Part 645 – National Range and Pasture Handbook

Subpart B – Ecological Sites, Ecological Site Descriptions: Ecological Classification as a Concept and Use in Conservation Planning and Resource Monitoring

645.0201 General Information

A. Purpose

Ecological Site Descriptions (ESDs) serve as a classification concept, which are integral to grazing land planning, monitoring, and assessment. The purpose of this subpart is to provide an explanation and understanding of ecological site descriptions as a decision-support tool for conservation planning and management on grazing lands. Ecological site descriptions also describe other inherent land uses such as pasture, agroforestry, and cropland. The objective of this subpart is to also augment sections of the National Ecological Site Handbook and provide additional dialogue on the importance of ecological sites in NRCS conservation activities.

B. Introduction

The Ecological Site is an essential ecological concept used in conservation planning, monitoring, evaluation, and adaptation of management for all land types and uses. Ecological Site Descriptions serve as references and are the working document for the following uses:

(i) Describe unique ecological parameters based on properties inherent to specific landscape features.

(ii) Use quantitative environmental factors and qualitative information based on field-observable features.

(iii) Provide an ecological reference and historical document that serves as a basis for land management activities related to the site.

(iv) Provide reference information for monitoring and assessment activities.

C. Ecological Site Reference Material

(1) The Natural Resources Conservation Service (NRCS) utilizes three handbooks that serve as technical and procedural references to support policies and responsibilities for the development of ecological site concepts and ecological site descriptions.

(i) Title 190, Interagency Ecological Site Handbook for Rangelands (190-IESHR): The 190-IESH for Rangelands was developed to implement the policy outlined in the Title 190, Rangeland Interagency Ecological Site Manual (RIESM). This policy provides direction to the Bureau of Land Management (BLM), U.S. Forest Service (USFS), and the NRCS to cooperatively identify and describe rangeland ecological sites for use in inventory, monitoring, evaluation, and management of the Nation’s rangelands. This is a response, in part, to direction from Congress in the Department of the Interior and Related Agencies Appropriations Act of 2002. This interagency handbook includes ecological sites as the component of ecological classification at local management levels and provides a standardized method to be used by the BLM, USFS, and NRCS to define, delineate, and describe terrestrial ecological sites on rangelands.

(ii) Title 190, National Ecological Site Handbook (190-NESH): Provides standards, guidelines, and definitions to support policies and indicates the responsibilities and procedures for conducting the collaborative process for development of ES concepts and ESD information. Responsibilities for ES activity are shared among disciplines, including soil science, range science, forestry, agronomy, wildlife biology, hydrology, and ecology.

The 190-NESH is specific to NRCS, but it adheres to the guidelines established in the Title 190, Interagency Ecological Site Handbook for Rangelands. The standards set in the NESH are specific for policy, development, and use by NRCS.

(iii) Title 190, National Range and Pasture Handbook, Part 645 (NRPH): 190-NRPH-645 reviews NRCS policies and procedures for assisting farmers, ranchers, groups, organizations, units of government, and others working through conservation districts in planning and applying resource conservation on non-Federal grazing lands throughout the United States. This handbook also serves as a general reference for grazing lands resource information and was developed by NRCS grazing lands specialists, using current technical references including textbooks, scientific publications, manuals, and expert knowledge.

(2) Other handbooks such as the National Soil Survey Handbook, Soil Survey Manual, National Forestry Handbook, National Forestry Manual, and National Biology Manual provide additional supporting information for ecological site development.[1] .Responsibilities for ES activities are shared among disciplines, including soil science, range science, forestry, agronomy, animal science, wildlife biology, hydrology, and ecology.

(3) The Ecosystem Dynamics Interpretative Tool (EDIT), a Web-based database, has replaced the Ecological Site Information System (ESIS) as the official repository of ESDs for the NRCS.

645.0202 Ecological Site Concept

A. Historical background

(1) Two underlying themes (or hypotheses) of plant ecology which categorize vegetation patterns across landscapes have emerged since the early 1900s: the community unit theory and the individualistic-continuum concept.

(i) The debate regarding the nature of community organization has been discussed for almost a century (Whittaker 1962; Shipley and Keddy 1987; Austin and Smith 1990; McIntosh 1995; Callaway 1997; Reinhart 2012) and started with a basic question: “are plant communities an organized system of co-occurring species, or an assemblage of a random collection of individualistic species arriving on a site that varies continuously with environmental change across the landscape?” Frederick E. Clements (1874–1945), an American plant ecologist who presented the view of organismic concept of communities – also called the community-unit concept – proposed that plant communities were holistic and interdependent (Clements, 1916). Plant communities were likened to a facsimile of an individual organism (growth, maturation, and death), visualized as natural units of coevolved species populations forming homogeneous, discrete, and recognizable vegetation units.

(ii) In contrast, Henry Allan Gleason (1882–1975), an American botanist, advocated the individualistic continuum concept or individualistic concept of community organization, where communities are a collection of species that have commonality with respect to adaptations to the abiotic environment (Gleason 1926, 1939). The transition to the individualistic viewpoint gained momentum when Whittaker (1967) used sophisticated gradient analyses, which showed patterns of species replacements along a gradient representing the continuum. Ecologists now recognize that species dynamics (existence, composition, fitness, distribution), are not wholly dependent on abiotic conditions and

[1] These handbooks and manuals may not reflect the most recent ESD guidelines and procedures. The purpose of Subpart B of the NRPH is to highlight and maintain current policy and technology changes regarding ESDs.

competition, but are highly affected by complex interactions within the plant community, mutualists, and consumers (Callaway 1997).

(2) In reality, vegetation and species populations in plant communities continuously intergrade along environmental gradients, or the continuum. However, plant communities with similar species assemblages are also repetitive and recognizable on the landscape. As Whittaker (1975) later stated: "…classifications of communities are often needed. There is no real conflict between the principle that communities are generally (but not universally) continuous with one another, and the practice of classifying these communities as a means of communication about them" (Whittaker 1975). Land managers recognize the fact that a continuum cannot be effectively managed. Ecologists recognize that plant species are distributed in space and respond according to unique genetic, physiological, life-cycle characteristics; and physical and environmental factors.

(3) Community-units are characterized as homogenous discrete community units organized in a hierarchical structure (e.g., plant communities, cover types, habitat types, and ecological sites). Although vegetation occurs along a continuum, ecological understanding and land management are facilitated by forming homogeneous recognizable groups such as the ecological site.

B. Ecological Site Definition

An ecological site is a conceptual classification of the landscape. It is a distinctive land unit based on a recurring landform with distinct soils (chemical, physical, and biological attributes), kinds and amounts of vegetation, hydrology, geology, climatic characteristics, inherent ecological resistance and resiliency, unique successional dynamics and pathways, natural disturbance regimes, geologic and evolutionary history including herbivore and other animal impacts, and response to management actions and natural disturbances. These discrete characteristics separate one ecological site from another.

C. Classifying Ecological Sites

(1) NRCS classifies rangeland and forestland into ecological sites for scientific study, evaluation, monitoring, planning activities, and management. Alternative land uses such as pasture and crop can be represented in the ecological site state-and-transition model.

(2) Ecological sites are classified and correlated with soil map units and components. When landscapes are categorized into ESs, unique ecological processes and abiotic factors allow for more specific, targeted management goals and objectives, monitoring plans, and assessments of management actions. The adoption of ESs as fundamental land units subdivides the landscape into groups representing discrete responses to environmental conditions and subsequent disturbances, which helps to identify appropriate management and restoration targets (Monaco et al. 2015). Ecological sites integrate ecological concepts (figure B-1), including plant and soil interactions, hydrologic dynamics, successional pathways, equilibrium and nonequilibrium concepts pertinent to the discrete aspects of community structure, ecological gradients, and spatial and temporal heterogeneity (Moseley et al. 2010) (figure B-2).

Figure B-1. Environmental and Ecological Factors associated with Ecological Sites.

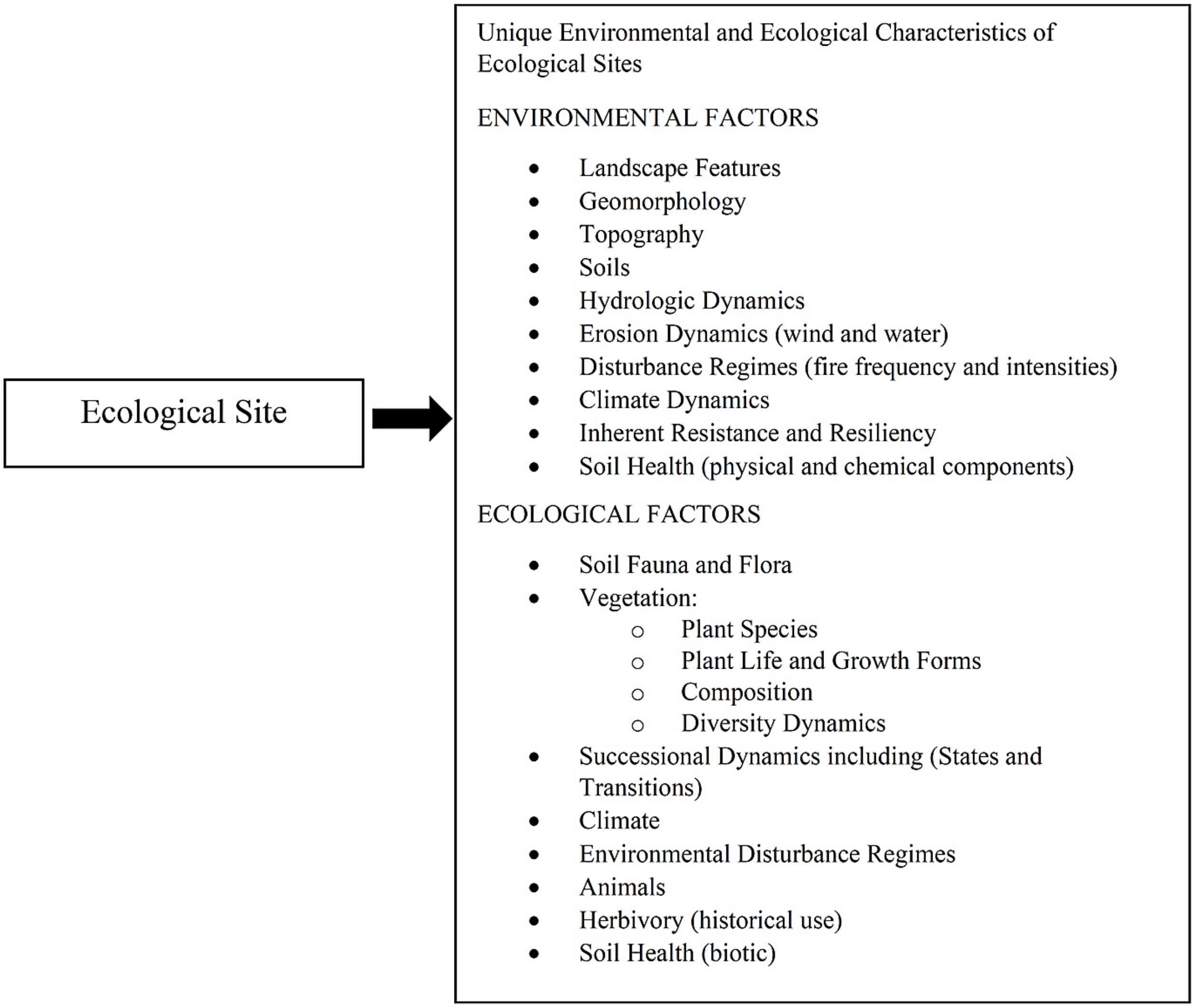
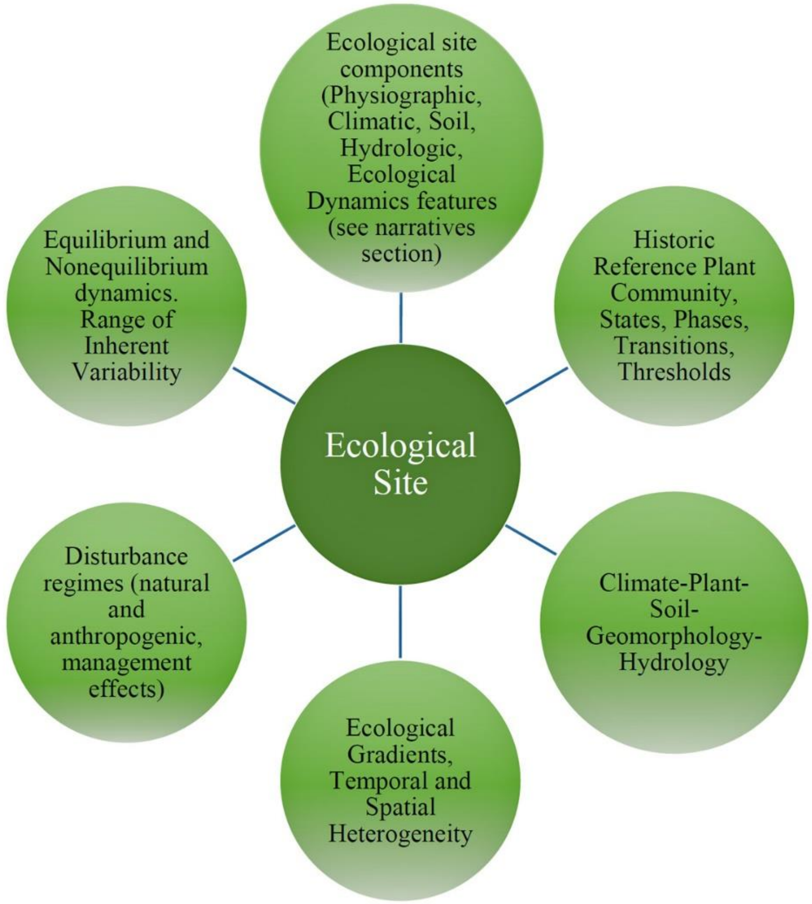


Figure B-2. Interacting ecological components and ecological factors relating to Ecological Sites.



645.0203 Developing Ecological Site Descriptions

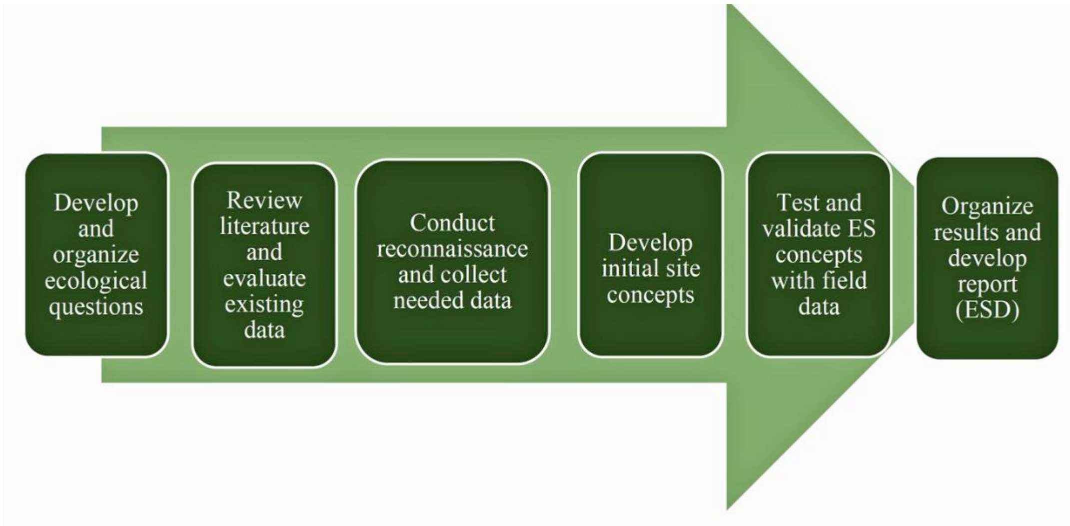
A. Ecological sites are described using the modal concept approach with typifies a representative example of plant community composition and associated environmental factors. The ESD contains information about the representative site concept rather than including detailed information about outlier aspects of the site. However, variability may be unusually high (e.g., mound-intermound; dune-interdune settings) in some ecological sites because of environmental factors; therefore, these dynamics need to be discussed.

B. Within NRCS, the ESD development effort is a collaborative effort between Soil Science and Resource Assessment, Science and Technology, Conservation Planning and Program Delivery Deputy Areas as well as State Technical and Field Office personnel.

(1) At the local level, NRCS Soil Survey Offices lead technical teams comprised of NRCS technical specialists, personnel from partnering state and federal agencies, universities, and non-government organizations, as well as landowners/managers and/or other stakeholders. Diverse technical teams ensure ESDs are reliable and credible.

(2) Figure B.3 illustrates the general steps in the ES development process. For specific standards, procedures, and guidance for developing ESDs please refer to Title 190, National Ecological Site Handbook (190-NESH).

Figure B-3. General steps in the ES development process.



645.0204 Contents of an Ecological Site Description

A. This section provides a summary of the contents of an ecological site description. For more detailed information, especially on how to develop these sections, see NESH 2017. The official repository of ESDs is the Ecosystem Dynamics Interpretative Tool (EDIT).

B. General Information – Status

(1) Draft: An established ESD in EDIT that has not undergone quality control and quality assurance and is not available to the public.
(2) Provisional: A provisional ESD has undergone quality control and quality assurance review and is viewable to the public. It contains a working state-and-transition model and sufficient information to identify the ecological site.
(3) Approved: An approved ESD has undergone quality control and quality assurance review. It must contain a defined set of criteria. In general, approved ESDs are a more comprehensive and complete document than a provisional ESD.
   (i) <u>Site ID</u>: Alphabetic and numeric characters that represent the Land Resource Region (LRR), Major Land Resource Area (MLRA), Land Resource Area (if applicable), and the ecological site ID number.
   (ii) <u>Legacy ID</u>: If applicable, the code that was used in the first generation of ESDs.
   (iii) <u>Ecological Site Name</u>: A descriptive abiotic common name and a biotic plant community name. The biotic name includes both the scientific and common plant species names.

C. Hierarchical Classification

(1) MLRA Notes: A description of residing MLRA and LRU (if applicable) (see Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin Handbook 296).
(2) Classification Relationship: A comparison of other ecological classifications (e.g., USDA Forest Service, US Environmental Protection Agency) to NRCS's classification (LRR, MLRA, LRU). If applicable stream and wetland classifications may be included.
(3) Ecological Site Concept: A summary of characteristic abiotic and biotic indicators, including ecological dynamics, that differentiate the site from others. This may include information on climate, topography, hydrology, geomorphology, vegetation, and soil characteristics.

(4) State Correlation: States where the ecological site has been identified.
(5) Associated Sites: Other ESs commonly located adjacent to or associated with the ES. A diagram is often used to denote landscape position in relation to other sites.
(6) Similar Sites: ESs that resemble the site.

D. Physiographic Features

A description of the physiographic features of the ES such as landscape position, landform, geology (lithology and stratigraphy), aspect, site elevation, slope, water table, flooding, ponding, and runoff potential.

E. Climate Features

A description of the climatic features that typify the ES and relate to its potential, and characterize the dynamics of the ES, such as storm intensity, frequency of catastrophic storm events, and drought and/or temperature cycles. Climatic features also include frost-free period, freeze-free period, mean annual precipitation, monthly moisture and temperature distribution, and location of climate stations used to evaluate and determine means and averages. Many ecological sites occur in areas for which appropriate climate station data are not available. Climate data included in an ESD may be extrapolated from climate models (e.g., PRISM). A listing of climate stations used is also included in the ESD.

F. Influencing Water Features

Description of water features or adjacent wetland or riparian water regimes that influence the vegetation or management of the site and make the site distinctive from other ESs. Information can include subsurface waterflow, seasonal groundwater levels, overland flow, streams, springs, wetland, and depressions. Use terminology associated with Wetland Classification (Cowardin 1979), Rosgen Stream Classification (Rosgen and Silvey 1996), or another established water or hydrology-related classification system.

G. Soil Features

(1) Representative soil features include soil physical and chemical attributes such as parent material, surface and subsurface texture, surface and subsurface fragments, drainage class, hydrologic conductivity (permeability class), depth to diagnostic horizons, soil depth, electrical conductivity, sodium adsorption ratio, calcium carbonate equivalent, soil reaction (pH), and available water capacity. The representative soil features narrative presents the inherent range that corresponds with the ecological site concept, while also describing expected variability associated with the ecological site.
(2) A new feature related to soil dynamics is soil health and quality. Discussion and information relative to these topics can be described for the reference state and succeeding alternative states. Soil carbon/Organic carbon dynamics can be discussed with baseline information to provide a reference for steady-state levels and potential losses attributed to various disturbances.

H. Hydrology Features

(1) This section contains information about site hydrology: run-on and runoff characteristics on the landscape, infiltration dynamics with respect to plant life/growth form and species, potential water holding capacity, drainage, and erosion dynamics and potential risks based on long-term average precipitation and from design storm frequencies (e.g., 2, 5, 10, 25, 50, 75, 100-year storms) (see subpart G). Eco-hydrologic topics including water flow patterns, overland flow, subsurface flows, evaporative rates, and discussion on their influence on plant compositional changes and corresponding hydrologic changes should also be included. The NOAA Atlas 14-point precipitation frequency estimates data can be included to provide

valuable information for discussions of rainfall intensity and frequency for the representative climate station associated with the ecological site.

(2) On rangelands, the Rangeland Hydrology and Erosion Model (RHEM) can be used to compare runoff and erosion risks and changes, with corresponding changes in the state-and-transition model (Williams et al. 2016). The RHEM model can also be used to evaluate pastureland sites[2]. The rangeland hydrology and erosion model evaluates runoff and erosion dynamics based on long term averages and for high intensity storm frequencies (2 to100-yr storm intensities) (see subpart G).

(3) The hydrologic features narrative should discuss the inherent range of variability that corresponds with the ecological site concept, while also explaining any allowable and typical variation across the ecological site (See subpart G for example on hydrology writeup with RHEM model information and interpretations). See Appendices A and B as example of a state and transition diagram with hydrology and erosion estimates associated with various states and phases.

