. Journal of Range Management **34**:259-264.

Tisdale, E. W., and M. Hironaka. 1981. The sagebrush - grass region: A review of the ecological literature. Forest, Wildlife and Range Experiment Station, University of Idaho **209**.

Tueller, P. T., and J. E. Clark. 1975. Autecology of pinyon-juniper species of the Great Basin and Colorado Plateau. Pages 27-40 *in* Proceedings of the pinyon-juniper ecosystem: A symposium. Utah State University, Logan, UT.

Turkowski, F. J., and R. K. Watkins. 1976. White-throated woodrat (*Neotoma albigula*) habitat relations in modified pinyon-juniper woodland of southwestern New Mexico. Journal of Mammalogy **57**:586-591.

USFS. 1937. Range plant handbook. U.S. Department of Agriculture, Forest Service, Washington, D.C.

USFS. 1988a. Range plant handbook. Reprint of 1937 edition. Dover Publications, New York, NY.

USFS. 1988b. Shrub live oak. Pages 743-744 *in* W. A. Dayton, T. Lommasson, B. C. Park, C. A. Kutzleb, O. Julander, A. R. Standing, S. S. Hutchings, L. W. Swift, E. P. Cliff, D. W. Hayes, M. L. Bomhard, W. R. Chapline, R. R. Hill, and L. Ellison, editors. Range plant handbook. United States Department of Agriculture Forest Service.

Vallentine, J. F. 1989. Range development and improvements. Academic Press, Inc., San Diego, CA.

Vollmer, J. L., and J. G. Vollmer. 2008. Controlling cheatgrass in winter range to restore habitat and endemic fire. Pages 57-60 *in* Proceedings—Shrublands under fire: Disturbance and recovery in a changing world. RMRS-P-52. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Cedar City, UT.

Wasser, C. H. 1982. Ecology and culture of selected species useful in revegetating disturbed lands in the West. FWS/OBS-82/56, U.S. Department of the Interior, Fish & Wildlife Service, Fort Collins, CO.

Weisberg, P. J., T. E. Dilts, O. W. Baughman, S. E. Meyer, E. A. Leger, K. J. V. Gunst, and L. Cleeves. 2017. Development of remote sensing indicators for mapping episodic die-off of an invasive annual grass (*Bromus tectorum*) from the Landsat archive. Ecological Indicators **79**:173-181.

Weisberg, P. J., and D. W. Ko. 2012. Old tree morphology in singleleaf pinyon pine (*Pinus monophylla*). Forest Ecology and Management **263**:67-73.

West, N. E. 1994. Effects of fire on salt-desert shrub rangelands. Pages 71-74 *in* Proceedings—Ecology and management of annual rangelands. General Technical Report INT-GTR-313. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, ID.

West, N. E., K. H. Rea, and R. J. Tausch. 1975. Basic synecological relationships in juniper-pinyon woodlands. Pages 41-53 *in* The pinyon-juniper ecosystem: A symposium. Utah State University Agricultural Experiment Station, Logan, UT.

West, N. E., R. J. Tausch, and P. T. Tueller. 1998. A management-oriented classification of pinyon-juniper woodlands of the Great Basin. General Technical Report RMRS-GTR-12, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Wildlife Action Plan Team. 2012. Nevada wildlife action plan. Nevada Department of Wildlife, Reno, NV.

Wood, M. K., B. A. Buchanan, and W. Skeet. 1995. Shrub preference and utilization by big game on New Mexico reclaimed mine land. Journal of Range Management **48**:431-437.

Wright, H. A. 1971. Why squirreltail is more tolerant to burning than needle-and-thread. Journal of Range Management **24**:277-284.

Wright, H. A. 1985. Effects of fire on grasses and forbs in sagebrush-grass communities. Pages 12-21 *in* Rangeland fire effects: A symposium; Boise, ID; November 27-29, 1984. U.S. Department of the Interior, Bureau of Land Management, Boise, ID.

Wright, H. A., and J. O. Klemmedson. 1965. Effect of fire on bunchgrasses of the sagebrush-grass region in Southern Idaho. Ecology **46**:680-688.

Wright, H. A., L. F. Neuenschwander, and C. M. Dritton. 1979. The role and use of fire in sagebrush-grass and pinyon-juniper plant communities: A state-of-the-art review. General Technical Report INT-58, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Young, R. P. 1983. Fire as a vegetation management tool in rangelands of the intermountain region. Pages 18-31 *in* Managing Intermountain rangelands—Improvement of range and wildlife habitats. Proceedings of Symposia: September 15-17, 1981, Twin Falls, Idaho June 22·24, 1982, Elko, Nevada. General Technical Report INT-GTR-157. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Ziegenhagen, L. L. 2003. Shrub reestablishment following fire in the mountain big sagebrush (*Artemisia tridentata* Nutt. ssp. *vaseyana* (Rydb.) Beetle) alliance. M.S. Thesis. Oregon State University, Corvallis, OR.

MLRA 27 Group 22: Alluvial flats and axial stream floodplains dominated by saltgrass

Description of MLRA 27 Disturbance Response Group 22

Disturbance Response Group (DRG) 22 consists of three ecological sites. The sites occur on alluvial flats, lake plains and axial stream floodplains. Slopes range from 0 to 2% and elevations range from 3,500 to 5,000 ft. The precipitation zone for these sites is 4–8 in. Slopes range from 0 to 4%, but less than 2% is typical. The fine-textured soils are deep to very deep and moderately well drained to poorly drained. The soil temperature regime is mesic and the soil moisture regimes are aridic bordering on xeric or aquic. The soils are salt and sodium affected, which decreases with depth. Seasonally high water tables are typically present within 20–60 in. of the soil surface for most sites. The reference plant communities are dominated by inland saltgrass (*Distichlis spicata*) and/or alkali sacaton (*Sporobolus airoides*). Other common species include alkaligrass (*Puccinellia* spp.), mountain rush *(Juncus articus* ssp. *littoralis*), basin wildrye (*Leymus cinereus*), black greasewood (*Sarcobatus vermiculatus*), Torrey's saltbush (*Atriplex torreyi*), and rubber rabbitbrush (*Ericameria nauseosa*). Total annual air-dry production ranges from 200 to 3,000 lb/ac. Shrubs and forbs are typically 5% or less of the total weight.

