Landscape Conservation Forecasting

Report to the Powell Ranger District, Dixie National Forest, USDA Forest Service
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Western margin of the Paunsaugunt Plateau, © Joel S. Tuhy, 1998.

By
Joel Tuhy, Louis Provencher, and Greg Low
The Nature Conservancy
Moab, Utah and Reno, Nevada

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Introduction

In 2005 the USDA Forest Service (USFS) and The Nature Conservancy (TNC) entered into a Challenge Cost Share Agreement. The general intent of the Agreement was to generate neutral scientific information in support of National Forest Plan revisions, and/or support of planning for project-level activities, on four National Forests in southern and eastern Utah – Dixie, Fishlake, Manti-La Sal and Ashley. Initial work by TNC and the Forests was very productive, resulting in identification of potential Species of Concern and Species of Interest under the Species Diversity section (43.2) of the 2005 Planning Rule. Attention was about to turn to Ecosystem Diversity (sec. 43.1) when the work became dormant upon challenge to the 2005 Planning Rule.

In February 2009 we revived this Agreement, working on the Dixie and Fishlake National Forests to refine an approach to landscape-level vegetation modeling and treatment analyses that those two Forests had already done internally several years prior. This current effort provides the opportunity to improve on that earlier work, in terms of better-quality data sources and advances in modeling and treatment analysis tools.

The purpose of this current project is to inform and guide the development of specific, cost-effective vegetation management strategies to maintain, enhance or restore the ecological integrity of lands in the Dixie and Fishlake National Forests. Special emphasis was placed on one District of each Forest: the Powell Ranger District (Dixie) and the Fremont River Ranger District (Fishlake).

The Powell Ranger District (District) supports a diversity of ecosystems in the higher-elevation country of south-central Utah. The District encompasses approximately 375,000 acres of largely undeveloped lands whose great physical diversity supports a large array of biotic habitats and species. Many decades of meeting multiple-use needs of people, coupled with underlying ecological functioning and disturbance regimes, provide opportunities to improve watershed health and restore resilient ecosystems through proactive collaboration across landscapes. The current interplay of socioeconomic and resource-management issues on the District is complex and challenging. An approach is needed that includes both adequate scientific rigor and the ability to identify specific sets of treatment projects (among many possibilities) that have optimal value, or return-on-investment, toward improving ecological conditions.

Process and Methods

The analyses and assessment done on the Powell Ranger District used an emerging TNC process that has come to be known as Landscape Conservation Forecasting (LCF). The LCF process comprises six general steps, listed as follows:

1. Develop maps of the major vegetation types, termed synonymously as biophysical settings or ecological systems, by interpreting and integrating LANDFIRE satellite imagery and National Forest vegetation maps.

2. Refine computerized predictive ecological models for the ecological systems by updating TNC's Great Basin "library" of models, some that were created by current and former Dixie and Fishlake Forest staff, with earlier Forest versions of the models.
3. Determine current condition of all ecological systems (a broad-scale measure of their "health"), using Ecological Departure (a.k.a., Fire Regime Condition or FRC) metrics and Fire Regime Condition Class (FRCC).
4. Use the computerized ecological models to forecast anticipated future condition of ecological systems under minimum management.
5. Use the computerized ecological models to forecast anticipated future condition of ecological systems under alternative management strategies.
6. Use Return-on-Investment analysis to assess which strategies for which ecological systems yield the most advantageous results.

All major vegetation types on the District were included in the overall analysis. Some vegetation types with minor areal coverage or minimal management need were not included in the more detailed assessment of management options. The assessment was developed using GIS integration of previously mapped data, predictive ecological models, and cost-benefit assessments. Two workshops and a conference call were held with managers and natural resource specialists from the District and the Forest to review and refine map data, refine ecological models, identify and explore potential vegetation management scenarios, and review findings.

TNC used the ecological departure procedure initially developed under the national LANDFIRE program to assess the project area's ecological condition. Ecological departure is an integrated, landscape-level estimate of the ecological condition of terrestrial and riparian ecological systems. Ecological departure incorporates species composition, vegetation structure, and disturbance regimes to estimate an ecological system's *departure* from its natural range of variability (NRV). NRV is the percentage of each vegetation succession class that would be expected in an ecological system across the landscape under a natural disturbance regime. Ecological departure (from NRV) is measured on a scale of 0 to 100, where higher numbers indicate greater departure. In addition, because of great variability in the cost and management urgency to address vegetation classes that are *uncharacteristic* (i.e. not part of NRV), a separate designation and calculation of "high-risk" vegetation classes – such as cheatgrass-invaded – was also applied.

TNC completed the following tasks that were reviewed at the two workshops with District and Forest staff people, as noted above:

- We integrated spatial data from two sources – (1) satellite imagery from LANDFIRE, and (2) National Forest soil-vegetation map data – to generate a single spatial data set of biophysical settings (= ecological systems), and their vegetation succession classes, across the District, with feedback and recommended adjustments from District and Forest staffs.
- We refined ecological models for each major ecological system, using reference and management models developed by TNC with Utah Partners for Conservation and Development in northwestern Utah, as well as with Great Basin National Park, the Bureau of Land Management, and the USDA Forest Service on the Humboldt-Toiyabe National Forest.

These models incorporated vegetation composition, structural classes and disturbance regimes to predict the natural range of succession classes.

- For each ecological system, we compared current succession-class distribution percentages with "natural" class distribution percentages (defined by NRV), and calculated each system's departure from its NRV. Each ecological system was assigned an ecological departure score ranging from 0% to 100% departure from NRV, and an associated ecological departure (= Fire Regime Condition) class of 1, 2 or 3 based on the departure score.
- We identified which ecological systems are likely to suffer future impairment over the next 20 years under minimum management, based on computer simulations using the predictive ecological models.

Nine focal ecological systems on the Powell Ranger District were selected for management treatment analyses, based upon their size, high departure from NRV, likelihood of high future departure and/or presence of high-risk vegetation classes. These included four forest systems, three sagebrush systems, an oak-shrub system, and the montane-subalpine riparian system:

Ponderosa Pine	102,760 acres
Aspen–Spruce-Fir	43,000 acres
Aspen–Mixed Conifer	41,310 acres
Mixed Conifer	33,350 acres
Black/Low Sagebrush	30,420 acres
Wyoming/Basin Big Sagebrush	21,140 acres
Montane Sagebrush Steppe	16,630 acres
Montane-Subalpine Riparian	12,450 acres
Gambel Oak–Mixed Mountain Brush	10,040 acres

As noted above, the underlying purpose of this project is to identify specific, cost-effective vegetation management strategies to maintain, enhance or restore the ecological integrity of lands on the Powell Ranger District. This statement of general purpose was expanded by District and Forest managers into a set of key **conservation and restoration objectives** for the project area, listed as follows:

- Maintain overall condition and prevent deterioration of native ecological systems.
- Reduce ecological departure for targeted ecological systems to a more properly functioning condition.
- Reduce and prevent expansion of high-risk vegetation classes (e.g., exotic species).
- Decrease fuel loads to reduce risk from wildfire to human settlements (WUI) & cultural resources in and around the forests.
- Help make treatment projects competitive for potential funding resources.
- Complement other multi-use objectives.

At and between the project's two workshops, management strategies were explored to achieve (or make progress toward) these stated conservation and restoration objectives for the nine focal ecological systems. Predictive state-and-transition computer models were used to simulate conditions under alternative future management scenarios. Using computer-based models, the likely future condition of the nine focal systems was assessed after 20 years under three primary management scenarios:

1. Minimum management – no actions except continuation of current livestock grazing, i.e. no prescribed fire, no thinning, no treatment of invasive species, etc.
2. Maximum management – management treatments geared to restore ecological condition (reduce ecological departure) to the greatest possible degree, regardless of budget.
3. Streamlined management – management strategies aimed at enhancing ecological condition for reduced cost.

A Return-on-Investment calculation was done for the maximum and streamlined management scenarios, to compare ecological benefits against costs, both *within* and *across* ecological systems. Land managers may select final strategies or treatment areas based upon a variety of additional factors, such as availability of financial resources, policy constraints, and other multiple-use objectives.

Key Findings

The primary findings of the Landscape Conservation Forecasting assessment on the Powell Ranger District are summarized below:

1. **The approximately 375,000-acre Powell Ranger District is a largely undeveloped landscape that includes a diversity of Utah High Plateau ecological systems, ranging from sagebrush shrublands to subalpine meadows and forests.**

2. **The current condition of the District's ecological systems varies in terms of departure from their natural condition.** Of the area's 13 ecological systems greater than 500 acres, two are slightly departed from their natural range of variability, ten are moderately departed, and one is highly departed.

3. **The primary cause of current ecological departure across the Powell District is that the aspen forest, mixed conifer forest and sagebrush systems are dominated by late succession classes.** The aspen-spruce fir and the aspen-mixed conifer forests together account for approximately 84,000 acres, and may have suffered even greater past conversion (loss) of aspen to conifer than the interpreted map data show. The three sagebrush systems collectively total approximately 68,000 acres.

4. **Nine ecological systems require special attention, based upon current condition and computer simulations over the next 20 years.** One of the targeted systems is currently highly departed from the natural range of variability and seven are moderately departed. Four of the targeted systems have, or are projected to have within 20 years, an undesirable percentage of high-risk vegetation classes. Key ecological management issues include:
   - ***Aspen forest systems*** **–** overabundance of late-succession classes, as well as aspen vegetation on a pathway of conversion to conifers.
   - ***Ponderosa pine and mixed conifer forests*** **–** overabundance of vegetation in the late-closed succession class; projected improvement in these forest systems over time was

dependent upon substantial wildfire which randomly occurred in the computer simulations, but is not assured.

- ***Sagebrush systems*** **–** current shortage of early-succession classes, plus projected increases in high-risk classes (e.g. pinyon-juniper encroachment, and increasing cover of cheatgrass within shrublands).
- ***Oak-brush*** **–** substantial encroachment by conifer trees.
- ***Riparian*** **–** projected dramatic increases in exotic forbs and uncharacteristic species (e.g. Wood's rose) without active management.

5. **Varied management strategies were explored for each targeted ecosystem, using computer simulations to test their effectiveness and adjust the scale of application. Multiple strategies are required for most ecosystems.**
    - ***Aspen forest*** strategies include: prescribed fire, conifer removal, and partial timber harvest – all to achieve a mixed age class structure closer to the natural range of variability.
      <u>Note</u>: The aspen-mixed conifer system includes two large areas with very different conditions as a result of a recent large fire. One of the areas requires active management, but mapping and modeling the two areas separately was beyond the scope of this project.
    - ***Ponderosa pine and mixed conifer forest*** strategies include: prescribed fire – along with combinations of mechanical thinning and varied types of timber harvest – applied adaptively to achieve an age class structure closer to the natural range of variability.
    - ***Sagebrush*** strategies include varied combinations of: prescribed fire; harrowing or mowing, with and without seeding to create a more diverse understory; mastication, chaining, or herbicide of late succession classes; mechanical thinning of tree-encroached sagebrush plus seeding with grass species; and herbicide application in shrublands with annual grasses.
    - ***Oak-brush*** strategies include: mechanical- or hand-thinning of encroaching conifer trees, prescribed fire, and thinning plus seeding of tree-encroached brush.
    - ***Riparian*** strategies include: ongoing weed inventory, spot application of herbicides to reduce exotic forbs, thinning of conifer trees, and Wood's rose reduction followed by herbicide to reduce invasive woody species.

6. **The streamlined management strategies <u>benefited all nine focal systems</u> as compared to current condition and/or minimum management scenarios.** The streamlined management achieved low ecological departure (close to the natural range of variability) for eight systems. For the dominant ponderosa pine system, streamlined management achieved low ecological departure in the absence of a (unpredictable) wildfire event. Moreover, the streamlined management strategies reduced or contained high-risk vegetation classes for all systems.

7. **The streamlined management scenarios accrued the highest "return on investment" for all relevant systems, as compared to the maximum management scenario.** *However, in several cases the maximum management scenarios would achieve even greater ecological benefits if additional management funds were to become available.* The ROI metric was not applicable for assessing alternative strategies in forest systems when projected income was generated from harvesting. TNC's area-weighted return on investment analysis showed favorable results across all ecological systems.

Introduction

In 2005 the USDA Forest Service (USFS) and The Nature Conservancy (TNC) entered into a Challenge Cost Share Agreement. The general intent of the Agreement was to generate neutral scientific information in support of National Forest Plan revisions, and/or support of planning for project-level activities, on four National Forests in southern and eastern Utah – Dixie, Fishlake, Manti-La Sal and Ashley. Initial work by TNC and the Forests was very productive, resulting in identification of potential Species of Concern and Species of Interest under the Species Diversity section (43.2) of the 2005 Planning Rule. Attention was about to turn to Ecosystem Diversity (sec. 43.1) when the work became dormant upon challenge to the 2005 Planning Rule.

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The purpose of this current project is to inform and guide the development of specific, cost-effective vegetation management strategies to maintain, enhance or restore the ecological integrity of lands in the Dixie and Fishlake National Forests. Special emphasis was placed on one District of each Forest: the Powell Ranger District (Dixie) and the Fremont River Ranger District (Fishlake); this report covers the Powell Ranger District (the "District"). The current interplay of socioeconomic and resource-management issues on the District is complex and challenging. An approach is needed that includes both adequate scientific rigor and the ability to identify specific sets of treatment projects (among many possibilities) that have optimal value, or return-on-investment, toward improving ecological conditions.

Background

The Powell Ranger District supports a diversity of ecosystems – forests, woodlands, shrublands, smaller herbaceous meadows, and riparian areas – in the higher-elevation country of south-central Utah. Though the vast majority of the District is undeveloped in the sense of lacking the footprint of roads and other permanent infrastructure, it does not necessarily possess the same ecological structure and function that developed there over the last several millennia. In the past century and a half, European human settlement has brought with it major changes to this landscape and its ecological communities.

In lower and middle elevation rangelands, domestic livestock grazing altered the structure and composition of grasslands and shrublands, especially in the late 1800s and early 1900s when huge unregulated herds of cattle and sheep grazed the country every year. In the mid to late 1900s, various non-native plants were introduced and then spread. Especially problematic were invasive annual grasses, which altered soil moisture conditions and otherwise took over communities of native plants. In concert with alterations from grazing and invasive plants, fire regimes have greatly changed in these rangelands in terms of increased frequency and severity, perpetuating and expanding the problem of invasive grasses that are well adapted to such conditions. Conversely, in certain shrublands a well-implemented policy of aggressive fire suppression, coupled with other land uses, has resulted in large areas being invaded by dwarf conifers (pinyon and juniper).

In middle and upper elevation habitats, domestic livestock grazing on the summer range likewise altered the structure and composition of vegetation throughout the shrublands, meadows and forest understories that occupy the country. Even more pervasively, the same aggressive and effective policy of fire suppression resulted in huge build-ups of fuels in the forested habitats, altering fire regime to where large areas are now at risk of major wildfires. This issue is compounded by the spread of pockets of human infrastructure – the wildland-urban interface – right into the middle of such areas with heavy fuel loadings.

By virtue of their proximity to water, the District's riparian habitats have an importance that is proportionally far greater than their small aggregate size. Over the years, many concentrated land uses in these narrow corridors have led to issues such as channel down-cutting, altered understory species composition, large reduction of native beaver populations, invasion of adjacent upland conifers (pinyon and juniper), and introduction and spread of aggressive invasive weeds.

Thus on the Powell Ranger District, many decades of meeting multiple-use needs of people, coupled with underlying ecological functioning and disturbance regimes, now provide opportunities to improve landscape health and restore resilient ecosystems. This Landscape Conservation Forecasting project aims to build a good foundation for this to happen.

Project Area

Located in Kane, Garfield, and (barely) Piute Counties, the Powell Ranger District encompasses approximately 375,000 acres of largely undeveloped lands in the High Plateaus region of Utah (Figure 1). The District is divided into two fairly different segments, roughly along the line of Utah Highway 12. To the north, the area represented by Mount Dutton (or locally, just "the Dutton") is largely comprised of rocks and parent materials of volcanic origin. To the south is the Paunsaugunt Plateau proper, where rocks are of sedimentary origin, chiefly the Tertiary-age Claron Limestone that forms the so-called Pink Cliffs, the highest step of southern Utah's Grand Staircase. The various parent materials and landforms, present through an elevational range roughly from 6,400 to 11,000 feet, create an area of great physical diversity that supports a large array of biotic habitats and species. A list of the District's major vegetation types, termed "ecological systems" by this project, is as follows:

Ecological System	Acres	Ecological System	Acres
Ponderosa Pine	102,760	Montane-Subalpine Riparian	12,450
Aspen–Spruce-fir	43,000	Gambel Oak–Mixed Mountain Brush	10,040
Pinyon-Juniper	41,730	Stable Aspen	4,100
Aspen–Mixed Conifer	41,310	Spruce-Fir	3,070
Mixed Conifer	33,350	Montane Chaparral	240
Black/Low Sagebrush	30,420	Subalpine Meadow	60
Wyoming/Basin Big Sagebrush	21,140	Mixed Salt Desert Scrub	50
Montane Sagebrush Steppe	16,630	Limber-Bristlecone Pine	10
Curlleaf Mountain Mahogany	13,750		

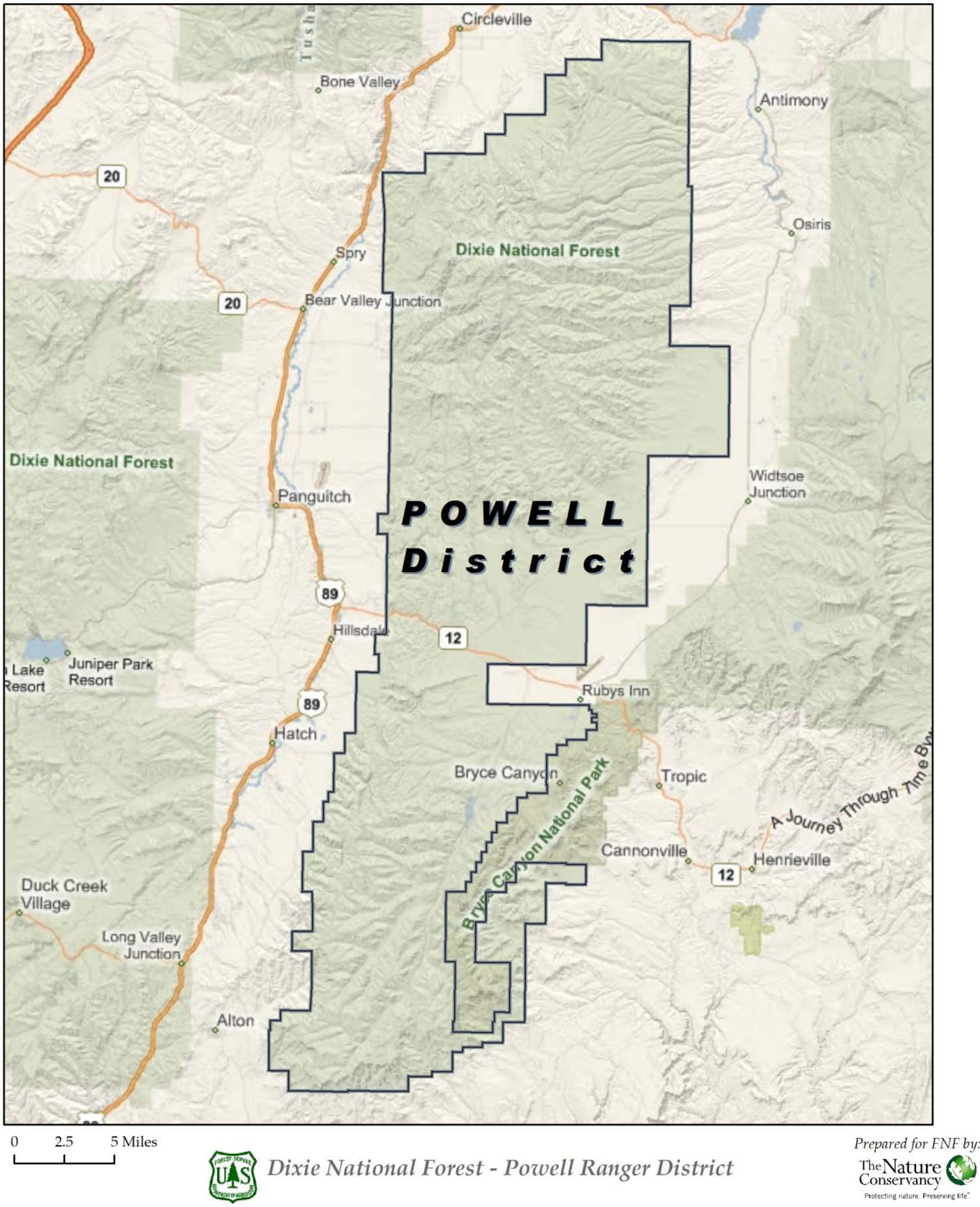


Figure 1. Powell Ranger District project area.