I. Ecological Dynamics

The ecological dynamics section provides historical context and describes how the ecological processes and plant communities of the site are impacted by and react to the natural variability of weather, fire, native herbivory, and other natural disturbances (see appendix B-B). Site resistance and resiliency to anthropogenic disturbances should also be addressed such as livestock grazing and dominant plant physiological response to grazing. Other general information regarding the dynamics of the site should be described, such as human management impacts. Use citations from the scientific literature and if expert knowledge is used, list in the "Other References" section of the ESD. References to climate, soil, hydrologic features are common to support discussion of ecological dynamics.

J. State and Transition Diagram

(1) A state-and-transition model (STM) describes the temporal dynamics of an ES. STMs display and describe the historic plant community or reference state, and multiple states and community phases (unique combinations of biotic and abiotic attributes), and the transitions between states (driving forces, processes, and thresholds). An STM provides a general graphical overview of ecological states and transitions, and the accompanying narrative describes these in detail (figure B-4). Although STMs graphically display specific successional trajectories or pathways, they do not explicitly explain or propose theories regarding plant successional dynamics that may be unique among plant community types (figures B-4, B-5. Also see Appendices B-A, B-B, B-C). The use and benefits of using STMs in conservation planning are to provide a framework for discussion with clients to address the ecological dynamics associated with current conditions and help assess and predict future changes – a roadmap of possibilities and can help predict the results of management actions.

[2] USDA NRCS and ARS are currently evaluating RHEM on pasturelands and this subpart will be updated with more examples when that effort is completed.

Figure B-4. Detailed example of rangeland state-and-transition model with community pathways (Loamy Calcareous Green River Basin R34AB126WY).

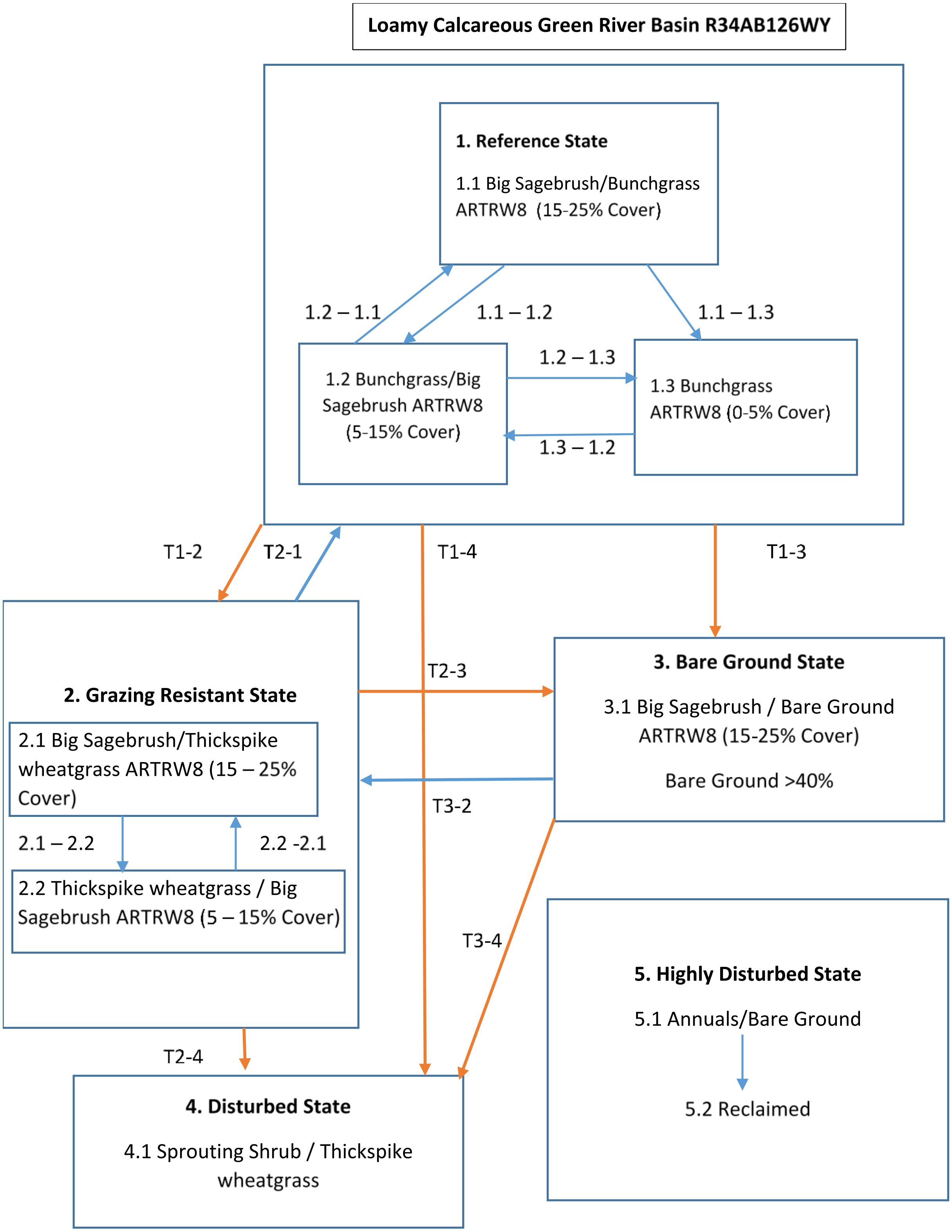
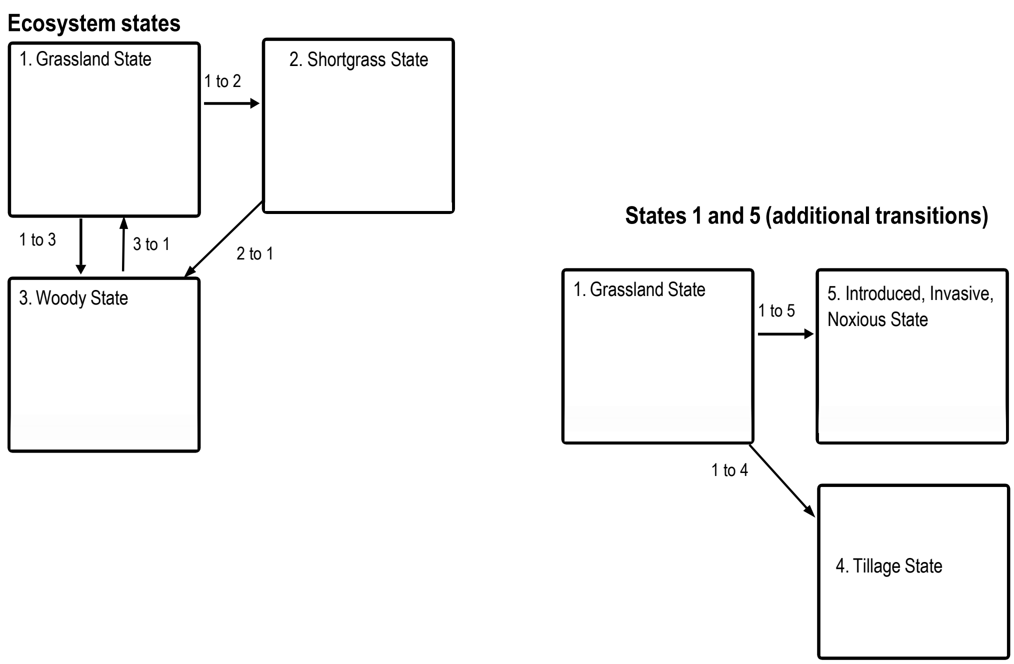


Table B-1. Pathways.

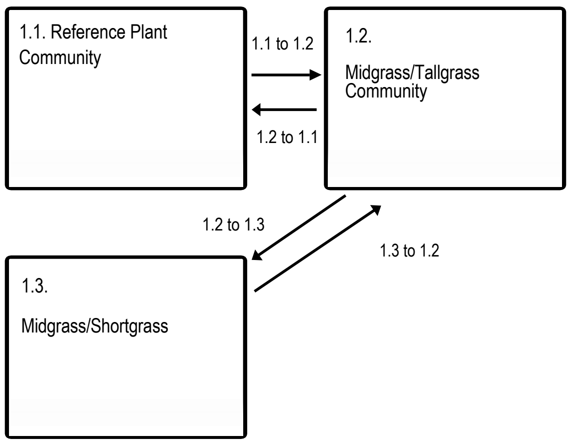
Community Pathways	1.1–1.2	Drought, insects and disease, mechanical, biological and chemical treatment, fire (wild and prescribed)
	1.1–1.3	Drought, insects and disease, mechanical, biological and chemical treatment, fire (wild and prescribed)
	1.2–1.1	Natural selection
	1.2–1.3	Drought, insects and disease, mechanical, biological and chemical treatment, fire (wild and prescribed)
	2.1–2.2	No disturbance
	2.2–2.1	Lack of sagebrush killing disturbances
State Transitions	T1–2	Continuous spring grazing
	T2–1	Mechanical, chemical treatments, fire, grazing, rest and deferment, and season of use change
	T1–3	Continuous high intensity early season grazing
	T1–4	Increased frequency of disturbance cycle (i.e., grazing, drought, fire, mechanical, biological, chemical treatments)
	T2–3	Continuous high intensity early season grazing
	T3–2	Changing grazing season of use and/or mechanical, chemical, and biological treatments
	T2–3	Increased frequency of disturbance cycle (i.e., grazing, drought, fire, mechanical, biological, chemical treatments)
	T3–4	Fire (wild and prescribed), drought, insects and disease, mechanical, biological, chemical treatments

Figure B-5. Ecosystem states, Loamy Hills HX076XY115.



1 to 2–Long-term, heavy, continuous overgrazing, no rest and recovery
1 to 3–Lack of fire and brush control
1 to 4–Tillage by machinery
1 to 5–Introduction of non-native species
3 to 1–Prescribed grazing, brush management, and prescribed burning

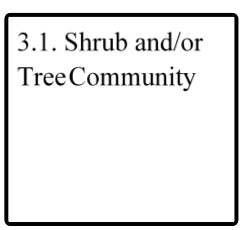
State 1 submodel, plant communities



1.1 to 1.2–Heavy, continuous grazing without adequate rest and recovery
1.1 to 1.1–Prescribed grazing that incorporates periods of deferment during the growing season
1.2 to 1.3–Long-term (>20 years) continuous grazing with no rest and no recovery
1.2to 1.2–Prescribed grazing with adequate rest and recovery period during the growing season

State 2 submodel, plant communities

State 3 submodel, plant communities



State 4 submodel, plant communities

State 5 submodel, plant communities

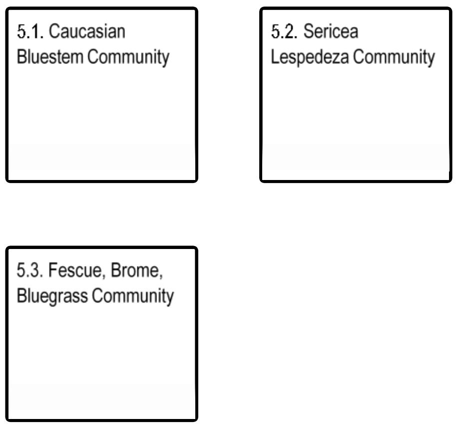


Figure B-6. Example of STM identifying several land uses within an ecological site.

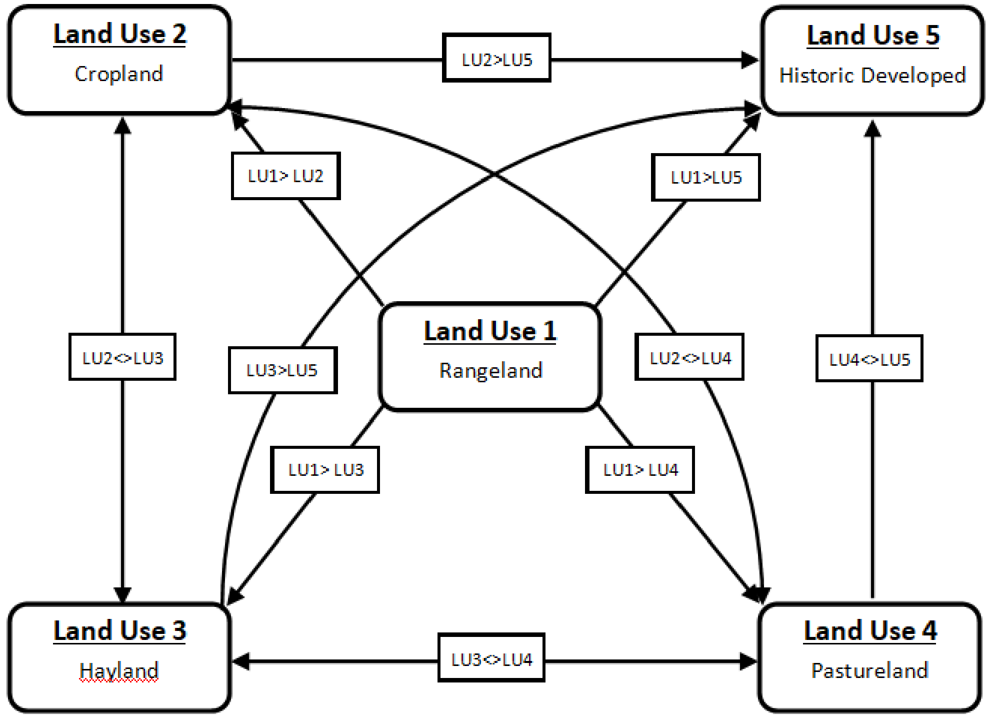
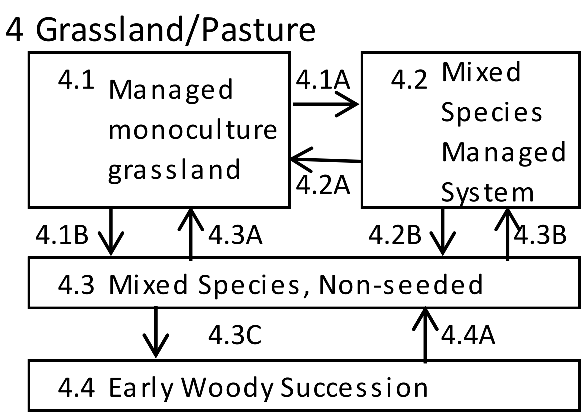


Figure B-7. An example of pastureland sub-state-within state-and-transition model.



(2) States

(i) An ecological state is a suite of temporally related plant community phases and associated dynamic soil properties that produce persistent characteristic structural and functional ecosystem attributes (Bestelmeyer 2009). States generally exhibit vegetation composition and structure, and ecological processes that are in equilibrium to self-sustain (negative feedback mechanisms) ecological resilience of the respective state and produce the largest array of potential ecosystem services (Bestelmeyer et al. 2009). Thus, states are often distinguished and described by differences in ecological processes, such as hydrology, nutrient cycling, or energy capture.

(ii) Ecological resilience is an indication of the amount of alteration required to shift an ecosystem from one stable state of reinforcing structure-function feedback mechanisms to a new stable state sustained by different structure-function feedback mechanisms (Briske et al. 2008). At-risk community phases exhibit conditions near structural or functional thresholds, beyond which shifts in ecological processes (positive feedback mechanisms) facilitate state transition. Structural thresholds are identified (structural indicators) based on changes in vegetation (composition, growth form, and distribution) and bare ground connectivity; whereas functional thresholds are identified (functional indicators) by shifts in processes (e.g., water infiltration and runoff, soil retention and erosion, nutrient cycling and distribution, solar energy capture and use) that promote ecological function and resilience of an alternative state. A STM typically includes an accompanying table with text descriptions of the plant community composition, community pathway and transition dynamics, and key structural and functional indicators (Williams et al. 2016).

(iii) The ES reference state and plant community phases generally exhibit vegetation composition and structure, and ecological processes that are in relative equilibrium to self-sustain (negative feedback mechanisms) ecological resilience of the respective state and produce the largest array of potential ecosystem services (Bestelmeyer et al. 2009).

(iv) The NESH states: "In all cases, the desired 'interpretive plant community' will be the reference state. If there is no data available for the reference state, describe the naturalized plant communities that occupy the site. The naturalized plant community that is most similar to the reference state becomes the interpretive plant community". As NESH instructs, in situations where the interpretive plant community cannot be identified, is not known, or no longer exists on the landscape, a surrogate reference state may be developed and described (see comments in paragraph below). Often times the interpretive plant community is based on the historic plant community. Debate often arises as to what the historic plant community was. If relict sites can be found, they can provide a basis for constructing the historic plant community; however, if there is doubt about historic conditions because of major plant community change and transformation in relation to introduced species, the default as NESH describes is the naturalized plant community. In the manual, interpreting indicators of rangeland health, Pellant et al. (2020) provide the following statement about historic plant communities as reference states: "Historical baseline: The inherent complexities of vegetation dynamics (e.g., how vegetation originated in an area and how it might change in the future) require an understanding of historic disturbance regimes, climatic variability (including climate change), and current vegetation. Although long-term trends in historic vegetation can be displayed over time periods spanning thousands of years using pollen analysis and other palaeoecological techniques, the relevance of ecological data to current state-and-transition models diminishes further back in time due to increasing differences in climate, disturbance regimes, and species distributions. In western North America, a 500-year or shorter period immediately preceding European settlement is a reasonable time period for describing the reference state (Winthers et al. 2005)."

(v) Deciding on what the historic plant community or the naturalized plant community is or was, is not a clear-cut endeavor. Some recommendations include, plant community composition based on pre-European man >200 years ago, finding relict sites, evaluating inherent native plant composition associated with the soil component, and compiling and evaluating historic literature and documents. Where introduced species such as cheatgrass, yellowstar thistle, knapweeds, leafy spurge etc., have naturalized and have transitioned as the dominant species, it may be difficult to identify a reference state. When all else, fails, document the situation and provide an honest assessment.

(3) Transitions

Transitions are simply the mechanisms by which state shifts occur and are commonly initiated by a trigger (e.g., wildfire, drought, long-term flooding, invasive plants, grazing) (Briske et al. 2006, 2008). A transition from one state to another is associated with "crossing a threshold" (Pellant et al. 2020). Ecological site transitions among states are often caused by a combination of factors and feedback mechanisms that alter plant community dynamics (e.g., Schlesinger et al. 1990) and that contribute directly to a loss of state resilience (Caudle et al. 2013). Transitions to alternate states may often be irreversible, especially where considerable plant compositional changes have occurred, accelerated runoff, and soil loss (sheet erosion, rill erosion, and/or gully erosion). Transitions (T) in state-and-transition models are used to designate downward and upward trends.

(4) Community phases

One or more plant community phases may exist in each state (see figure B-4, there are three community phases in State 1). The described disturbance regime (for each state) cause shifts between identified community phases. Shifts between phases are described using arrows and narrative. Descriptions of plant community phases include information such as species composition, annual primary production by species (lbs/ac), percent foliar and ground cover, canopy structure: height above ground (ft), and growth curves. Plant species are often grouped with similar species based on their structure and ecological function.

(5) Alternate Land Use State-and-Transition Models

(i) Ecological site descriptions may contain one or several interconnected STMs depending on land use (range, forest, pasture, crop). Figures B-5, 7, and 8 contain examples of STMs which incorporate various land uses. Each land use will have its own subset STM.

(ii) Pasture states are now a formal part of state-and-transition models and replace many of the components of Forage Suitability Groups (FSGs). The concept of FSGs was to group soils with similar landform and agronomic properties such as available water-holding capacities, pH, slope, drainage class, frequency and duration of flooding, depth to restrictive layers, surface soil texture, cation exchange capacity, sodium adsorption rations, salt contents, permeability classes, natural potassium and phosphorous reserves, and organic matter levels etc. with the ability to sustain a suite of forage species. Forage suitability groups contained similar information as ESDs (climate, physiographic features, soil features, water features, plant growth curves, etc.), which are now included in the ESD, thus eliminating duplicity. Appendix B-C shows some key attributes of example descriptions for a pastureland state.

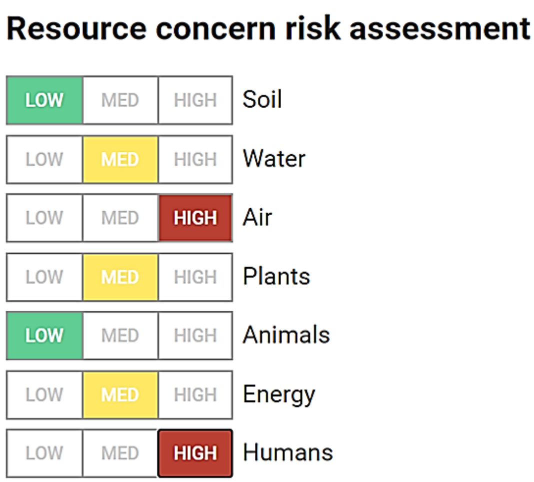
(6) Resource Concerns Risk Assessment in STMs

(i) NRCS resource concerns are organized by the following categories: soil, water, air, plants, animals, energy, and human considerations (SWAPA+H). A resource concern is the resource condition that does not meet minimum acceptable condition levels as established by resource planning criteria.

(ii) Planning criteria are established for all NRCS resource concerns and may be assessed using tools specific to land use or through client input and planner observation. The information contained in the ecological site description may be adequate to determine the likely outcome of an assessment tool and the probability of a resource concern.

(iii) Environmental and management drivers between states are often associated with resource concerns that have and/or are occurring. For example, a historic grassland site that is moving toward a woody invaded state is associated with several resource concerns such as invasive plants and other pests, productivity, soil health concerns, changes in plant structure and composition, and erosion (water and wind). By associating these resource concerns that alter the plant community, STMs can be used to display the three levels of risk or probability that a resource concern's presence within that state or plant community. This level of risk can be displayed as either Low, Medium, or High within a color-coded risk assessment table (figure B-8). Green values imply no resource concern exists, yellow indicates a moderate probability of a resource concern, and red indicates a high probability that a resource concern exists. A yellow value would require additional field assessment to determine whether a resource concern is present or not. Note: only one resource concern in a SWAPA+H category need be present or be represented on the table. The resource concern(s) considered are indicated in the resource concerns check list in EDIT.