Disturbance Response Group 22 Ecological Sites:

Saline Meadow – Modal	R027XY005NV
Dry Saline Meadow	R027XY090NV
Sodic Bottom	R027XY089NV

Modal Site:

The Saline Meadow (R027XY005NV) is modal site for this group as it has the most acres mapped. It occurs on alluvial flats, lake plains and axial stream floodplains. Slope gradients range from 0 to 2% and elevation ranges from 3,500 to 5,000 ft. Soils correlated to this site are moderately well drained to poorly drained and deep to very deep. Soils are calcareous and strongly salt and sodium affected in the upper profile, typically decreasing with depth. Soil textures are typically silt loam, silty clay loam or loam. Runoff is slow to very slow and ponding occurs in some areas. A seasonally high water table at 20–60 in. depths is common. This site receives additional moisture during the winter and spring as run-on from higher landscapes or from brief overflow from adjacent streams. Capillary rise of the groundwater enhances soil moisture during the growing season. The site is dominated by alkali sacaton, inland saltgrass and mountain rush. Total annual air-dry production ranges from 1,200 lb/ac to 3,000 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 27, Fallon-Lovelock Area (MLRA 27) is almost entirely in Nevada with < 1% in California. The entire area occurs in the rain shadow of the Sierra Nevada mountains and is influenced by Pleistocene Lake Lahontan. Extensive playas occur throughout the area and are a result of the drying of ancient Lake Lahontan. To the west, MLRA 27 has a gradual boundary with MLRA 26 (Carson Basin and Mountains) and to the east has a very gradual boundary with MLRA 24 (Humboldt Basin and Range Area). From west to east the soil temperature increases and the soil moisture decreases, resulting in vast areas dominated by salt-desert shrub communities. Isolated mountain ranges trending north to south are separated by broad desert plains and valleys. Elevations range from 3,300 to 5,900 ft with some mountain peaks over 7,800 ft. The average annual precipitation ranges from 4 to 11 in. and as much as 20 in. at the highest elevations. The majority of annual precipitation is received during late fall and winter occurring mainly as snow. High-intensity, convective thunderstorms also contribute significantly to annual precipitation (NRCS 2022). 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 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).

Hydrology, Drought, Groundwater Interpretations:

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 1988a).

Inland saltgrass, a common perennial grass in this group, is a warm-season, rhizomatous species that grows 10–60 cm (4–24 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 8–12 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.

Mountain rush, also known as Baltic rush, is a perennial, rhizomatous grass-like plant. Mountain rush is widespread throughout the West and also occurs in Europe and Asia (USFS 1988a). It often occurs in wetland habitats and is classified as a facultative wetland plant but can also tolerate seasonal drought (Stevens 2012). *Juncus* species can tolerate shade and flooded, anaerobic soil conditions. They can also tolerate mild to moderate soil salinities and alkaline to calcareous soils (Stevens 2012).

Basin wildrye is a large, cool-season perennial bunchgrass with an extensive deep coarse fibrous root system (Reynolds and Fraley 1989). Clumps may reach up to 6 ft in height (Ogle et al. 2012b). Basin wildrye does not tolerate long periods of inundation; it prefers cycles of wet winters and dry summers and is most commonly found in deep soils with high water holding capacities or seasonally high water tables (Perryman and Skinner 2007, Ogle et al. 2012b).

Seasonally high water tables have been found to be necessary for maintenance of site productivity and reestablishment of basin wildrye stands 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, channel incision or water pumping will decrease basin wildrye production and establishment, while black greasewood, rubber rabbitbrush, and invasive weeds increase. Farming and abandonment may facilitate the creation of surface vesicular crust, increased surface ponding, and decreased infiltration; which leads to dominance by sprouting shrubs and an annual understory.

The ecological sites in this DRG have moderate resilience to disturbance and resistance to invasion. Primary disturbances on these ecological sites are drought, fire, flooding, farming, and groundwater pumping or other disturbances leading to a lowered seasonal water table. These disturbances may facilitate an increase in shrubs and a decrease in the perennial grasses. Non-

native species such as cheatgrass (*Bromus tectorum*), broadleaved pepperweed or tall whitetop (*Lepidium latifolium*), hoary cress or whitetop (*Cardaria draba*), Russian thistle *(Salsola tragus*), annual wheatgrass (*Eremopyrum triticeum*), fivehorn smotherweed (*Bassia hyssopifolia*) or field bindweed *(Convolvulus arvensis*) are potential invaders on this site. Five possible stable states have been identified for this DRG.

Agricultural History:

These ecological sites occur in the Lovelock, Fallon, and Yerington areas, with many of the locations now under cultivation. Early settlers called the Lovelock Valley 'Big Meadows" because of the lush growth of native plants (Langan 1965). The development of irrigation began in 1862 when water was diverted from the Humboldt River. Irrigation expanded and as many as 24,000 ac of the Lovelock Valley was irrigated (Langan 1965).

In the Fallon area, agricultural development began in the early 1850s when overland stage travel was at its peak (Strahorn 1909). The first permanent settlements were made on the Carson River and the South Branch of the Carson at points where the overland trails crossed the rivers. Later settlements occurred on adjacent lands where it was possible to irrigate from the spring flow of the rivers to grow crops for local consumption. Large scale agricultural development started after the construction of the Newlands Project by the U.S. Reclamation Service (Headley and Venstrom 1930).

In the Yerington area, the major sources of irrigation water are the east and west forks of the Walker River and the Carson River. The Walker River Irrigation District was organized in April 1919 to improve irrigation operations on the river. Water is distributed through a complex system of ditches throughout the Mason and Smith valleys (Archer 1984). Main crops of importance include alfalfa, wheat, oats, lettuce, onions, garlic and pasture.

Fire Ecology:

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). Higher production sites would have experienced fire more frequently than lower production sites.

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 2–4 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).

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 groundwater, alkali sacaton never advanced beyond the vegetative phase of growth to the flowering stage.

Mountain rush is top-killed by fire during the growing season. It establishes after fire through seed and/or lateral spread by rhizomes (Wehking 2002).

Basin wildrye is relatively resistant to fire, particularly dormant season fire, as plants sprout from surviving root crowns and rhizomes (Zschaechner 1985). Fire maintained the grass dominance of these ecosystems, therefore increases in the fire return interval favors increases in the shrub component of the plant community. The reduction of grasses potentially facilitates increases in bare ground, shrub and invasive non-native plant cover.

Livestock/Grazing Interpretations:

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 1988a). 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).

The forage value of mountain rush depends on stage of maturity, density of stand, and intensity of use (USFS 1988a). Mountain rush has low palatability for cattle but they will graze it late in

the growing season after more palatable plants are eaten (Stevens 2012). Mountain rush will withstand heavier grazing use than most forage plants because of its strongly developed system of underground stems. It is often one of the last plants of a meadow to disappear on overgrazed or eroded area (USFS 1988a). *Juncus* species are also used by a wide range of mammal and avian species for food and habitat (Stevens 2012).

Basin wildrye is valuable forage for livestock (Ganskopp et al. 2007) and wildlife, but is intolerant of heavy, repeated, or 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). Inadequate rest and recovery from defoliation causes a decrease in basin wildrye and an increase in black greasewood and rubber rabbitbrush along with inland saltgrass and beardless wildrye (*Leymus triticoides*).