Objectives

Key objectives for the Powell Ranger District Landscape Conservation Forecasting Project identified by project participants were as follows:

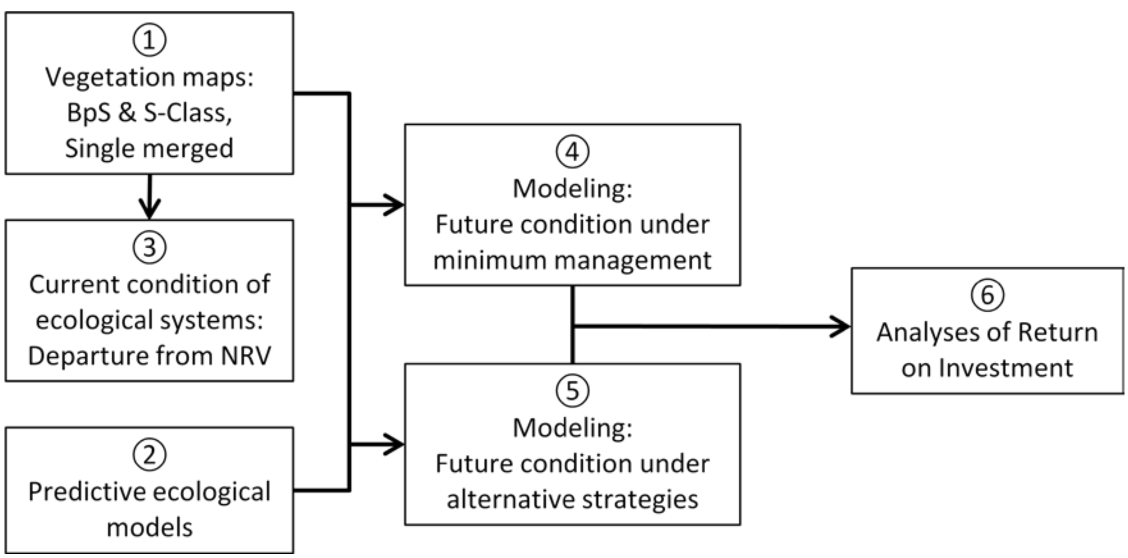
- Maintain overall condition and prevent deterioration of native ecological systems.
- Reduce ecological departure for targeted ecological systems to a more properly functioning condition.
- Reduce and prevent expansion of high-risk vegetation classes (e.g., exotic species).
- Decrease fuel loads to reduce risk from wildfire to human settlements (WUI) & cultural resources in and around the forests.
- Help make treatment projects competitive for potential funding resources.
- Complement other multi-use objectives.

Process and Methods

The Landscape Conservation Forecasting process used on the Powell Ranger District consists of six primary components or steps, as follows:

1. Develop maps of the major vegetation types, termed synonymously as biophysical settings or ecological systems, by interpreting and integrating LANDFIRE satellite imagery and National Forest vegetation maps.
2. Refine computerized predictive ecological models for the ecological systems by updating TNC's Great Basin "library" of models, some that were created by current and former Dixie and Fishlake Forest staff, with earlier Forest versions of the models.
3. Determine current condition of all ecological systems (a broad-scale measure of their "health"), using Ecological Departure (a.k.a., Fire Regime Condition or FRC) metrics and Fire Regime Condition Class (FRCC).
4. Use the computerized ecological models to forecast anticipated future condition of ecological systems under minimum management.
5. Use the computerized ecological models to forecast anticipated future condition of ecological systems under alternative management strategies.
6. Use Return-on-Investment analysis to assess which strategies for which ecological systems yield the most advantageous results.

A simple schematic diagram that displays the relationship of these components to each other is presented below:



In terms of project chronology, the majority of the work on these steps was done by TNC staff members in Nevada and Utah beginning in late 2009. On two occasions, late April and mid July 2010, Workshops were held among TNC, District/Forest staffs, and a few other specialists, to view and revise products that TNC had generated to-date. A rough timeline of the work done on the project's components is presented below:

	Dec 2009	Jan 2010	Feb 2010	Mar 2010	Apr 2010	Workshop 1 April 27-28	May 2010	Jun 2010	Jul 2010	Workshop 2 July 14-15	Aug 2010	Sep 2010
Vegetation maps: single merged						Major Review						
Predictive ecological models						Observe & Comment						
Current condition of ecological systems						Observe & Comment				Observe & Comment		
Modeling: future condition min mgmt						Observe & Comment				Observe & Comment		
Modeling: future condition alt strategies						Generate & Evaluate				Major Evaluation		
Return-on-Investment analyses						Observe				Observe		
Report preparation												

Detailed descriptions of methods used in each of the project's component six steps are presented in the subsections that follow.

Vegetation Mapping

Mapping Biophysical Settings and S-Classes

The foundation of the mapping component of this project is the stratification of the landscape into biophysical settings (BpS), which represent potential vegetation. More specifically, the BpS is represented by the "type" of dominant vegetation that is expected in the physical environment under natural ecological conditions and disturbance regimes. Preferably, biophysical settings are mapped by interpreting ecological sites from Natural Resource Conservation Service (NRCS) soil surveys to major vegetation types. The NRCS defines ecological site as "a distinctive kind of land with specific physical characteristics that differs from other kinds on land in its ability to produce a distinctive kind and amount of vegetation." (*National Forestry Manual*, www.nrcs.usda.gov/technical/ECS/forest/2002_nfm_complete.pdf). Biophysical settings are composed of one or more ecological sites sharing the same dominant upper-layer species.

This project did not have available to it the comprehensive coverage of NRCS soil surveys and associated ecological sites needed to achieve the preferred method for mapping biophysical settings, as noted above. Therefore, spatial data of vegetation-type distributions from three different sources were integrated or merged to generate one final vegetation map product. The three input sources were:

1. LANDFIRE satellite imagery, which for each grid cell (pixel) includes: (1) the biophysical setting type; and (2) the succession class or "S-Class" of the BpS type that currently occupies the grid cell. These LANDFIRE geodata were primary in the sense that all other products had to adopt their structure, because only these LANDFIRE spatial layers provided the critical S-Class (more intuitively, vegetation class) layer used to measure ecological departure.

2. The Dixie National Forest's vegetation/soils map that shows the distribution of existing vegetation types as polygons, according to the Forest's vegetation classification system.

3. The recent Sanford fire burn-severity geodata from the USFS Remote Sensing Application Center (RSAC).

The integration of the first two sources was accomplished by a three-step process:

(1) After a review of all LANDFIRE biophysical settings (BpS), TNC merged minor with larger ones (e.g., Great Basin Semi-Desert Grassland was nested in Wyoming Big Sagebrush), or combined ecologically-compatible BpS for simplicity (e.g., Black-Low sagebrush); then

(2) TNC painstakingly evaluated both the "concept" and the mapped distributions of all of the major vegetation (BpS) types that appeared in both the LANDFIRE and National Forest input sources; and then

(3) TNC wrote a lengthy set of queries or decision rules as to how those input data were to be depicted, pixel by pixel, on the output of the single merged map. This last step was essentially a crosswalk and merge of BpS between the LANDFIRE and National Forest geodata. The full set of queries for the Powell Ranger District (and, in fact, the entire Dixie National Forest), appears in Appendix 1.

For each BpS pixel in the raster data, it was next necessary to assign the correct vegetation class for any changed BpS (as a result of queries). Different BpS that were merged may have the same code of vegetation classes; however, the codes could correspond to distinct succession or uncharacteristic classes. This step involved another set of queries to crosswalk vegetation classes from a changed BpS to a "retained" BpS. This re-assignment of the vegetation class attributes was done according to field-informed knowledge of Great Basin and High Plateaus ecological systems by one of the project's principals (L. Provencher). A short description of each vegetation class by BpS used in the analyses is presented in Appendix 2.

A draft version of the single merged vegetation map was presented by TNC for review by District and Forest staff members at the project's first Workshop in late April 2010. Substantive comments by these reviewers, who know the vegetation well, were then used to refine the maps. This refinement was done by adjusting the relevant query statements that define the pixels' BpS assignment – not by manually changing the BpS identity of individual pixels. Moreover, District and Forest staff suggested that the vegetation class layer of LANDFIRE be updated with new geodata from the large Sanford fire. TNC downloaded RSAC's geodata and transformed the LANDFIRE vegetation classes from different ecological systems using knowledge of fire effects. Essentially, high severity, medium severity, and low severity fire effects resulted, respectively, in transition to the early, open/same, and same (self loop) vegetation classes. Fire effects in classes with annual grasses often created *annual-grasslands*, whereas uncharacteristic classes without cheatgrass became *early-shrub*. Subsequent adjustment of the pixels' S-Class assignments was then done as noted in the paragraph above.

The accuracy of the resulting final merged vegetation map was deemed to be sufficiently good by the District and Forest to serve as the basis for the project's subsequent analyses. The types and acreages of biophysical settings, also termed ecological systems, in the project area are shown in Table 1. TNC will deliver an electronic copy of the full Geographic Information System (GIS) project, including input and output raster layers, and queries to the GIS specialist of each Forest.

Table 1. Ecological Systems of the Powell Ranger District project area.

Ecological System	**Acres**	**Percent of project area**
Ponderosa Pine	102,760	27.5%
Aspen–Spruce-fir	43,000	11.5%
Pinyon-Juniper	41,730	11.2%
Aspen–Mixed Conifer	41,310	11.0%
Mixed Conifer	33,350	8.9%
Black/Low Sagebrush	30,420	8.1%
Wyoming/Basin Big Sagebrush	21,140	5.7%
Montane Sagebrush Steppe	16,630	4.4%
Curlleaf Mountain Mahogany	13,750	3.7%
Montane-Subalpine Riparian	12,450	3.3%
Gambel Oak–Mixed Mountain Brush	10,040	2.7%
Stable Aspen	4,100	1.1%
Spruce-Fir	3,070	0.8%
Montane Chaparral	240	0.1%
Subalpine Meadow	60	<0.1%
Mixed Salt Desert Scrub	50	<0.1%
Limber-Bristlecone Pine	10	<0.1%
Total	**374,110**	**100.0%**

Biophysical Setting Descriptions and Natural Range of Variability (NRV)

In order to measure the current (or future) ecological "health" of each ecological system, it was necessary first to define for each System its so-called Natural Range of Variability (NRV). NRV is the relative amount (percentage) of each vegetation class that would be expected to occur in a biophysical setting under natural disturbance regimes.

The NRV was calculated with the state-and-transition modeling software Vegetation Dynamics Development Tool (VDDT, ESSA Technologies; Forbis *et al*. 2006, Provencher *et al*. 2007; Provencher *et al*. 2008). To determine the NRV for each ecological system in the project area, we modified models from a TNC Great Basin and Mojave Desert ecoregion library developed in northwestern Utah, eastern Nevada, and California (originally LANDFIRE models; Hann and Bunnell 2001, Rollins 2009) with modeling data from the Fishlake and Dixie 2005 Forest Plan Revisions. The LANDFIRE geodata were based on vegetation classes as defined in TNC's models, whereas the USFS 2005 models pre-dated LANDFIRE and its standards. Therefore, we could not simply "merge" TNC and USFS models. Moreover, the USFS VDDT projects were sufficiently old that we could not open them with the current software version. As an alternative, we inventoried the USFS input text files that contained the disturbance (name codes, values, and age) information by ecological system and documentation captured on MS Powerpoint presentations. These data were cross-walked to TNC's model content; as a result, modifications, deletions or additions were made to TNC's models to conform to the local USFS understanding of system dynamics and management options. When USFS dynamics appeared odd, we audited modeling assumptions with USFS staff. The natural range of variability for each ecological system is listed below in Table 2.

Table 2. The natural range of variability for ecological systems of the Powell District.

	Natural Range of Variability (%)[1]					
Ecological System	**A**	**B**	**C**	**D**	**E**	**U**
Ponderosa Pine	7	3	43	46	1	0
Aspen–Spruce-fir	13	39	43	5	0	0
Pinyon-Juniper	2	7	25	66	0	0
Aspen–Mixed Conifer	17	42	35	4	2	0
Mixed Conifer	28	35	7	5	26	0
Black/Low Sagebrush	17	48	25	10	0	0
Wyoming/Basin Big Sagebrush	16	28	41	6	9	0
Montane Sagebrush Steppe	21	44	21	10	3	0
Curlleaf Mountain Mahogany	8	11	13	17	51	0
Montane-Subalpine Riparian	34	44	22	0	0	0
Gambel Oak–Mixed Mountain Brush	9	33	50	7	0	0
Stable Aspen	9	25	44	22	0	0
Spruce-Fir	14	43	1	42	0	0
Montane Chaparral	16	84	0	0	0	0
Subalpine Meadow	11	89	0	0	0	0
Mixed Salt Desert Scrub	17	76	7	0	0	0
Limber-Bristlecone Pine	10	14	77	0	0	0

1. Standard LANDFIRE coding for the 5-box vegetation model: A = early-development; B = mid-development, closed; C = mid-development, open; D = late-development, open; E = late-development, closed; and U = uncharacteristic. This terminology was often modified (Appendix 2).

Assessment of Current Ecological Condition – Calculating Ecological Departure

Once the biophysical settings and their current vegetation classes were mapped, TNC used the ecological departure procedure originally developed under the national LANDFIRE program to assess the ecological condition of each BpS in the project area. Ecological departure is a broad-scale measure of ecosystem "health" – an integrated, landscape-level estimate of the ecological condition of terrestrial and riparian ecological systems. Ecological departure incorporates species composition, vegetation structure, and disturbance regimes to estimate an ecological system's *departure* from its natural range of variability (NRV).

The fundamental inputs of ecological departure analysis are two-fold, both of which were described above: (1) mapping the distribution of biophysical settings (ecological systems) in the project area – i.e., the dominant vegetation types expected in the physical environment under a natural disturbance regime; and (2) mapping the current vegetation succession classes of each ecological system. The level of departure, or dis-similarity, from NRV for each ecological system was calculated by comparing the current vegetation succession-class distribution with the expected "natural" distribution (see Table 2).

Ecological departure is scored on a scale of 0% to 100% departure from NRV: Zero percent represents NRV while 100% represents total departure [i.e., the higher the number, the greater the departure]. Further, a coarser-scale metric known as Fire Regime Condition Class (FRCC) is used by federal agencies to group ecological departure scores into three classes: FRCC 1 represents ecological systems with low (<34%) departure; FRCC 2 indicates ecological systems with moderate (34 to 66%) departure; and FRCC 3 indicates ecological systems with high (>66%) departure (Hann *et al*. 2004). For purposes of consistent terminology, on this Powell District project we refer to FRCC as Ecological Departure Class. An example of ecological departure and corresponding ecological departure class is shown in Table 3.

Table 3. Example of calculation of Ecological Departure and Ecological Departure Class.

	Current Vegetation Class[1]						
	A	B	C	D	E	U	Total
Natural range of variability (%)	20	50	15	10	5	0	100
Current acres by class in project area	182	7,950	58,718	6,659	264	46,123	119,894
Current presence of classes (%)	0.2	6.6	49.0	5.6	0.2	37.4	
Ecological Departure (%)[2] (a.k.a. Fire Regime Condition)	0.2	6.6	15	5.6	0.2	0	72.4
Ecological Departure Class[3] (a.k.a. Fire Regime Condition Class)							3

1. Legend modified from LANDFIRE: A = early-development; B = mid-development, closed; C = mid-development, open; D = late-development, open; E = late-development, closed; and U = uncharacteristic.
2. Ecological Departure (ED) = 100% $-\sum_{i=1}^{n} \min\{Current_i, NRV_i\}$
3. Ecological Departure Class: 1 for 0% • ED • 33%; 2 for 34% • ED • 66%; 3 for 67% • ED • 100%.

Refinement of Predictive Ecological Models

On a separate, concurrent track early in the project, TNC worked to create or refine state-and-transition predictive ecological models for each major ecological system on the District. A state-and-transition model is a discrete, box and arrow representation of the continuous variation in vegetation composition and structure of an ecological system (Bestelmeyer *et al*., 2004). An example of a state-and-transition model for mountain big sagebrush from eastern Nevada (Forbis *et al*. 2006) is shown in Figure 2. Different boxes in the model belong either: (a) to different *states*, or (b) to different *phases* within a state. States are formally defined in rangeland literature (Bestelmeyer *et al*., 2004) as: persistent vegetation and soils per potential ecological sites that can be represented in a diagram with two or more boxes (phases of the same state). Different states are separated by "thresholds." A threshold implies that substantial management action would be required to restore ecosystem structure and function. Relatively reversible changes (e.g., fire, flooding, drought, insect outbreaks, and others), unlike thresholds, operate between phases within a state. For example, the boxes showing vegetation classes A-E in Figure 2 belong to one state, but are different phases of vegetation succession within that one state.

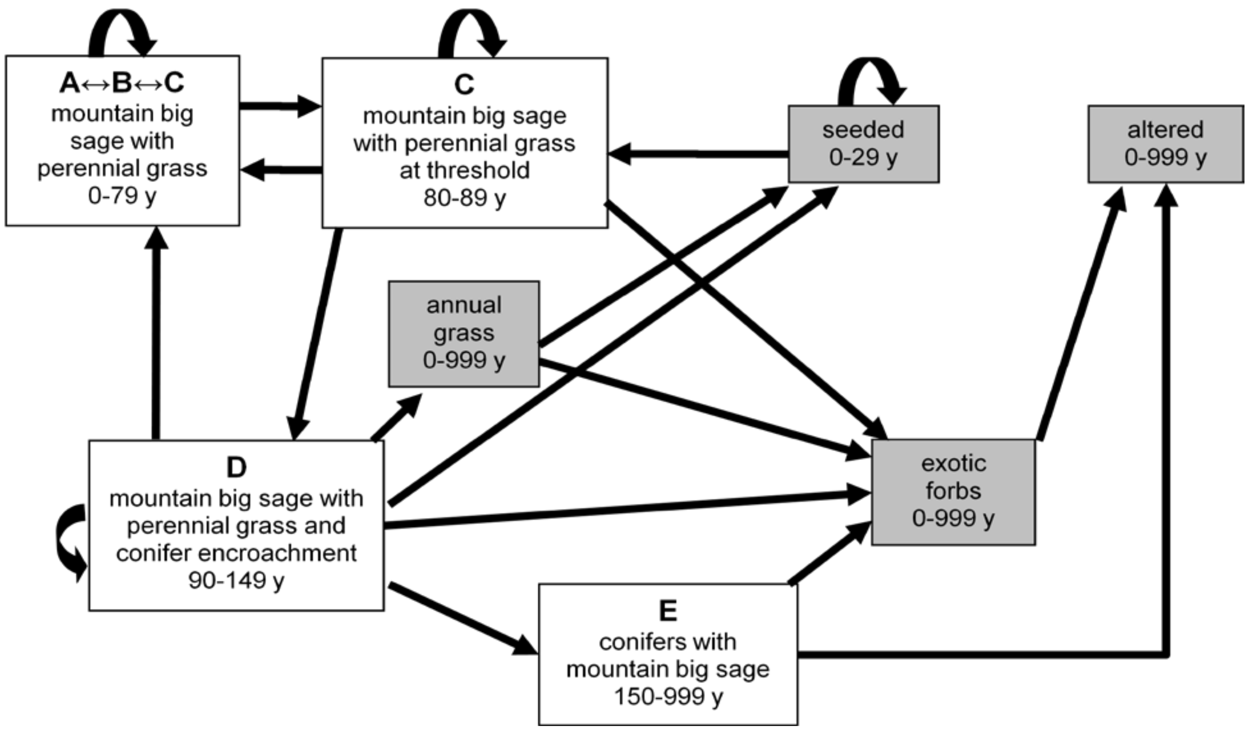


Figure 2. Example of state-and-transition model for mountain big sagebrush based on a VDDT model from Forbis *et al*. (2006).