Figure B-8. Resource Concern Risk Assessment Table from EDIT. Risk concerns can be designated by color code.



(7) Management Interpretations
(i) Management implications inherent to a community phase or state are described. Management interpretations include topics such as grazing management (suitability/limitations), fire behavior, brush management or pest management techniques, range and pasture seeding, wildlife considerations, pasture management (soil fertility and/or amendments, equipment limitations, etc.), and other interpretations.
(ii) Other aspects of management interpretations can be considered and/or included in EDIT as tables and narrative. They include: 1) grazing accessibility, 2) grazing forage palatability, 3) annual forage, 4) wood products, 5) pastureland management, 6) agronomic management, 7) recreational uses, 8) wildlife habitat suitability, 9) wildlife plants, 10) fire occurrence and characteristics, 11) fuel models and fire fuel characteristics, 12) fire behavior site characteristics, and 13) other products.

(8) Supporting Information
Supporting information includes, but is not limited to, type location, references, author/coauthor, and reviewers, etc.

(9) Rangeland Health Information

Rangeland health analysis is tied to the ecological site and the information contained within the ESD. Rangeland health reference information for the 17 indicators used to determine the preponderance of evidence for soil and surface stability, hydrologic function, and biotic integrity can be found in EDIT.

K. Other Ecological Site Components (See NESH)

(1) Animal community
(2) Recreational uses
(3) Wood products
(4) Other products
(5) Other information
(6) Inventory data references
(7) References
(8) Other references
(9) Contributors
(10) Approval
(11) Acknowledgments

L. Rangeland health reference sheet

(1) The rangeland health reference sheet provides documentation for expected conditions of the 17 indicators relative to the reference state (appendix B-D). The rangeland health reference sheet is integral to evaluating the 17 indicators of the rangeland health matrix. The reference sheet and corresponding ecological site matrix (appendix B-E) describes the range of expected spatial and temporal variability of each indicator within the natural disturbance regime based on each ecological site (or equivalent unit).
(2) Coinciding with the ecological site reference sheet (appendix B-D), an ecological site-specific evaluation matrix (appendix B-E) is a valuable tool to evaluate each rangeland health indictor based on general descriptions of key characteristics for each degree of departure (none to slight . . . extreme). Pellant et al. (2020), interpreting indicators of rangeland health contains a generic evaluation matrix; however, it is strongly recommended that an ecological site-specific matrix be developed that can be used to evaluate a suite of ecological sites (see matrix example, appendix B-E).
(3) Pellant et al. (2020) recommends that a cadre of knowledgeable individuals work in tandem to develop reference sheets and coinciding matrices as the 17 indicators are associated with various environmental factors (plants, soils, and hydrology).
(4) A reference sheet cannot be created without a complete ecological site description; however, if the respective ecological site description and/or soil survey does not exist, a protocol called "Describing Indicators of Rangeland Health" (DIRH) may be used to evaluate the 17 indicators and derive a preponderance of evidence for the three attributes. A guide for DIRH (Pellant et al. 2020) is as follows:

Table B-2. Guide for Implementing Describing Indicators of Rangeland Health (DIRH).

Soil Survey Status	Ecological Site Description Status	Identify Soil Map Unit Component?	Identify Ecological Site?	Complete IIRH?
A soil survey exists.	Ecological site description exists.[1]	Yes	Yes	Yes[2]
No soil survey exists, but soils are comparable to soils described in another soil survey within the major land resource area.	Ecological sites are described for the major land resource area, including the precipitation zone.	Yes	Yes	Yes
No relevant soil information exists.	Ecological sites are not described for the major land resource area.	No, follow DIRH instructions.	No	No, follow DIRH instructions.

[1] If a soil survey exists, it should include soils/ecological site correlations.
[2] Refer to appendix B-D to develop a reference sheet if one does not exist.

M. Identifying Ecological Sites

(1) Identifying the correct corresponding ecological site with the soil component is imperative in planning and monitoring/assessment activities. Several tools require identification of the ecological site:
(i) Calculating Similarity Index
(ii) Interpreting Indicators of Rangeland Health
(iii) Assessing Apparent Rangeland Trend
(iv) Monitoring plant species composition (e.g., foliar cover, production by species)
(v) Assessing potential forage species for rangeland seedings
(vi) Assessing status of forage production by species
(vii) Evaluating other ecological information in discussions with landowners

(2) Appendices F and G provide detailed instructions for identifying soil map units, soil components, and correlated ecological sites.

N. Approval Process

(1) Responsibilities for ES activity are shared among disciplines, including soil science, range science, forestry, agronomy, wildlife biology, hydrology, and ecology. The steps needed to collect, analyze and synthesize information on-site attributes, site correlation and classification, site dynamics, and site interpretations are all separate, but they must be coordinated so that all ES activity can be efficient (NESH 2017).

(2) NRCS state offices: 1) provide ecological site technical services and assistance within the state as needed; 2) ensure existing ES information is evaluated by knowledgeable personnel; 3) provide technical input during the development of ES information; and 4) ensure it meets the state's needs for conservation planning, implementation, monitoring, and assessment. The state office also works with area and field offices to assist in field data collection and investigations for ES development.

(3) The state office also develops local ecological site interpretations as needed and leads Rangeland Health reference sheet development. State staff have the ability to enter this data into the EDIT (Ecosystem Dynamics Interpretive Tool) with login permissions from the National Ecological Site Team (NEST). Upon login, EDIT provides instructions where field

data can be stored for review, as well as provides Reference Sheet templates for Reference Sheet data input. For a full list of Ecological Site Development Roles and Responsibilities, see the National Ecological Site Handbook (NESH) part 630.3.

645.0204 Application of Ecological Sites

Ecological Sites (ESs) and their descriptions (ESDs) are concepts that are used to describe and communicate ecological information at a discrete site level. They are an important tool for providing the ecological basis for evaluating ecosystem health, both in the National Resource Inventory (NRI), and during monitoring and assessment activities. In conservation planning, they are important in developing land management objectives, selecting conservation practices, and communicating ecosystem responses to management (Williams et al. 2016; USDA 2013).

(1) Ecological Applications
- (i) Provide ecological site information to NRCS customers at a finite scale of land classification – the Ecological Site
- (ii) Document and archive information about the ecological dynamics of a site
- (iii) Provide baseline ecological information for hydrologic models, such as Rangeland Hydrology and Erosion Model (RHEM)
- (iv) Provide ecological foundation for soil and plant health
- (v) Plant community baseline data for scientific research and experimental studies
- (vi) Provide baseline ecological information for land health assessments and evaluations
- (vii) Document and archive information about livestock and wildlife grazing and management approaches
- (viii) On-site and watershed scale modeling
- (ix) Use in GIS level modeling tools
- (x) Model and compare management scenarios with vegetation change
- (xi) Management interpretations for wildlife habitat
- (xii) Provides classification for NRI data collection and analyses

(2) Conservation Planning Applications:
- (i) Provide the best available information to assist with resource inventories, identifying resource concern probabilities, setting objectives, and selecting and implementing conservation practices to achieve goals
- (ii) Provide reference conditions for numerous resource management tools (e.g. Interpreting Indicators of Rangeland Health, Rangeland Hydrology and Erosion Model, Determining Indicators of Pastureland Health, Pasture Condition Scoring, Soil Health Assessments, etc.)
- (iii) Selecting suitable native species for restoration projects
- (iv) Selecting suitable forage species for planting on grazed lands
- (v) Risk analysis and assessment of alternatives
- (vi) Performance criteria for ecological outcomes assessment
- (vii) Provide a basis for recommending adaptive changes to management decisions to achieve desired goals and objectives
- (viii) Help prioritize conservation planning and management decisions
- (ix) Provide a basis for interpreting observed resource concerns
- (x) Incorporate climate change and management responses at the individual field and property level

645.0205 Accessing Ecological Site Descriptions

Ecological Site Descriptions can be accessed through Web Soil Survey: https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm.

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645.0207 Appendices

Appendix B-A. – State-and-transition models

Figure B-A-1. Example of a rangeland state-and-transition model (Williams et al. 2016) showing fundamental components for hydrologic data (Stringham et al. 2003; Briske et al. 2005, 2006, 2008; Bestelmeyer et al. 2009, 2010).

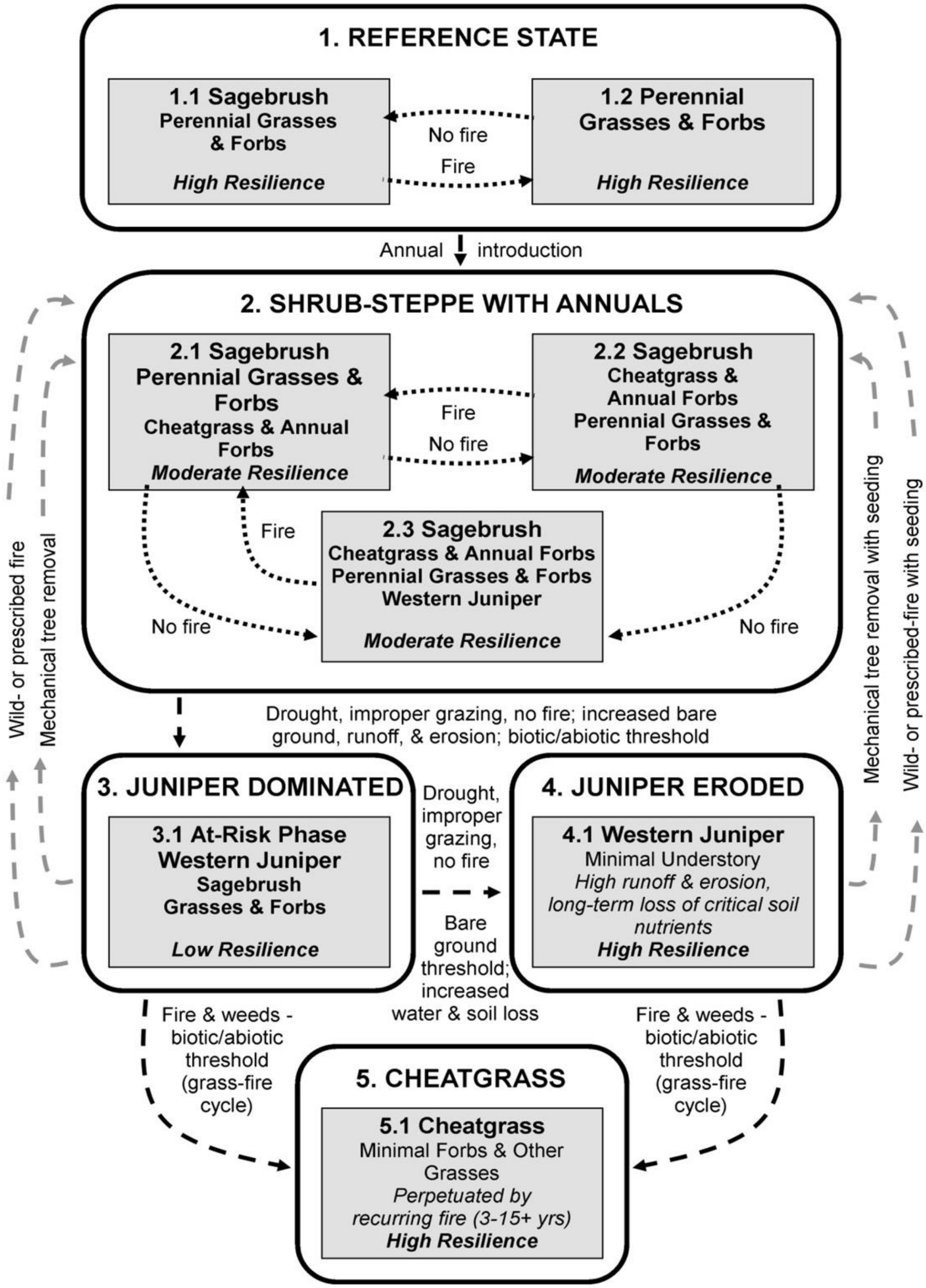
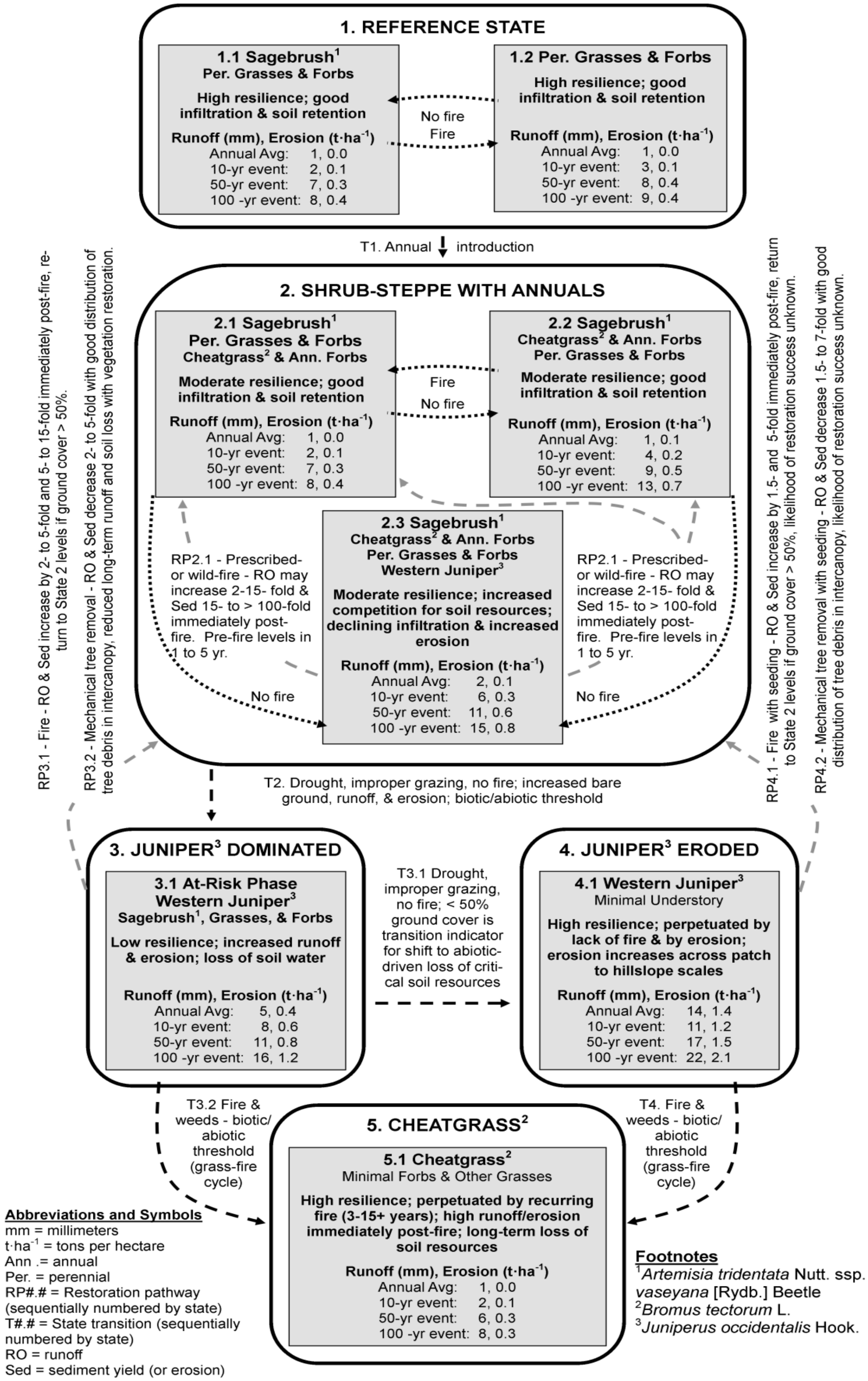


Figure B-A-2. State and Transition with hydrology and erosion estimates using RHEM.



Appendix B-B. – Rangeland Ecological Site Narrative with Emphasis on Hydrology and Erosion (Hydrologic Function)

The tall forb community type extends from the southern Wasatch range in Utah northward into Montana, east and west slopes of the Teton Range on the Idaho-Wyoming border, eastward into the Big Horn Mountains, along the southern border of the Jarbridge Mountains in Idaho-Nevada, the Ruby Mountains of Nevada, and the Uinta Mountains in Utah (Winward 1994). Tall forb communities are not unique to the United States, they also occur worldwide in high elevations throughout Europe, middle Asia, and Eurasia (Seffer et al, 1989; Ermakov 2003; Michl et al. 2010; Nowak et al. 2020). The community type is found on all aspects and slope gradients on deeper soils (>0.5m) and where soil moisture is adequate for nearly season-long plant growth. Representative sites are typically dominated by mixed forbs 16-48 inches (40-122 cm) in height with graminoid species occurring in minor amounts. On the average, perennial forb species comprise about 70-80 percent of the species composition, 20-30 percent grasses and grass-likes, and shrubs (0-2) percent. Average, total annual production is 2,200 lbs/ac (1980 kg ha) in a normal year. Production in a favorable year is 2,800 lbs/ac (2520 kg/ha). Production in an unfavorable year is 1,300 lbs/ac (1,170 kg ha). Tall forb communities occur at elevations between 6,300–10,000 ft (1,920–3,048 m); habitats include small openings in forest, and in larger open parklands within Douglas-fir (*Pseudotsuga menziesii*) and spruce-fir (*Picea engelmannii-Abies lasiocarpa*) stands. Tall forb vegetation is commonly associated as an understory layer in mountain big sagebrush *Artemisia tridentata* Nutt. ssp. *vaseyana* (Rydb.) Beetle (mountain big sagebrush), *Artemisia tridentata* ssp. *spiciformis* (subalpine big sagebrush), *Populus tremuloides* (aspen), and open Douglas-fir and spruce-fir sites when contiguous to tall forbs communities.

Tall forb plant communities have evolved in a montane climate characterized by cool, dry summers and cold, wet winters. Average annual precipitation of this site typically ranges from 22 inches or more. About three-quarters of the moisture is received during the plant dormant winter period (October–May). Frost heaving is common in tall forb communities (Goodrich, 2009). Average frost-free period is from 60–80 days. About half of the total site precipitation occurs as snow and usually remains in place during the winter with some drifting. Annual snowfall averages 150 to 200 inches (381–508 cm) per year.

Temperatures vary significantly between summer and winter and between daily maximums and minimums and is primarily due to high elevation and dry air, which permits rapid incoming and outgoing radiation. Mean annual air temperature is 33.3°F (16.0°F Avg. Min. to 50.6°F Avg. Max.). Prominent forb species found within the tall forb community type include: *Geranium viscosissimum* (Sticky geranium), *Potentilla glandulosa*, *P. groenlandica*, *Geranium richardsonii* (Richardson's geranium), *Balsamorhiza macrophylla* Nutt. (cutleaf balsamroot), *Ligusticum filicinum* (fernleaf licorice-root), *Aconitum columbianum* (Columbia monkshood), *Agastache urticifolia* (nettleleaf), *Osmorhiza occidentalis* (western sweetroot), *Thalictrum fendleri* (meadowrue), *Delphinium* (larkspur spp.), *Hackelia floribunda* (stickseed), *Polygonum douglasii* (knotweed), *Henium hoopesii* (sneezeweed), *Oxalis dichondrifolia* (peonyleaf woodsorrel) (Winward 1994; USDA-NRCS 2009). Major grass species found within the type include *Elymus trachycaulus* (slender wheatgrass), *Bromus carinatus* (mountain bromegrass), *Melica spectabilis* (purple oniongrass), *Achnatherum nelsonii* (Columbia needlegrass), *Phleum alpinum* (alpine timothy), *Poa reflexa* (nodding bluegrass), *Carex raynoldsii* (Raynolds' sedge), and *Carex microptera* (smallwing sedge) (USDA-NRCS 2009).

Herbivory has historically occurred in this community type; herbivores include mule deer**,** Rocky Mountain elk, and small rodents, especially pocket gophers. Livestock also utilize tall forb plant communities and in general, prolonged heavy grazing by cattle results in forb dominated communities, while heavy sheep use results in grass dominated communities (Ellison 1954; Winward

1994). State and transition changes concomitant with soil loss due to improper management caused by intensive livestock grazing causes a shift from mesic to xeric plant species. When this shift has occurred and state and transition thresholds are crossed (figure B-B-2), species like *Geranium viscosissimum* (sticky purple geranium), *Achillea millefolium* (western yarrow), *Taraxacum officinale* (dandelion), annual invasive mountain tarweed (*Madia glomerata*), and *Lomatium* spp. (biscuitroot) increase and become dominant. Tarweed contains allelopathic substances that inhibit growth of seedlings (Carnahan and Hull 1962). Continual overgrazing and repeated disturbance also result in vegetation shifts to *Wyethia amplexicaulis* (mule-ears), *Veratrum californicum* (California falsehellebore), *Lathyrus lanzwertii* (aspen peavine), and *Rudbeckia* spp. (coneflower) (Winward 1994). There are examples of dominant mules-ear stands in the Bridger-Teton National Forest (figure 1). The species is a highly competitive and aggressive—it monopolizes soil moisture and light and excludes other more desirable species and persists when grazing pressure is reduced or eliminated (Mueggler et al. 1951; Gregory 1983; Matthews 1993). Mule-ears reproduces by seed and resprouts from underground rootstalks or from the plant crown (Mueggler et al. 1951; Young et al. 1979). Another invasive species, *Taraxacum officinale* (common dandelion) is an indicator of livestock driven plant community dynamics, while decreases in dandelion are often associated with pocket gopher activity (USDA-NRCS 2009). Pocket gophers appear to be forb dependent (Goodrich and Cameron 2010), prefer forbs (oniongrass is an exception) and areas with high snow cover, and can enhance infiltration capacity and create open niches for seedling establishment. Soils with pocket gophers and no livestock grazing tend to be looser and more friable with higher total porosity and lower bulk density (USDA-NRCS 2009).

Figure B-B-1a. *Wyethia amplexicaulis* (mule-ears), postgrazing.