Hydrology of these sites is also critical for site function and maintenance. Seasonally high water tables have been found necessary for maintenance of site productivity and reestablishment of the perennial grasses following disturbances such as fire, drought or excessive herbivory (Eckert Jr et al. 1973). Lowering of the water table through extended drought, groundwater pumping or channel incision will decrease perennial grass production and establishment while shrubs and invasive weeds increase. Farming of saline-sodic soils may cause an increase in soil pH in the surface horizons leading to soil surface sealing, increased ponding and reduced infiltration. Additionally, farming may facilitate the creation of a cemented layer (plow pan) causing a reduction in root penetration of seedlings. Cessation of farming leads to rabbitbrush dominance, increased bare ground and the potential for weed invasion.

State and Transition Model Narrative for Group 22

This is a text description of the states, phases, transitions, and community pathways possible in the State and Transition model for the MLRA 27 Disturbance Response Group 22.

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 alkali sacaton, inland saltgrass, and mountain rush. Other common species include basin wildrye, western wheatgrass

(*Pascopyrum smithii*), black greasewood and Torrey's saltbush. Forbs and other grasses and grass-likes make up smaller components. Potential vegetation composition by air-dry weight is 85% grasses and grass-likes, 10% forbs and less than 5% shrubs. Approximate ground cover (basal and crown) is 40–55%. Total annual air-dry production is 1,200–3,000 lb/ac.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
Long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge which may reduce phreatophytic plants. Fire will decrease or eliminate the non-sprouting shrub cover and allow the perennial grasses to dominate the site. Sprouting shrubs may increase.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.3:
Absence of disturbance over time, significant herbivory, long-term drought or combinations of these would allow the shrub overstory to dominate the site and reduce the perennial grasses. Inland saltgrass may increase in the understory depending on the timing and intensity of herbivory. Heavy spring utilization will favor an increase in shrubs.

Community Phase 1.2:
This community phase is characteristic of a post-disturbance, early-seral community phase. Alkali sacaton and inland saltgrass dominate the community. Sprouting shrubs such as black greasewood and rubber rabbitbrush will likely sprout and return to pre-burn levels within a few years.

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 perennial grasses to increase and shrubs may decrease.

Community Phase 1.3 (At Risk):
Black greasewood, rubber rabbitbrush and Torrey's saltbush (*Atriplex torreyi*) increase in the absence of disturbance. Decadent shrubs dominate the overstory and deep-rooted perennial grasses in the understory are reduced either from competition with shrubs, herbivory, drought or combinations of these. Inland saltgrass and mountain rush are minor components.

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 or a low severity fire would reduce some shrub cover and allow for the perennial grasses to dominate the site.

Community Phase Pathway 1.3b, from Phase 1.3 to 1.2:
High severity fire, because of shrub dominance, significantly reduces shrub cover and allow for the perennial grasses to dominate the site. Sprouting shrubs will also 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 and/or perennial plants, such as cheatgrass, Russian thistle, fivehorn smotherweed, annual wheatgrass, whitetop, and broadleaved pepperweed. Saltcedar (*Tamarix ramosissima*) may also invaded ponded areas.

Slow variables: Over time the annual and/or perennial 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.

T1B: Transition from Reference State 1.0 to Agricultural State 5.0:

Trigger: Settlement of the area which included damming of the Carson, Humboldt, Truckee, and Walker rivers, construction of canals, diversion of water for irrigation, plowing and brush removal, land leveling and building furrows for irrigation.

Slow variables: Over time, local drainage improvement effectively lowered the water table. Increase in salt salinity from furrow irrigation. Reduction in soil organic carbon from the conversion of rangeland to cropland.

Threshold: Removal of native vegetation by soil disturbance causes loss of soil structure, soil compaction, reduced infiltration, increased wind and water erosion, loss of organic matter and nutrient-rich topsoil, and reduced moisture retention. These changes make restoration extremely challenging.

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 annual or perennial 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:

The plant community is dominated by alkali sacaton, inland saltgrass, and mountain rush. Other common species include basin wildrye, western wheatgrass, and black greasewood. Forbs and other grasses and grass-likes make up smaller components. Non-native species such as broadleaved pepperweed, whitetop, Russian thistle, fivehorn smotherweed and/or field bindweed may be present.

Saline Meadow (R027XY005NV), Current Potential State 2.1, T. Stringham, June 2024

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
Long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge or a low severity fire would decrease the non-sprouting shrub cover and allow the understory perennial grasses/grasslikes to increase. Brush treatments would also reduce the shrub overstory and allow the perennial grasses to increase.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.3:
Absence of disturbance over time, inappropriate grazing management, long-term drought, lowering of the water table by groundwater pumping or channel incision or combinations of these would allow the shrub overstory to dominate the site and reduce perennial grasses. Inland saltgrass may increase in the understory depending on the timing and intensity of grazing. Heavy spring utilization will favor an increase in shrub cover.

Community Phase 2.2:
This community phase is characteristic of a post-disturbance, early-seral community phase. Alkali sacaton and inland saltgrass dominate the community. Black greasewood, rubber rabbitbrush and Torrey's saltbush will decrease initially. Black greasewood and rubber rabbitbrush will likely resprout. Annual non-native species are stable to increasing in the community.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Time, lack of disturbance, release from long-term drought, and appropriate grazing management.

Community Phase 2.3 (At Risk):
Black greasewood, rubber rabbitbrush and Torrey's saltbush increase in the absence of disturbance. Decadent shrubs dominate the overstory and deep-rooted perennial grasses in the understory are reduced either from competition with shrubs, inappropriate grazing management, drought or combinations of these. Inland saltgrass and mountain rush are minor components.

Community Phase Pathway 2.3a, from Phase 2.3 to 2.1:
Heavy late fall/winter grazing causing mechanical damage to shrubs, low severity fire, and/or reduced groundwater recharge due to long-term reduction in winter snow accumulation, groundwater pumping or channel incision. Brush treatments will also decrease the shrub overstory and give a competitive advantage for existing perennial grasses.

Community Phase Pathway 2.3b, from Phase 2.3 to 2.2:
High severity fire, because of shrub dominance, significantly reduces shrub cover and allow for the perennial grasses to dominate the site. Sprouting shrubs will also increase.

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

Trigger: Inappropriate cattle/horse grazing and/or lowering of the water table, will decrease or eliminate perennial grasses and grass-likes and favor shrub establishment and growth. Soil disturbing brush treatments will reduce shrub cover and possibly increase non-native plant species.

Slow variables: Long-term decrease in perennial grass/grass-like density.

Threshold: Loss of perennial grasses 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 has one community phase, characterized by the dominance of black greasewood, rubber rabbitbrush and Torrey's saltbush. This site has crossed a biotic threshold and site processes are being controlled by shrubs. Bare ground has increased and non-native plant species may be increasing.

Community Phase 3.1:
Decadent shrubs dominate the site. Perennial grasses/grass-likes are trace to missing. Annual or perennial non-native species may be present and may be increasing in the understory.