Core Reference Models and Descriptions

State-and-transition models were used to represent vegetation classes and dynamics of each major ecological system on the Powell District. A general description of model dynamics is presented in Appendix 3.

At their core, all models had the LANDFIRE reference condition represented by some variation around the A-B-C-D-E succession classes (see Table 2). The A-E class models typically represented succession, usually from herbaceous vegetation to increasing woody species dominance where the dominant woody vegetation might be shrubs or trees. The vegetation classes of pre-settlement vegetation described in the Natural Range of Variability (Table 2) were considered to be each ecological system's core reference condition. As such, the reference condition does not describe vegetation condition caused by post-settlement management or unintentional actions (e.g., release of cheatgrass).

Management Models

In addition to modeling reference conditions, the predictive models included a management component to allow managers to simulate future conditions under alternative management strategies and scenarios. The vegetation classes of all ecological systems are briefly defined in Appendix 2. A complete description of the models (model dynamics) is found in Appendix 3, and model parameter values (probabilistic transitions) are shown in Appendix 4.

High-Risk Vegetation Classes

The models for most of the District's ecological systems included *uncharacteristic* (U) classes. Uncharacteristic classes are classes that would not be expected under a natural disturbance regime (i.e., outside of reference conditions), such as invasion by non-native annual grasses or forbs, tree-encroached shrublands, and entrenched riparian areas. Ecological departure calculations do not differentiate among the uncharacteristic classes – i.e. all U-classes are treated as equally outside of NRV. However, the cost and management urgency to restore different uncharacteristic classes varies greatly. TNC therefore recommended that ecological departure should not be the only metric used to assess future conditions (described later in this report). TNC developed a separate designation and calculation of *high-risk vegetation classes* in consultation with partners. A high-risk class was defined as an uncharacteristic vegetation class that met at least one of the three following criteria: (1) • 5% cover of invasive non-native species, (2) very expensive to restore, or (3) a direct pathway to one of these classes (invaded or very expensive to restore).

Based on staff experience, TNC split LANDFIRE's native and exotic U classes for the purpose of modeling (see Appendix 2 for initial conditions of vegetation classes). For example, in a situation where LANDFIRE interpreted 10,000 acres of native uncharacteristic vegetation in montane sagebrush steppe, TNC decided (using local knowledge) that a 50:50 split between depleted and tree-encroached sagebrush would be reasonable. All choices were reviewed by local District and Forest staff, and necessary revisions then made by TNC.

Accounting for Variability in Disturbances and Climate

The basic VDDT state-and-transition models incorporate stochastic disturbance rates that vary around a mean value for a particular disturbance associated with each succession class for each ecological system. For example, fire is a major disturbance factor for most ecological systems, including replacement fire, mixed severity fire and surface fire. These fire regimes have different rates (i.e., mean fire return interval) that are incorporated into the models for each ecological system where they are relevant. However, in real-world conditions the disturbance rates are likely to vary appreciably over time and more than provided by VDDT's default variability. To simulate strong yearly variability for fire activity, drought-induced mortality, non-native species invasion rates, tree encroachment rate, loss of herbaceous understory, flooding, cottonwood and willow recruitment, and low flows detrimental to cottonwood and willow seedlings, TNC incorporated *temporal multipliers* in the model run replicates.

A temporal multiplier is a number in a yearly time series that multiplies a base disturbance rate in the VDDT models: e.g., for a given year, a temporal multiplier of one implies no change in a disturbance rate, whereas a multiplier of zero is a complete suppression of the disturbance rate, and a multiplier of three triples the disturbance rate.

Fire Activity

Data were available for fire activity between 1980 and 2009 in the ca. 130,000-acre Ward Mountain area of eastern Nevada near Ely, and four nearby areas. Areas were located on either the Egan or Schell Creek Range west-southwest, southeast, northwest, and north-northeast of Ward Mountain. TNC used these data because they were recently analyzed, not too far away from southwestern Utah, and introduced a level of variability that made simulations more realistic. Data from the Federal Fire Occurrence Website were downloaded for the whole western U.S.A. and time series of fire size from 1980 to 2006 were extracted from five "clipped" areas each the same size and shape as Ward Mountain with ARC GIS 9.3. Five time series of fire activity were used as replicates for all scenarios. Time series were 29 years long; time series for 75 years were created by re-sampling the fire series data using the yearly total area burned divided by the temporal average of total area burned.

The five time series (i.e., one time series per replicate) were uploaded into VDDT, and yearly probability multiplier values multiplied the average wildfire rate in the models. All replicates had several peaks of fire activity with the second replicate being the most severe (Figure 3).

Upland Variability

The additional temporal multipliers in Figure 3 were inter-related and dependent on measurements of Snow-Water-Equivalent (SWE) from a NRCS-maintained weather station (Bostetter, ID) close to the intersection of Nevada, Idaho, and Utah. We assumed that rates of *annual grass-invasion* and *exotic forb-invasion* were greatest in wetter years and least in drier years. Therefore, these parameters had temporal multipliers equal to the value of SWE for a given year divided by the average SWE (Figure 3). Tree encroachment (*Tree-Invasion* parameter in the model) similarly responded to SWE, but we assumed a much slower process. The temporal multiplier for tree encroachment was, therefore, the square-root of the SWE temporal multipliers when • 1, but simply 0.9×SWE temporal multiplier when it was <1. *Drought*, *insect/disease*, and *understory-loss* rates were all expressions of stress incurred during dry years. We assumed that drought was positively correlated to temperature and inversely correlated to SWE. We used a temperature temporal multiplier obtained from a re-sampled temperature time series (1871 to 1999) for the northern Sierra Nevada as eastern Nevada is strongly influenced by the Pacific Ocean (personal communication, Dr. M. Dettinger, USGS, 2008). The equation for drought was somewhat complicated because we wanted the temperature temporal multiplier to modify the SWE temporal multiplier and assumed that SWE had a much greater effect than temperature on drought levels:

$$\text{Yearly drought temporal multiplier} = 1/(TM_{SWE}*EXP^{\{-3.46*(MAX\{1,TM_{temp}\}-1)\}}),$$

where TM_{SWE} and TM_{temp} are the temporal multipliers, respectively, for SWE and temperature (Figure 3). As temperature increases, the TM_{SWE} becomes a smaller number, and drought level increases. For years colder than average ($TM_{temp} < 1$), only SWE has an influence because the exponential function equals one due to the zero value of (MAX – 1) function. The temporal multipliers for insect/disease and loss of understory rates were equal to the drought temporal multiplier.

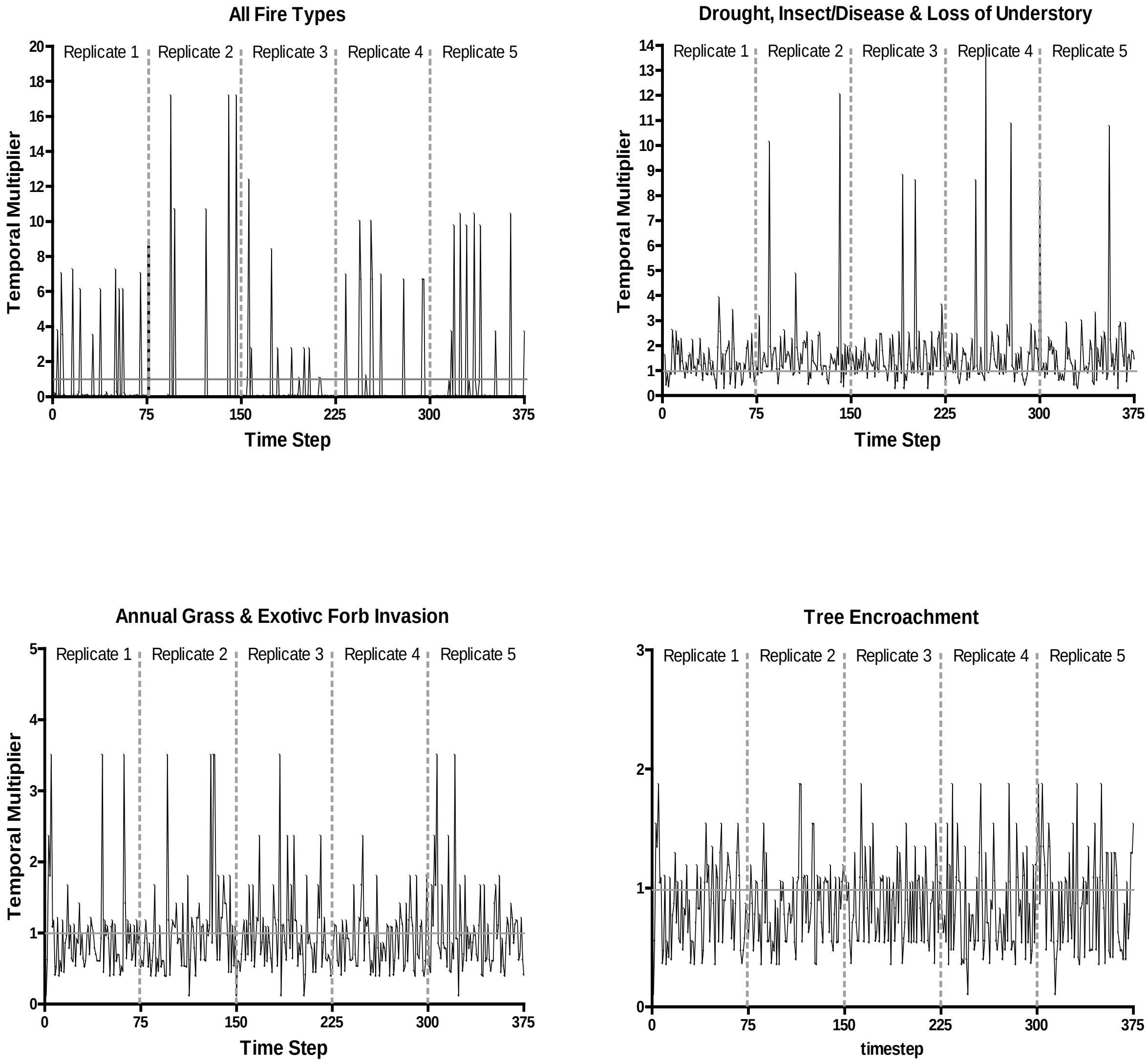


Figure 3. Five replicates of temporal probability multipliers for fire activity; drought, insect/disease and understory loss; annual grass and exotic forb invasion; and tree encroachment rates. Each replicate is numbered and represented by 75-year period. The horizontal gray line for temporal multiplier = 1 represents the "no-change" or neutral parameter line.

<u>Riparian Variability</u>

Montane-subalpine riparian systems were strongly dependent on flow variation for flood events. We did not have at our disposal gage data from the Ranger District; however, we had recently developed long term flow temporal multipliers for the lower Truckee River (Sparks Truckee River gage) and the snowpack of both the Sierra Nevada and Eastern Nevada and western Utah are highly influenced by the Pacific Ocean. We used these temporal multipliers to introduce strong variability to the riparian systems realizing that actual local gage data would provide a different pattern of variability. Variability of the 7-year, 20-year, and 100-year flood events are all based on filtering for increasingly higher values of annual peak flow. The 7-year flood events encompass the full time series of peak flow divided by the temporal average. Based on known flood events for the Truckee River, the 20-year and 100-year flood thresholds, respectively, corresponded to 1 and 3.69 of the 7-year flood temporal multiplier series (i.e., all values less than the threshold were zero) (Figure 4).

Two other related riparian disturbances were used during the first two years of succession: *cottonwood-willow recruitment* and *low-flow-kill*. *Cottonwood-willow recruitment* was based on two components that determined with a 95% success rate whether spring-early summer flows match cottonwood and willow seed deposition on wetted mineral surfaces (i.e., 5% of times recruitment would fail) and if peak flows where sufficiently high that year (TM > 0.77 or a 5-year flood event; Figure 4). The 95% rate of success was randomly drawn from a uniform distribution in MS Excel (RAND() function). Both conditions had to be met for successful recruitment. *Low-flow-kill* was a source of mortality to the same seedlings and based on the lowest water months of the year: August and September. Lower flows caused greater mortality. If the average August and September flow TM was >1, *Low-flow-kill* was zero, otherwise it was the inverse of the TM (Figure 4).

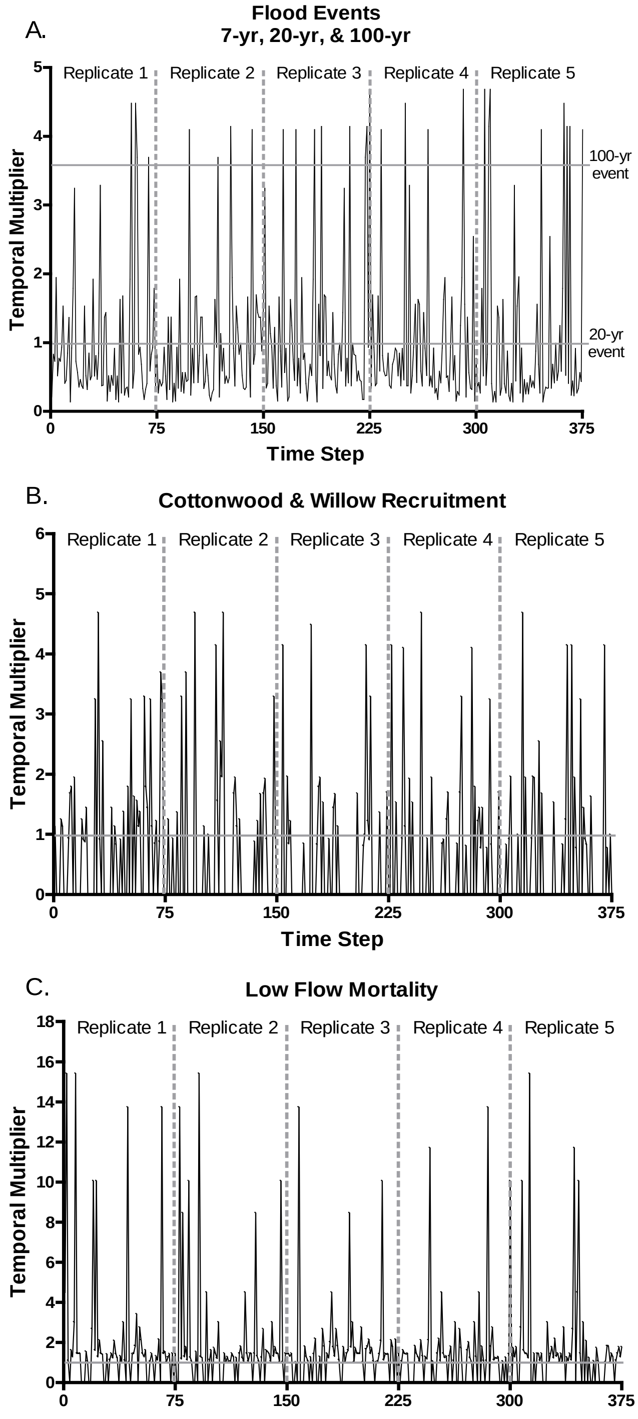


Figure 4. Riparian temporal multipliers a) for 7-year, 20-year, and 100-year flood events, b) for cottonwood and willow recruitment, and c) for low average August and September flows that kill cottonwood and willow seedlings. For the 20-year and 100-year flood events, respectively, all values below their threshold are zero. Data obtained from the Sparks Truckee River U.S. Geological Survey gage. The horizontal gray line for temporal multiplier = 1 represents the "no-change" or neutral parameter line.

Assessment of Future Ecological Condition – Minimum Management

Ecological departure provides a robust measure of *current* ecological condition, which informs land managers of their restoration needs. In addition, managers need to assess which ecological systems are likely to become more altered in the future in the absence of proactive management. Predictive state-and-transition computer models (Bestelmeyer *et al*., 2004) are a key tool in assessing future condition because they process the remote sensing-based information of vegetation classes and simulate management scenarios.

Using the computer-based models that had been developed, TNC simulated the likely future condition of each ecological system after 20 years, assuming *minimum management*. Minimum management essentially represents a custodial level of multiple-use management with no proactive projects other than the continuation of domestic livestock grazing and current fire management practices that are typically oriented toward suppression; it achieves no inventory or treatment of exotic forbs, no prescribed fire, no vegetation treatments, no special management of livestock, etc. Potential sources of future ecosystem-degradation were explicitly modeled, and included increased invasion rates of non-native species (cheatgrass and exotic forbs), increased tree encroachment rates in shrublands, reduced mean fire return intervals in shrublands, increased older age classes and fuel loadings in forest systems, entrenchment of and water diversion from creeks and wet meadows, and excessive herbivory by livestock and wildlife.

The two primary indicators chosen for assessing future condition were *Ecological Departure* and the percentage of *High-Risk Vegetation Classes* in each system after 20 years. As defined above, ecological departure is an integrated measure of composition, structure, and disturbance regime, and was the key metric previously used to assess current condition. The importance of including % High-Risk Vegetation Classes as the second indicator was amplified when some model simulations showed that an ecological system's overall ecological departure score could decrease through targeted restoration strategies (an improvement), whereas its area of high-risk vegetation classes simultaneously increased (a degradation).

Similar to the grouping of Ecological Departure scores into three Ecological Condition Classes, the cover of High-Risk Vegetation Classes was stratified into four categories:

- Low: 0% cover of high-risk vegetation classes, no future risk posed to ecological system condition.

- Medium: 1-10% cover of high-risk vegetation classes, acceptable future risk posed to ecological system.

- High: 11-30% cover of high-risk vegetation classes, future vegetation classes have the potential to catalyze even greater degradation of ecological system and will require significant resources to contain, let alone restore.

- Very high: >30% cover of high-risk vegetation classes, the system will be highly degraded, perhaps beyond the ability of managers to recover the ecological system.