Figure B-B-1b.

b) Midseason, Mule-ears/forb community. Typical dieback of forbs associated with fall has occurred. In addition, light snow has fallen over the area and started to knock over vegetation. The effect of snowfall knocking overvegetation is very similar to that of sheep moving through an area in late summer/early fall at other forb sites observed this grazing season. Livestock have been removed from the area in preparation of winter conditions.

The effects of livestock grazing on soil surface stability and hydrologic function (resistance/resilience) are associated with the degree to which soil surface physical conditions and spatial and temporal changes in plant foliar and ground cover and species composition are altered. Since tall forb communities are prone to increasing bare ground with heavy livestock/wildlife use, the risk of accelerated runoff and soil loss can be significant. This change often accelerates increased water runoff and soil erosion. As with any rangeland plant community, crossing ecological thresholds where soil loss occurs is usually irrevocable (Weltz and Spaeth 2012).

Fire has historically occurred on the site at intervals of 20–50 years. Occasional and frequent fire is a dynamic that affects State 1 and 2 in the Ecological Site state-and-transition model (figure B-B-2). The Historic Plant Community (HPC) is the Reference State (State 1), and movement from State 1A to B and C occurs depending on the natural and anthropogenic disturbances that impact plant community composition and productivity (figure B-B-2).

Maintaining biotic integrity of tall forb plant communities is a key issue, and information about soil and surface stability and hydrologic function are needed to assess risks associated with various management scenarios including grazing by livestock (USFS Preliminary Science Summary June 2020). Tall forb species do not provide significant foliar and ground cover protection against erosion until late spring and early summer, and depauperate conditions advance again in late summer and fall when the leaves senesce (figure B-B-3). Vegetative cover and biomass have a major effect on hydrology and soil loss as indicated by numerous field studies (figure B-B-3) (Tromble et al. 1974; Wood and Blackburn 1981; Gifford 1985; Blackburn et al. 1986; Thurow et al. 1986; Wilcox et al. 1988; Abrahams et al. 1995; Spaeth et al. 1996a,b; Weltz et al. 1998; Williams et al. 2014; Nouwakpo et al. 2018; Zobell et al. 2020; Spaeth 2021). In addition, rainfall simulation experiments have shown that plant life form and individual species (taxa) also can have a profound influence on hydrology and erosion (Dee et al. 1966, Spaeth et al. 1996a, b; Pierson et al. 2002a, b; USDA-NRCS 2020; Spaeth 2021). Levels of foliar cover necessary for site protection against accelerated soil erosion on rangelands vary from 20% in Kenya to 100% for some Australian conditions. Most studies indicate that cover of 50 to 75% is probably sufficient to prevent degradation from accelerated soil erosion processes. However, every soil-plant complex is unique with respect to plant composition and hydrologic dynamics (Gifford 1985). The tall forb plant community type is especially unique with respect to resistance and residency ecological dynamics; therefore, patent management practices associated with rangeland management (prescribed grazing, deferment, prescribed fire, brush and/or herbaceous weed management) may not be remedial in the context of the state-and-transition model or produce desired results in the short-term, or often long-term as well.

Site conditions relative to tall forb community type physiography; plant foliar, ground cover, and production dynamics; phenological and seasonal changes in plant composition; rodent activity; and grazing by livestock and wildlife all have an effect on hydrologic function. Since soil and surface stability, hydrologic function, and biotic integrity are of primary interest in the tall forb community type, the forthcoming Environmental Impact Statement should evaluate the dynamics of each of these assessments for the major environmental states associated with a benchmark State-and-transition model. Plant species composition and soils can be expected to change among various tall forb ecological sites (ES); however, developing and ES description based on a coarser resolution representing a tall forb association is an important first step to assessing hydrology and erosion dynamics with varied plant community composition and various management scenarios (see figure B-B-3). The Rangeland Hydrology and Erosion Model (RHEM) model utilizes foliar cover by plant growth form (note standing dead including caespitose grasses, sod forming grasses, forbs, shrubs, and trees), and ground cover which includes basal plant stems, litter, rock, and microphytes. Infiltration, runoff, and soil loss is strongly influenced by vegetal foliar cover, ground cover, and biomass (Wilcox et al. 1988; Spaeth et al. 1996 a,b; USDA-NRCS 2020). The effects of livestock grazing on hydrologic resistance/resilience are associated with the degree to which grazing affects surface soil conditions by altering the above dynamics of the plant community. The dynamics and role between foliar and basal cover, and biomass in protecting the soil surface are influenced by temporal changes throughout the year as plants grow and senesce (Spaeth 2021). The relationships of these three parameters are especially important in tall forb communities as vegetation and litter cover and biomass change significantly throughout the growing season.

Figure B-B-2. State-and-transition model: Adapted from Ecological Site Description: SUBALPINE LOAMY 22, Site ID: R043BY024ID; Major Land Resource Area E43B.

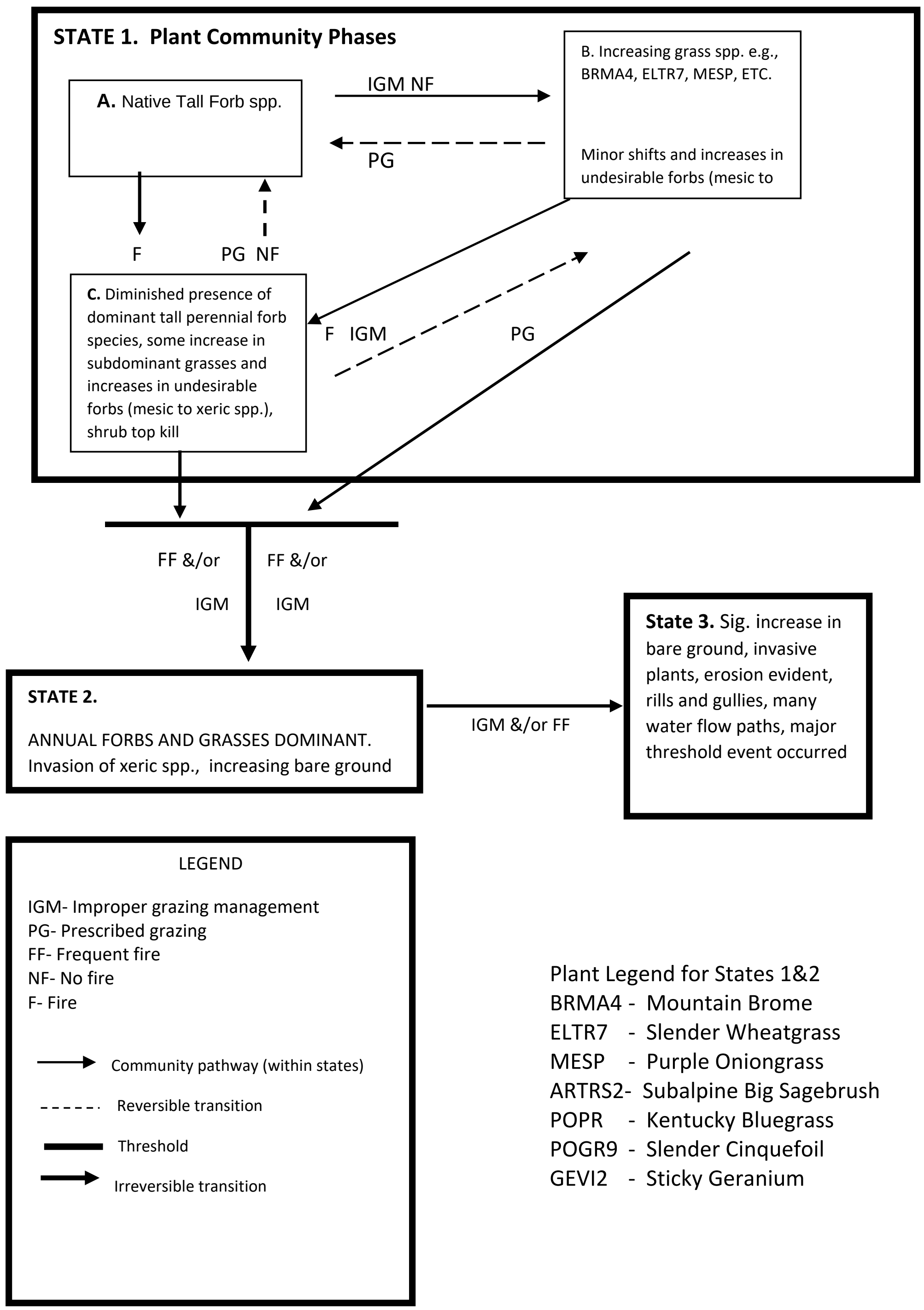
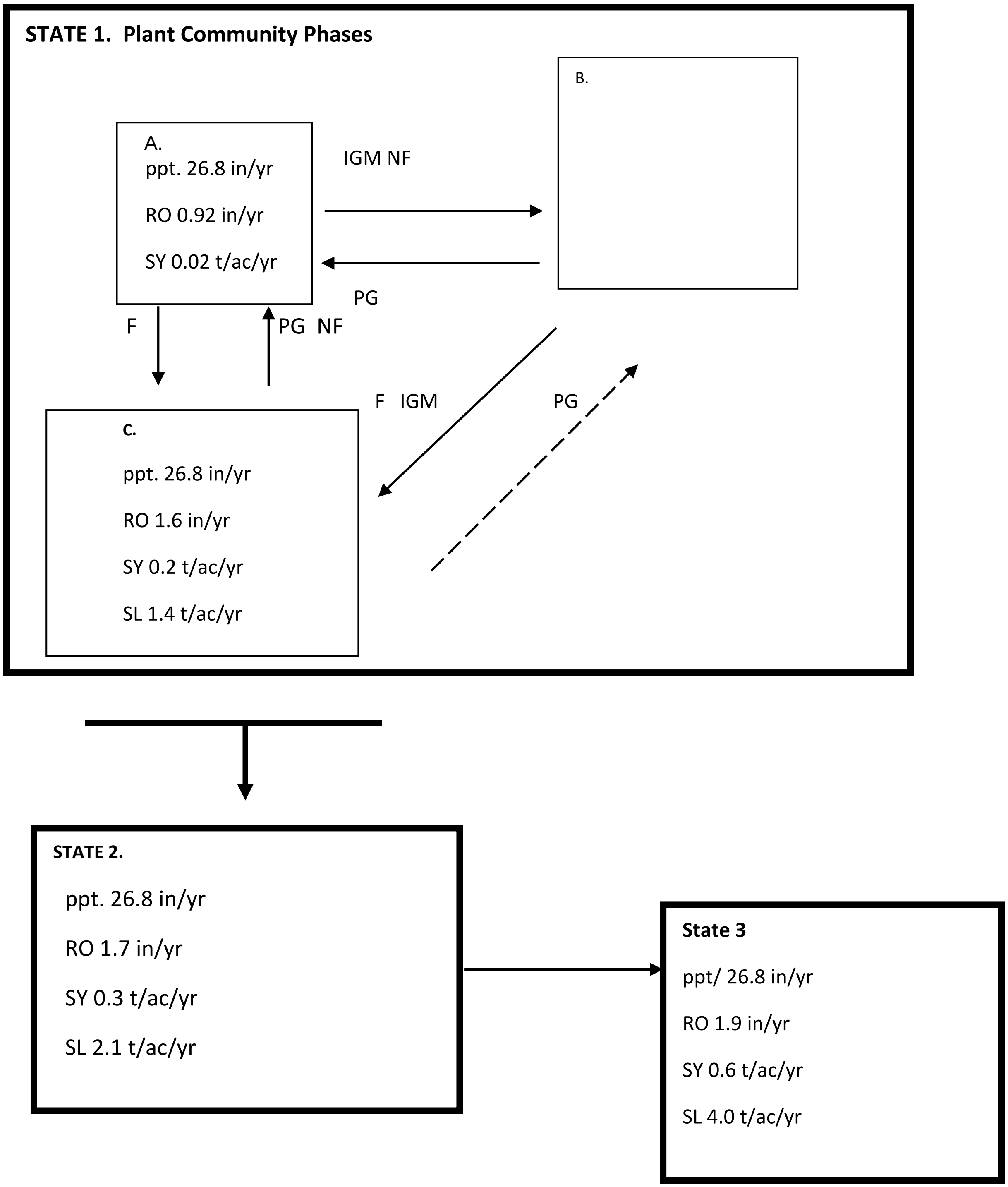
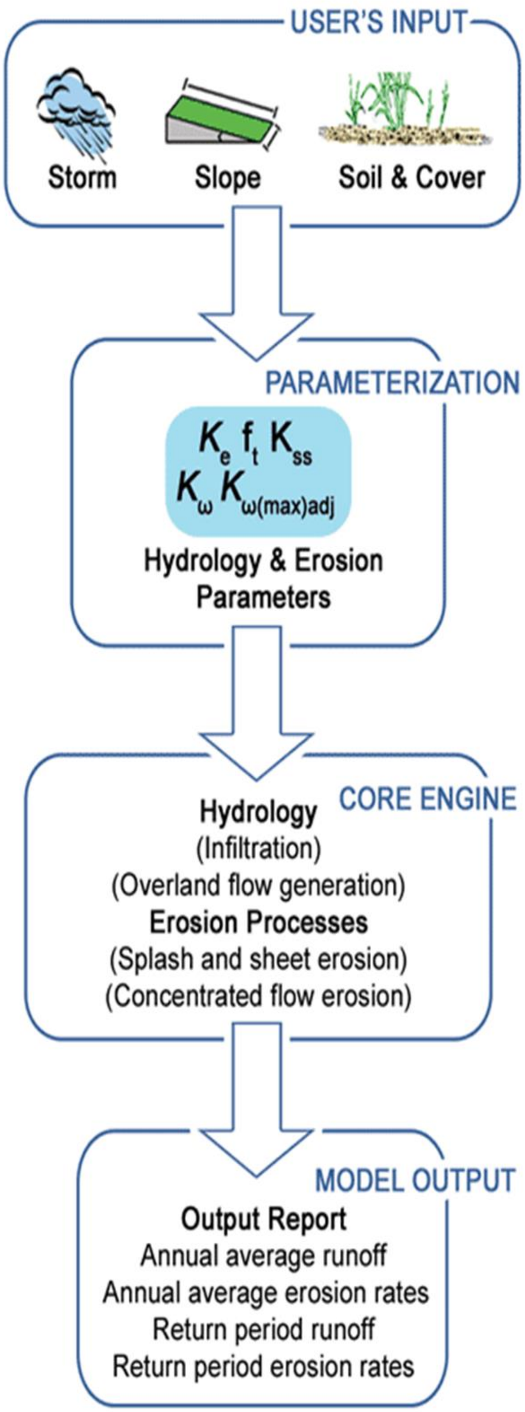


Figure B-B-3. State-and-transition model diagram with RHEM hydrology and erosion assessments. ppt= avg. annual precipitation inches., RO = runoff inches., SY – Sediment yield t/ac/yr, and SL = soil loss t/ac/yr.



The RHEM model is a physically based erosion prediction tool for rangeland applications and is based on fundamentals of infiltration, hydrology, plant science, hydraulics, and erosion mechanics (figure B-B-4) (Nearing et al. 2011).

Figure B-B-4. A flowchart of Rangeland Hydrology and Erosion Model (RHEM), from https://apps.tucson.ars.ag.gov/rhem/about.



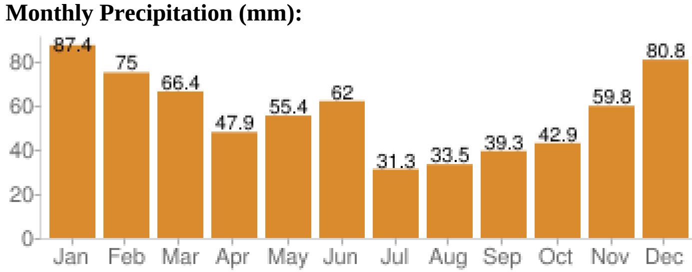
Site environmental variables are used as RHEM model inputs [soil texture, slope length, slope steepness, slope shape, dominant plant life form, percentage of canopy cover, and percentage of ground cover by component (rock, litter, basal area, and microbiotic crusts)]. Climate (precipitation intensity, duration, and frequency) is estimated with the Climate Stochastic Weather Generator (CLIGN) (Nicks et al. 1995) containing 300 years of daily precipitation data. The RHEM model provides estimates of the average annual soil loss during a 300-year time span and for 2-, 5-, 10-, 25-, 50-, and 100-year return runoff events, which provide an assessment of site vulnerability from heavier than average rainfall storm events and the consequences of accelerated soil loss from raindrop splash and sheet-flow, and rill soil-erosion processes.

Table B-B-1. Summary of RHEM parameters associated with State-and-transition model. Initial data parameterization of State 1 Reference.

RHEM Parameters	**State 1 Reference**	**State 1-C**	**State 2**	**State 3**
RHEM Version	**2.3**	**2.3**	**2.3**	**2.3**
State ID	ID	ID	ID	ID
Climate Station	Island Park Dam	Island Park Dam	Island Park Dam	Island Park Dam
Soil Texture	Silty Clay Loam	Silty Clay Loam	Silty Clay Loam	Silty Clay Loam
Soil Water Saturation %	25	25	25	25
Slope Length (feet)	164.04	164.04	164.04	164.04
Slope Shape	Concave	Concave	Concave	Concave
Slope Steepness %	18	18	18	18
Bunch Grass Foliar Cover %	8	10	15	5
Forbs and/or Annual Grasses Foliar Cover %	68	40	15	5
Shrubs Foliar Cover %	0	0	0	0
Sod Grass Foliar Cover %	0	0	2	2
TOTAL FOLIAR COVER %	**76**	**50**	**32**	**12**
Basal Cover %	12	3	2	1
Rock Cover %	10	10	10	10
Litter Cover %	20	5	5	2
Biological Crusts Cover %	2	2	1	1
TOTAL GROUND COVER %	**44**	**20**	**18**	**14**

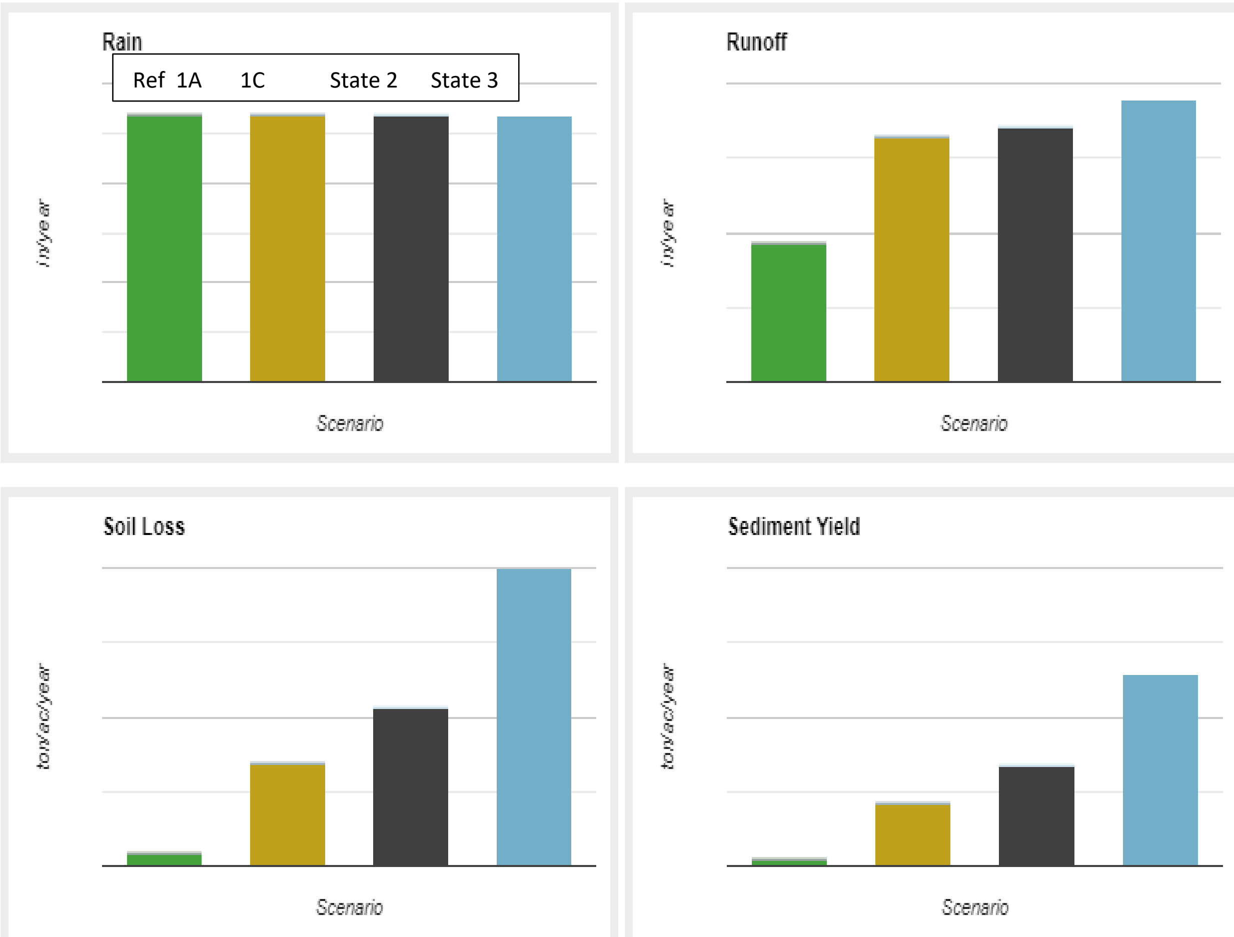
Name: ISLAND PARK DAM
ID: 104598
Elevation: 1,920.24 m (6,300 ft)
Lat: 44.42 Long: -111.4

Avg. Precipitation: 681.66 mm (26.84 in)
Monthly Precipitation (mm):



Currently using this station!

Figure B-B-5. Rangeland Hydrology and Erosion Model (RHEM) data estimates of four ecological states associated and described in State-and-transition model (figure B-B-3). State 1 = Reference State or Historic Plant Community, State 1-C a transitional phase in State 1, State 2, a new state with threshold transformation, and State 3, a new state with permanent threshold transformation.