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 phreatophytic shrubs. 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.

R3A: Restoration Pathway from Shrub State 3.0 to Current Potential State 2.0:

Restoration from the Shrub State to the Current Potential State would require mechanical or chemical brush treatment and control of non-native annual and/or perennial species. Restoration may also require raising the water table, including repair of incised channel(s) and/or reduced groundwater pumping. Seeding of native grasses may be necessary if they are severely reduced or no longer present in the community. Fire with a follow-up herbicide treatment can also be used to remove the shrub cover.

Annual / Perennial Invasive State 4.0:

This state consists of one community phase in which annual and/or or perennial invasive species control site processes. It is characterized by the loss of cropland, hay or pasture plant species and increased bare ground. Feedbacks contributing to the stability of this state include a seed bank of annual/perennial invasive species, water table reduction, plow pan, soil surface degradation or loss, nutrient loss, and increased bare ground patch size.

Community Phase 4.1 (At-Risk):
This community phase is the result of loss of irrigation water and loss of cropland, hay or pasture plant species. Conservation (farming) practices are no longer implemented and the site is allowed to naturally recolonize. The vegetative cover is dominated by non-native annual and/or perennial species. Bare ground is extensive, leaving the field susceptible to wind erosion. Trace amounts of seeded species may be present and bare ground interspaces are large and connected. Site function is controlled by non-native

vegetation. Soil erosion and redistribution is occurring. Site is at-risk of transitioning to an Abiotic State especially after several years of drought.

Saline Meadow (R027XY005NV), Annual/Perennial Invasive State 4.1, T. Stringham, June 2025

Agricultural State 5.0:

This state is characterized by an irrigated agriculture phase with either cropland, hayland or pasture. Irrigation water is critical to the production of crops in this MLRA because of low precipitation. Once irrigation water is removed the lasting effects on the soil include diminished soil stability, altered soil structure, compaction, reduced infiltration and increased wind and water erosion.

Community Phase 5.1 (Irrigated Agriculture):
This community phase is either cropland, hayland or pasture actively maintained by irrigation water during the growing season. Typical crops include alfalfa, corn, oats and wheat. Conservation practices implemented include pasture and hay planting, irrigation water management, nutrient management, forest harvest management, conservation crop rotation, and cover crop.

T5A: Transition from Agricultural State 5.0 to Annual State 4.0:

Trigger**:** Cessation of farming practices including the removal of irrigation water and the loss of cropland, hay or pasture species. Residual nitrogen and phosphorus from prior fertilizer applications favors fast-growing, early-successional non-native invasive species which dominate the site.

Slow variables: Long-term increase in non-native annual species and their associated seed bank. Native seed banks are depleted. Soil redistribution is significant.

Threshold: Reduced cover of seeded, cropland, hay or pasture plant species due to the removal of irrigation and farming practices facilitates invasion of non-native annual species. Changes in plant community composition and spatial variability of vegetation due to the loss of crop, hay or pasture species truncates energy capture spatially and temporally thus impacting nutrient cycling and distribution. Soil compaction, soil surface degradation and redistribution lead to decreased infiltration, increased flow path length, crusting, salt accumulation on the soil surface and altered soil biology.

States Not Observed in Group 22:

Abiotic State: This state may occur after several years of drought and the site transitions from the Annual State to the Abiotic State. This state may also occur from the Shrub State after land clearing or groundwater withdrawal. The 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.

Potential Resilience Differences with other Ecological Sites in this Group

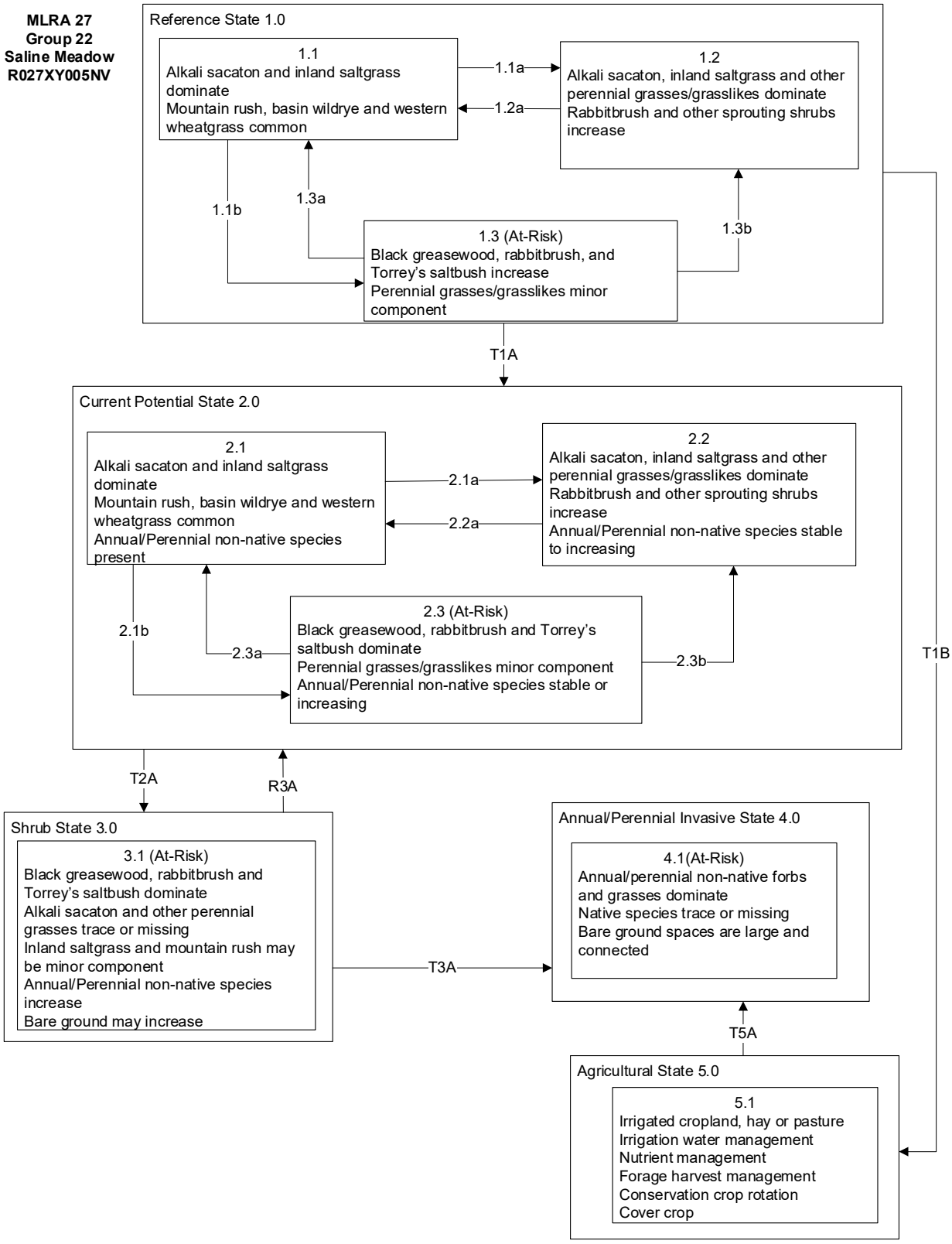
Sodic Bottom (R027XY089NV):