A special, critical type of high-risk class was found to occur under predicted future conditions in few of the ecological systems that were modeled. This is the class of *Vegetation Conversion*. Conversion is a situation wherein the impairment or degradation to the ecological system is so extreme that the underlying biophysical setting is literally changed (converted), probably irrevocably or at least for a very long time. This is far more serious than just changes of state (crossing of thresholds) within an ecological system, because conversion represents the loss of the ecological system itself – or actually, the replacement of the ecological system by another one – that no type of management (minimum or active) can reverse. Typical examples of conversion involve severe changes to soil properties, such as wholesale stripping away of topsoil or pervasive alteration of chemical properties (e.g. salinization), though these were not seen in this project's model runs. In this project, the most-often seen type of conversion was irrevocable loss of aspen clones from the Aspen–Spruce-Fir and Aspen–Mixed Conifer ecological systems, from various causes, converting them respectively to (pure) Spruce-Fir and Mixed Conifer systems.

Assessment of Future Ecological Condition – Alternative Management Strategies

Nine focal ecological systems on the Powell Ranger District were selected for active-management analyses, based upon their size, high departure from NRV, likelihood of high future departure and/or presence of high-risk vegetation classes. These included four forest systems, three sagebrush systems, an oak-shrub system, and the montane-subalpine riparian system:

Ponderosa Pine	102,760 acres
Aspen–Spruce-Fir	43,000 acres
Aspen–Mixed Conifer	41,310 acres
Mixed Conifer	33,350 acres
Black/Low Sagebrush	30,420 acres
Wyoming/Basin Big Sagebrush	21,140 acres
Montane Sagebrush Steppe	16,630 acres
Montane-Subalpine Riparian	12,450 acres
Gambel Oak–Mixed Mountain Brush	10,040 acres

As noted previously, the fundamental purpose of this project is to identify specific, cost-effective vegetation management strategies to maintain, enhance or restore the ecological integrity of lands on the Powell Ranger District. The assessment of current ecological condition, and of future ecological condition under minimum management, are merely precursors to this ultimate endpoint. Thus, TNC and District/Forest staff members worked jointly on three interrelated tasks toward achieving this fundamental purpose: (1) develop a set of more-specific guiding *objectives*; (2) list a comprehensive set of management *strategies* that the District can implement; and (3) analyze the results [per the three future-condition indicators above] of various alternative management *scenarios*, i.e., combinations of management strategies that have a similar theme.

Objectives

Project participants agreed upon the following objectives to guide the development of management strategies for conservation and restoration of ecological systems:

- Maintain overall condition and prevent deterioration of native ecological systems.
- Reduce ecological departure for targeted ecological systems to a more properly functioning condition.
- Reduce and prevent expansion of high-risk vegetation classes (e.g., exotic species).
- Decrease fuel loads to reduce risk from wildfire to human settlements (WUI) & cultural resources in and around the forests.
- Help make treatment projects competitive for potential funding resources.
- Complement other multi-use objectives.

Varied management strategies and scenarios were developed as a means of achieving the above objectives for the nine ecological systems, and the effectiveness of strategies was tested using the predictive ecological models. These activities are described in the following two sub-sections.

Management Strategies

The Powell Ranger District Project's ecological assessment focused on developing management strategies to achieve the agreed-upon objectives. As such, all strategies were fundamentally designed to: (1) improve the condition of ecological systems that are currently in an undesirable condition, and/or (2) abate the most serious future threats to ecological systems or human settlements. Working with District/Forest staffs and Workshop participants, a comprehensive list of potential management strategies was developed for all of the targeted ecological systems. A cost-per-acre and yearly application rate budget was determined for each management strategy, using various published sources as well as the local experience of managers. The array of management strategies included the following:

- Aspen-conifer strategies included: prescribed fire, conifer removal, partial harvest, and fencing.
- Mixed conifer strategies included: prescribed fire, partial harvest, regeneration harvest, salvage, and thinning.
- Ponderosa pine strategies included: prescribed fire, partial harvest, shelterwood harvest, salvage harvest, Fecon/burn, and mechanical thinning.
- Gambel oak–mountain brush strategies included: hand-thinning with/without seeding, mechanical thinning, and prescribed fire.
- Sagebrush strategies included: harrowing with/without seeding, chaining with/without seeding, mastication of invading conifers, prescribed fire, and herbicide application.
- Montane-subalpine riparian strategies included: continued weed inventory and spot application of herbicides, thinning of invading conifers, treatment of undesirable understory shrubs, and temporary exclosure fencing.

Initial draft sets of management strategies were developed by TNC and District/Forest staffs in the April 2010 Workshop. TNC then conducted VDDT computer runs of the state-and-transition models to test and refine a suite of strategies for each of the targeted ecological systems over a 20-year time horizon. These models also included a "failure rate" for many management strategies to reflect that some management actions only partially succeed at restoring a vegetation class. Because the VDDT software that was used does not have an optimization mechanism, this required testing many different combinations of alternative management strategies and levels of treatment. This trial-and-error process created a robust set of strategies that reduced ecological departure and cover of high-risk vegetation classes while minimizing cost.

Management Scenarios

Management scenarios basically represent common "themes" or approaches for grouping individual management strategies, so that the effectiveness of sets-of-strategies can be better compared within and across ecological systems. Based on past experience in Nevada and Utah, TNC recommended the use of three management scenarios that have become more-or-less standardized in the Landscape Conservation Forecasting process. These three scenarios are listed below, and described in somewhat more detail in Table 4.

1. Minimum management – no actions except continuation of domestic livestock grazing and current fire management practices that are typically oriented toward suppression.

2. Maximum management – management treatments geared to restore ecological condition (reduce ecological departure) to the greatest possible degree, regardless of budget or policy/management constraints.

3. Streamlined management – management strategies aimed at enhancing ecological condition for reduced cost, based on funding that the District realistically could receive.

Each scenario required budgets for each ecological system, which included costs of all management strategies. Budgets were also expressed as area limits, which was the maximum area that could be treated per year for individual actions. If computer simulations reached a given management strategy's annual area limit, that management strategy was subsequently discontinued in the simulation for that year. Cost information for each management strategy for each ecological system, under all scenarios, is listed in Appendix 5.

Computer Simulations and Reporting Variables

The three scenarios – MINIMUM MANAGEMENT, MAXIMUM MANAGEMENT, and STREAMLINED MANAGEMENT – were simulated for each ecological system for 20 (50) years using VDDT. Five replicates were run for each scenario to simulate strong yearly variability for fire activity and other disturbances. The two reporting variables for simulations, i.e. the indicators of future ecological condition, were: (1) ecological departure score, (2) percentage area of high-risk vegetation classes (including conversions, if any).

Table 4. Descriptions of Management Scenarios for the Powell District.

MANAGEMENT SCENARIOS
MINIMUM MANAGEMENT
A control scenario that only included natural disturbances, unmanaged non-native species invasion, traditional livestock grazing, and current fire management practices typically oriented toward suppression. Fire suppression by agencies was simulated by reducing natural, reference fire return intervals using time series that reflected current fire events from nearby areas. Fire event data were obtained from the Federal Fire Occurrence Website. In essence, this scenario can be considered a no-treatment control, but does not represent current management. Further description of this scenario was presented above under the subsection heading of ***Assessment of Future Ecological Condition – Minimum Management***
MAXIMUM MANAGEMENT
This scenario allocated unlimited management funds with the goal of reducing ecological departure and high-risk vegetation classes to the greatest extent possible. Management strategies were applied in an attempt to reduce ecological departure significantly and/or maintain high-risk vegetation classes below 10% of the area of the ecological system. This scenario assumed no financial or other resource constraints on strategy implementation (i.e., annual agency budgets were often exceeded).
STREAMLINED MANAGEMENT
The streamlined management scenario was the result of management strategies identified by District and Forest staffs, at and following the two Workshops. It was usually effective at reducing ecological departure and high-risk vegetation classes while recognizing anticipated agency budgets, management funding availability, policy constraints, traditional management practices, and other management objectives. Strategies were sought that produced the highest Return-On-Investment.

Return On Investment (ROI) Analysis

The final step in the process was the calculation of benefits (magnitude of ecological improvement) as compared to costs (of management strategies). TNC developed and employed intra- and inter-system return-on-investment (ROI) metrics to determine which of the scenarios (MAXIMUM or STREAMLINED) produced the greatest ecological benefits per dollar invested across multiple scenarios *within* each ecological system, and *across* the nine targeted ecological systems, in relation to MINIMUM MANAGEMENT. The two ROI metrics calculated were:

(1) <u>Ecological intra-system ROI</u>. The change of ecological departure and high-risk vegetation classes between the MINIMUM MANAGEMENT scenario and the MAXIMUM or STREAMLINED MANAGEMENT scenario in year 20, divided by total cost of each scenario over 20 years.

(2) <u>Ecological system-wide inter-system ROI</u>. The change of ecological departure and high-risk vegetation classes between the MINIMUM MANAGEMENT scenario and the MAXIMUM or STREAMLINED MANAGEMENT scenario in year 20, multiplied by total area of the ecological

system, divided by total cost of each scenario over 20 years. Correction factors were used to bring all measures to a common order of magnitude.

The ROI values are a useful tool for land managers to decide where to allocate scarce management resources among many possible choices on lands that they administer. Of course, managers may also select final strategies or treatment areas based upon a variety of additional factors, such as availability of financial resources, policy constraints, and other multiple-use or societal objectives.

Findings

Current Ecological Condition

The Powell Ranger District is a largely undeveloped landscape that includes a diversity of Utah High Plateau ecological systems, ranging from sagebrush shrublands to subalpine meadows and forests (Table 1; Figure 5). Among all the ecological systems mapped on Figure 5, Ponderosa pine was the most abundant, comprising almost 103,000 acres or over 27% of the project area. Other abundant systems included aspen–spruce-fir (~12%), pinyon-juniper (~11%), aspen–mixed conifer (11%), and mixed conifer (~9%). Three different sagebrush systems (black/low, Wyoming/Basin, and montane steppe) collectively cover over 18% of the area. Other systems were more localized, such as curlleaf mountain mahogany, Gambel oak–mixed mountain brush, and the linear stringers of montane-subalpine riparian.

Ecological Departure

The measure of ecological departure is scored on a scale of 0% to 100% departure from NRV: Zero percent represents NRV while 100% represents total departure [i.e., the higher the number, the greater the departure]. Further, a coarser-scale metric known as Fire Regime Condition Class (FRCC) is used by federal agencies to group ecological departure scores into three classes: FRCC 1 represents ecological systems with low (<34%) departure; FRCC 2 indicates ecological systems with moderate (34 to 66%) departure; and FRCC 3 indicates ecological systems with high (>66%) departure (Hann *et al*. 2004). For purposes of consistent terminology, on this Powell District project we refer to FRCC as Ecological Departure Class.

Ecological departure analysis works well for large, relatively undeveloped landscapes (i.e., ~100,000 to 1,000,000+ acres). However, the departure scores of ecological systems become increasingly uncertain as landscape size decreases, and also when system size decreases, especially for systems with longer return intervals of stand replacing disturbances. The approximately 375,000-acre Powell Ranger District project area was of adequate size to assess the majority of its ecological systems, including the abundant forest and sagebrush types. However, departure scores for systems with small areal representation in the project area would have a higher degree of uncertainty.

The current condition of the Powell District's ecological systems varies in terms of departure from their NRV. Of the area's thirteen ecological systems greater than 500 acres, two are slightly departed from their NRV, ten are moderately departed, and one is highly departed (Table 5). The actual reason for current departure – i.e., the *dis-similarity* between the mix of vegetation classes currently present versus the mix of classes "expected" in NRV – differs for each individual ecological system. In general, however, most systems currently exhibit an over-abundance of late-successional and/or uncharacteristic classes. For each ecological system, the acreage and percentage of current vegetation classes, percentage of classes in NRV, and resulting ecological departure score, are fully shown in Appendix 6.

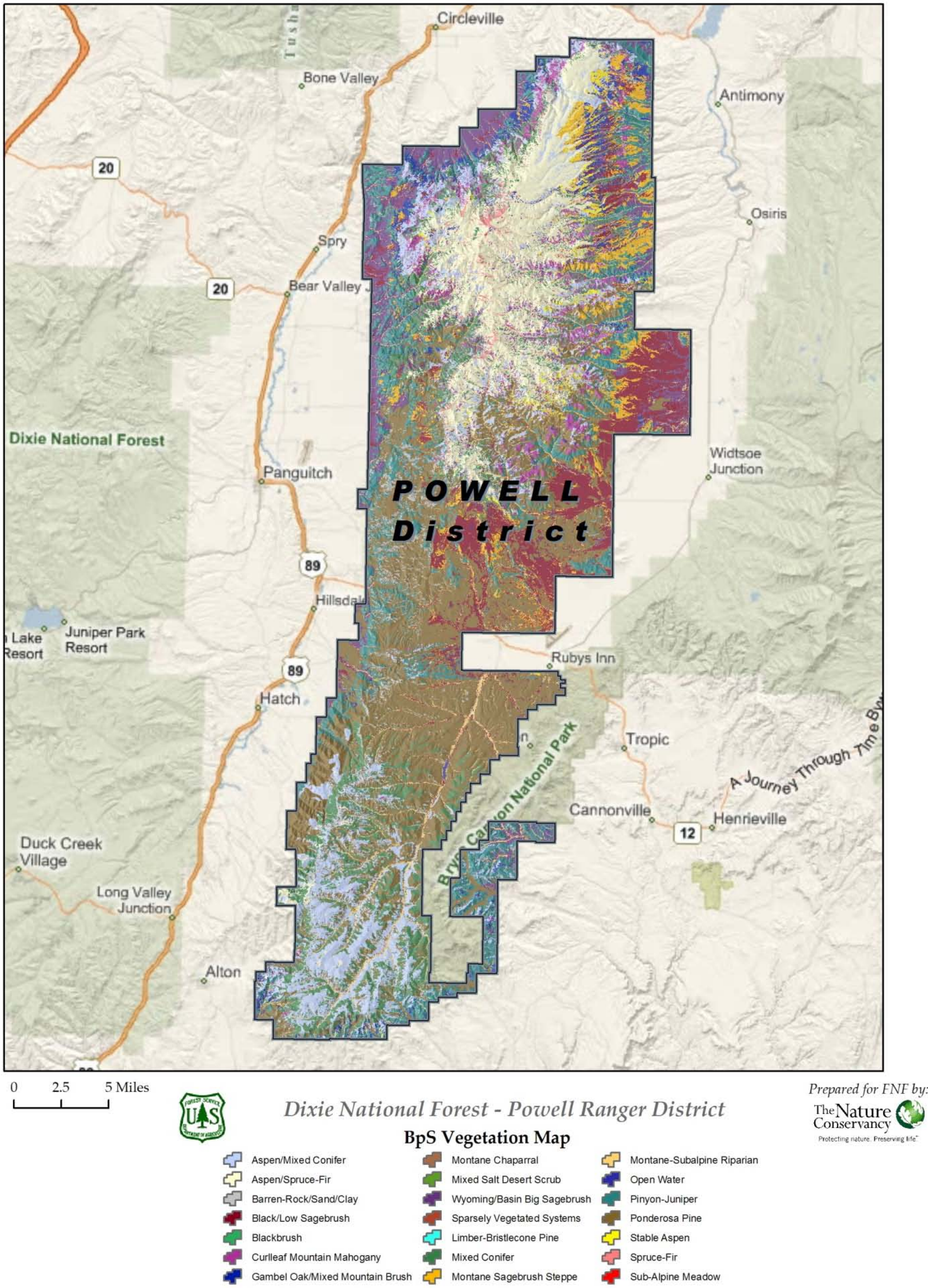


Figure 5. Ecological systems (biophysical settings) of the Powell Ranger District.

Table 5. Ecological departure percentage of ecological systems of the Powell District; systems in boldface type are the nine selected for active management analyses. Ecological departure scores are classed as good (0-33%, Class 1, green); fair (34-66%, Class 2, yellow); and poor (>66%, Class 3, red).

Ecological System	% Departure	Acres
Ponderosa Pine	**32**	**102,760**
Aspen–Spruce-fir	**65**	**43,000**
Pinyon-Juniper	29	41,730
Aspen–Mixed Conifer	**71**	**41,310**
Mixed Conifer	**46**	**33,350**
Black/Low Sagebrush	**39**	**30,420**
Wyoming/Basin Big Sagebrush	**61**	**21,140**
Montane Sagebrush Steppe	**55**	**16,630**
Curlleaf Mountain Mahogany	48	13,750
Montane-Subalpine Riparian	**38**	**12,450**
Gambel Oak–Mixed Mountain Brush	**56**	**10,040**
Stable Aspen	61	4,100
Spruce-Fir	43	3,070
Montane Chaparral	69	240
Subalpine Meadow	76	60
Mixed Salt Desert Scrub	91	50
Limber-Bristlecone Pine	29	10
Total Acres		**374,110**

High-Risk Vegetation Classes

The models for most of the District's ecological systems included *uncharacteristic* (U) vegetation classes. Uncharacteristic classes are classes that would not be expected under a natural disturbance regime (i.e., outside of reference conditions), such as invasion by non-native annual grasses or forbs, tree-encroached shrublands, and entrenched riparian areas. Ecological departure calculations do not differentiate among the uncharacteristic classes – i.e. all U-classes are treated as equally outside of NRV. Specific codes used in the models for uncharacteristic classes are listed at the end of Appendix 5.

The cost and management urgency to restore different uncharacteristic classes varies greatly. TNC thus developed a separate designation and calculation of a subset of Uncharacteristic classes – termed *high-risk vegetation classes* – in consultation with partners. A high-risk class was defined as an uncharacteristic vegetation class that met at least two of the three following criteria: (1) • 5% cover of invasive non-native species, (2) very expensive to restore, or (3) a direct pathway to one of these classes (invaded or very expensive to restore).

The importance of including high-risk vegetation classes as an indicator of ecological condition (i.e., in addition to ecological departure) was illustrated by some model simulations showing that an ecological system's overall ecological departure score decreased through targeted restoration strategies (an improvement), whereas its area of high-risk vegetation classes simultaneously increased (a degradation).

Similar to the grouping of ecological departure scores into three ecological condition classes, the cover of high-risk vegetation classes was stratified into four categories:

- Low: 0% cover of high-risk vegetation classes, no future risk posed to ecological system condition.
- Medium: 1-10% cover of high-risk vegetation classes, acceptable future risk posed to ecological system.
- High: 11-30% cover of high-risk vegetation classes, future vegetation classes have the potential to catalyze even greater degradation of ecological system and will require significant resources to contain, let alone restore.
- Very high: >30% cover of high-risk vegetation classes, the system will be highly degraded, perhaps beyond the ability of managers to recover the ecological system.

The Powell District's ecological systems vary in terms of the current amount of high-risk classes that they possess. Of the area's thirteen systems greater than 500 acres, one has a High amount of high-risk vegetation classes (11-30%) – though just barely; five systems have a Medium amount of high-risk classes (1-10%); and seven systems have no high-risk classes (Table 6). For each ecological system, the current percentage of individual high-risk vegetation classes is shown in Appendix 7.

Table 6. Percent of ecological systems currently represented by high-risk vegetation classes on the Powell District; systems in boldface type are the nine selected for active management analyses. Stress to ecological systems is ranked as: low (0%, dark green); medium (1-10%, light green); and high (11-30%, yellow).

Ecological System	% High Risk Classes
Ponderosa Pine	**3**
Aspen–Spruce-fir	**0**
Pinyon-Juniper	0
Aspen–Mixed Conifer	**1**
Mixed Conifer	**0**
Black/Low Sagebrush	**7**
Wyoming/Basin Big Sagebrush	**7**
Montane Sagebrush Steppe	**0**
Curlleaf Mountain Mahogany	0
Montane-Subalpine Riparian	**9**
Gambel Oak–Mixed Mountain Brush	**11**
Stable Aspen	0
Spruce-Fir	0
Montane Chaparral	0
Subalpine Meadow	0

Predicted Future Ecological Condition – Minimum Management

Ecological departure and percentage of high-risk classes provide robust measures of *current* ecological condition, which informs land managers of their restoration needs. In addition, managers need to assess which ecological systems are likely to become more altered in the *future* in the absence of proactive management. Predictive state-and-transition computer models (Bestelmeyer *et al*., 2004) are a key tool in assessing future condition because they process the remote sensing-based information of vegetation classes and simulate management scenarios.