	State 1 A Reference	State 1-C	State 2	State 3
Avg. Precipitation (inches/year)	26.8	26.8	26.8	26.8
Avg. Runoff (inches/year)	0.92	1.64	1.69	1.9
Avg. Sediment Yield (ton/ac/year)	0.02	0.21	0.34	0.6
Avg. Soil Loss (ton/ac/year)	0.15	1.36	2.13	4.0

Figure B-B-5 shows the RHEM output for State 1A, 1C, State 2 and State 3. The values in the graph and table are based on long-term average. In Case Study I, average precipitation is 26.8 in/yr (68 cm/yr). Runoff, soil loss, and sediment yield are shown in figure B-B-5). Runoff in the reference state is negligible (< 1 inch/yr), and almost double in State 1C, State 2, and State 3. Soil loss for reference State 1 was 0.15 tons/ac/yr, and increased 9-fold for State 1C (1.4 tons/ac/yr), 14-fold for State 2 (2.1 tons/ac/yr), and 27-fold for State 3 (4 tons/ac/yr) (for a point of reference, see Text Box 1). Soil loss tolerance factors are commonly used in NRCS (Spaeth 2021). The USDA-NRCS (2018) defines the T-factor as: "the maximum rate of annual soil loss that will permit crop ('or site productivity') productivity to be sustained economically and indefinitely on a given soil." Soil loss tolerance or permissible soil loss/sustainability factors are assigned to most soils by USDA Natural Resources Conservation Service T commonly ranges from 1 to 5 tons/ac/yr (2.2–11.2 Mg/ha/yr), the lower T value is typic of many arid and semiarid rangelands; the upper range is for class 1 cropland soils derived originally from grasslands. In conservation planning, if associated T-factors are less than the assigned value for the soil, then erosion is considered to be at sustainable limits. However, controversy surrounds the T value concept, especially on rangelands: Nearing (2002) contends that T values for US and soils worldwide are inadequate for two reasons: the original science is outdated, and environmental issues have changed. New research is needed and a more scientific approach to the concept is needed. Li et al. (2009) propose that three criteria be considered in developing or revising the concept: 1) soil formation should be considered in determining T values; 2) determine long-term relationships between erosion and productivity, and 3) examine the relationship between soil loss and deterioration of the soil and water quality both on-site and off-site. In figure B-B-5, erosion thresholds are included with state and transition states and phases (figure B-B-2).

Figure B-B-6 has three horizontal lines that represent critical soil loss similar to expected hydrologic and erosion risks with State 3, threshold soil loss which State 2 has crossed and State 1C is at a point where the community can shift to 1B and in time possibly to 1A. The alternatives for state 1C require immediate management changes and action. State 3 has transgressed beyond an environmental threshold and is representative of a permanent state change.

Figure B-B-6. RHEM data from figure B-B-5 above with runoff plotted on second Y axis.

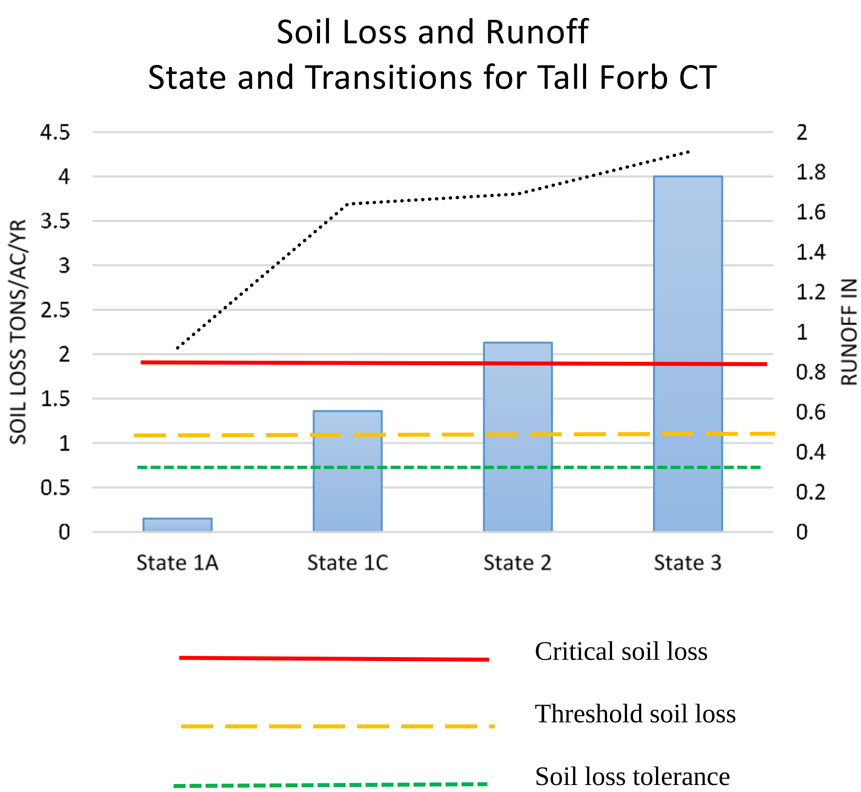
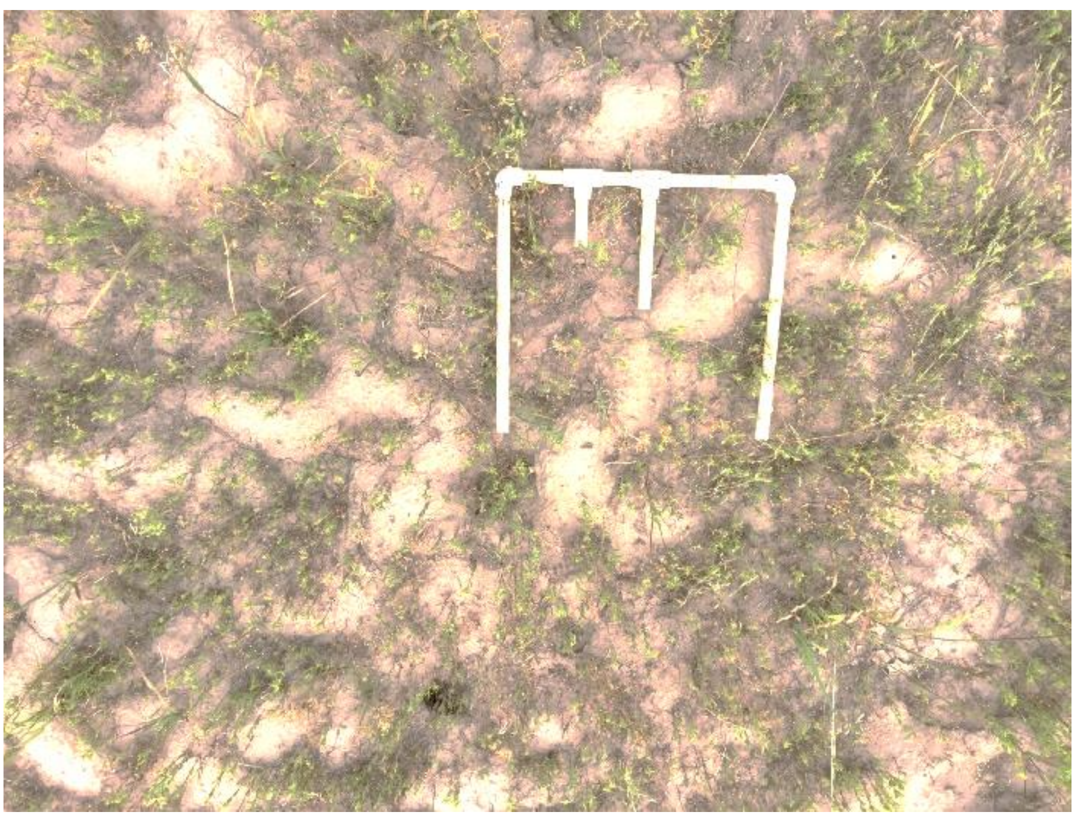


Figure B-B-7. (a) Tall Forb Community Type: visual examples of State 1A Reference (Historic Plant Community), **(b)** State 1C phase, **(c)** State 3, complete state transformation.

a)

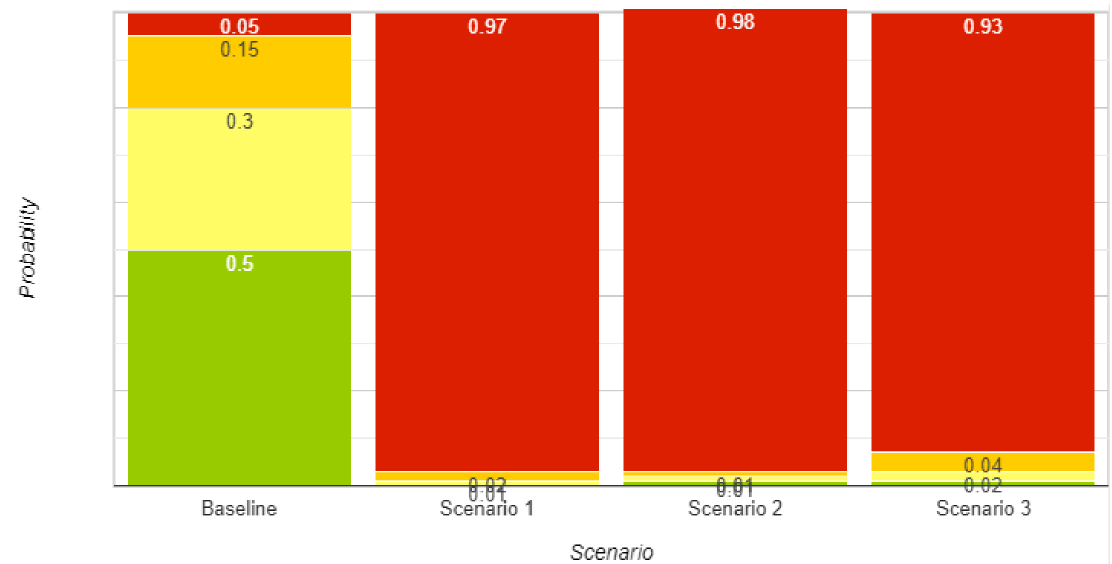
b)

c)



Risk Analyses

Figure B-B-8. Graph represents probability classes (Low, Medium, High, or Very High) of soil loss occurrence for any simulation year. Low, Medium, High, and Very High thresholds are based on the 50, 80, and 95 percentiles for probability of occurrence of yearly soil loss for the baseline condition and corresponding comparison scenarios created on parameterization input screen.



For example, the baseline considers that 5% (red bars) of the years are categorized as “Very High” soil loss. The red bars in the other scenarios represent the fraction of years in the RHEM simulation that also fall in the that same range of yearly soil losses as defined in the Probability Classes Soil Loss table below graph. Note that RHEM is reporting soil losses here and not sediment yields, which will be different, particularly when using S-shape or concave slope shapes.

Probability Classes Soil Loss tons/ac/yr	Baseline (State 1 Ref)	Scenario 1 State 1C	Scenario 2 State 2	Scenario 3 State 3
Low x < 0.149	0.5	0	0.01	0.01
Medium 0.149 <= x < 0.249	0.3	0.01	0.01	0.02
High 0.249 <= x < 0.373	0.15	0.02	0.01	0.04
Very High x > 0.373	0.05	0.97	0.98	0.93

In assessing the probability risks for the reference plant community (State 1A), figure B-B-8 shows that there is a 50 percent chance that soil loss will be less than 0.149 tons/ac/yr, a 30 percent chance that soil loss will be between 0.149 and 0.249 tons/ac/yr, a 15 percent chance that soil loss will be between 0.249 and 0.373 tons/ac/yr, and a 5 percent chance that soil loss will be greater than 0.373 tons/ac/yr. In comparison, state 3 has a 1 percent chance that soil loss will be less than 0.149 tons/ac/yr, and a 98 percent chance that soil loss will be greater than 0.373 tons/ac/yr. In table B-B-5, note that average long-term average soil loss is 4 tons/ac/yr, which is a critical level of soil loss and will result in a transition to an eroded site without likely restoration to a facsimile of the original tall forb plant community and diversity dynamics.

Risks Associated with Design Storm Events

Table B-B-2. Return frequency storm events for Tall Forb Community Type State 1 Ref, State 1C, State 2, and State 3. A return frequency storm is the size of the largest runoff or erosion event that is expected to occur on average once during the designated time period 2–100 years.

2 YEAR RETURN FREQUENCY RESULTS FOR YEARLY MAXIMUM DAILY

	REF STATE 1A	STATE 1C	STATE 2	STATE 3
Rain (inches)	1.388	1.388	1.388	1.388
Runoff (inches)	0.374	0.503	0.510	0.538
Sediment Yield (ton/ac)	0.007	0.066	0.106	0.202
Soil Loss (ton/ac)	0.054	0.417	0.654	1.184

5 YEAR RETURN FREQUENCY RESULTS FOR YEARLY MAXIMUM DAILY

	REF STATE 1A	STATE 1C	STATE 2	STATE 3
Rain (inches)	1.826	1.826	1.826	1.826
Runoff (inches)	0.615	0.803	0.812	0.847
Sediment Yield (ton/ac)	0.018	0.159	0.256	0.477
Soil Loss (ton/ac)	0.101	0.754	1.167	2.089

10 YEAR RETURN FREQUENCY RESULTS FOR YEARLY MAXIMUM DAILY

	REF STATE 1A	STATE 1C	STATE 2	STATE 3
Rain (inches)	2.215	2.215	2.215	2.215
Runoff (inches)	0.841	1.011	1.022	1.056
Sediment Yield (ton/ac)	0.026	0.224	0.357	0.673
Soil Loss (ton/ac)	0.132	0.976	1.521	2.671

25 YEAR RETURN FREQUENCY RESULTS FOR YEARLY MAXIMUM DAILY

	REF STATE 1A	STATE 1C	STATE 2	STATE 3
Rain (inches)	2.701	2.701	2.701	2.701
Runoff (inches)	1.107	1.393	1.414	1.475
Sediment Yield (ton/ac)	0.042	0.341	0.542	1.019
Soil Loss (ton/ac)	0.176	1.307	2.020	3.566

50 YEAR RETURN FREQUENCY RESULTS FOR YEARLY MAXIMUM DAILY

	REF STATE 1A	STATE 1C	STATE 2	STATE 3
Rain (inches)	2.912	2.912	2.912	2.912
Runoff (inches)	1.535	1.873	1.883	1.915
Sediment Yield (ton/ac)	0.051	0.410	0.632	1.250
Soil Loss (ton/ac)	0.199	1.523	2.400	4.095

100 YEAR RETURN FREQUENCY RESULTS FOR YEARLY MAXIMUM DAILY

	REF STATE 1A	STATE 1C	STATE 2	STATE 3
Rain (inches)	3.989	3.989	3.989	3.989
Runoff (inches)	1.708	2.097	2.131	2.236
Sediment Yield (ton/ac/yr)	0.070	0.567	0.902	1.663
Soil Loss (ton/ac/yr)	0.278	2.013	3.164	5.740

Table B-B-3. (a) RHEM tables representing storm return frequencies on a daily time-step for State 2, State 2 has departed from reference HPC conditions and according to the State-and-transition model diagram (figure B-B-3) is most likely a permanent shift from State 1; **(b)** RHEM tables representing storm return frequency data based on yearly total.

a)

State 2: RETURN FREQUENCY RESULTS FOR YEARLY MAXIMUM DAILY						
VARIABLE	**2 YR**	**5 YR**	**10 YR**	**25 YR**	**50 YR**	**100 YR**
Rain (inches)	1.4	1.8	2.2	2.7	2.9	4.0
Runoff (inches)	0.5	0.8	1.0	1.4	1.9	2.1
Soil Loss (ton/ac)	0.7	1.2	1.5	2.0	2.4	3.2
Sediment Yield (ton/ac)	0.1	0.3	0.4	0.5	0.6	0.9

b)

State 2: RETURN FREQUENCY RESULTS FOR YEARLY TOTALS						
VARIABLE	**2 YR**	**5 YR**	**10 YR**	**25 YR**	**50 YR**	**100 YR**
Rain (inches)	20.5	24.1	25.8	27.5	29.0	31.9
Runoff (inches)	1.5	2.5	3.0	3.8	4.5	4.9
Soil Loss (ton/ac/yr)	1.9	3.2	4.0	4.8	5.2	6.3
Sediment Yield (ton/ac)	0.3	0.5	0.7	0.9	1.1	1.4

Table B-B-3 shows the hydrology and soil loss for 2 to 100-year return frequency storms. For example, the long-term average soil loss for state 2 is 2.13 tons/ac/yr (figure B-B-6); however, one 5-year storm event can generate 1.2 tons/acre of soil loss, and the yearly total with a 5-yr storm generated 3.2 tons/ac/yr (table B-B-3b). Likewise, in evaluating a 50-yr storm event for State 2, the long-term average soil loss is 2.13 tons/ac/yr, a 50-yr storm could generate 2.4 tons/ac/yr, and the yearly total including a 50-yr storm could generate 5.2 tons/ac/yr (table B-B-3b). On rangelands, and especially the tall forb plant community, events from single 2–100-year storm events can generate soil loss levels that are either close to or significantly greater than long-term average soil loss rates. It is the rare or high intensity storms that can cause hydrologic events that shift the plant community over a threshold, especially when coupled with low plant cover and improper management from grazing or other uses. Land managers must be cognizant of the effects and risks associated with intense storm events as they can initiate rills that eventually form gullies. In summary, range managers should not be complacent with seemingly low average annual soil loss values, and examine the risks associated with higher intensity storm events.

Appendix B-C. – Example of Pastureland State as an Alternate Land Use

Figure B-C-1. Example of Pastureland state as an alternate land use with state-and-transition model. Ecological site F131AY504LA Delta Plain - Natural Levees and Ridge Hardwoods.

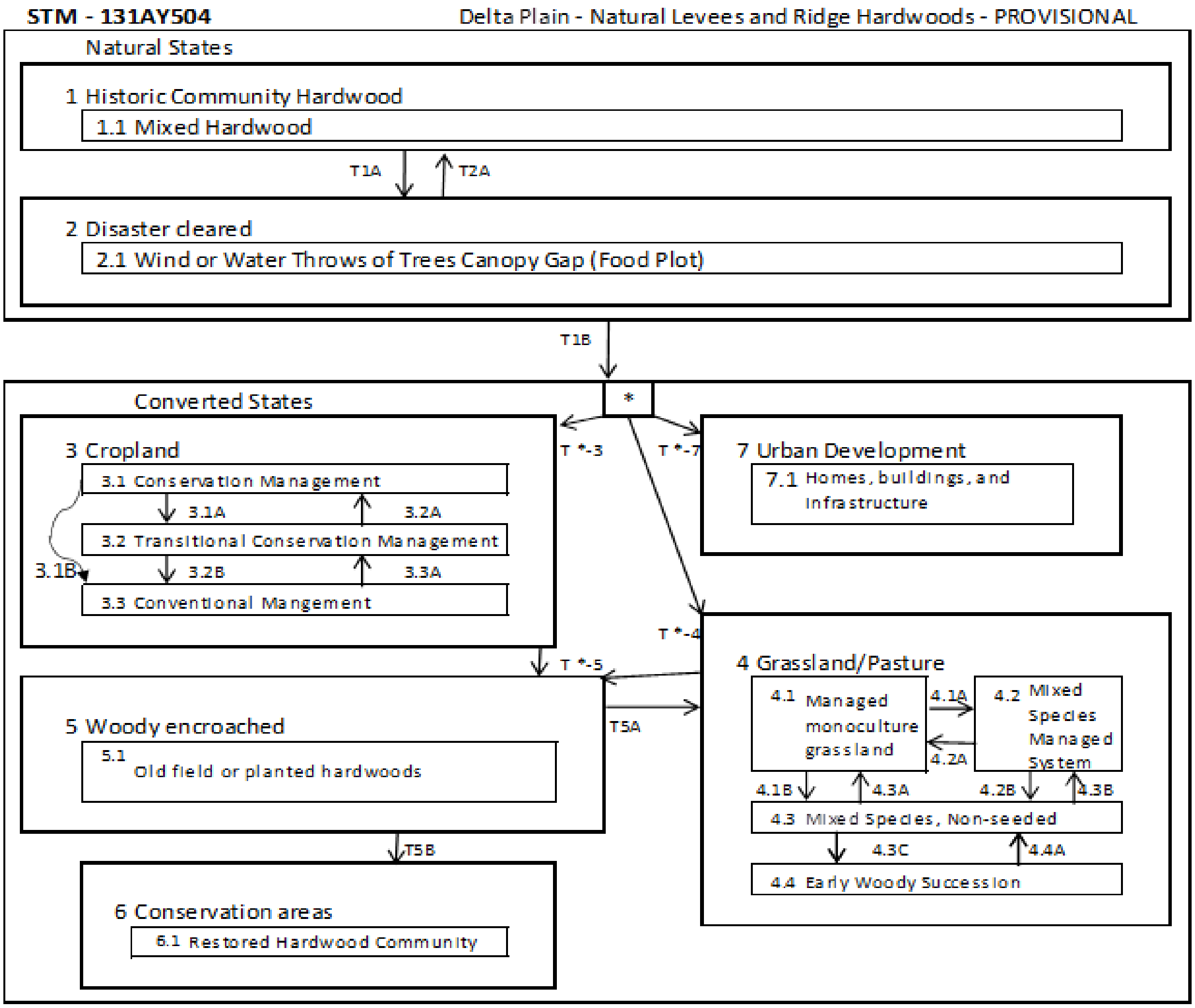


Diagram Legend

T1A	Wind or water Force causing canopy gaps.
T2A	Regeneration of Hardwood species.
T1B	Clear and established the desired Community
T *-3	Establish and manage crop rotation.
3.1A	Soil disturbance (Tillage) which reduces Soil Health.
3.2A	No-till, Cover crops, Reduced Till - Soil Health Improvements
3.1B/3.2B	Conventional tillage, seeding, and fertility Management for crops.
3.3A	No-till, Cover crops, Reduced Till with Soil Health Improvements as a goal.
T *-4	Establish desired forage species and manage for grazing.
4.1A/4.3B	Seeding and/or Management for desired species composition
4.2A/4.3A	Seeding, fertilizing, management/ removal of unwanted species
4.1B/4.2B	Species Management without overseeding.
4.3C	Lack of disturbance: No or minimal Mowing, burning, herbivory or Brush Mgmt. and/or Plant or natural regeneration of woody species.
4.4A	Brush mgmt./ removal of unwanted plants
T *-5	Plant or natural regeneration of woody species.
T5A	Heavy Brush mgmt.
T5B	Manage succession for historic community.
T *-7	Construct and maintain urban infrastructure.