This site occurs on alluvial flats, axial-stream floodplains and on the fringe of intermittent lakes. Slopes are less than 2% and elevations range from 4,000 to 4,800 ft. The soils of this site are very deep and poorly to somewhat poorly drained. Soils are strongly saline-alkaline. The soils are typically saturated during the late winter and early spring. During drier periods, the water table lowers to depths > 60 in. The reference plant community is dominated by inland saltgrass. Potential vegetative composition is approximately 95% grass and grass-like plants, with 5% or less forbs and shrubs. Total annual air-dry production ranges from 200 to 1,000 lb/ac. With site deterioration, inland saltgrass cover initially increases as other perennial grasses and grass-like plants decrease and the amount of salt-crusted, bare ground increases. Locations that are ponded for prolonged periods may be dominated by annual wheatgrass or foxtail barley (*Hordeum jubatum*). This site has similar resilience as the modal and would have the same ecological states.

Dry Saline Meadow (R027XY090NV):

This site occurs on alluvial flats, lake plains and axial-stream floodplains. Slopes are less than 2% and elevations range from 4,000 to 4,800 ft. The soils of this site are very deep and poorly to somewhat poorly drained. They are strongly salt and sodium affected. There is often a water table at or near the surface during the spring that usually stabilizes at depths below 40 in. during the early summer. The reference plant community is dominated by inland saltgrass. Potential vegetative composition is approximately 95% grass and grass-like plants, with 5% or less forbs and shrubs. Total annual air-dry production ranges from 1,000 to 2,200 lb/ac. With site deterioration, inland saltgrass cover initially increases as other perennial grasses and grass-like plants decrease and the amount of salt-crusted, bare ground increases. This site has similar resilience as the modal.

Modal State and Transition Model for Group 22 in MLRA 27



MLRA 27
Group 22
Saline Meadow
R027XY005NV
KEY

Reference State 1.0 Community Pathways
1.1a: Long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge. Fire will decrease or eliminate the non-sprouting shrub cover and allow the perennial bunchgrasses to dominate the site. Sprouting shrubs may increase.
1.1b: Time and lack of disturbance such as fire, long-term spring/summer drought or combinations of these would allow the shrub overstory to dominate the site and reduce the perennial bunchgrasses. Inland saltgrass may increase in the understory depending on timing and intensity of herbivory by wildlife. Heavy spring utilization will favor shrubs.
1.2a: Time and lack of disturbance and/or release from chronic winter drought will allow perennial grasses to increase and shrubs may decrease.
1.3a: Long-term reduction in winter snow accumulation may lead to reduced groundwater recharge, or low severity fire would reduce non-sprouting shrub cover and allow for the perennial grasses to dominate the site.
1.3b: High severity fire, because of shrub dominance, significantly reduces shrub cover and allows for increases in perennial grasses and sprouting shrubs.

Transition T1A: Introduction of non-native annual/perennial plants.

Transition T1B: Settlement of the area and beginning of agriculture.

Current Potential State 2.0 Community Pathways:
2.1a: Long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge, or low severity fire would reduce non-sprouting shrub cover and allow for the understory perennial grasses to increase. Brush treatments would also reduce the shrub overstory and allow the perennial grasses to increase. Non-native species are likely to increase after fire.
2.1b: Time and lack of disturbance such as fire, long-term spring/summer drought, inappropriate grazing management, lowering of groundwater or combinations of these. Shrubs and inland saltgrass increase.
2.2a: Time, lack of disturbance, release from chronic winter drought, and/or appropriate grazing management.
2.3a: Heavy late fall/winter grazing causing mechanical damage to shrubs, low severity fire, and/or reduced groundwater recharge due to a long-term reduction in winter snow accumulation, groundwater pumping or channel incision. Brush treatments will also decrease the shrub overstory.
2.3b: High severity fire, because of shrub dominance, significantly reduces shrub cover and increases perennial grasses. Sprouting shrubs will increase.

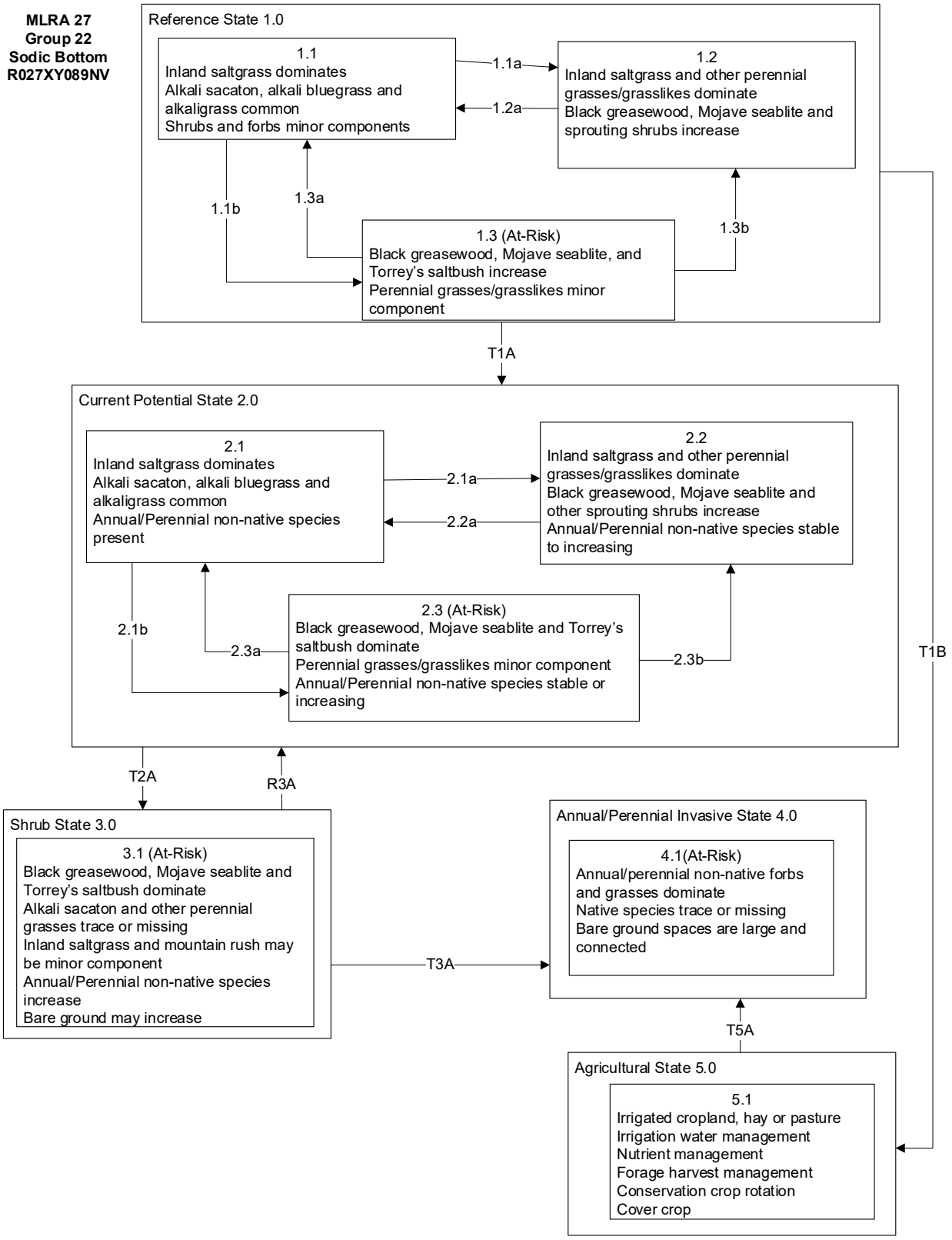
Transition T2A: Long-term inappropriate cattle/horse grazing, and/or lowering of the water table will decrease or eliminate perennial grasses/ grass-likes and favor shrub establishment and growth. Soil disturbing treatments will also reduce shrub cover and possibly increase non-native plant cover.