Using computer-based models, TNC simulated the likely future condition (ecological departure and percentage of high-risk vegetation classes) of each ecological system after 20 years, assuming *minimum management*. Minimum management essentially represents a custodial level of multiple-use management with no proactive projects other than the continuation of fire suppression and traditional domestic livestock management; it achieves no inventory or treatment of exotic forbs, no prescribed fire, no vegetation treatments, no special management of livestock, etc. Potential sources of future ecosystem-degradation were explicitly modeled, and included increased invasion rates of non-native species (cheatgrass and exotic forbs), increased tree encroachment rates in shrublands, reduced mean fire return intervals in shrublands, increased older age classes and fuel loadings in forest systems, entrenchment of and water diversion from creeks and wet meadows, and excessive herbivory by livestock and wildlife.

Ecological Departure

Ecological departure scores predicted under minimum management for the District's ecological systems are presented in Table 7. All systems except one show a predicted improvement (i.e. decline) in ecological departure score over this 20 year period, some dramatically so. The exception was a large increase in departure (decline in condition) in the montane-subalpine riparian system. For each ecological system, the predicted future percentage of all vegetation classes and resulting future ecological departure score under minimum management are shown in Appendix 7.

This predicted ecological improvement nearly across-the-board in the absence of any active management appears to be counter-intuitive. Two possible explanations may be advanced for this result: (1) many ecological systems respond slowly in terms of their change in departure over time, especially if they are dominated by late successional classes which just become older; and (2) the ecological models incorporated the "escape" of fires into the systems, assuming that aggressive suppression efforts would not be effective in every case. Of these two explanations, the second is perhaps the more influential in producing the counter-intuitive results. More specifically, the predictive models included a modest failure rate for traditional fire suppression activities, as well as varied fire cycles based upon historical data. The models ran five replicates, one of which included a large fire, which actually served to reduce ecological departure for many systems (e.g., the aspen-conifer and Ponderosa pine) by "naturally" increasing their early successional classes. It is important to note that this future ecological improvement due to escaped fire(s) in the "modeling world" may not actually come to pass in the real world.

Table 7. Current and predicted future (under minimum management) ecological departure of ecological systems of the Powell District; systems in boldface type are the nine selected for active management analyses. Ecological departure scores are classed as good (0-33%, Class 1, green); fair (34-66%, Class 2, yellow); and poor (>66%, Class 3, red).

	Ecological Departure	
Ecological System	**Current Condition**	**Minimum Mgmt – 20 years***
Ponderosa Pine	**32**	**16**
Aspen–Spruce-fir	**65**	**35**
Pinyon-Juniper	29	24
Aspen–Mixed Conifer	**71**	**32**
Mixed Conifer	**46**	**27**
Black/Low Sagebrush	**39**	**38**
Wyoming/Basin Big Sagebrush	**61**	**54**
Montane Sagebrush Steppe	**55**	**35**
Curlleaf Mountain Mahogany	48	40
Montane-Subalpine Riparian	**38**	**68**
Gambel Oak–Mixed Mountain Brush	**56**	**38**
Stable Aspen	61	40
Spruce-Fir	43	19
Montane Chaparral	69	6
Subalpine Meadow	76	34
Mixed Salt Desert Scrub	91	–
Limber-Bristlecone Pine	29	–

* Minimum Management over 20 years assumes no treatment of exotic forbs, no prescribed fire, traditional management of livestock.

High Risk Vegetation Classes

In contrast to the widespread predicted improvements in ecological departure (except for riparian) under 20 years of minimum management, most of the District's ecological systems were predicted to have increases – some dramatic – in the percentage of high-risk classes (Table 8). For each ecological system, the predicted future percentage of individual high-risk vegetation classes under minimum management is shown in Appendix 7. These predicted increases in high-risk vegetation classes reflect the critical need to continue active management practices aimed specifically at improving ecological condition and reducing high-risk classes.

Prioritizing Actions for Implementation: Return-on-Investment

Recognizing this critical need to continue active management – and fulfill the underlying purpose of this project – District and Forest staff identified strategies for two active-management scenarios within the nine ecological system analyzed in more detail. These two active-management scenarios were referred to as MAXIMUM MANAGEMENT and STREAMLINED MANAGEMENT (Table 4). The performance of management strategies at achieving desired

Table 8. Current and predicted future (under minimum management) percent of high-risk vegetation classes of ecological systems of the Powell District; systems in boldface type are the nine selected for active management analyses. Stress to ecological systems is ranked as: low (0%, dark green); medium (1-10%, light green); high (11-30%, yellow), and very high (>30%, red).

	High Risk Classes	
Ecological System	**Current Condition**	**Minimum Mgmt – 20 years***
Ponderosa Pine	**3**	**4**
Aspen–Spruce-fir	**0**	**7**
Pinyon-Juniper	0	1
Aspen–Mixed Conifer	**1**	**8**
Mixed Conifer	**0**	**0**
Black/Low Sagebrush	**7**	**14**
Wyoming/Basin Big Sagebrush	**7**	**20**
Montane Sagebrush Steppe	**0**	**8**
Curlleaf Mountain Mahogany	0	1
Montane-Subalpine Riparian	**9**	**51**
Gambel Oak–Mixed Mountain Brush	**11**	**14**
Stable Aspen	0	2
Spruce-Fir	0	0
Montane Chaparral	0	0
Subalpine Meadow	0	0

* Assuming minimum management over 20 years (no treatment of exotic forbs, no prescribed fire, traditional management of livestock).

objectives over 20 years in both scenarios was evaluated by TNC using ecological models. Future forecasts of ecological-condition metrics (departure and high-risk classes) under the MAXIMUM and STREAMLINED MANAGEMENT scenarios were compared with future condition metrics under MINIMUM MANAGEMENT. These comparisons informed a cost-benefit analysis developed by TNC – i.e., "Return on Investment" or ROI – to assist with prioritization of on-the-ground actions.

The project employed two types or scales of ROI analyses. In the first, the ecological benefits accrued from active management (both scenarios), were compared to the costs of securing those benefits, *within* each ecological system. This scale of ROI analysis was termed *Ecological intra-system ROI*, and is defined as follows:

- Ecological intra-system ROI. The change of ecological departure and high-risk vegetation classes between the MINIMUM MANAGEMENT scenario and the MAXIMUM or STREAMLINED MANAGEMENT scenario in year 20, divided by total cost of each scenario over 20 years.

For all of the nine ecological systems analyzed in detail, management strategies of the STREAMLINED MANAGEMENT scenario produced a higher Ecological intra-system ROI compared to MAXIMUM MANAGEMENT (Table 9). This is primarily because the cost reductions of the STREAMLINED scenario were proportionally greater than the corresponding reductions in ecological improvement, relative to the MAXIMUM scenario. The formula for calculating intra-system ROI was not designed for management scenarios that yield net income, as was the case in the Powell District's forested systems (on account of predicted revenue from timber harvest), so the value was reported as "positive" if ecological improvement was predicted to occur.

Table 9. Ecological intra-system return on investment (ROI) for the nine ecological systems of the Powell District selected for active management analyses. This scale of ROI evaluates costs and ecological benefits of strategies for the MAXIMUM and STREAMLINED MANAGEMENT scenarios (relative to MINIMUM MANAGEMENT) *within* the systems.

	Intra-System ROI Relative to MINIMUM MANAGEMENT	
Ecological System	**MAXIMUM MANAGEMENT**	**STREAMLINED MANAGEMENT**
Ponderosa Pine	—	N/A[1]
Aspen–Spruce-fir	Positive[2]	Positive[2]
Aspen–Mixed Conifer	Positive[2]	Positive[2]
Mixed Conifer	Positive[2]	Positive[2]
Black/Low Sagebrush	9.1	17.9
Wyoming/Basin Big Sagebrush	29.3	40.1
Montane Sagebrush Steppe	43.8	58.3
Montane-Subalpine Riparian	88.7	115.9
Gambel Oak–Mixed Mountain Brush	57.7	88.2

1. Results (as measured by Ecological Departure score) of STREAMLINED MANAGEMENT are the same as for MINIMUM MANAGEMENT in the Ponderosa Pine system (see Appendix 7).
2. ROI formula was not designed for management in systems that yield net income; instead it is reported as "positive" if ecological improvement is predicted to occur.

In the second scale of ROI analyses, the ecological benefits accrued from active management in the STREAMLINED scenario were compared to the costs of securing those benefits, *across* ecological systems. This scale of ROI analysis was termed *Ecological system-wide inter-system ROI,* and is defined as follows:

- Ecological system-wide inter-system ROI. The change of ecological departure and high-risk vegetation classes between the MINIMUM MANAGEMENT scenario and the STREAMLINED MANAGEMENT scenario in year 20, multiplied by total area of the ecological system, divided by total cost of each scenario over 20 years. Correction factors were used to bring all measures to a common order of magnitude.

At this scale we assessed the ROI for the STREAMLINED MANAGEMENT scenario across ecological systems. For this element, TNC applied the area weighted, inter-system ROI metric to determine which of the systems produced the greatest ecological benefits per dollar invested across the nine ecological systems, as compared to MINIMUM MANAGEMENT (Table 10). The formula for calculating inter-system ROI was not designed for management scenarios that yield net income, as was the case in the Powell District's forested systems (on account of predicted

Table 10. Ecological system-wide inter-system return on investment (ROI) for the nine ecological systems of the Powell District selected for active management analyses. This scale of ROI evaluates costs and ecological benefits of strategies for the STREAMLINED MANAGEMENT scenario relative to MINIMUM MANAGEMENT *across* the systems.

	System-Wide Inter-System ROI Relative to MINIMUM MANAGEMENT
Ecological System	**STREAMLINED MANAGEMENT**
Ponderosa Pine	N/A[1]
Aspen–Spruce-fir	Positive[2]
Aspen–Mixed Conifer	Positive[2]
Mixed Conifer	Positive[2]
Black/Low Sagebrush	1.1
Wyoming/Basin Big Sagebrush	1.7
Montane Sagebrush Steppe	2.0
Montane-Subalpine Riparian	2.8
Gambel Oak–Mixed Mountain Brush	1.8

1. Results (as measured by Ecological Departure score) of STREAMLINED MANAGEMENT are the same as for MINIMUM MANAGEMENT in the Ponderosa Pine system(see Appendix 7).
2. ROI formula was not designed for management in systems that yield net income; instead it is reported as "positive" if ecological improvement is predicted to occur.

revenue from timber harvest), so the value was reported as "positive" if ecological improvement was predicted to occur.

Ecological system-wide inter-system ROI can be used to assist with prioritizing allocation of limited resources across multiple systems in a landscape. If management funding is limited, TNC recommends consideration of this metric for selecting which ecological systems receive priority investments. In the Powell Ranger District project area, the systems with the highest inter-system ROI included montane-subalpine riparian and montane sagebrush steppe.

In summary, these various ROI values are useful tools for land managers to decide where to allocate scarce management resources among many possible choices on lands that they administer. Of course, managers may also select final strategies or treatment areas based upon a variety of additional factors, such as availability of financial resources, policy constraints, and other multiple-use or societal objectives.

Management Strategies and Scenarios

Introduction

For the nine ecological systems analyzed in greater detail, management strategies were developed under the two primary active-management scenarios: MAXIMUM MANAGEMENT and STREAMLINED MANAGEMENT. All strategies were designed to improve the condition of ecological systems that are currently in an undesirable condition and/or to abate serious future threats to ecological systems. Different types of strategies and degrees of application were tested to achieve specific objectives under the two scenarios. Total annual costs for strategy implementation were calculated for each ecological system under each scenario, as well as any one-time costs.

All scenarios for each ecological system were then tested via computer simulations using VDDT to determine whether or not they achieved the desired objectives. Outcomes were calculated for ecological departure and high-risk classes over 20 years.

Summary descriptions of active-management modeling results are presented for each of the nine ecological systems that were selected for such analyses: Ponderosa pine, aspen–spruce-fir, aspen–mixed conifer, mixed conifer, black/low sagebrush, Wyoming/basin big sagebrush, montane sagebrush steppe, montane-subalpine riparian, and Gambel oak–mixed mountain brush. Each system description includes text and a summary table that together provide the following information:

1. Brief description of the ecological system in the Powell Ranger District project area.

2. Management objectives for the system under the STREAMLINED MANAGEMENT scenario.

3. Management strategies, acres treated, and costs for the system under the STREAMLINED MANAGEMENT scenario.

4. Summary of outcomes.

Following these individual descriptions of the nine ecological systems, a final sub-section summarizes outcomes in terms of predicted ecological condition – ecological departure and high-risk classes – of the STREAMLINED MANAGEMENT scenario relative to MINIMUM MANAGEMENT and current condition.

Ponderosa Pine Ecological System

Ponderosa pine forests and woodlands occur at lower and middle elevations of the Powell District. They generally occupy sites intermediate between dwarf-woodland or shrubland systems on warmer/drier sites, and mixed conifer or aspen–mixed conifer systems on cooler/wetter sites. The Ponderosa pine system occurs on all slopes and aspects, and on a diversity of parent materials – igneous (extrusive volcanic) and sedimentary (limestone) being the predominant materials on the Powell District. Ponderosa pine is the dominant conifer. Lesser amounts of other conifers mix in depending on site conditions: pinyon pine and Utah juniper where warmer/drier; Douglas-fir and white fir where cooler/wetter. Understories are often shrubby, typically with species of sagebrush, bitterbrush and manzanita.

At present, this system exhibits a low degree of ecological departure (Score = 32; Table 5), and the current amount of high-risk vegetation classes is small (3%; Table 6). Current amounts of the two later-successional classes (D and E) differ from "expected" NRV values (Appendices 6 and 7), though not greatly so. The earliest vegetation class is slightly more abundant than what would be "expected" in NRV, likely as a result of natural succession following the recent large Sanford Fire in the northern part of the District. The ecological condition metrics and their components shown in Appendices 6 and 7 represent District-wide averages. In reality, the northern and southern parts of the District have become substantially different from each other with regard to the ponderosa pine system. If analyses were run for the two parts separately (beyond the scope of this project), it is likely that the northern part would show better ecological condition, and the southern part worse, than the District-wide averages presented here.

Ecological departure improves substantially over 20 years in a regime of minimum management (to a score of 16; Table 7 and Appendix 7). However, as noted earlier, this may be an artifact of model runs that incorporated the "escape" of fires into this system, thereby increasing the (modeled) early-succession classes – a situation that is not guaranteed to occur in the real world. The predicted amount of high-risk vegetation classes after 20 years of minimum management shows a slight (and probably insignificant) increase from the current situation (to 4%; Table 8 and Appendix 7).

In the two Workshops, District and Forest staff focused on treatments designed to revert acres in late-succession classes back to early-succession classes, and to remove excessive amounts of other conifers from the understory or overstory. These treatments included combinations of prescribed fire, harvest, and other mechanical means of tree-removal.

Management Objectives

The main objectives of the STREAMLINED MANAGEMENT scenario over 20 years were as follows (see also in Table 11):

- Improve ecological condition of ~103,000 acres of Powell RD Ponderosa Pine forests from 32% departure from NRV to 16% departure (Ecological Departure Class 1).

- Contain high-risk vegetation classes to less than 5%.

Management Strategies and Costs

The main strategies of the STREAMLINED MANAGEMENT scenario over 20 years were to treat approximately 1,650 acres/year of ponderosa pine forest with a combination of prescribed fire, harvest and mechanical thinning to achieve desired age class structure (see details in Table 11). The average annual cost of these treatments was $91,250, though this presumes that revenue from timber harvest will be returned to the District. Actual out-of-pocket average annual costs of these treatments would be $161,250.

Outcomes

- STREAMLINED MANAGEMENT showed no predicted change in ecological departure score relative to MINIMUM MANAGEMENT (both at 16; see Appendix 7). However, STREAMLINED MANAGEMENT would achieve this result on the basis of real active treatments – assuming they would be implemented – rather than on the assumption of a modeled fire that may not occur. Given the uncertainty of amount and timing of natural fires in the system, it is recommended that some combination of prescribed fire and/or carefully designed harvest practices be deployed adaptively as management strategies.
- The predicted percentage of high-risk classes also remained constant under the STREAMLINED MANAGEMENT scenario relative to MINIMUM MANAGEMENT (both at 4%; see Appendix 7), though both remained under the objective of a 5% maximum. These specific high-risk classes – non-native annual grasses with and without trees – are difficult to eliminate entirely, and to maintain them at current low levels is better than having them increase dramatically. Even in the MAXIMUM MANAGEMENT scenario (and all of the scenarios) these same high-risk classes remain constant at 4% after 20 years.

Table 11. STREAMLINED MANAGEMENT scenario for the Ponderosa Pine Ecological System in the Powell Ranger District project area.

Project	**Powell Ranger District - Dixie National Forest**					
Ecological System	**Ponderosa Pine**					
Objective	Improve ecological condition of ~103,000 acres of Powell RD Ponderosa Pine forest from 32% departure from NRV to 16% departure (Ecological Departure Class 1) and contain high-risk vegetation classes to less than 5% … over 20 years.					
Ave. Acres Treated/Year						1,650
Total Ecosystem Acres						102,759
Strategy	Treat approximately 1650 acres/year of ponderosa pine forest with a combination of prescribed fire, harvest and mechanical thinning to achieve desired age class structure.					
Management Actions		*One Time Costs*	*# Years*	*Acres/Year*	*Cost/Acre*	*Cost/Year*
	Prescribed fire to increase open succession classes		20	750	$ 100	$ 75,000
	Mechanical thinning from below in closed succession classes		20	400	$ 150	$ 60,000
	Partial harvest to reduce late succession classes		20	200	$ (200)	$ (40,000)
	Shelterwood harvest that maintains seed trees to reduce late-closed succession class and restore early succession classes		20	100	$ (200)	$ (20,000)
	Fecon machine thinning of conifers followed by prescribed fire		20	150	$ 175	$ 26,250
	Salvage harvest of dead trees		20	50	$ (200)	$ (10,000)
Average Cost/Year	***including one time costs of***	**$ -**				**$ 91,250**
Number of Years						**20**
Total Cost						**$ 1,825,000**
Notes						

Aspen–Spruce-Fir Ecological System

Aspen–spruce-fir forests occur at upper elevations of the Powell District. The main conifers in this system are Engelmann spruce and subalpine fir. Understories are diverse, with various amounts of low shrubs, forbs and grasses. At present, this system exhibits a moderate degree of ecological departure that borders on being high (Score = 65; Table 5), although the current amount of high-risk vegetation classes is negligible (0%; Table 6). The main basis for heightened ecological departure at present is an over-abundance of the late successional class, i.e. closed-canopy subalpine conifer forests, and corresponding under-representation of mid-successional classes (Appendices 6 and 7). The earliest vegetation class is far more abundant than what would be "expected" in NRV, primarily as a result of natural succession following the recent large Sanford Fire in the northern part of the District. The ecological condition metrics and their components shown in Appendices 6 and 7 represent District-wide averages. In reality, the northern and southern parts of the District have become substantially different from each other with regard to the aspen–spruce-fir system. If analyses were run for the two parts separately (beyond the scope of this project), it is likely that the northern part would show much better ecological condition, and the southern part much worse, than the District-wide averages presented here.