State 4

Converted State - Pasture or Grassland

Figure B-C-2. Photo of converted state, pasture or grassland (see Fig. B-C-1 state-and-transition model).

Pasture or Grassland

This state is characterized by a monoculture or a mixture of forage species that have been planted or allowed to establish from naturalized species. Pasture and Hayland Group 2C - Deep bottomland soils with loamy surface layers and loamy subsoils. Somewhat poorly drained to well drained alkaline bottomlandsoils of high natural fertility. 0–8% slopes. Most slopes are 0–3%. Only a few soils occur on 3–5% slopes.

This site is suited for forage production; however, there are some natural wetness limitations. When site hydrology has been altered with drainage systems, forage species may be established. Drainage system control must be implemented and maintained as wet conditions will reduce forage growth production and limit the ability of livestock to graze. When the site is utilized for forage production, wetness conditions and/or flooding must be monitored to prevent loss of livestock or forage crop. Additionally, adjacent higher elevation areas or protected areas may be needed for the storage of harvested forage or holding of livestock when wet or flooded conditions occur. Some forage operations on this site may not experience extreme wetness events in any year; however, preplanning and resources to meet the needs of the livestock should be part of the operational plan.

Nitrogen fertilization is required for higher levels of grass production. It is not practical to apply high rates of fertilizer due to the wetness limitation potential of the site which normally occurs from December through June. To prevent extreme acidity in the subsoil when high rates of acidifying nitrogen are used, the surface soil should not be allowed to become more acid than 5.0 pH and lime should be applied at more frequent intervals.

Adapted Grasses and Legumes

Hybrid bermudagrass, common bermudagrass, dallisgrass, bahiagrass, and johnsongrass are the better adapted warm season perennials. Overflow hazards should be controlled to reduce the limitations of forage species. A variety of clover species are having varying degrees of success, depending on site conditions and annual climate trends (arrowleaf clover, berseem clover, crimson clover red clover, white clover, subterranean clover, ball clover, balsana clover, vetch, winter peas). Seeding dates range from mid-September to mid-November (see LSU Cool Season Pasture and Forage Varieties Pub. 2334). Legumes do not commonly persist as long-term perennial stands on this site. Periodic brush control is needed to prevent the area from reverting to woodland.

Dominant Resource Concerns

- Classic gully erosion
- Compaction
- Organic matter depletion
- Aggregate instability
- Nutrients transported to surface water
- Pesticides transported to surface water
- Objectionable odors
- Plant productivity and health Plant structure and composition
- Plant pest pressure
- Feed and forage imbalance
- Inadequate livestock shelter
- Inadequate livestock water quantity, quality, and distribution

Community 4.1

Managed monoculture grassland

Typically, this phase is characterized by planting forage species for hay production. Forage plantings generally consist of a single grass species. Introduced native and/or non-native forage species can be seeded. Forage is usually harvested as hay or haylage, although grazing may occur periodically. These sites are highly productive for forage and can provide ecological benefits to control soil erosion. Allowing for adequate rest and regrowth of desired species is required to maintain sustained productivity. Maintenance of monoculture stands also requires control of unwanted species which will require Pest Management and Nutrient Management to maintain the needed fertility for production of the species.

Generally, application of fertilizer and lime, is needed to establish and maintain improved desirable pastures. Bahiagrass and common bermudagrass, may be sustained under natural fertility and pH levels. Introduced legumes require higher pH, phosphorus, and potassium levels than most grasses. Introduced grasses, such as hybrid bermudagrass, require a higher level of sustained fertility, maintain pH above 6.0, and good surface drainage, to persist. Implementation of managed grazing of grass species will promote deeper root growth in the soil profile in order to tap into the available nutrient reservoir and available moisture.

Conservation practices should include Managed Grazing, or Forage Harvest Management, Nutrient and Pest Management and other site-specific facilitating practices.

Dominant plant species

- Bermudagrass (*Cynodon dactylon*)
- Bahiagrass (*Paspalum notatum*)
- Dallisgrass (*Paspalum dilatatum*)

Dominant resource concerns: Plant productivity and health Plant structure and composition Feed and forage imbalance.

Table B-C-1. Annual production by plant type.

Plant Type	Low (lbs/Acre)	Representative Value (lbs/Acre)	High (lbs/Acre)
Grass/Grasslike	6,000	8,000	10,000
Total	6,000	8,000	10,000

Growth Curves

Figure B-C-3. Plant community growth curve (percent production by month). LA0001, Hybrid Bermuda grass.

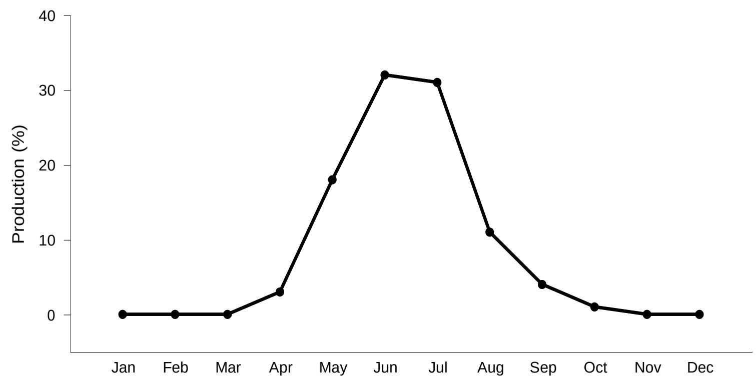


Figure B-C-4. Plant community growth curve (percent production by month). LA0006, Common Bermudagrass.

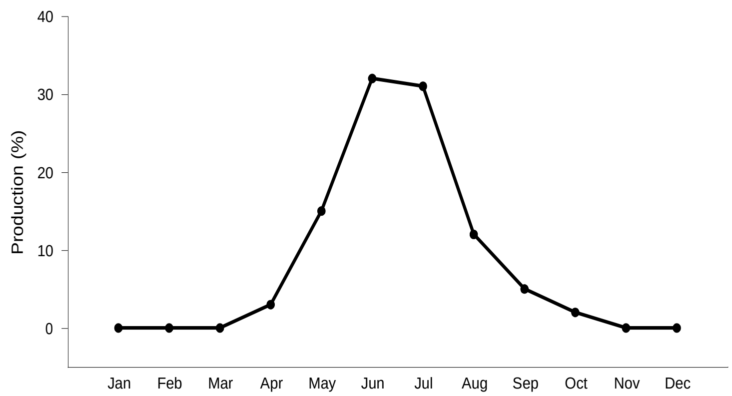


Figure B-C-5. Plant community growth curve (percent production by month). LA0012, Bahia grass.

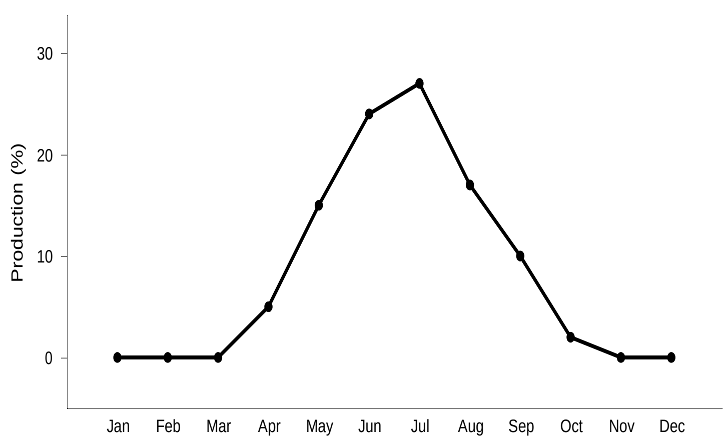
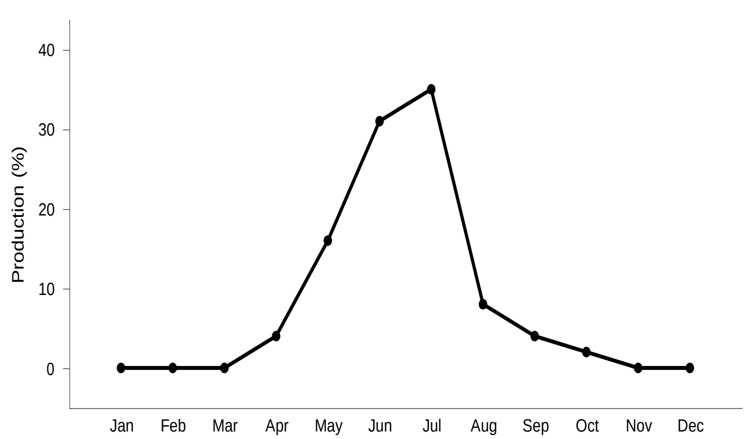


Figure B-C-6. Plant community growth curve (percent production by month). LA0016, Dallisgrass.



Community 4.2

Mixed Species Managed System

Figure B-C-7. Photo of mixed species managed system (see figure B-C-1 state-and-transition model).

This community is characterized by mixed species composition of grasses and legumes, which are planted or establish naturally. Typically introduced perennial warm season grasses are the foundation of the stand which is periodically over seeded with adapted cool season forages such as annual rye and legumes to extend the grazing season. This community phase can be highly productive for grazing and haying operations and can provide beneficial habitat for some wildlife species.

Maintenance of grass stands also requires a collection of management practices such as managed grazing, brush management, pest management, and nutrient management to maintain production of the desired species. Managed grazing includes maintaining proper grazing heights, timing, and stocking rates. Supporting or facilitating practices including fences, water lines and watering facilities can be used to maintain this state phase.

Dominant resource concerns

Compaction, inadequate livestock water quantity, quality, and distribution

Community 4.3

Mixed Species, Non-seeded

Figure B-C-8. Photo of mixed species, non-seeded pasture state (see figure B-C-1 state-and-transition model).

This community is characterized by a stand where non-seeded mixtures of native and naturalized non-native species occur. This state phase is associated with abandonment of cropping i.e., idle cropland that is not being utilized for forage production. This phase represents low management inputs after cropping such as no initial seeding of pasture species or periodic attempts of over seeding with adapted forage species. Forage is usually grazed and/or harvested as stored forage, hay or haylage. Common established species may include Bermudagrass, Bahia grass, Vasey grass, and carpet grass. This state is productive, forage and grazing management can maintain forage stands and protect soils from excessive runoff and erosion. A common hazard associated with this phase is overgrazing which favors less productive and less palatable weedy species, especially in areas where livestock congregate. Proper stocking rates and/or grazing systems that allow for adequate rest and plant regrowth are required to maintain productivity.

When forage species are afforded adequate recovery time between grazing intervals, they will develop deeper root systems and greater leaf area allowing for the capture of greater solar energy allowing adequate photosynthetic fixation of carbohydrates for plant growth. Conversely when plants are not allowed to recover adequately, root development will be restricted, and forage and biomass production will be reduced. Maintenance of grass stands also requires pest management for control of unwanted weedy and woody species.

Dominant resource concerns

Sheet and rill erosion, compaction, plant productivity and health, plant structure and composition, feed and forage imbalance

Community 4.4

Early Woody Succession

Figure B-C-9. Photo of early woody succession state (see figure B-C-1 state-and-transition model).

When the ecological threshold is crossed to where the stem diameter exceeds 2–3 inches and tree densities exceed 100–300 stems per acre, the site has transitioned to the Woody Encroached State. This community is characterized by diverse species composition of grasses and forbs with an increasing composition of woody species (native and non-native) that are immature and low stature. If this community phase is not managed, and no brush management measures are taken, the plant community will transition to the woodland encroached State (5). Control of woody species will require input of extensive resources to return to a grassland or cropland state. In this phase, woody stature is large enough to inhibit agricultural cropping implements and equipment to return the site to a cropland phase. Woody invasive species grow quickly and can be difficult and expensive to control. Some Invasive woody species, such as tallow trees (*Triadica sebifera*) will invade and grow to produce seeds in as few as three years. If the restored hardwood community is desired, proper management is required to control invasive plants. This phase can be beneficial habitat for some wildlife species.

Dominant Resource Concerns

Sheet and rill erosion, compaction, plant productivity and health, feed and forage imbalance.

Appendix B-D. – Example Rangeland health reference sheet

Loamy Hills HX076XY115

Indicators

1. **Rills:** No natural rill formation common on the Loamy Hills ecological site.

2. **Water flow patterns:** Natural water flow patterns are vegetated and non-scoured. Visual inspection should not find litter, soil, gravel redistribution, or pedestalling of vegetation or stones that intercept the flow of water as a result of overland flow. On steeper slopes, 15-30%, water flow patterns may be more apparent due to site steepness but remain stable and vegetated.

3. **Pedestals or terracettes:** There is no evidence of pedestals or terracettes that would indicate the movement of soil by water and/or by wind on this site.

4. **Bare ground:** Averages of less than 5% bare ground. Bare ground on this site is the remaining ground cover after accounting for ground cover [vegetation (basal and canopy [foliar] cover), litter, standing dead vegetation, gravel/rock, and visible biological crust (e.g., lichen, mosses, algae)].

5. **Gullies:** No evidence of accelerated water flow resulting in downcutting or formation of gullies.

6. **Wind scoured and/or depositional areas:** No wind-scoured or blowout areas where the finer particles of the topsoil have blown away, sometimes leaving residual gravel, rock, or exposed roots on the soil surface. No areas of redeposited soil from other sites due to the wind erosion and deposition.

7. **Litter movement:** No evidence of litter movement (i.e., dead plant material that is in contact with the soil surface on shallow slopes). On slopes greater that 15%, some movement may be observable from recent higher intensity storms. Litter dams are not expected.

8. **Soil surface resistance to erosion:** Soil surface aggregates are stabilized by soil organic matter which has been fully incorporated into aggregates at the soil surface, adhesion of decomposing organic matter to the soil surface, and biological crusts. Soil stability from the soil stability test should be in the range of 5-6. Soil stability may temporarily decline following fire due to hydrophobicity of organic materials on the soil surface.

9. **Soil surface loss and degradation:** Labette OSD: Using clay loam surface texture, and Manhattan KS climate station. Cover values 95% bunchgrass, 1% sod grasses, 3% forbs, 1% shrubs.

   At 0–5% slope, Rangeland Hydrology and Erosion Model (RHEM) prediction < 0.6 tons/ac; 5–10% slope < 0.8 tons/ac; 10–15% slope < 1.0 tons/ac; 15–30% slope < 2.5 tons/ac.

Table B-D-1. RHEM Model parameters.

RHEM parameters	0–5%	5–10%	10–15%	15–30%
Avg. Precipitation (inches/year)	32.548	32.548	32.548	32.548
Avg. Runoff (inches/year)	8.321	8.415	8.447	8.443
Avg. Sediment Yield (ton/ac/year)	0.584	0.800	1.083	2.451
Avg. Soil Loss (ton/ac/year)	0.587	0.804	1.089	2.469

In the Interpreting Indicators of Rangeland Health manual, examples of using the RHEM model are not discussed. However, RHEM predictions of current soil erosion can provide an indicator of active erosion compared to a reference condition.

A--0 to 23 centimeters (0 to 9 inches); very dark gray (10YR 3/1) silty clay loam, very dark brown (10YR 2/2) moist; strong fine and medium granular structure; slightly hard, friable, slightly plastic and slightly sticky; few tubular pores; many fine roots; slightly acid; gradual smooth boundary, 15 to 30 centimeters thick (6 to 12 inches).

BA--23 to 38 centimeters (9 to 15 inches); very dark grayish brown (10YR 3/2) silty clay loam, very dark brown (10YR 2/2) moist; strong fine and very fine subangular blocky structure; hard, firm, slightly plastic and slightly sticky; many tubular pores; many fine roots; slightly acid; gradual smooth boundary, 0 to 20 centimeters thick (0 to 8 inches).

10. **Effect of community composition and distribution on infiltration:** Deep rooted perennial bunchgrasses comprise the plant functional and structural groups of the Reference Plant Community (see functional and structural group worksheet) and plant composition tables in ESD. Transitions to sod forming species beginning in state 1.2 can be associated with higher runoff potential and less infiltration capacity. As the site transgresses toward state 1.2 and other states outside of reference conditions, overall site water balance is affected with less water storage for plant growth and subsequent production.

11. **Compaction layer:** No compaction layers (0–6 in) occurs naturally on this site. Soil structure is similar to that described in Indicator 9. If soil is compacted, physical features will include platy, blocky, dense soil structure over less dense soil layers, horizontal root growth, and increase bulk density.

12. **Functional/Structural Groups:** This site is dominated by native warm season tallgrasses, with lesser percentages of subdominant midgrasses and shortgrasses (about 86% of total production). Cool season native grasses are also an important component of this ecological site (0.4–2% of total production). Native forbs comprise about 12% of the total production, and shrub/vines about 2%.

Relative Dominance of F/S Groups for Community Phases in the Reference State Minimum expected number of species for dominant and subdominant groups is included in parenthesis

Dominance Category

Dominant (5 FSG):

Group 1 Tallgrass dominant (30–60% of RV production; 1500–3000 lbs/ac). Big bluestem (1500–3000 lbs/ac); Indiangrass (200–610 lbs/ac), switchgrass (150–405 lbs/ac); composite dropseed (20–100 lbs/ac), and eastern gamagrass (0–405 lbs/ac).

Subdominant (4 FSG):
Group 2 Midgrass subdominant (16–22% RV production; 800–1100 lbs/ac). Little bluestem (800–1010 lbs/ac); sideoats grama (20–100 lbs/ac); purple lovegrass (0–50 lbs/ac); and porcupinegrass (0–50 lbs/ac).

Minor Graminoids (8 FSG):
Group 3 Shortgrass trace (1–2% RV production; 60–100 lbs/ac). Blue grama (0–70 lbs/ac), hairy grama (0–40 lbs/ac).
Group 4 Cool-season grass Trace (0.4–2% RV production; 20–100 lbs/ac). Western wheatgrass (10–50 lbs/ac), sedge (0–25 lbs/ac), Canada wildrye (10–50 lbs/ac), Virginia wildrye (0–30 lbs/ac), prairie junegrass (0–25 lbs/ac), Scribner's rosette grass (0–40 lbs/ac).
Minor Forbs (5 FSG, includes dominant forbs)
Group 5 forbs (5–12% RV production; 250–600 lbs/ac). Three most dominant forb species are compassplant, Nutgall's sensitive briar, and Illinois bundleflower. See reference plant community for entire list.
Minor Shrubs (2 FSG)
Group 6 shrub (0.5–2% RV production; 25–100 lbs/ac). leadplant (15–50 lbs/ac), Jersey tea 15–50 lbs/ac).

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13. **Dead of dying plant parts:** Recruitment of plants is occurring and there is a mixture of many age classes of plants. The majority of the plants are alive and vigorous. Some mortality and decadence is expected for the site, due to drought, unexpected wildfire, or a combination of the two events. This would be expected for both dominant and subdominant groups.

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14. **Litter cover and depth:** Plant litter is distributed evenly throughout the site. There is no restriction to plant regeneration due to depth of litter. When prescribed burning is implemented, there will be little litter the first half of the growing season.

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15. **Annual production:** Native species, current year growing season production is included in production data (introduced species are not calculated). Site potential (total annual production) ranges from 3,000 lbs in a below-average rainfall year and 6,500 lbs in an above-average rainfall year. The representative value for this site is 5,000 lbs production per year (see ESD species composition table).

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16. **Invasive Plants:** Reference plant community--no noxious weeds present. Common invasive native plants are osage orange, honeylocust, elms, and eastern redcedar. These species are not components of the native plant composition on this site. Invasive species composition > 2% foliar cover is indicative of shifts to slight to moderate departure.

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17. **Vigor with an emphasis on reproductive capability of perennial plants:** Plants in all functional structural groups are capable of reproducing annually under normal climate conditions. Current management activities (principally grazing) do not adversely affect the capability of plants to reproduce.

Appendix B-E. – Example of Ecological Site Matrix with Corresponding Rangeland Health Reference Sheet

Ecological Site: R151XY005LA; Brackish Firm Mineral Marsh 55–64 PZ.

Reference data for rangeland health matrix.

State 1.1 Reference Community: Saltmeadow cordgrass / Bulrush / Seashore Paspalum Community

Saltmeadow cordgrass (*Spartina patens*) is the dominant species in this phase. Saltmeadow cordgrass is typically found where salinity levels are between 3 and 9 ppt and water depth is up to 6 inches. Secondary herbaceous vegetation is directly influenced by factors such as elevation, water depth, and salinity. Variations in one or more of these factors can result in the plant community shifting back and forth from species that are typically associated with more saline conditions to species that are generally associated with fresh marsh.

Seashore paspalum (*Paspalum vaginatum*), chairmakers bulrush (*Schoenoplectus americanus*), saltmarsh bulrush (*Bolboschoenus robustus*), and California bulrush (*Schoenoplectus californicus*) are the most significant sub-dominant species. Seashore saltgrass is found in the drainageways within the site. Seashore paspalum can withstand more saline conditions and longer periods of inundation than saltmeadow cordgrass. Low growing and sod-forming grasses and grass-like plants such as dwarf spikerush (*Eleocharis parvula*), and fragrant flatsedge (*Cyperus odoratus*) are minor components of this plant community. Common reed (*Phragmites asutralis*) occurs in areas that are fresh water or slightly elevated. Widgeongrass (*Ruppia martitima*) is a submerged aquatic species that is typically found in open water areas within the brackish marsh and is an excellent duck food.