Transition T3A: Long-term winter drought and/or groundwater pumping lowers groundwater reducing vitality of phreatophytic shrubs. May be combined with inappropriate grazing facilitating an increase in density and production of annual non-native forbs.

Restoration R3A: Restoration from the Shrub State to the Current Potential State would require mechanical or chemical brush treatment and control on non-native plant species. Restoration may also require raising the water table, repair of incised channels and reduction in groundwater pumping. Seeding of native species may also be necessary. Prescribed fire with a follow-up herbicide treatment can also be used to reduce shrub cover.

Transition T5A: Cessation of farming practices including the removal of irrigation water and loss of cropland, hay or pasture species. Invasion by non-native annual/perennial species leads to dominance of those species.

Additional State and Transition Models for Group 22 in MLRA 27



MLRA 27
Group 22
Sodic Bottom
R027XY089NV
KEY

Reference State 1.0 Community Pathways
1.1a: Long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge. Fire will decrease or eliminate the non-sprouting shrub cover and allow the perennial bunchgrasses to dominate the site. Sprouting shrubs may increase.
1.1b: Time and lack of disturbance such as fire, long-term spring/summer drought or combinations of these would allow the shrub overstory to dominate the site and reduce the perennial bunchgrasses. Inland saltgrass may increase in the understory depending on timing and intensity of herbivory by wildlife. Heavy spring utilization will favor shrubs.
1.2a: Time and lack of disturbance and/or release from chronic winter drought will allow perennial grasses to increase and shrubs may decrease.
1.3a: Long-term reduction in winter snow accumulation may lead to reduced groundwater recharge, or low severity fire would reduce non-sprouting shrub cover and allow for the perennial grasses to dominate the site.
1.3b: High severity fire, because of shrub dominance, significantly reduces shrub cover and allows for increases in perennial grasses and sprouting shrubs.

Transition T1A: Introduction of non-native annual/perennial plants.

Transition T1B: Settlement of the area and beginning of agriculture.

Current Potential State 2.0 Community Pathways:
2.1a: Long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge, or low severity fire would reduce non-sprouting shrub cover and allow for the understory perennial grasses to increase. Brush treatments would also reduce the shrub overstory and allow the perennial grasses to increase. Non-native species are likely to increase after fire.
2.1b: Time and lack of disturbance such as fire, long-term spring/summer drought, inappropriate grazing management, lowering of groundwater or combinations of these. Shrubs and inland saltgrass increase.
2.2a: Time, lack of disturbance, release from chronic winter drought, and/or appropriate grazing management.
2.3a: Heavy late fall/winter grazing causing mechanical damage to shrubs, low severity fire, and/or reduced groundwater recharge due to a long-term reduction in winter snow accumulation, groundwater pumping or channel incision. Brush treatments will also decrease the shrub overstory.
2.3b: High severity fire, because of shrub dominance, significantly reduces shrub cover and increases perennial grasses. Sprouting shrubs will increase.

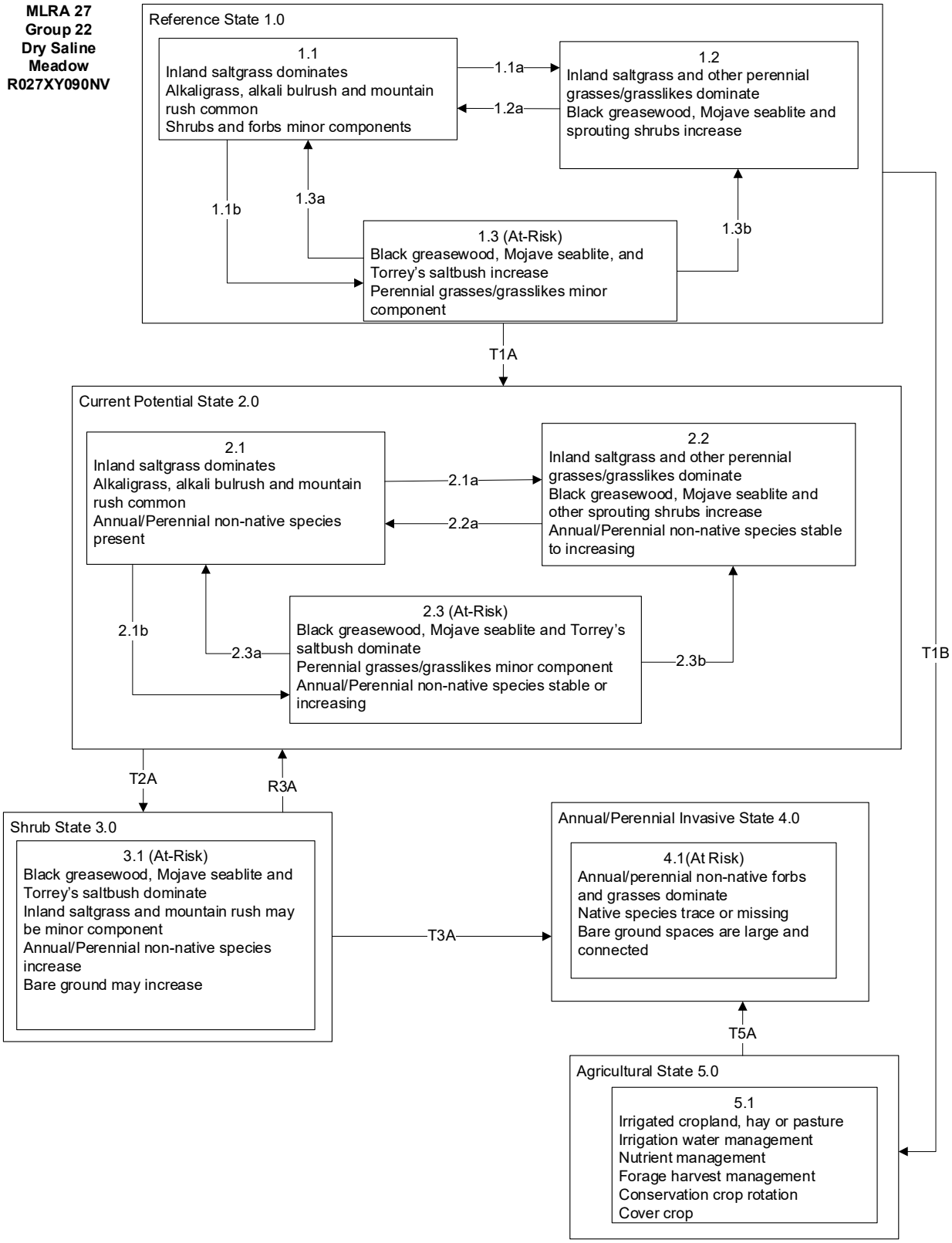
Transition T2A: Long-term inappropriate cattle/horse grazing, and/or lowering of the water table will decrease or eliminate perennial grasses/ grass-likes and favor shrub establishment and growth. Soil disturbing treatments will also reduce shrub cover and possibly increase non-native plant cover.