Ecological departure improves dramatically over 20 years in a regime of minimum management (to a score of 35; Table 7 and Appendix 7). However, as noted earlier, this may be an artifact of model runs that incorporated the "escape" of fires into this system, thereby increasing the (modeled) early-succession classes – a situation that is not guaranteed to occur in the real world. Of greater tangible concern is the predicted increase in high-risk vegetation classes without active management (to 7%; Table 8 and Appendix 7). These represent the conversion of some acres of the over-abundant late-succession (conifer dominated) class into a pure conifer system – essentially the loss of aspen clones.

In the two Workshops, District and Forest staff focused on treatments designed to revert acres in the late-succession class back to early-succession classes, and (correspondingly) try to prevent further loss of aspen. These treatments included combinations of prescribed fire, harvest, and other mechanical means of tree-removal.

Management Objectives

The main objectives of the STREAMLINED MANAGEMENT scenario over 20 years were as follows (see also in Table 12):

- Improve ecological condition of ~43,000 acres of Powell RD Aspen–Spruce-Fir forest from 65% departure from NRV to 28% departure (Ecological Departure Class 1).

- Contain loss of aspen to less than 10%.

Management Strategies and Costs

The main strategies of the STREAMLINED MANAGEMENT scenario were to treat approximately 1,600 acres/year of Aspen–Spruce-Fir forest over an initial five-year period with a combination of prescribed fire, conifer removal and partial harvest (see details in Table 12), with the system then allowed to "run" for another 15 years. The average annual cost of these treatments was actually a net revenue of $27,500, which presumes that revenue from timber harvest will be returned to the District. Actual out-of-pocket average annual costs of these treatments would be $5,000.

Outcomes

- STREAMLINED MANAGEMENT resulted in an improved ecological departure score relative to MINIMUM MANAGEMENT (28 versus 35; see Appendix 7), with the added benefit that the improvement would be based on real active treatments – assuming they would be implemented – rather than on the assumption of a large modeled fire that may not occur. Given the uncertainty of amount and timing of natural fires in the system, it is recommended that some combination of prescribed fire and/or carefully designed harvest practices be deployed adaptively as management strategies.
- The predicted percentage of high-risk classes was only slightly improved under the STREAMLINED MANAGEMENT scenario (6% in STREAMLINED, 7% under minimum management; see Appendix 7), though both remained under the objective of a 10% maximum. The slow conversion to pure conifers (loss of aspen) in this system is a difficult situation that could be expensive to forestall or reverse – even in the MAXIMUM MANAGEMENT scenario, the same high-risk classes were essentially the same as under minimum management (both 7%) but at a much greater cost for the former.

Table 12. STREAMLINED MANAGEMENT scenario for the Aspen–Spruce-Fir Ecological System in the Powell Ranger District project area.

Project	**Powell Ranger District - Dixie National Forest**					
Ecological System	**Aspen–Spruce-Fir**					
Objective	Improve ecological condition of ~43,000 acres of Powell RD Aspen–Spruce-Fir forest from 65% departure from NRV to 28% departure (Ecological Departure Class 1) and contain loss of aspen to less than 10% … over 20 years.					
Ave. Acres Treated/Year						1,600
Total Ecosystem Acres						43,002
Strategy	Treat approximately 1600 acres/year of Aspen–Spruce-Fir forest over five years with a combination of prescribed fire, conifer removal and partial harvest.					
Management Actions		*One Time Costs*	*# Years*	*Average Acres/Year*	*Cost/Acre*	*Cost/Year*
	Prescribed fire to restore early succession classes		5	200	$ 100	$ 20,000
	Removal of conifers to prevent loss of aspen		5	1,000	$ (50)	$ (50,000)
	Partial harvest to reduce late succession classes		5	400	$ (200)	$ (80,000)
Average Cost/Year	***including one time costs of***	**$ -**				**$ (27,500)**
Number of Years						**20**
Total Cost						**$ (550,000)**
Notes						

Aspen–Mixed Conifer Ecological System

Aspen–mixed conifer forests occur at middle and upper elevations of the Powell District. The main conifers in this system are Douglas-fir, white fir and Ponderosa pine. Understories are diverse, with various amounts of tall or low shrubs, forbs and grasses. At present, this system exhibits a high degree of ecological departure (Score = 71; Table 5), although the current amount of high-risk vegetation classes is minimal (1%; Table 6). The main basis for heightened ecological departure at present is an over-abundance of late-successional classes, i.e. dominated by the mixed conifers, and corresponding under-representation of mid-successional classes (Appendices 6 and 7). The earliest vegetation class is slightly more abundant than what would be "expected" in NRV, primarily as a result of natural succession following the recent large Sanford Fire in the northern part of the District. The ecological condition metrics and their components shown in Appendices 6 and 7 represent District-wide averages. In reality, the northern and southern parts of the District have become substantially different from each other with regard to the aspen–mixed conifer system. If analyses were run for the two parts separately (beyond the scope of this project), it is likely that the northern part would show much better ecological condition, and the southern part much worse, than the District-wide averages presented here.

Ecological departure improves dramatically over 20 years in a regime of minimum management (to a score of 32; Table 7 and Appendix 7). However, as noted earlier, this may be an artifact of model runs that incorporated the "escape" of fires into this system, thereby increasing the (modeled) early-succession classes – a situation that is not guaranteed to occur in the real world. Of greater tangible concern is the predicted increase in high-risk vegetation classes without active management (to 8%; Table 8 and Appendix 7). These represent the conversion of some acres of the over-abundant late-succession (conifer dominated) classes into a pure conifer system – essentially the loss of aspen clones.

In the two Workshops, District and Forest staff focused on treatments designed to revert acres in the late-succession classes back to early-succession classes, and (correspondingly) try to prevent further loss of aspen. These treatments included combinations of prescribed fire, harvest, and other mechanical means of tree-removal.

Management Objectives

The main objectives of the STREAMLINED MANAGEMENT scenario over 20 years were as follows (see also in Table 13):

- Improve ecological condition of ~41,000 acres of Powell RD Aspen–Mixed-Conifer forest from 71% departure from NRV to 24% departure (Ecological Departure Class 1).

- Contain loss of aspen to less than 10%.

Management Strategies and Costs

The main strategies of the STREAMLINED MANAGEMENT scenario over 20 years were to treat approximately 600 acres/year of Aspen–Mixed Conifer forest with a combination of prescribed fire, conifer removal and partial harvest (see also in Table 13). Specifically, 200 acres of each of the three specific treatments were applied per year for the 20 years. The average annual cost of these treatments was actually a net revenue of $26,000, which presumes that revenue from timber harvest will be returned to the District. Actual out-of-pocket average annual costs of these treatments would be $24,000.

Outcomes

- STREAMLINED MANAGEMENT resulted in an improved ecological departure score relative to MINIMUM MANAGEMENT (24 versus 32; see Appendix 7), with the added benefit that the improvement would be based on real active treatments – assuming they would be implemented – rather than on the assumption of a large modeled fire that may not occur. Given the uncertainty of amount and timing of natural fires in the system, it is recommended that some combination of prescribed fire and/or carefully designed harvest practices be deployed adaptively as management strategies.

- The predicted percentage of high-risk classes was not improved under the STREAMLINED MANAGEMENT scenario (8% in both cases; see Appendix 7), though both remained under the objective of a 10% maximum. The slow conversion to pure conifers (loss of aspen) in this system is a difficult situation that could be expensive to forestall or reverse – even in the MAXIMUM MANAGEMENT scenario, the same high-risk classes were only reduced to 6% at a much greater cost.

Table 13. STREAMLINED MANAGEMENT scenario for the Aspen–Mixed Conifer Ecological System in the Powell Ranger District project area.

Project	**Powell Ranger District - Dixie National Forest**					
Ecological System	**Aspen–Mixed Conifer**					
Objective	Improve ecological condition of ~41,000 acres of Powell RD Aspen–Mixed Conifer forest from 71% departure from NRV to 24% departure (Ecological Departure Class 1) and contain loss of aspen to less than 10% … over 20 years.					
Ave. Acres Treated/Year						600
Total Ecosystem Acres						41,310
Strategy	Treat approximately 600 acres/year of Aspen–Mixed Conifer forest with a combination of prescribed fire, conifer removal and partial harvest.					
Management Actions		*One Time Costs*	*# Years*	*Average Acres/Year*	*Cost/Acre*	*Cost/Year*
	Prescribed fire to restore early succession classes		20	200	$ 120	$ 24,000
	Removal of conifers to prevent loss of aspen		20	200	$ (50)	$ (10,000)
	Partial harvest to reduce late succession classes		20	200	$ (200)	$ (40,000)
Average Cost/Year	*including one time costs of*	**$ -**				**$ (26,000)**
Number of Years						**20**
Total Cost						**$ (520,000)**
Notes						

Mixed Conifer Ecological System

Mixed conifer forests generally occur at middle to upper elevations of the Powell District. They tend to occupy sites intermediate between (purer) Ponderosa pine forests on warmer/drier sites, and subalpine conifer forests (with or without aspen) on cooler/wetter sites. The mixed conifer system occurs on all slopes and aspects, and on a diversity of parent materials. Douglas-fir and white fir are the most abundant conifers. Lesser amounts of other conifers mix in depending on site conditions: Ponderosa pine, blue spruce, pinyon pine, Utah juniper, Rocky Mountain juniper, limber pine, and bristlecone pine. Understories are diverse, with various amounts of low shrubs, forbs and grasses.

At present, this system exhibits a moderate degree of ecological departure (Score = 46; Table 5). The current amount of high-risk vegetation classes is negligible (0%; Table 6) The main basis for the level of ecological departure at present is an over-abundance of late-successional classes, and under-representation of the early and mid-closed classes (Appendices 6 and 7).

Ecological departure improves substantially over 20 years in a regime of minimum management (to a score of 27; Table 7 and Appendix 7). However, as noted earlier, this may be an artifact of model runs that incorporated the "escape" of fires into this system, thereby increasing the (modeled) early-succession classes – a situation that is not guaranteed to occur in the real world. The predicted amount of high-risk vegetation classes after 20 years of minimum management remains at the negligible level (0%; Table 8 and Appendix 7).

In the two Workshops, District and Forest staff focused on treatments designed to revert acres in later succession classes back to earlier succession classes. These treatments included combinations of prescribed fire, harvest, and other mechanical means of tree-removal.

Management Objectives

The main objective of the STREAMLINED MANAGEMENT scenario over 20 years was as follows (see also in Table 14):

- Improve ecological condition of ~33,000 acres of Powell RD Mixed Conifer forests from 46% departure from NRV to 24% departure (Ecological Departure Class 1).

Management Strategies and Costs

The main strategies of the STREAMLINED MANAGEMENT scenario over 20 years were to treat approximately 900 acres/year of Mixed Conifer forests with varied management treatments to achieve desired age class structure (see details in Table 14). The average annual cost of these treatments was actually a net revenue of $72,500, which presumes that revenue from timber harvest will be returned to the District. Actual out-of-pocket average annual costs of these treatments would be $42,500.

Outcomes

- STREAMLINED MANAGEMENT resulted in a slightly improved ecological departure score relative to MINIMUM MANAGEMENT (24 versus 27; see Appendix 7), though this difference may be insignificant. However, STREAMLINED MANAGEMENT would achieve this result on the basis of real active treatments – assuming they would be implemented – rather than on the assumption of a large modeled fire that may not occur. Given the uncertainty of amount and timing of natural fires in the system, it is recommended that some combination of prescribed fire and/or carefully designed harvest practices be deployed adaptively as management strategies.

- The predicted percentage of high-risk classes remained at 0% under the STREAMLINED MANAGEMENT scenario.

Table 14. STREAMLINED MANAGEMENT scenario for the Mixed Conifer Ecological System in the Powell Ranger District project area.

Project	**Powell Ranger District - Dixie National Forest**					
Ecological System	**Mixed Conifer**					
Objective	Improve ecological condition of ~33,000 acres of Powell RD Mixed Conifer forest from 46% departure from NRV to 24% departure (Ecological Departure Class 1) … over 20 years.					
Ave. Acres Treated/Year						900
Total Ecosystem Acres						33,354
Strategy	Treat approximately 900 acres/year of Mixed Conifer forest with varied management treatments to achieve desired age class structure.					
Management Actions		*One Time Costs*	*# Years*	*Acres/Year*	*Cost/Acre*	*Cost/Year*
	Prescribed fire primarily to reduce late-closed succession class		20	250	$ 125	$ 31,250
	Mechanical thinning from below in closed succession classes		20	75	$ 150	$ 11,250
	Partial harvest to reduce late succession classes		20	400	$ (200)	$ (80,000)
	Regeneration harvest that maintains seed trees to reduce late-closed succession class and restore early succession classes		20	150	$ (200)	$ (30,000)
	Salvage harvest of dead trees		20	25	$ (200)	$ (5,000)
Average Cost/Year	***including one time costs of***	**$ -**				**$ (72,500)**
Number of Years						**20**
Total Cost						**$ (1,450,000)**
Notes						

Black/Low Sagebrush Ecological System

This ecological system comprises sites that support black sagebrush and low sagebrush on shallow, often rocky soils where a root-limiting layer exists. Low sagebrush tends to grow where claypan layers exist in the soil profile and soils are often saturated during a portion of the year. Black sagebrush tends to grow where either a calcareous or volcanic cement layer exists in the soil profile. Although these two sagebrush types do not usually grow in combination, they do share similar fire regimes and are considered to be upper-elevation dwarf sagebrushes. Dwarf sagebrushes generally have relatively low fuel loads, with low-growing and cushion forbs and scattered bunch grasses in the understory.

At present, this system exhibits a moderate degree of ecological departure (Score = 39; Table 5). The main basis for the level of ecological departure at present is a roughly equal proportional imbalance between the mid and late-open successional classes (Appendices 6 and 7). The current amount of high-risk vegetation classes is in the Medium range (7%; Table 6), primarily in the form of annual grasses with the shrubs (Appendix 7).

Ecological departure remains essentially the same over 20 years in a regime of minimum management (score of 38; Table 7 and Appendix 7). Of larger concern, however, is the predicted doubling in high-risk vegetation classes without active management (to 14%; Table 8 and Appendix 7). These largely represent the increase of annual grass cover (with and without shrubs) and increase of the depleted understory class (Appendix 7).

In the two Workshops, District and Forest staff focused on treatments designed to revert acres in the late-open succession class back to the mid class, and to keep ahead of encroachment by trees. These treatments included combinations of harrowing (with and without seeding), and mastication of encroaching conifers.

Management Objectives

The main objectives of the STREAMLINED MANAGEMENT scenario over 20 years were as follows (see also in Table 15):

- Improve ecological condition of ~30,000 acres of Powell RD Black/Low Sagebrush from 39% departure from NRV to 29% departure (Ecological Departure Class 1).

- Contain projected high-risk vegetation classes to less than 15%.

Management Strategies and Costs

The main strategies of the STREAMLINED MANAGEMENT scenario over 20 years were to treat approximately 275 acres/year of late-succession and tree-encroached black/low sagebrush (see details in Table 15). The average annual cost of these treatments was $28,000.

Outcomes

- STREAMLINED MANAGEMENT resulted in a moderately improved ecological departure score relative to MINIMUM MANAGEMENT (29 versus 38; see Appendix 7), by transforming acres of the late-open class into the mid class.

- The predicted percentage of high-risk classes remained virtually constant under the STREAMLINED MANAGEMENT scenario relative to MINIMUM MANAGEMENT (see Appendix 7), though both remained under the objective of a 15% maximum. These particular high-risk classes are difficult to reduce, let alone eliminate entirely, and to hold their predicted increase (under minimum management) constant through active management is better than having them increase dramatically. Even in the MAXIMUM MANAGEMENT scenario, these same high-risk classes remain essentially constant after 20 years, but at a much greater cost.

Table 15. STREAMLINED MANAGEMENT scenario for the Black/Low Sagebrush Ecological System in the Powell Ranger District project area.

Project	**Powell Ranger District - Dixie National Forest**					
Ecological System	**Black/Low Sagebrush**					
Objective	Improve ecological condition of ~30,000 acres of Powell RD Black/Low Sagebrush from 39% departure from NRV to 29% departure (Ecological Departure Class 1) and contain projected high-risk vegetation classes to less than 15% … over 20 years.					
Ave. Acres Treated/Year						275
Total Ecosystem Acres						30,420
Strategy	Treat approximately 275 acres/year of late-succession and tree-encroached black/low sagebrush.					
Management Actions		***One Time Costs***	***# Years***	***Acres/Year***	***Cost/Acre***	***Cost/Year***
	Dixie Harrow late succession class to restore mid succession class		20	200	$ 100	$ 20,000
	Masticate tree-encroached (with and without annual grasses) and apply seed to		20	25	$ 160	$ 4,000
	Masticate emerging conifers to prevent future tree encroachment		20	50	$ 80	$ 4,000
Average Cost/Year	***including one time costs of***	**$ -**				**$ 28,000**
Number of Years						**20**
Total Cost						**$ 560,000**
Notes						

Wyoming/Basin Big Sagebrush Ecological System

This ecological system occurs mainly at lower elevations of the Powell District, and covers large expanses on foothills, terraces, slopes and plateaus.. It occupies sites intermediate between salt desert shrublands at lower elevations, and montane sagebrush steppe and pinyon-juniper woodlands at higher elevations. Wyoming big sagebrush is the dominant species in this shrubland system, and rubber rabbitbrush may be co-dominant. Perennial forb cover is usually <10%. Perennial grass cover may reach 20-25% on more-productive sites. As defined for this project, this system also includes frequent, individually small stands of Basin big sagebrush that typically occur on valley-bottom alluvial terraces along streams and washes. Sites that support these two subspecies of big sagebrush were considered to be similar enough ecologically to be analyzed as a single unit. Finally, this system is important habitat for the Greater sage-grouse and many sagebrush-obligate species.

At present, this system exhibits a moderate degree of ecological departure that borders on being high (Score = 61; Table 5) The main basis for the level of ecological departure at present is a great preponderance of acres in late-successional classes, with corresponding under-representation of early and mid classes (Appendices 6 and 7). The current amount of high-risk vegetation classes is in the Medium range (7%; Table 6), primarily in the form of annual grasses with the shrubs (Appendix 7).

Ecological departure decreases slightly over 20 years in a regime of minimum management (to a score of 54; Table 7 and Appendix 7). Of greater concern, however, is the predicted near-tripling in high-risk vegetation classes without active management (to 20%; Table 8 and Appendix 7). These largely represent the effects of substantial tree-encroachment and the increase of annual grasses (Appendix 7).

In the two Workshops, District and Forest staff focused on treatments designed to revert acres in late succession classes back to early and mid classes, and to slow or reverse the encroachment of trees and invasion of annual grasses. These treatments included combinations of prescribed fire, chaining, mowing, thinning, mastication of encroaching conifers, seeding, and herbicide for trees and annual grasses.

Management Objectives

The main objectives of the STREAMLINED MANAGEMENT scenario over 20 years were as follows (see also in Table 16):

- Improve ecological condition of ~21,000 acres of Powell RD Wyoming/Basin Big Sagebrush from 61% departure from NRV to 36% departure (Ecological Departure Class 2).

- Contain high-risk vegetation classes to less than 15%.

Management Strategies and Costs

The main strategies of the STREAMLINED MANAGEMENT scenario over 20 years were to treat approximately 325 acres/year of late succession, tree-encroached, and annual-grass-invaded Wyoming/Basin Big Sagebrush (see details in Table 16). The average annual cost of these treatments was $29,900.

Outcomes

- STREAMLINED MANAGEMENT resulted in a greatly improved ecological departure score relative to MINIMUM MANAGEMENT (36 versus 54; see Appendix 7), by transforming acres of late-succession classes into early and mid classes.