The primary forbs found on this site are southern cattail (*Typha domingensis*), saltmarsh morningglory (*Ipomoea sagittate*), and Virginia saltmarsh mallow (*Kosteletzkya virginica*). Shrubs are rare to non-existent on this site in its pristine state, however a few widely scattered shrubs may occur. Those shrubby species may include Jesuit's bark (*Iva frutescens*), eastern baccharis (*Baccharis halimifolia*), and California desert-thorn (*Lycium carolinianum*). Fire is a major management tool for this plant community. Without fire the accumulated saltmeadow cordgrass not only suppresses other vegetation, but it can also reduce its own annual production because the old growth suppresses the potential for new, vigorous growth. Prescribed fire allows species such as dwarf spikerush and seashore saltgrass to increase both spatially and in biomass production.

Table B-E-2. Species production estimate Table for ESD.

Plant Type	Low (lbs/acre)	Representative Value (lbs/acre)	High (lbs/acre)
Grass/Grasslike	4,500	11,150	13,500
Forb	500	750	1,250
Shrub/Vine	10	100	250
Total	5,010	12,000	15,000

Figure B-E-1. Evaluation Matrix: R151XY005LA; Brackish Firm Mineral Marsh 55–64 PZ.

*State*_________ *Office*_________ *Date* ____________
*Authors:*____

	Departure from Reference Sheet				
Indicator	**Extreme to Total**	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**None to Slight**
1. Rills	No past or recent rills evident.	No past or recent rills evident.	No past or recent rills evident.	No past or recent rills evident.	No past or recent rills evident.
2. Water Flow Patterns	Water flow patterns are extensive and numerous, unstable with active erosion/ scouring or extensive recent deposition.	More numerous than expected; deposition and cut areas common.	Nearly matches what is expected for the site; erosion is minor with some instability. Some deposition occurring.	Little evidence of minor erosion. Flow patterns are stable and occasional to frequent tidal surge or overwash from adjacent beach area.	Water flow patterns are stable and well vegetated. Minimal evidence of past or current deposition.
3. Pedestals and/or Terracettes	Abundant active pedestalling and numerous terracettes.	Moderate active pedestalling; Terracettes common.	Slight active pedestalling mainly in flow paths and interspaces. Occasional terracettes present.	No active pedestaling or terracette formation Some evidence of past pedestal formation especially in flow paths.	Typically none – Cordgrass spp. can pedestal naturally as material gets deposited around the plant and then gets naturally eroded off.
4. Bare Ground	Bare ground is >30%.	Bare ground 20–30%.	Bare ground 10–20%.	Bare ground 5–10%.	Generally, bare ground should be less than 5% and randomly distributed throughout.
5. Gullies	Common, with active erosion. No vegetation present.	Moderate in number with indications of active erosion, vegetation is infrequent.	Occasional in number with indications of active erosion; vegetation is intermittent.	Uncommon, vegetation is stabilizing the bed. No signs of active erosion.	Typical gullies are not evident on site. Scour channels from past storm events may be present but are stable.
6. Wind Scoured, Blowout, and/or Depositional Areas	N/A	N/A	N/A	N/A	N/A

Departure from Reference Sheet					
Indicator	**Extreme to Total**	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**None to Slight**
7. Litter Movement (wind or water)	Large amounts of litter and debris are deposited, removed or moved from place to place on the site by intense storms or tidal surge.	Significant amounts of litter moved from place to place on the site by intense storms or tidal surge.	Moderate amounts of litter moved from place to place on the site by intense storms or tidal surge.	Slight movement except with intense storms or tidal surge.	Litter movement infrequent except with intense storms or tidal surge.
8. Soil Surface Resistance to Erosion	Soil surface stability is severely reduced.	Soil surface is slightly stable.	Soil surface is moderately stable.	Soil surface is stable but showing signs of reduced aggregates and organic matter.	Soil surface is typically stable.
9. Soil Surface Loss or Degradation	Surface organic layer rarely present and then only in association with protected areas.	25–50% of the surface organic layer is absent.	Less than 25% of the surface organic matter is absent.	Some signs of past loss of surface organic matter with stable surface now.	0–3 inches dark gray mucky clay, 3–48 inches very dark gray to gray clay, 48–52 inches gray loamy fine sand, 52–80 inches gray clay loam to gray clay.
10. Effects of Plant Community Composition and Distribution Relative to Infiltration	N/A	N/A	N/A	N/A	Hydrologic dynamics consist of high water table and saturated soil conditions 70% of the time. Plant community composition has little effect on infiltration.

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Departure from Reference Sheet					
Indicator	**Extreme to Total**	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**None to Slight**
11. Compaction Layer	None	None	None	None	None
12. Functional/ Structural Groups (F/S Groups) **See Functional/ Structural Groups Worksheet**	Few dominant plant functional groups dominate the site. Significant non dominant plants are present.	Dominant plant functional groups represented by scattered few individual species. Less dominant functional groups now dominate the site.	Dominant plant functional groups occur, but no longer dominate. Shift from dominant to subdominant functional group has occurred.	Dominant plant functional groups are diminished but still dominate. Sub dominant plants groups are represented in slightly higher proportion. Less number of species in most functional groups.	Dominant plants: Warm-season grass and grass-likes. Sub dominant plants: Sod forming grasses. Other plants: Annual grasses are infrequent. Perennial forbs present

Relative Dominance of F/S Groups for Community Phases in the Reference State
Minimum expected number of species for dominant and subdominant groups is included in parenthesis

Dominance Category

Dominant grasses (2 FSG): saltmeadow cordgrass (1,000–16,000 lbs/ac), California bulrush (0–6,000 lbs/ac)

Subdominant grasses (3 FSG): seashore paspalum (500–4,000 lbs/ac), chairmakers bulrush (500–4,000 lbs/ac), coast cockspur grass (0–1,800 lbs/ac)

Forbs: Alligatorweed (3 FSG): (0–1,000 lbs/ac); southern cattail (0–500 lbs/ac), herb of grace (0–200 lbs/ac), saltmarsh morningglory (0–100 lbs/ac), and Virginia saltmarsh mallow (0–100 lbs/ac).

Minor shrubs (0–1 FSG): (0–100 lbs/ac): Jesuit's bark, eastern baccharis, California desert-thorn

13. Dead of Dying Plants or Plant Parts	Significant amount of dead or decadent plants are present (greater than 30%).	Frequent amount of dead or decadent plants are present (20-30%).	Moderate amount of dead or decadent plants are present (10–20%).	Slightly greater (5–10%) dead and/or decadence present.	Perennial grasses will naturally exhibit a minor amount (less than 5%) of senescence and some mortality every year.
14. Litter Cover and Depth	N/A	N/A	N/A	N/A	Significant amount of litter from onsite plant production. Decomposition of litter is rapid above water table.

Departure from Reference Sheet					
Indicator	**Extreme to Total**	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**None to Slight**
15. Annual Production	Productivity less than 20% of potential production.	Productivity 20–40% of potential production.	Productivity 40–60% of potential production.	Productivity 60–80% of potential production.	6000 to 20,000 pounds per acre.
16. Invasive Plants	Dominate the site.	Common throughout the site.	Scattered throughout the site.	Present primarily in disturbed areas.	Chinese Tallow Tree.
17. Vigor with an Emphasis on Reproductive Capability of Perennial Plants	Ability of plants to produce seed or vegetative tillers is severely reduced relative to recent climatic conditions.	Ability of plants to produce seed or vegetative tillers is greatly reduced relative to recent climatic conditions.	Ability of plants to produce seed or vegetative tillers is somewhat limited relative to recent climatic conditions.	Ability of plants to produce seed or vegetative tillers is only slightly limited relative to recent climatic conditions.	All perennial species should be capable of reproducing every year unless disrupted by catastrophic events occurring immediately prior to, or during the reproductive phase.

Figure B-E-2. Rangeland Health Reference Sheet

Author(s)/participant(s): ______________________________

Date: ______ MLRA: 151 **Ecological Site:** Brackish Firm Mineral Marsh Site ID: R151XY005LA This *must* be verified based on soils and climate (see Ecological Site Description). Current plant community *cannot* be used to identify the ecological site.

Composition (Indicators 10 and 12) based on: _X_ Annual Production, __Cover Produced During Current Year __Biomass

Indicators. For each indicator, describe the potential for the site. Where possible, (1) use numbers, (2) include expected range of values for above- and below-average years and natural disturbance regimes for **each** community within the reference state, when appropriate and (3) cite data. Continue descriptions on separate sheet.
1. Number and extent of rills: No recent or past rills evident
2. Presence of water flow patterns: Water flow patterns are stable and well vegetated. Minimal evidence of past or current deposition.
3. Number and height of erosional pedestals or terracettes: Typically, None – Cordgrass spp. can pedestal naturally as material gets deposited around the plant and then gets naturally eroded off.
4. Bare ground from Ecological Site Description or other studies (rock, litter, lichen, moss, plant canopy are *not* bare ground): Generally, should be less than 5% and randomly distributed throughout.
5. Number of gullies and erosion associated with gullies: Typical **g**ullies are not evident on site. Scour channels from past storm events may be present but are stable.
6. Extent of wind scoured, blowouts and/or depositional areas: None
7. Amount of litter movement (describe size and distance expected to travel): Litter movement slight except with intense storms or tidal surges.
8. Soil surface (top few mm) resistance to erosion (stability values are averages – most sites will show a range of values): Soil surface is typically stable.
9. Soil surface Loss and Degradation): 0–3 inches dark gray mucky clay, 3–48 inches very dark gray to gray clay, 48–52 inches gray loamy fine sand, 52–80 inches gray clay loam to gray clay
10. Effect of plant community composition (relative proportion of different functional groups) and spatial distribution on infiltration and runoff: Hydrologic dynamics consist of high-water table and saturated soil conditions 70% of the time. Plant community composition has little effect on infiltration
11. Presence and thickness of compaction layer (usually none; describe soil profile features which may be mistaken for compaction on this site): None
12. Functional/Structural Groups (list in order of descending dominance by above-ground production or live foliar cover): **<u>Dominance Category</u>** Dominant grasses (2 FSG): saltmeadow cordgrass (1,000–16,000 lbs/ac), California bulrush (0–6,000 lbs/ac) Subdominant grasses (3 FSG): seashore paspalum (500–4,000 lbs/ac), chairmakers bulrush (500–4,000 lbs/ac), coast cockspur grass (0–1,800 lbs/ac) Forbs: Alligatorweed (3 FSG): (0–1,000 lbs/ac); southern cattail (0–500 lbs/ac), herb of grace (0–200 lbs/ac), saltmarsh morningglory (0–100 lbs/ac), and Virginia saltmarsh mallow (0–100 lbs/ac) Minor shrubs (0–1 FSG): (0–100 lbs/ac): Jesuit's bark, eastern baccharis, California desert-thorn

13. Amount of plant mortality and decadence (include which functional groups are expected to show mortality or decadence): Perennial grasses will naturally exhibit a minor amount (less than 5%) of senescence and some mortality every year.

14. Average percent litter cover (______%) and depth (______ inches): Significant amount of litter from onsite plant production. Decomposition of litter is rapid above water table.

15. Expected annual production (this is TOTAL above-ground production, not just forage production):
6000 to 20,000 pounds per acre

16. Potential invasive (including noxious) species (native and non-native). List species which characterize degraded states, and which have the potential to become a dominant or co-dominant species on the site if their future establishment and growth is not actively controlled by management interventions. (Species that become dominant for only one to several years (e.g., short-term response to drought or wildfire) are not invasive plants.): Chinese Tallow tree

17. Perennial plant reproductive capability: All perennial species should be capable of reproducing every year unless disrupted by catastrophic events occurring immediately prior to, or during the reproductive phase.

Appendix B-F. – Determining the Ecological Site

The ecological site must be determined at each planning and/or monitoring evaluation area to ensure that the correct reference sheet is used to conduct the IIRH assessment. Ecological sites are delineated based on climate, physiographic, soil, water, hydrologic, and vegetation composition and production features. Soil surveys provide the foundation for describing and mapping ecological sites and help identify the soil map unit and corresponding soil components at the site evaluation area.

Steps in Determining the Ecological Site

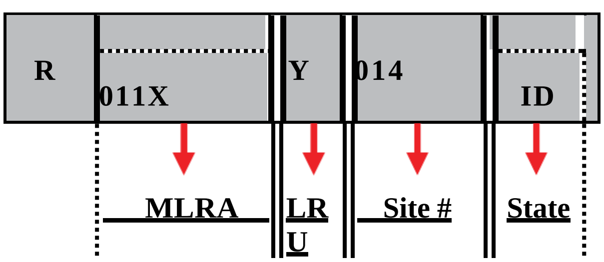
(1) A list of the ecological sites that are likely to occur at an evaluation area should be compiled.

This step does not determine the ecological site at a specific evaluation area as soil map units are commonly comprised of more than one soil map unit component. Each component in a soil map unit may be correlated to a different ecological site. In addition to the soil components listed in a soil map unit description, soil inclusions (soils representing less than 15% of the soil map unit area) are found in most soil map units and may be correlated to different ecological sites (Reid 2021; Pellant et al. 2020).

(2) Use the unique ecological site ID, rather than the ecological site name.

- Thisprevents accidentally using an ecological site description with the same name from a different land resource unit/major land resource area.
- Ecological sites are grouped into land resource units(LRUs), which are then grouped into major land resource areas (MLRAs) within each state. Refer to the U. S. Department of Agriculture Handbook 296 for further information. Each ecological site description has a unique code that identifies the MLRA, LRU, ecological site number, and state. For example, ecological site description code R011XY014ID is interpreted as shown in figure B-F-1.

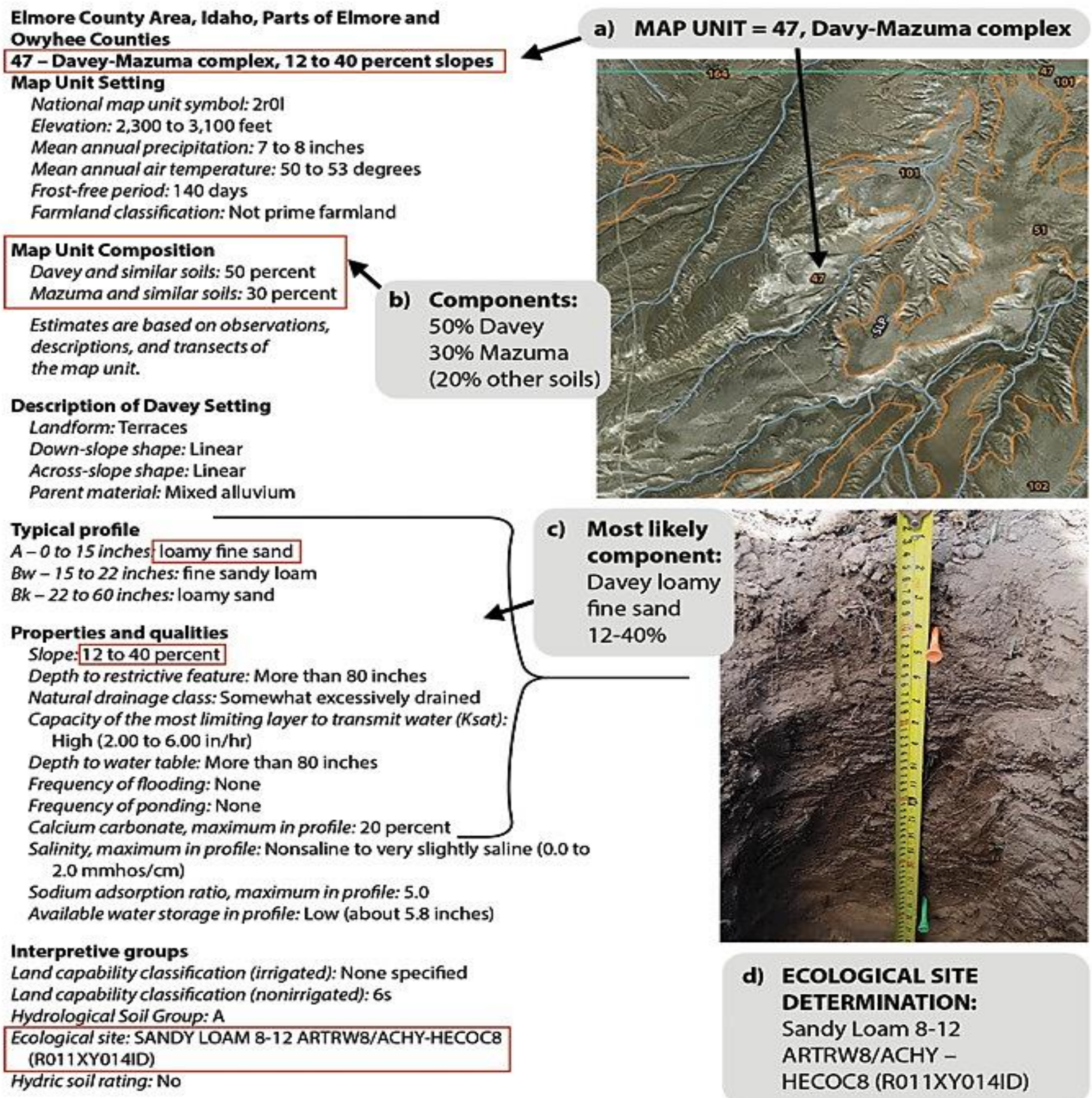
Figure B-F-1. Components of an ecological site description code. "R" at the beginning of the code shows it is a rangeland ecological site (Pellant et al. 2020).



(3) Observe the site evaluation area soils and physiography.

- After reviewing the soil survey map unit and component data and listing the possible correlated ecological sites in an evaluation area, the final ecological site determination is made in the field by observing the site evaluation area's soils and physiographic characteristics and comparing these characteristics to the descriptions provided in the ecological site description or soil survey. An example of an ecological site determination is shown in figure B-F-2.

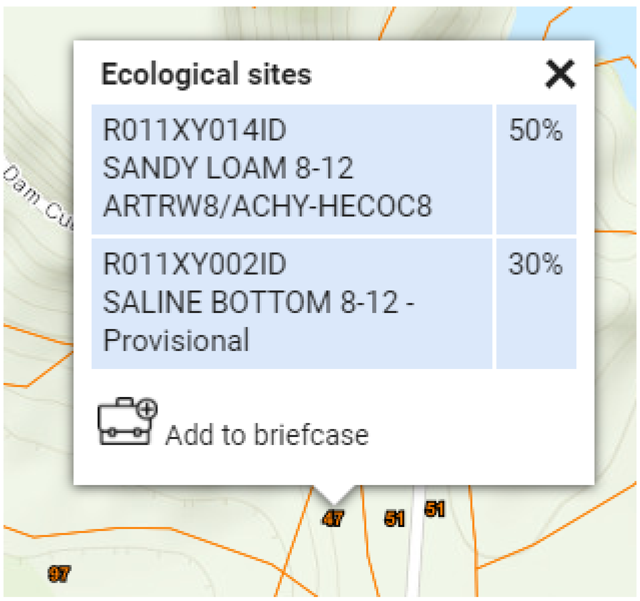
Figure B-F-2. Example of using a soil survey to identify the ecological site of a site evaluation area. **(a)** After determining the location of the evaluation Area of Interest (AOI), use the soil survey map to determine potential soils in the AOI. In this example, the evaluation area is in Map Unit 47 of the Elmore Area County Soil Survey. **(b)** Refer to the map unit composition to determine the soil component(s) in the evaluation area.



- For this area, the major components in map unit 47 are Davey (50%) and Mazuma (30%). **(c)** Compare physiographic features of the evaluation area with those of the soil component's setting and slope. In this example, the slope of the evaluation area matches the slope of the Davey soil component (12–40%). The soil component is then identified by digging a soil pit and comparing to the description of the Davey soil component **(d)** After determining the soil component in the evaluation area, document the information in the ecological site determination section on page 1 of the evaluation sheet (Pellant et al. 2020).

- Digging to a minimum depth of 20–25 inches (51–64 cm) is usually required to distinguish ecological sites in most areas. “Shallow” ecological sites are often distinguished by soils less than 20 inches (51 cm) in depth. It is strongly recommended to dig a deeper hole if possible; greater depths will increase the accuracy of soil and ecological site identification.
- Record observations of soil horizons and their depth, texture, and effervescence and other diagnostic characteristics, such as soil structure, color, grade, and size.
- Mobile apps and other technological tools are increasingly available and can facilitate soil identification when using soil pits. It is also recommended to consult a soil scientist or resource specialist familiar with soil identification if there is uncertainty about the soils.
- Ecological site mapping in EDIT (Ecosystem Dynamics Interpretive Tool). Visit the EDIT website (edit.jornada.nmsu.edu) and navigate to the ecological site descriptions catalog. Using the MLRA mapping feature, zoom in to the area of interest. The soil map unit polygons will appear as you zoom in. Click on the soil map unit. A list of ecological sites associated with the dominant soil components within that soil map unit will be provided if the ecological site correlations are available in the underlying database. The correlated soils and ecological site description status can be found by clicking on each listed ecological site.

Figure B-F-3. Snapshot of EDIT tool soil map feature with two soils components correlated to two different ecological sites (Reid 2021).



(4) Obtain ecological site correlations from soil survey data.

- When ecological site mapping correlations are not available in EDIT, or when additional soils information is required, consult electronic or hard copies of soils surveys. Most soil map unit descriptions include component ecological site correlations.
- The availability of soil surveys in paper or electronic format varies across the Western United States; however, most are available with internet searches. Soil surveys are now published electronically as they are revised and updated, so hard copies of soil surveys may no longer contain the most up-to-date information. Third-order soil surveys, which

are most commonly available for rangelands, are somewhat coarse and usually represent associations or complexes of multiple soils. They may also include soil inclusions, which may or may not be listed in the soil survey thereby making a precise correlation to an ecological site cannot be made.

(5) Soil survey information can be accessed in the following ways:

- Web Soil Survey (https://websoilsurvey.sc.egov. usda.gov) provides interactive tools for navigating to and delineating an area of interest. An area of interest, such as a management unit, can also be imported to Web Soil Survey as a shapefile. Multiple management units can also be attributed and imported into Web Soil Survey to give ecological site inventory statistics by management unit. Note that Web Soil Survey has a maximum area of interest resolution of 100,000 acres.
- Spatial and tabular soils data can be downloaded from Web Soil Survey, allowing these data to be used with other spatial data sets with desktop geographic information system applications, such as ArcGIS.
- If published soils data are not available for the area of interest, contact the local NRCS office to see if unpublished information is available.