Transition T3A: Long-term winter drought and/or groundwater pumping lowers groundwater reducing vitality of phreatophytic shrubs. May be combined with inappropriate grazing facilitating an increase in density and production of annual non-native forbs.

Restoration R3A: Restoration from the Shrub State to the Current Potential State would require mechanical or chemical brush treatment and control on non-native plant species. Restoration may also require raising the water table, repair of incised channels and reduction in groundwater pumping. Seeding of native species may also be necessary. Prescribed fire with a follow-up chemical treatment can also be used to reduce shrub cover.

Transition T5A: Cessation of farming practices including the removal of irrigation water and loss of cropland, hay or pasture species. Invasion by non-native annual/perennial species leads to dominance of those species.

MLRA 27
Group 22
Dry Saline
Meadow
R027XY090NV



MLRA 27
Group 22
Dry Saline Meadow
R027XY090NV
KEY

Reference State 1.0 Community Pathways
1.1a: Long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge. Fire will decrease or eliminate the non-sprouting shrub cover and allow the perennial bunchgrasses to dominate the site. Sprouting shrubs may increase.
1.1b: Time and lack of disturbance such as fire, long-term spring/summer drought or combinations of these would allow the shrub overstory to dominate the site and reduce the perennial bunchgrasses. Inland saltgrass may increase in the understory depending on timing and intensity of herbivory by wildlife. Heavy spring utilization will favor shrubs.
1.2a: Time and lack of disturbance and/or release from chronic winter drought will allow perennial grasses to increase and shrubs may decrease.
1.3a: Long-term reduction in winter snow accumulation may lead to reduced groundwater recharge, or low severity fire would reduce non-sprouting shrub cover and allow for the perennial grasses to dominate the site.
1.3b: High severity fire, because of shrub dominance, significantly reduces shrub cover and allows for increases in perennial grasses and sprouting shrubs.

Transition T1A: Introduction of non-native annual/perennial plants.

Transition T1B: Settlement of the area and beginning of agriculture.

Current Potential State 2.0 Community Pathways:
2.1a: Long-term reduction in winter snow accumulation due to drought may lead to reduced groundwater recharge, or low severity fire would reduce non-sprouting shrub cover and allow for the understory perennial grasses to increase. Brush treatments would also reduce the shrub overstory and allow the perennial grasses to increase. Non-native species are likely to increase after fire.
2.1b: Time and lack of disturbance such as fire, long-term spring/summer drought, inappropriate grazing management, lowering of groundwater or combinations of these. Shrubs and inland saltgrass increase.
2.2a: Time, lack of disturbance, release from chronic winter drought, and/or appropriate grazing management.
2.3a: Heavy late fall/winter grazing causing mechanical damage to shrubs, low severity fire, and/or reduced groundwater recharge due to a long-term reduction in winter snow accumulation, groundwater pumping or channel incision. Brush treatments will also decrease the shrub overstory.
2.3b: High severity fire, because of shrub dominance, significantly reduces shrub cover and increases perennial grasses. Sprouting shrubs will increase.

Transition T2A: Long-term inappropriate cattle/horse grazing, and/or lowering of the water table will decrease or eliminate perennial grasses/ grass-likes and favor shrub establishment and growth. Soil disturbing treatments will also reduce shrub cover and possibly increase non-native plant cover.

Transition T3A: Long-term winter drought and/or groundwater pumping lowers groundwater reducing vitality of phreatophytic shrubs. May be combined with inappropriate grazing facilitating an increase in density and production of annual non-native forbs.

Restoration R3A: Restoration from the Shrub State to the Current Potential State would require mechanical or chemical brush treatment and control on non-native plant species. Restoration may also require raising the water table, repair of incised channels and reduction in groundwater pumping. Seeding of native species may also be necessary. Prescribed fire combined with a follow-up chemical treatment can also be used to reduce shrub cover.

Transition T5A: Cessation of farming practices including the removal of irrigation water and loss of cropland, hay or pasture species. Invasion by non-native annual/perennial species leads to dominance of those species.

References

Alpert, P. 1990. Water sharing among ramets in a desert population of *Distichlis spicata* (Poaceae). American Journal of Botany **77**:1648-1651.

Archer, W. M. 1984. Soil Survey of Lyon County Area, Nevada. U.S.D.A. Soil Conservation Service, Washington D.C.

Bates, J. D., T. Svejcar, R. F. Miller, and R. A. Angell. 2006. The effects of precipitation timing on sagebrush steppe vegetation. Journal of Arid Environments **64**:670-697.

Beatley, J. C. 1975. Climates and vegetation pattern across the Mojave/Great Basin Desert transition of southern Nevada. The American Midland Naturalist **93**:53-70.

Bock, C. E., and J. H. Bock. 1978. Response of birds, small mammals, and vegetation to burning sacaton grasslands in southeastern Arizona. Journal of Range Management **31**:296-300.

Brakie, M. 2007. Plant guide for alkali sacaton (*Sporobolus airoides*). U.S. Department of Agriculture, Natural Resources Conservation Service, East Texas Plant Materials, Nacogdoches, TX.