- The predicted percentage of high-risk classes showed only half the increase under the STREAMLINED MANAGEMENT scenario relative to MINIMUM MANAGEMENT (see Appendix 7), and remained under the objective of a 15% maximum. These particular high-risk classes are difficult to reduce, let alone eliminate entirely, and to reduce their predicted increase (under minimum management) through active management is better than having them increase dramatically. Strategies in the MAXIMUM MANAGEMENT scenario were predicted to decrease the high-risk classes even further, but at basically double the cost of the STREAMLINED scenario.

Table 16. STREAMLINED MANAGEMENT scenario for the Wyoming/Basin Big Sagebrush Ecological System in the Powell Ranger District project area.

Project	**Powell Ranger District - Dixie National Forest**					
Ecological System	**Wyoming/Basin Big Sagebrush**					
Objective	Improve ecological condition of ~21,000 acres of Powell RD Wyoming/Basin Big Sagebrush from 61% departure from NRV to 36% departure (Ecological Departure Class 2) and contain high-risk vegetation classes to less than 15%… over 20 years.					
Ave. Acres Treated/Year						325
Total Ecosystem Acres						21,141
Strategy	Treat approximately 325 acres/year of late succession, tree-encroached, and annual-grass-invaded Wyoming/Basin Big Sagebrush.					
Management Actions		*One Time Costs*	*# Years*	*Acres/Year*	*Cost/Acre*	*Cost/Year*
	Chain and seed later succession sagebrush to restore earlier classes		20	50	$ 70	$ 3,500
	Apply herbicide-spyke to later succession sagebrush to restore earlier classes and remove encroaching conifers		20	50	$ 40	$ 2,000
	Masticate late succession classes to restore earlier classes		20	75	$ 80	$ 6,000
	Apply prescribed fire or hebicide Plateau plus seed to treat cheatgrass and restore earlier succession classes		20	50	$ 70	$ 3,500
	Thin tree-encroached sagebrush and apply herbicide and seed		20	50	$ 160	$ 8,000
	Apply herbicide Plateau to treat cheatgrass underneath shrubs		20	50	$ 50	$ 2,500
	Mow plus herbicide & seed to treat shrubs with annual grass		20	20	$ 220	$ 4,400
Average Cost/Year	***including one time costs of***	**$ -**				**$ 29,900**
Number of Years						**20**
Total Cost						**$ 598,000**
Notes						

Montane Sagebrush Steppe Ecological System

The montane sagebrush steppe system occurs at moderate to upper elevations of the Powell District. It occupies sites transitional to or intermingling with pinyon-juniper woodlands, montane mixed shrublands, and several types of coniferous forests (with or without aspen). Mountain big sagebrush is usually the dominant species, though several other shrubs are often present and may be abundant, including rubber rabbitbrush, snowberry, bitterbrush, gooseberry, and serviceberry. The herbaceous layer is usually well represented, with a diverse mix of mostly native grasses and forbs, but bare ground may be common in particularly arid or disturbed occurrences.

At present, this system exhibits a moderate degree of ecological departure (Score = 55; Table 5) The current amount of high-risk vegetation classes is negligible (0%; Table 6) The main basis for the level of ecological departure at present is an over-abundance of acres in late-successional classes, with corresponding under-representation of mid classes (Appendices 6 and 7).

Ecological departure improves substantially over 20 years in a regime of minimum management (to a score of 35; Table 7 and Appendix 7), from an apparent transformation of late classes into early and mid classes. The reason for this is unclear, but may be an artifact of model runs that incorporated the "escape" of fires into this system, as was the case with the forested systems on the District – a situation that is not guaranteed to occur in the real world. Of greater concern, however, is the predicted increase in high-risk vegetation classes without active management (to 8%; Table 8 and Appendix 7). These largely represent the effects of dominance by native early shrubs (considered as high-risk on the Powell District) and encroachment by trees (Appendix 7).

In the two Workshops, District and Forest staff focused on treatments designed to revert acres in late succession classes back to mid classes, and to keep ahead of encroachment by trees. These treatments included combinations of prescribed fire, chaining, herbicide application, and mastication of encroaching conifers.

Management Objectives

The main objectives of the STREAMLINED MANAGEMENT scenario over 20 years were as follows (see also in Table 17):

- Improve ecological condition of ~17,000 acres of Powell RD Montane Sagebrush Steppe from 55% departure from NRV to 21% departure (Ecological Departure Class 1).

- Contain high-risk vegetation classes to less than 10%.

Management Strategies and Costs

The main strategies of the STREAMLINED MANAGEMENT scenario over 20 years were to treat approximately 200 acres/year of late succession Montane Sagebrush Steppe with prescribed fire, herbicide and mechanical treatment (see details in Table 17). The average annual cost of these treatments was $12,000.

Outcomes

- STREAMLINED MANAGEMENT resulted in a greatly improved ecological departure score relative to MINIMUM MANAGEMENT (21 versus 35; see Appendix 7), by transforming acres of late-succession classes into early and mid classes.

- The predicted percentage of high-risk classes remained virtually constant under the STREAMLINED MANAGEMENT scenario relative to MINIMUM MANAGEMENT (see Appendix 7), though both remained under the objective of a 10% maximum. These particular high-risk classes are difficult to reduce, let alone eliminate entirely, and to hold their predicted increase (under minimum management) constant through active management is better than having them increase dramatically. Even in the MAXIMUM MANAGEMENT scenario, these same high-risk classes remain essentially constant after 20 years, but at basically double the cost of the STREAMLINED scenario.

Table 17. STREAMLINED MANAGEMENT scenario for the Montane Sagebrush Steppe Ecological System in the Powell Ranger District project area.

Project	**Powell Ranger District - Dixie National Forest**					
Ecological System	**Montane Sagebrush Steppe**					
Objective	Improve ecological condition of ~17,000 acres of Powell RD Montane Sagebrush Steppe from 55% departure from NRV to 21% departure (Ecological Departure Class 1) and contain high-risk vegetation classes to less than 10% … over 20 years.					
Ave. Acres Treated/Year						200
Total Ecosystem Acres						16,633
Strategy	Treat approximately 200 acres/year of late succession Montane Sagebrush Steppe with prescribed fire, herbicide and mechanical treatment.					
Management Actions		***One Time Costs***	***# Years***	***Acres/Year***	***Cost/Acre***	***Cost/Year***
	Prescribed fire in late succession classes to restore early class		20	50	$ 50	$ 2,500
	Apply herbicide-spyke to prevent Early Shrubs		20	50	$ 70	$ 3,500
	Chain late-closed succession class to restore mid succession classes		20	50	$ 40	$ 2,000
	Masticate emerging conifers to prevent future tree encroachment		20	50	$ 80	$ 4,000
Average Cost/Year	***including one time costs of***	**$ -**				**$ 12,000**
Number of Years						**20**
Total Cost						**$ 240,000**
Notes						

Montane-Subalpine Riparian Ecological System

This ecological system occurs as narrow stringers along the margins of perennial streams and other intermittent or ephemeral drainage courses throughout the District, where surface water or groundwater supports mesic or hydric vegetation. Given its broad concept, the system comprises numerous individual riparian vegetation types, though several species tend to be frequent and locally abundant. Such native woody species include cottonwood (mostly narrowleaf), several willows, alder, dogwood, skunkbush, and Wood's rose. The herbaceous layer is largely dominated by graminoids, including numerous species of sedges, rushes and grasses. While forbs are rarely dominant, a diversity of individual species occurs in these sites. In some locations, especially along narrow drainages at higher elevations, upland forest tree species such as Engelmann spruce, subalpine fir and aspen may be abundant in the riparian zone. Hydrological events (flooding) are the major disturbance agents in this system. Beaver were historically important in many riparian habitats of the District ('Paunsaugunt" roughly translates as "home of the beaver").

At present, this system exhibits a moderate degree of ecological departure, though toward the lower end of that range (Score = 38; Table 5) The main basis for the level of ecological departure at present is a preponderance of acres in the mid-successional class, with corresponding under-representation of early and late classes (Appendices 6 and 7). The current amount of high-risk vegetation classes is toward the upper end of the Medium range (9%; Table 6), in the form of exotic forbs (weeds) in the herbaceous layer (Appendix 7).

Ecological departure deteriorates dramatically over 20 years in a regime of minimum management (to a score of 68; Table 7 and Appendix 7), mainly from steep declines in early and mid native successional classes, exacerbated by the shifting of many acres to uncharacteristic classes. Of even greater concern is the predicted massive increase in high-risk vegetation classes without active management (to 51%; Table 8 and Appendix 7). These represent effects of explosive spread of exotic forbs (weeds), and substantial encroachment/spread of undesirable shrubs and trees in riparian zones (Appendix 7).

In the two Workshops, District and Forest staff focused on treatments designed to locate and treat weed infestations, and reduce the encroachment/spread of undesirable shrubs and trees. These treatments included combinations of weed inventory, herbicide, prescribed fire, and thinning of encroaching shrubs and conifers.

Management Objectives

The main objectives of the STREAMLINED MANAGEMENT scenario over 20 years were as follows (see also in Table 18):

- Improve ecological condition of ~12,000 acres of Powell RD Montane-Subalpine Riparian from 38% departure from NRV to 27% departure (Ecological Departure Class 1).

- Reduce projected high-risk vegetation classes from 51% to 19%.

Management Strategies and Costs

The main strategies of the STREAMLINED MANAGEMENT scenario over 20 years were to conduct periodic weed inventory and monitoring along riparian areas with spot treatment of exotic weeds (estimated 150 acres/year), restore 150 acres/year of shrub-forb encroached areas, and thin conifers (see details in Table 18). The average annual cost of these treatments was $31,500.

Outcomes

- STREAMLINED MANAGEMENT resulted in a moderately improved ecological departure score relative to MINIMUM MANAGEMENT (27 versus 38; see Appendix 7), largely by avoiding losses of and/or transforming acres into early and mid succession classes.

- The predicted percentage of high-risk classes is far less under the STREAMLINED MANAGEMENT scenario relative to MINIMUM MANAGEMENT, though even with such active management the high-risk classes more than double from their current condition (see Appendix 7). Exotic forbs (weeds) and encroaching undesirable shrubs can be particularly difficult to reduce, or even maintain at current levels. To hold their predicted increase per the STREAMLINED MANAGEMENT scenario to just double the current condition is better than having them increase dramatically under minimum management. The MAXIMUM MANAGEMENT scenario achieves a large predicted reduction from current condition in these difficult high-risk classes, but at significantly greater cost than that of the STREAMLINED scenario. This is worth keeping in mind as a good use of increased future funds that the District might receive.

Table 18. STREAMLINED MANAGEMENT scenario for the Montane-Subalpine Riparian Ecological System in the Powell Ranger District project area.

Project	Powell Ranger District - Dixie National Forest					
Ecological System	Montane-Subalpine Riparian					
Objective	Improve ecological condition of ~12,000 acres of Powell RD Montane-Subalpine Riparian from 38% departure from NRV to 27% departure (Ecological Departure Class 1) and reduce projected high-risk vegetation classes from 51% to 19% … over 20 years.					
Ave. Acres Treated/Year						310
Total Ecosystem Acres						12,449
Strategy	Conduct periodic weed inventory and monitoring along riparian areas with spot treatment of exotic weeds (estimated 150 acres/year), restore 150 acres/year of shrub-forb encroached areas, and thin conifers.					
Management Actions		*One Time Costs*	*# Years*	*Acres/Year*	*Cost/Acre*	*Cost/Year*
	Weed inventory and monitoring		20	500	$ -	$ -
	Spot treatment of invasive weeds		20	150	$ 50	$ 7,500
	Prescribed fire followed by herbicide application in shrub-forb encroached areas		20	150	$ 150	$ 22,500
	Thin encroaching conifers		20	10	$ 150	$ 1,500
Average Cost/Year	*including one time costs of*	**$ -**				**$ 31,500**
Number of Years						**20**
Total Cost						**$ 630,000**
Notes						

Gambel Oak–Mixed Mountain Brush Ecological System

The Gambel oak–mixed mountain brush system occurs at lower and middle elevations of the Powell District. With a coverage of 10,000 acres it is the smallest of the nine types selected for analyses of active management on the Powell District, smaller even than the riparian system (in the aggregate). Vegetation consists of tall shrubs or small trees that range from continuous dense cover to more patchy in a mosaic with low-shrubby or herbaceous vegetation. Gambel oak is usually present and often the dominant species. Common and abundant associates include Utah serviceberry, true mountain mahogany, snowberry, sagebrush, and numerous grasses and forbs.

At present, this system exhibits a moderate degree of ecological departure (Score = 56; Table 5) The main basis for the level of ecological departure at present is an over-abundance of acres in early and late successional classes, with corresponding under-representation of mid classes (Appendices 6 and 7). The current amount of high-risk vegetation classes is at the lower end of the High range (11%; Table 6), in the form of encroachment by trees of pinyon pine and juniper (Appendix 7).

Ecological departure improves substantially over 20 years in a regime of minimum management (to a score of 38; Table 7 and Appendix 7), from an apparent transformation of early and late classes into mid classes. The reason for this is unclear, but may be an artifact of model runs that incorporated the "escape" of fires into this system, as was the case with the forested systems on the District – a situation that is not guaranteed to occur in the real world. Of greater concern, however, is the predicted moderate increase in high-risk vegetation classes without active management (to 14%; Table 8 and Appendix 7). This represents the continued encroachment by dwarf conifer trees (Appendix 7).

In the two Workshops, District and Forest staff focused on treatments designed to revert acres in the late succession class back to mid classes, and to keep ahead of encroachment by conifers. These treatments included combinations of prescribed fire, hand thinning, mechanical thinning, and seeding.

Management Objectives

The main objectives of the STREAMLINED MANAGEMENT scenario over 20 years were as follows (see also in Table 19):

- Improve ecological condition of ~10,000 acres of Powell RD Gambel Oak–Mixed Mountain Brush from 56% departure from NRV to 27% departure (Ecological Departure Class 1).

- Reduce projected high-risk vegetation classes from 14% to 4%.

Management Strategies and Costs

The main strategies of the STREAMLINED MANAGEMENT scenario over 20 years were to treat 110 acres/year of conifer-invaded late succession class and tree-encroached of Gambel Oak–

Mixed Mountain Brush (see details in Table 19) The average annual cost of these treatments was $11,900.

Outcomes

- STREAMLINED MANAGEMENT resulted in a moderately improved ecological departure score relative to MINIMUM MANAGEMENT (27 versus 38; see Appendix 7), by actions that promote the increase of acres in the mid successional classes.

- The predicted percentage of high-risk classes declined significantly under the STREAMLINED MANAGEMENT scenario relative to MINIMUM MANAGEMENT (down to 4%; see Appendix 7). This represents the relative ease and corresponding success of reducing the encroachment of dwarf conifers – relative to difficult/costly problems such annual grasses and exotic forbs in other systems.

Table 19. STREAMLINED MANAGEMENT scenario for the Gambel Oak–Mixed Mountain Brush Ecological System in the Powell Ranger District project area.

Project	**Powell Ranger District - Dixie National Forest**					
Ecological System	**Gambel Oak–Mixed Mountain Brush**					
Objective	Improve ecological condition of ~10,000 acres of Powell RD Gambel Oak–Mixed Mountain Brush from 56% departure from NRV to 27% departure (Ecological Departure Class 1) and reduce projected high-risk vegetation classes from 14% to 4% … over 20 years.					
Ave. Acres Treated/Year						110
Total Ecosystem Acres						10,444
Strategy	Treat 110 acres/year of conifer-invaded late succession class and tree-encroached of Gambel Oak–Mixed Mountain Brush.					
Management Actions		***One Time Costs***	***# Years***	***Acres/Year***	***Cost/Acre***	***Cost/Year***
	Hand thin conifers in late succession class to restore mid succesion class		20	20	$ 125	$ 2,500
	Masticate and seed tree-encroached brush to restore early succession class		20	50	$ 120	$ 6,000
	Apply prescribed fire to restore early succession class		20	20	$ 90	$ 1,800
	Mechanically thin conifers in late succession class to restore early succesion class		20	20	$ 80	$ 1,600
Average Cost/Year	***including one time costs of***	**$ -**				**$ 11,900**
Number of Years						**20**
Total Cost						**$ 238,000**
Notes						

Summary of Management Scenarios

Table 20 provides a summary of ecological condition metrics – ecological departure and high-risk classes – for the nine ecological systems at the current time, and after 20 years under the MINIMUM MANAGEMENT and STREAMLINED MANAGEMENT scenarios.

The column in Table 20 headed "Area-Weighted ROI" displays the Ecological System-wide inter-system Return on Investment (see Table 10). This is a metric that allows comparison of ROI for the STREAMLINED MANAGEMENT scenarios across or among the ecological systems on a normalized basis. The formula for calculating inter-system ROI was not designed for management scenarios that yield net income, as was the case in the Powell District's forested systems (on account of predicted revenue from timber harvest), so the value was reported as "positive" if ecological improvement was predicted to occur.

This Area-Weighted ROI value was positive for all nine systems. However, the differences between ROI values for the individual systems were not really substantial enough to serve as a clear basis for deciding to emphasize actions in any particular systems.

Table 20. Summary of ecological forecasts for management scenarios in nine ecological systems of the Powell District.

Ecological System	Ecological Departure: Current Condtion	Ecological Departure: Minimum Mgmt 20 yrs	Ecological Departure: Stream-lined Mgmt	High Risk Classes: Current Condtion	High Risk Classes: Minimum Mgmt 20 yrs	High Risk Classes: Stream-lined Mgmt	Acres	Streamlined Mgmt Avg. Annual Cost (over 20 yrs)	Area-Weighted ROI[1]	Streamlined Mgmt Avg. Annual Cost (out of pocket)
Ponderosa Pine	32	16	16	3	4	4	103,000	$ 91,250	N/A	$ 161,250
Aspen–Spruce-Fir	65	35	28	0	7	6	43,000	$ (27,500)	Positive	$ 5,000
Aspen–Mixed Conifer	71	32	24	1	8	8	41,000	$ (26,000)	Positive	$ 24,000
Mixed Conifer	46	27	24	0	0	0	33,000	$ (72,500)	Positive	$ 42,500
Black/Low Sagebrush	39	38	29	7	14	13	30,000	$ 28,000	1.1	$ 28,000
Wyoming/Basin Big Sagebrush	61	54	36	7	20	14	21,000	$ 29,900	1.7	$ 29,900
Montane Sagebrush Steppe	55	35	21	0	8	8	17,000	$ 12,000	2.0	$ 12,000
Montane-Subalpine Riparian	38	68	27	9	51	19	12,000	$ 31,500	2.8	$ 31,500
Gambel Oak–Mxd Mtn Brush	56	38	27	11	14	4	10,000	$ 11,900	1.8	$ 11,900
Total								**$ 78,550**		**$ 346,050**

1. Area-Weighted ROI = Improvement (reduced departure + reduced high risk classes) vs. minimum mgmt x total system acres / cost (normalized).

Conclusions

The primary findings of the Landscape Conservation Forecasting assessment on the Powell Ranger District are summarized below:

1. **The approximately 375,000-acre Powell Ranger District is a largely undeveloped landscape that includes a diversity of Utah High Plateau ecological systems, ranging from sagebrush shrublands to subalpine meadows and forests.**

2. **The current condition of the District's ecological systems varies in terms of departure from their natural condition.** Of the area's 13 ecological systems greater than 500 acres, two are slightly departed from their natural range of variability, ten are moderately departed, and one is highly departed.

3. **The primary cause of current ecological departure across the Powell District is that the aspen forest, mixed conifer forest and sagebrush systems are dominated by late succession classes.** The aspen-spruce fir and the aspen-mixed conifer forests together account for approximately 84,000 acres, and may have suffered even greater past conversion (loss) of aspen to conifer than the interpreted map data show. The three sagebrush systems collectively total approximately 68,000 acres.