(6) Use soil survey information to identify ecological site correlations.

- Using Web Soil Survey, import or navigate to and select the area of interest. Soil map units for the area of interest can now be viewed in the “Soil Map” tab (Pellant et al. 2020).
- There are multiple ways to view ecological site interpretations in Web Soil Survey depending on the user’s needs. Perhaps the most efficient method to obtain ecological site information correlated to map unit components is to go to the “Soil Data Explorer” tab in the first tier and select the “Ecological Sites” tab in the second tier and then selecting “View All Ecological Sites Info” (figures B-F-4, 5, and 6) (Reid 2021).

Figure B-F-4. Soils Data Explorer tab and second tier Ecological Sites tab (tabs in red) (Reid 2021).

Figure B-F-5. View all Ecological Sites Info tab (Reid 2021).

Figure B-F-6. Summary of Ecological sites by map unit (Pellant et al. 2020).

Table — Ecological Sites by Map Unit Component —

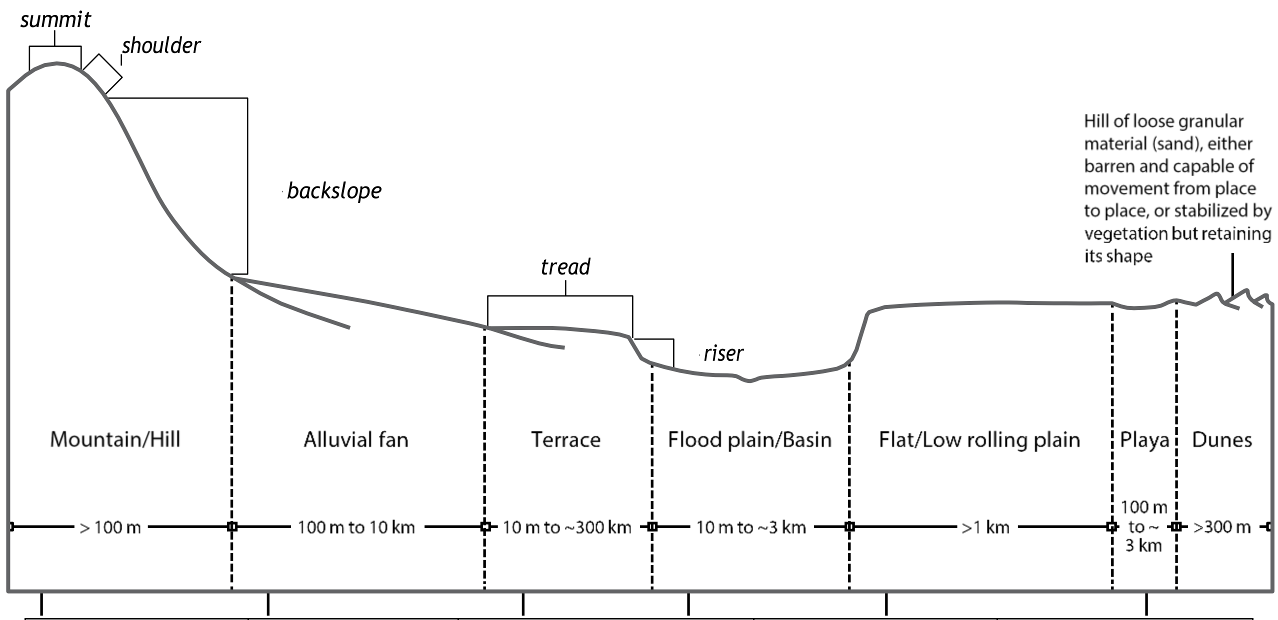
Elmore County Area, Idaho, Parts of Elmore and Owyhee Counties

Elmore County Area, Idaho, Parts of Elmore and Owyhee Counties

Map unit symbol	Map unit name	Component name (percent)	Ecological site	Acres in AOI	Percent of AOI
47	Davey-Mazuma complex, 12 to 40 percent slopes	Davey (50%)	R011XY014ID — SANDY LOAM 8-12 ARTRW8/ACHY-HECOC8	15,941.8	0.6%
		Mazuma (30%)	R011XY002ID — SALINE BOTTOM 8-12 - Provisional		

- Ecological site maps generated using Soil Data Viewer or Web Soil Survey will represent the site correlated with the dominate soil(s) in each soil map unit, whereas the EDIT interface provides a list of ecological sites associated with the major soil components and their percentages for the map unit. The user must determine which other ecological sites might occur based on the components of each soil map unit. The secondary major soil components and inclusions may represent different ecological sites, which are identified under the map unit component description in the soil survey (Pellant et al. 2020).
- Obtain the ecological site description(s). After compiling the list of expected ecological sites to be found in the field, refer to EDIT (edit.jornada.nmsu.edu) to obtain ecological site description reports. If the required ecological site description is not available online, contact the state NRCS rangeland management specialist to see if a draft is available for use. Examine copies of the relevant ecological sites and soil map unit and soil series descriptions, in the field as they may help with interpretation of soil profile and matching the discrete ecological site.
- In the evaluation area, compare the physiographic characteristics to the soil description in the ecological site description (i.e., are the ranges in elevation, slope, aspect, etc., within those described for the ecological site?). Use figure B-F-7 to help determine the topographic position of the site evaluation area. The site evaluation area's characteristics should fit with the ecological site descriptions physiographic characteristics.

Figure B-F-7. Generic landscape units (mountain/hill, alluvial fan, terrace, floodplain/basin, flat/low rolling plain, playa, dunes) to describe topographic position (Herrick et al. 2017).



Elevated area, nearly level, usually with a sink or depression. Summit area where water collects. Surrounded by no visible outlet. Surrounding slopes generally with steep sides.	Low, outspread mass of loose materials and/or rock material deposited by water, common with gentle slopes shaped like an open fan.	Step-like surface bordering a valley or shoreline that represents the former position of a flood plain, lake, or sea shore.	Nearly level plain that borders a stream and is subject to inundation under goo stage conditions.	Extensive region of comparatively smooth, level and/or

- Be aware of the key characteristics that differentiate the potential ecological sites in the area. For example, the soil map unit may represent a soil complex that alternates between a shallow claypan with a restrictive layer at a given depth and a deeper loamy soil; another example is a soil map unit that contains loamy and sandy soils that result in different ecological sites. Knowing these likely soil differences will make the ecological site identification process easier and more efficient.
- Dig a sufficient number of soil pits in the evaluation area to confirm that it is within a single ecological site. If more than one ecological site occurs within the site evaluation area, each site must be assessed separately.
- To complete the ecological site determination, compare the observations from the evaluation area to those from the soil information source. If the soil characteristics observed in the evaluation area have major differences from those described in the soil information source, determine whether another information source, such as a different ecological site description or soil component description, better matches the evaluation area characteristics. In some instances, none of the soil components listed for the map unit will match the soils found at an evaluation area within that map unit. In this situation, it can be helpful to review soil descriptions from adjacent map units, or even adjacent soil

survey areas, to identify the correct soil and correlated ecological site description (Pellant et al. 2020).

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Appendix B-G. – Describing and Hand-Texturing Soils

Soil texture is perhaps the most important soil properties used in conservation planning. Soil texture is an integral property related to hydrology, erosion dynamics, soil aggregate stability, intrinsic organic matter levels and dynamics, plant adaptability, and production. Soil texture influences plant growth by its effect on aeration, water intake rate, available water capacity, cation-exchange capacity, saturated hydraulic conductivity, erodibility, and workability (NRCS NSSH).

Describing and texturing soils can be determined after digging a soil pit or hole at the beginning of the soil determination process. By definition, soil texture is the relative proportion, by weight, of particle size classes (sand, silt, and clay) less than 2 mm in equivalent diameter (NRCS NSSH). Soil texture is directly related to parent material and the weathering processes of that material. Changes in texture as related to depth are an indication of how a soil was formed (NRCS NSSH).

Soil texture class can be determined fairly easily in the field by rubbing moist soil between the fingers (figure B-G-1). Good accuracy can be obtained from field estimates of soil texture if estimates are periodically validated against laboratory results or reference samples (NRCS NSSH). Generally, soil texture can be estimated by feeling the overall grittiness, which represents the sand particles, and estimating the overall contribution of fine particles based on plasticity and stickiness, which represents the silt and clay particles. There is no field quick mechanical-analysis procedure that is as accurate as the fingers of an experienced specialist, especially if standard reference samples are available and local conditions are considered (SSFLMM v2).

The basic soil textural classes, in order of increasing proportion of fine particles, are sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay (figure B-G-2). The sand, loamy sand, and sandy loam classes may be further divided by specifying “coarse,” “fine,” or “very fine” (figure B-G-3). One must be familiar with local soil chemical and physical characteristics as certain soil properties can cause incorrect estimates of soil texture if not considered (NRCS 2020). Field criteria used to estimate texture class should be adjusted based on local conditions (NRCS SSM). In certain situations, the quantity of estimated clay may be too high based on some overriding soil physical or chemical property. Therefore, clay content must be adjusted lower than field estimates to provide an accurate estimation of texture class.

For example:

In some environments, clay aggregates are so strongly cemented together that they feel like fine sand or silt, with cementing agents varying by location. In humid climates, iron oxide may be the cementing agent, in desert climates, silica may be the cementing agent, and in arid regions, calcium carbonate can be the cementing agent. In this case, field estimation of soil texture takes prolonged rubbing in order to breakdown larger aggregates to reveal that soil separates are dominated by clays and not silt loams. (Pellant et al. 2020; SSFLMM v2).

Soils with large amounts of silt and sand sized platy minerals such as mica, vermiculite, and shale can make the texture seem finer than the texture determined in the laboratory (SSFLMM v2). The presence of sticky, plastic clays such as smectite can make the soil seem to have higher clay content than it does (SSFLMM v2).

Excessive salts can cause either overestimation or underestimation of clay. Large amounts of calcium carbonate, gypsum, or other salts tend to cause problems in determining soil textures. Some salts reduce the amount of stickiness and thus lead to an underestimation of clay and some salts like clay sized calcium carbonate often result in an overestimation of clay content. Sodium salts tend to make soil particles disperse and thus can lead to a higher estimate of clay content (SSFLMM v2).

Clay content in soils with high organic matter can result in an underestimation in clay content due to the organic matter lowering the plasticity and diluting the volume of mineral matter.

Some soils derived from granite contain grains that resemble mica but are softer. Rubbing breaks down these grains and reveals they are dominated by clay particles. These grains resist dispersion, causing field and laboratory determinations to disagree, unless proper precautions are taken (SSFLMM v2).

Many soil conditions and components previously mentioned can cause inconsistencies between field texture estimates and standard laboratory data. Cementing agents, sodium content, organic matter content, calcium carbonate content, large clay crystals and/or mineral grains are possible causes.

The following figures can help with hand-texturing soils and describing soil structure, rock fragment content, and effervescence.

Figure B-G-1. Guide to Texture by Feel (adapted and modified from Thien 1979).

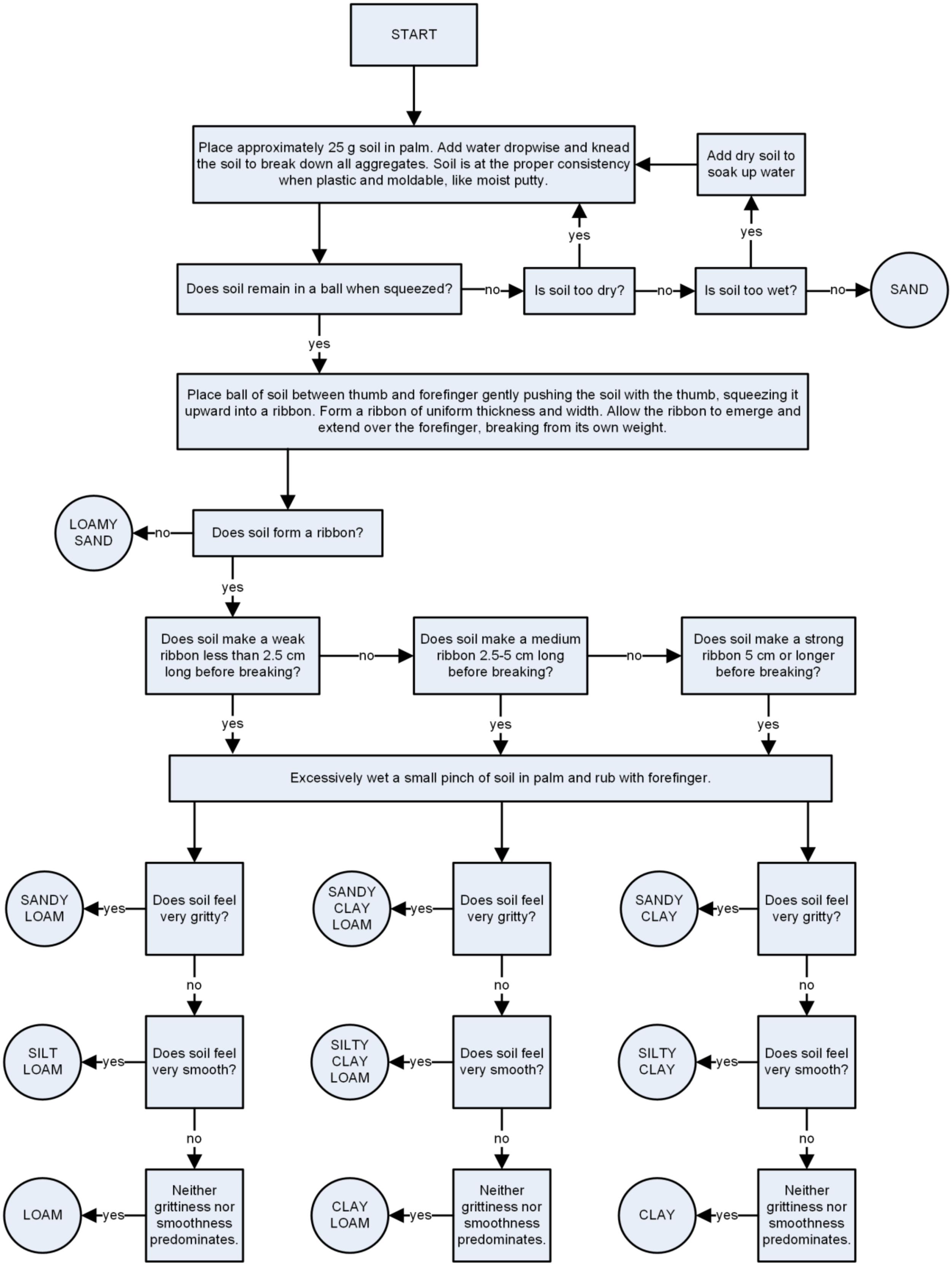
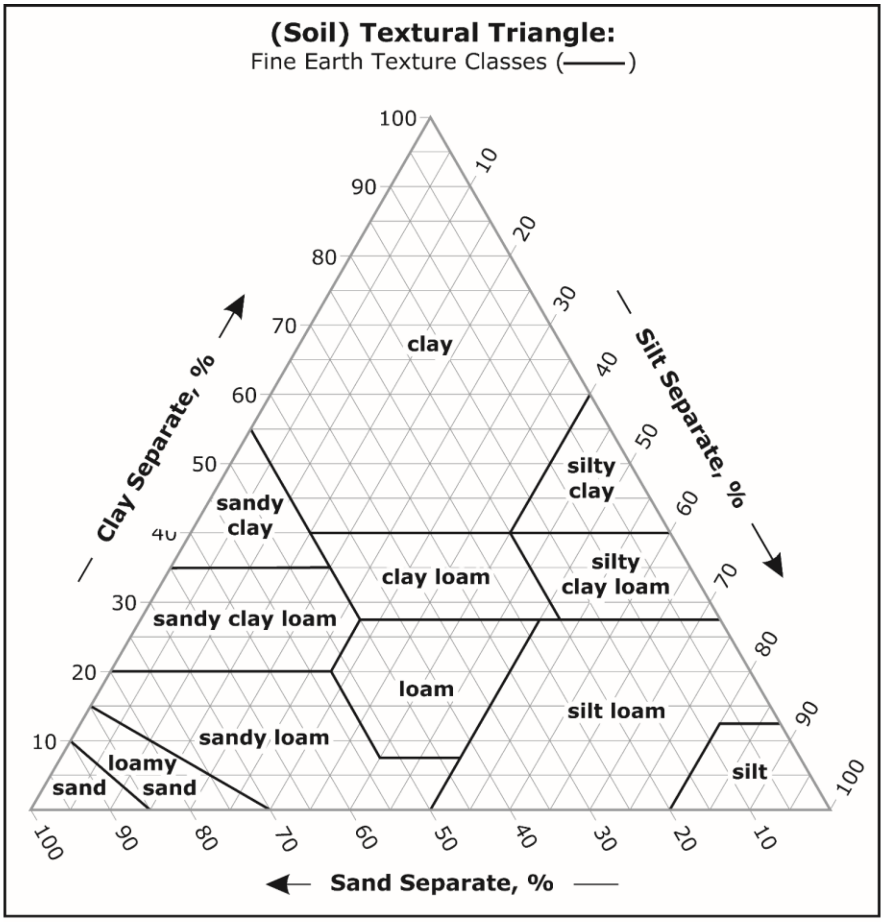


Figure B-G-2. Soil Texture Modifiers (FBDSS v 3.0).



TEXTURE MODIFIERS—Conventions for using "Rock Fragment Texture Modifiers" and for using textural adjectives that convey the "% volume" ranges for **Rock Fragments - Quantity and Size**.

Frag. Content Vol. %	Rock Fragment Modifier Usage
<15	No texture class modifier (noun only; e.g., *loam*).
15 to <35	Use fragment-size adjective with texture class; e.g., *gravelly loam*.
35 to <60	Use "**very**" with fragment-size adjective with texture class; e.g., *very gravelly loam*.
60 to <90	Use "**extremely**" with fragment-size adjective with texture class; e.g., *extremely gravelly loam*.
≥90	No adjective or modifier. If ≤10% fine earth, use the appropriate fragment-size class name for the dominant size class; e.g., *gravel*. Use **Terms Used in Lieu of Texture** (see table on p. 2–43).

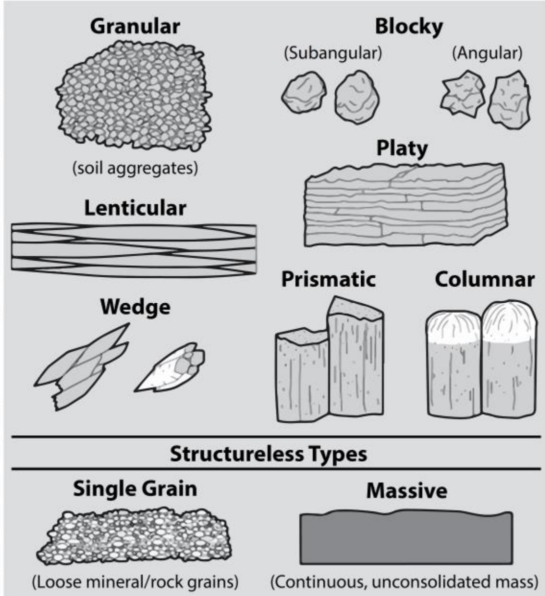
Figure B-G-3. Summary of common soil descriptors: **A.** Effervescence classes used to describe the entire soil matrix using 1 M HCL (Soil Science Division Staff 2017); **B.** Soil structure classes by size and shape; **C.** Examples of soil structure types; **D.** Soil structure grades and descriptions; and **E.** Particle size classes (Pellant et al. 2020).

A. Effervescence class	Criteria
Noneffervescent	No bubbles form
Very slightly effervescent	Few bubbles form
Slightly effervescent	Numerous bubbles form
Strongly effervescent	Bubbles form low foam
Violently effervescent	Thick foam forms quickly

B. Soil Structure Classes by Size and Shape

Class	Platy and granular (mm)	Prismatic, columnar, and wedge (mm)	Blocky and lenticular
Very fine	< 1	< 10	< 5
Fine	1 to < 2	10 to < 20	5 to < 10
Medium	2 to < 5	20 to < 50	10 to < 20
Coarse	5 to < 10	50 to < 100	20 to 50
Very coarse	≥ 10	100 to < 500	≥ 50
Extremely coarse	N/A	≥ 500	N/A

C. Examples of Soil Structure Types



D. Soil Structure Grades and Descriptions

Weak	The units are barely observable in place. When they are gently disturbed, the disturbed soil material parts into a mixture of whole and broken units, the majority of which exhibit no planes of weakness.
Moderate	The units are well formed and evident in undisturbed soil. When disturbed, the soil material parts into a mixture of mostly whole units, some broken units, and material that is not in units. Peds part from adjoining peds to reveal nearly entire faces that have properties distinct from those of fractured surfaces.
Strong	The units are distinct in undisturbed soil. They separate cleanly when the soil is disturbed. When removed, the soil material separates mainly into whole units. Peds have distinctive surface properties.

E. USDA Particle Size Classes

FINE EARTH			ROCK FRAGMENTS		
Class	Subclass	Size (mm)	Class	Subclass	Size (mm)
Clay	Fine	< 0.0002	Gravel	Fine	2-5[1]
	Coarse	0.0002-0.002			
Silt	Fine	0.002-0.02		Medium	5-20
	Coarse	0.02-0.05			
Sand	Very Fine	0.05-0.1		Coarse	20-76
	Fine	0.1-0.25			
	Medium	0.25-0.5	Cobbles	-	76-250
	Coarse	0.5-1.0	Stones	-	250-600
	Very Coarse	1.0-2.0	Boulders	-	> 600

[1] Note that particles from 2-5 mm are considered gravel (rock) for purposes of soil description and identification. However, only fragments ≥ 5 mm are recorded as rock for purposes of calculating ground cover.

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