Caudle, D., J. DiBenedetto, M. Karl, H. Sanchez, and C. Talbot. 2013. Interagency ecological site handbook for rangelands. U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.

Chambers, J. C., B. A. Bradley, C. S. Brown, C. D'Antonio, M. J. Germino, J. B. Grace, S. P. Hardegree, R. F. Miller, and D. A. Pyke. 2013. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of western North America. Ecosystems **17**:360-375.

Comstock, J. P., and J. R. Ehleringer. 1992. Plant adaptation in the Great Basin and Colorado Plateau. The Great Basin Naturalist **52**:195-215.

Eckert Jr, R. E., A. D. Bruner, and G. J. Klomp. 1973. Productivity of tall wheatgrass and Great Basin wildrye under irrigation on a greasewood-rabbitbrush range site. Journal of Range Management **26**:286-288.

Everett, R. L., P. T. Tueller, J. B. Davis, and A. D. Brunner. 1980. Plant phenology in galleta-shadscale and galleta-sagebrush associations. Rangeland Ecology & Management/Journal of Range Management Archives **33**:446-450.

Ganskopp, D., L. Aguilera, and M. Vavra. 2007. Livestock forage conditioning among six northern Great Basin grasses. Rangeland Ecology & Management **60**:71-78.

Headley, F. B., and C. Venstrom. 1930. Economic History of the Newlands Irrigation Project. University of Nevada.

Hickey, W. C., Jr., and H. W. Springfield. 1966. Alkali sacaton: Its merits for forage and cover. Journal of Range Management **19**:71-74.

Krall, J. L., J. R. Stroh, C. S. Cooper, and S. R. Chapman. 1971. Effect of time and extent of harvesting basin wildrye. Journal of Range Management **24**:414-418.

Langan, L. N., E. Cole, and R. Mayhugh. 1965. Soil Survey of the Lovelock Area, Nevada. U.S. Government Printing Office, Washington D.C.

Majerus, M. E. 1992. High-stature grasses for winter grazing. Journal of Soil and Water Conservation **47**:224-225.

Marcum, K. B., and D. M. Kopec. 1997. Salinity tolerance of turfgrasses and alternative species in the subfamily Chloridoideae (Poaceae). International Turfgrass Society Research Journal **8**:735-742.

Mathie, A. M., T. L. Welborn, D. D. Susong, and M. L. Tumbusch. 2011. Phreatophytic land-cover map of the northern and central Great Basin ecoregion: California, Idaho, Nevada, Utah, Oregon, and Wyoming. Pamphlet to accompany Scientific Investigations Map 3169, U.S. Department of the Interior, U.S. Geological Survey, Reston, VA.

Meinzer, O. E. 1927. Plants as indicators of ground water. Water-Supply Paper 577, U.S. Department of the Interior, U.S. Geological Survey, Washington, D.C.

Miller, R. F., S. T. Knick, D. A. Pyke, C. W. Meinke, S. E. Hanser, M. J. Wisdom, and A. L. Hild. 2008a. Characteristics of sagebrush habitats and limitations to long-term conservation. Administrative Report, U.S. Department of the Interior; U.S. Geological Survey, Reston, VA.

Monsen, S. B., R. Stevens, and N. L. Shaw. 2004a. Grasses. Pages 295-424 *in* S. B. Monsen, R. Stevens, and N. L. Shaw, editors. Restoring western ranges and wildlands, vol. 2. Gen. Tech. Rep. RMRS-GTR-136-vol-2. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Newman, S. D., and M. Gates. 2000. Plant guide for saltgrass (*Distichlis spicata*). U.S. Department of Agriculture, Natural Resource Conservation Service, Alexandria, LA.

NRCS. 2022. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. Handbook 296, U.S. Department of Agriculture, Natural Resources Conservation Service.

Ogle, D. G., D. Tilley, and L. St. John. 2012b. Plant guide for basin wildrye (*Leymus cinereus*). U.S. Department of Agriculture, Natural Resources Conservation Service, Idaho State Office & the National Plant Data Center, Aberdeen, ID.

Paysen, T. E., R. J. Ansley, J. K. Brown, G. J. Gottfried, S. M. Haase, M. G. Harrington, M. G. Narog, S. S. Sackett, and R. C. Wilson. 2000. Chapter 6: Fire in western shrubland, woodland, and grassland ecosystems. Pages 121-159 *in* J. K. Brown and J. K. Smith, editors. Wildland fire in ecosystems: Effects of fire on flora. General Technical Report RMRS-GTR-42-Vol. 2. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Perryman, B. L., and Q. D. Skinner. 2007. A Field Guide to Nevada Grasses. Indigenous Rangeland Management Press, Lander, WY.

Pritchett, D. W., and S. J. Manning. 2009. Effects of fire and groundwater extraction on alkali meadow habitat in Owens Valley, California. Madroño **56**:89-98.

Qian, Y. L., J. A. Cosenza, S. J. Wilhelm, and D. Christensen. 2006. Techniques for enhancing saltgrass seed germination and establishment. Crop Science **46**:2613-2616.

Reynolds, T. D., and L. Fraley, Jr. 1989. Root profiles of some native and exotic plant species in southeastern Idaho. Environmental and Experimental Botany **29**:241-248.

Skaradek, W., and C. Miller. 2010. Plant fact sheet for saltgrass (*Distichlis spicata*). USDA NRCS Cape May Plant Materials Center, Cape May, NJ.

Stevens, M., Hoag, C., Tilley,D., and L. St. John. 2012. Plant Guide for Mountain Rush (Juncus articus Willd. ssp. littoralis (Engelm.) Hulten. Aberdeen Plant Materials Center, Aberdeen, ID.

Strahorn, A. T. a. C. V. D. 1909. Soil Survey of the Fallon Area, Nevada. USDA-Natural Resources Conservation Service.

Stuart, D. M., G. E. Schuman, and A. S. Dylla. 1971. Chemical characteristics of the coppice dune soils in Paradise Valley, Nevada. Soil Science Society of America Journal. Division S-5 - Soil Genesis, Morphology, and Classification **35**:607-611.

USFS. 1988a. Range plant handbook. Reprint of 1937 edition. Dover Publications, New York, NY.

Wehking, P. M. 2002. The role of the seedbank in the restoration of a basin big sagebrush-dominated riparian ecosystem to a dry meadow. University of Nevada, Reno.

Zschaechner, G. A. 1985. Studying rangeland fire effects: A case study in Nevada. Pages 66-84 *in* Rangeland fire effects: a symposium; Boise, ID; November 27-29, 1984. U.S. Department of the Interior, Bureau of Land Management, Idaho State Office, Boise, ID.

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 27 STM Project**

   Field notes and landscape photographs collected between 2021 and 2026.

3. **List of all site visits for the MLRA 27 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 soil-derived dominant DRG features and site visit locations.