4. **Nine ecological systems require special attention, based upon current condition and computer simulations over the next 20 years.** One of the targeted systems is currently highly departed from the natural range of variability and seven are moderately departed. Four of the targeted systems have, or are projected to have within 20 years, an undesirable percentage of high-risk vegetation classes. Key ecological management issues include:
   - ***Aspen forest systems*** – overabundance of late-succession classes, as well as aspen vegetation on a pathway of conversion to conifers.
   - ***Ponderosa pine and mixed conifer forests*** – overabundance of vegetation in the late-closed succession class; projected improvement in these forest systems over time was dependent upon substantial wildfire which randomly occurred in the computer simulations, but is not assured.
   - ***Sagebrush systems*** – current shortage of early-succession classes, plus projected increases in high-risk classes (e.g. pinyon-juniper encroachment, and increasing cover of cheatgrass within shrublands).
   - ***Oak-brush*** – substantial encroachment by conifer trees.
   - ***Riparian*** – projected dramatic increases in exotic forbs and uncharacteristic species (e.g. Wood's rose) without active management.

5. **Varied management strategies were explored for each targeted ecosystem, using computer simulations to test their effectiveness and adjust the scale of application. Multiple strategies are required for most ecosystems.**
   - ***Aspen forest*** strategies include: prescribed fire, conifer removal, and partial timber harvest – all to achieve a mixed age class structure closer to the natural range of variability.

Note: The aspen-mixed conifer system includes two large areas with very different conditions as a result of a recent large fire. One of the areas requires active management, but mapping and modeling the two areas separately was beyond the scope of this project.

- ***Ponderosa pine and mixed conifer forest*** strategies include: prescribed fire – along with combinations of mechanical thinning and varied types of timber harvest – applied adaptively to achieve an age class structure closer to the natural range of variability.
- ***Sagebrush*** strategies include varied combinations of: prescribed fire; harrowing or mowing, with and without seeding to create a more diverse understory; mastication, chaining, or herbicide of late succession classes; mechanical thinning of tree-encroached sagebrush plus seeding with grass species; and herbicide application in shrublands with annual grasses.
- ***Oak-brush*** strategies include: mechanical- or hand-thinning of encroaching conifer trees, prescribed fire, and thinning plus seeding of tree-encroached brush.
- ***Riparian*** strategies include: ongoing weed inventory, spot application of herbicides to reduce exotic forbs, thinning of conifer trees, and Wood's rose reduction followed by herbicide to reduce invasive woody species.

6. **The streamlined management strategies benefited all nine focal systems as compared to current condition and/or minimum management scenarios.** The streamlined management achieved low ecological departure (close to the natural range of variability) for eight systems. For the dominant ponderosa pine system, streamlined management achieved low ecological departure in the absence of a (unpredictable) wildfire event. Moreover, the streamlined management strategies reduced or contained high-risk vegetation classes for all systems.

7. **The streamlined management scenarios accrued the highest "return on investment" for all relevant systems, as compared to the maximum management scenario.** *However, in several cases the maximum management scenarios would achieve even greater ecological benefits if additional management funds were to become available.* The ROI metric was not applicable for assessing alternative strategies in forest systems when projected income was generated from harvesting. TNC's area-weighted return on investment analysis showed favorable results across all ecological systems.

Recommendations for Follow-up and Future Work

Achievable in the near-term future (have all the data):

- Split the Powell District into its two internally-similar sub-areas (Mount Dutton and Paunsaugunt Plateau) and, using spatial data and models already in-hand, re-run all of the condition metrics (departure, high-risk classes) and modeling of scenarios (MINIMUM, STREAMLINED, MAXIMUM) in each sub-area for the same nine ecological systems. This would test the validity of suspected large differences between the two sub-parts – the northern part generally being in fairly good condition (at least for forested systems) from effects of the Sanford fire, and the southern part being in poor or deteriorating condition. This suspected bi-polar situation was not apparent (or tested for) by the current project which treated the entire District as one unit, with ecological-condition metrics being an average of all sites for each ecological system.

Achievable in the near- to medium-term future:

- Develop and apply a credible, realistic way to depict the effects of elk herbivory – the spatial-representation of elk AUM-equivalents – in the models on the Dixie NF.

- Consider exporting the Landscape Conservation Forecasting process and results to other Districts of the Dixie National Forest, such as Escalante and Cedar City. This would require a bit of additional background work such as District staff review of the current "merged" Dixie vegetation map for their District, possible fine-tuning of ecological state-and-transition models, etc.

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Appendices

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Appendix 1. Vegetation query statements for the Dixie National Forest.

MODELNAME (NEW BPS) in BOLD

Aspen–Spruce-Fir
Where: ((("LANDFIRE" = Rocky Mountain Alpine Dwarf-Shrubland or "LANDFIRE" = Southern Rocky Mountain Montane-Subalpine Grassland) AND ("DIX_V" = Aspen or "DIX_V" = Aspen / Spruce-Fir or "DIX_V" = Spruce-Fir)) or (("LANDFIRE" = Rocky Mountain Alpine/Montane Sparsely Vegetated Systems or "LANDFIRE" = Rocky Mountain Aspen Forest and Woodland or "LANDFIRE" = Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland or "LANDFIRE" = Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland - Low Elevation or "LANDFIRE" =Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland or "LANDFIRE" = Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland - High Elevation or "LANDFIRE" =Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland or "LANDFIRE" = Rocky Mountain Subalpine-Montane Mesic Meadow or "LANDFIRE" = Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland - Low Elevation or "LANDFIRE" =Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland) AND ("DIX_V" = Aspen / Grass-Forbs or "DIX_V" = Aspen / Mixed Conifer or "DIX_V" = Aspen / Spruce-Fir or "DIX_V" = Black Sage / Silver Sage or "DIX_V" = Limber Pine / Bristlecone Pine or "DIX_V" = Mixed Conifer / Aspen or "DIX_V" = Mountain Big Sage / Aspen or "DIX_V" = Mountain Big Sage / Spruce-Fir or "DIX_V" = Rock / Limber Pine / Bristlecone or "DIX_V" = Sedge / Grass-Forbs or "DIX_V" = Sheep Fescue or "DIX_V" = Silver Sage or "DIX_V" = Spruce-Fir or "DIX_V" = Spruce-Fir / Grass-Forbs or "DIX_V" = Spruce-Fir / Sedge or "DIX_V" = Spruce-Fir / Sheep Fescue)) or ("LANDFIRE" = Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland - High Elevation AND "DIX_V" = Spruce-Fir))

Aspen–Mixed Conifer
Where: (("LANDFIRE" = Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland or "LANDFIRE" = Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland - Low Elevation or "DIX_V" = Aspen or "DIX_V" = Aspen / Grass-Forbs or "DIX_V" = Aspen / Mixed Conifer) or (("LANDFIRE" = Rocky Mountain Bigtooth Maple Ravine Woodland or "LANDFIRE" = Southern Rocky Mountain Ponderosa Pine Woodland) and "DIX_V" =Mixed Conifer / Aspen) or ("LANDFIRE" = Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland - Low Elevation and ("DIX_V" = Mountain Big Sage / Black Sage or "DIX_V" = Black Sage / Mountain Big Sage or "DIX_V" = Mountain Big Sage)) or (("LANDFIRE" = Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland or "LANDFIRE" = Southern Rocky Mountain Ponderosa Pine Woodland or "LANDFIRE" = Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland or "LANDFIRE" = Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland - Low Elevation or "LANDFIRE" = Rocky Mountain Lower Montane-Foothill Shrubland or "LANDFIRE" = Southern Rocky Mountain Ponderosa Pine Savanna or "LANDFIRE" = Great Basin Semi-Desert Chaparral) and "DIX_V" = Mountain Big Sage / Aspen) or (("LANDFIRE" = Southern Rocky Mountain Ponderosa Pine Woodland or "LANDFIRE" = Rocky Mountain Bigtooth Maple Ravine Woodland or "LANDFIRE" = Inter-Mountain Basins Curl-leaf Mountain Mahogany Woodland and Shrubland or "LANDFIRE" = Inter-Mountain Basins Montane Sagebrush Steppe - Low Sagebrush) and "DIX_V" = Aspen / Gambel Oak) or ("LANDFIRE" = Rocky Mountain Aspen Forest and Woodland and "DIX_V" = Grass Forbs) or (("LANDFIRE" = Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland or "LANDFIRE" = Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland or "LANDFIRE" = Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland or "LANDFIRE" = Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland) and ("DIX_V" = Mountain Big Sage / Black Sage or "DIX_V" = Pinyon Juniper)) or ("LANDFIRE" = Rocky Mountain Aspen Forest and Woodland AND "DIX_V" = Grass Forbs))

Stable Aspen
Where: (("DIX_V" = Mountain Big Sage / Aspen and "LANDFIRE" = Rocky Mountain Gambel Oak-Mixed Montane Shrubland - Continuous) or ("DIX_V" = Aspen and "LANDFIRE" = Rocky Mountain Aspen Forest and Woodland))

Appendix 1. Vegetation query statements for the Dixie National Forest.

Pinyon-Juniper
Where: (("LANDFIRE" = Colorado Plateau Pinyon-Juniper Shrubland or "LANDFIRE" = Colorado Plateau Pinyon-Juniper Woodland or "LANDFIRE" = Great Basin Pinyon-Juniper Woodland or "LANDFIRE" = Inter-Mountain Basins Juniper Savanna) or (("LANDFIRE" = Southern Rocky Mountain Ponderosa Pine Savanna or "LANDFIRE" = Southern Rocky Mountain Ponderosa Pine Woodland) and "DIX_V" = Pinyon Juniper) or (("LANDFIRE" = Southern Rocky Mountain Ponderosa Pine Savanna or "LANDFIRE" = Southern Rocky Mountain Ponderosa Pine Woodland) AND "DIX_V" = Pinyon Juniper))

Ponderosa Pine
Where: (("LANDFIRE" = Southern Rocky Mountain Ponderosa Pine Woodland or "LANDFIRE" = Southern Rocky Mountain Ponderosa Pine Savanna or "DIX_V" = Pinyon Juniper / Mountain Brush or "DIX_V" = Ponderosa Pine or "DIX_V" = Ponderosa Pine / Aspen or "DIX_V" = Ponderosa Pine / Mixed Conifer or "DIX_V" = Ponderosa Pine / Mountain Big or "DIX_V" = Rock / Ponderosa Pine) and not ("LANDFIRE" = Barren-Rock/Sand/Clay and "DIX_V" = Rock / Ponderosa Pine) and not ("LANDFIRE" = Rocky Mountain Gambel Oak-Mixed Montane Shrubland - Patchy and "DIX_V" = Pinyon Juniper / Mountain Brush) AND NOT (("LANDFIRE" = Southern Rocky Mountain Ponderosa Pine Savanna or "LANDFIRE" = Southern Rocky Mountain Ponderosa Pine Woodland) AND "DIX_V" = Pinyon Juniper))

Gambel Oak
Where: ("LANDFIRE" = Rocky Mountain Gambel Oak-Mixed Montane Shrubland or "LANDFIRE" = Rocky Mountain Gambel Oak-Mixed Montane Shrubland - Patchy or "LANDFIRE" = Rocky Mountain Gambel Oak-Mixed Montane Shrubland - Continuous or "LANDFIRE" = Rocky Mountain Lower Montane-Foothill Shrubland or "LANDFIRE" = Rocky Mountain Bigtooth Maple Ravine Woodland or "LANDFIRE" = Colorado Plateau Pinyon-Juniper Woodland or "LANDFIRE" = Great Basin Pinyon-Juniper Woodland or "DIX_V" = Black Sage / Gambel Oak or "DIX_V" = Gambel Oak or "DIX_V" = Mountain Brush or "DIX_V" = Mountain Brush / Pinyon Juniper or "DIX_V" = Pinyon Juniper / Mountain Brush or "DIX_V" = Ponderosa Pine / Mountain Brush)

Spruce-Fir
Where: (("LANDFIRE" = Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland or "LANDFIRE" = Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland or "LANDFIRE" = Rocky Mountain Lodgepole Pine Forest) and not ("LANDFIRE" = Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland and "DIX_V" = Rock / Spruce-Fir))

Curlleaf Mountain Mahogany
Where: ("LANDFIRE" = Inter-Mountain Basins Curl-leaf Mountain Mahogany Woodland and Shrubland or "DIX_V" = Curlleaf Mountain Mahogany or "DIX_V" = Curlleaf Mountain Mahogany / M)

Wyoming/Basin Big Sagebrush
Where: ("LANDFIRE" = Inter-Mountain Basins Semi-Desert Shrub-Steppe or "LANDFIRE" = Inter-Mountain Basins Big Sagebrush Steppe or "LANDFIRE" = Inter-Mountain Basins Big Sagebrush Shrubland or "LANDFIRE" = Inter-Mountain Basins Greasewood Flat)

Mixed Conifer
Where: (("LANDFIRE" = Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland or "LANDFIRE" = Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland) and not "DIX_V" = Ponderosa Pine or "DIX_V" = Ponderosa Pine / Aspen or "DIX_V" = Ponderosa Pine / Mixed Conifer) or ("LANDFIRE" = Rocky Mountain Aspen Forest and Woodland and "DIX_V" = Mixed Conifer)

Appendix 1. Vegetation query statements for the Dixie National Forest.

Montane Sagebrush Steppe
Where: ("LANDFIRE" = Inter-Mountain Basins Montane Sagebrush Steppe or "LANDFIRE" = Inter-Mountain Basins Montane Sagebrush Steppe - Mountain Big Sagebrush)

Black/Low Sagebrush
Where: (("LANDFIRE" = Great Basin Xeric Mixed Sagebrush Shrubland or "LANDFIRE" = Inter-Mountain Basins Montane Sagebrush Steppe - Low Sagebrush or "LANDFIRE" = Colorado Plateau Mixed Low Sagebrush Shrubland or "LANDFIRE" =Columbia Plateau Low Sagebrush Steppe) or ("LANDFIRE" = Great Basin Semi-Desert Chaparral AND "DIX_V" = Black Sage))

Montane-Subalpine Riparian
Where: ("LANDFIRE" = Inter-Mountain Basins Riparian Systems or "LANDFIRE" = Rocky Mountain Montane Riparian Systems or "LANDFIRE" = Rocky Mountain Subalpine/Upper Montane Riparian Systems)

Chaparral
Where: (("LANDFIRE" = Great Basin Semi-Desert Chaparral or "LANDFIRE" = Mogollon Chaparral or "LANDFIRE" = Sonora-Mojave Semi-Desert Chaparral) AND NOT ("DIX_V" = Black Sage / Mountain Big Sage or "DIX_V" = Mountain Big Sage or "DIX_V" = Mountain Big Sage / Black Sage))

Subalpine Meadow
Where: ("LANDFIRE" = Rocky Mountain Alpine Dwarf-Shrubland or "LANDFIRE" = Rocky Mountain Alpine Turf or "LANDFIRE" = Rocky Mountain Subalpine-Montane Mesic Meadow or "LANDFIRE" = Southern Rocky Mountain Montane-Subalpine Grassland)

Blackbrush
Where: ("LANDFIRE" = Mojave Mid-Elevation Mixed Desert Scrub or "LANDFIRE" = Colorado Plateau Blackbrush-Mormon-tea Shrubland)

Limber-Bristlecone Pine
Where: ("LANDFIRE" = Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland or "DIX_V" = Limber Pine / Bristlecone Pine or "DIX_V" = Rock / Limber Pine / Bristlecone)

Appendix 2. Descriptions of vegetation classes of biophysical settings for the Dixie and Fishlake National Forests.

Class Code	Class abbreviation and brief description
	Aspen-Mixed Conifer
A	*Early*; 0-100% cover aspen <5m; mountain snowberry and *Ribes* common; 0-19 yrs
B	*Mid*1-*closed*: 40-99% cover aspen <5-10m; mountain snowberry and *Ribes* common; 11-39 yrs
C	*Mid*2-*closed*: 40-99% cover aspen 10-24m; conifer saplings visible in mid-story; mountain snowberry and *Ribes* common; 40-79 yrs
D	*Late*1-*open*: 0-39% cover aspen 10-25 m; 0-25% mixed conifer cover 5-10 m; mountain snowberry and *Ribes* common; >80 yrs
E	*Late*1-*closed*: 40-80% cover of mixed conifer 10-50m; <40% cover of aspen 10-25m; mountain snowberry and *Ribes* present; >100 yrs
U	Mixed conifer
	Aspen-Spruce Fir **1061s**
A	*Early*: 50-100% cover aspen <2m; mountain snowberry and *Ribes* common; 0-9 yrs
B	*Mid*1-*closed*: 40-99% cover aspen <5-10m; mountain snowberry and *Ribes* common; 10-39 yrs
C	*Mid*2-*open*: 10-30% cover aspen 10-24m; 10% cover of subalpine fir and spruce; mountain snowberry and *Ribes* common; 40-169 yrs
D	*Late*1-*closed*: 40-50% cover of subalpine fir and spruce cover 25-50m; <40% cover of aspen; mountain snowberry and *Ribes* common; >169 yrs
U	*NAS-closed (No Aspen)*: >50% subalpine fir and spruce cover; aspen absent or in trace amount
	Black-Low Sagebrush **1079an**
A	*Early*: <10% cover rabbitbrush; 10-40% cover of grass; <50% cover mineral soil; 0-25 yrs
B	*Mid*1-*open*: 10-20% cover of black sagebrush and rabbitbrush; 10-30% grass cover; <40% cover of mineral soil; 25-119 yrs
C	*Late1-Open*: 1-10% pinyon-juniper sapling cover; 20-30% cover of black sagebrush; 10-30% cover of grasses; 120-194 yrs
D	*Late*1-*Closed*: 10-40% cover of pinyon or juniper 5-10m high; <10% black sagebrush cover; <10% grass cover; >195 yrs
U	*ES*: *Early*-Shrub:10-40% cover rabbitbrush species
U	*TE*: Tree-Encroached: >40% pinyon or juniper cover 5-10m; <5% shrub cover; <5% herbaceous cover
U	*DP*: Depleted: 20-50% cover of black sagebrush; <5% herbaceous cover; <10% pinyon or juniper sapling cover
U	*SAP*: Shrub-Annual-Grass-Perennial-Grass: 20-50% cover of black sagebrush; >5% cover of native grass; 5-20% cheatgrass cover; <10% pinyon or juniper sapling cover
U	*SA*: Shrub-Annual-Grass: 20-50% cover of black sagebrush; <5% cover of native grass; 5-20% cheatgrass cover; <10% pinyon or juniper sapling cover
U	*AG*: Annual-Grass; 10-40% cover of cheatgrass
U	*SE*: Seeded-Non-Native; Seeded-Non-Native; native or introduced plant species; seed mix cover 5-20%
	Blackbrush **1082**
A	*Early*: 0-200 yrs; 0-50% cover of spiny menodora, horsebrush, and snakeweed at lower elevations; rabbitbrush, big sagebrush, and desert bitterbrush higher elevations
B	*Mid*-closed: 200+ yrs; 10-50% cover blackbrush <1.0m; 10% cover of grasses (desert needlegrass, Indian ricegrass, galleta grass, fluff grass, and threeawn), other shrubs present, including Joshua trees woodlands
C	*Late-open*: 400+ years; same as mid-closed also with juniper trees

Appendix 2. Descriptions of vegetation classes of biophysical settings for the Dixie and Fishlake National Forests.

Class Code	Class abbreviation and brief description
U	*SA*: Shrub-Annual-Grass; 10-50% cover of blackbrush or other shrubs <1.0m tall, 0-20% cheatgrass/red brome cover
U	*AG*: Annual-Grasses; 5-30% cheatgrass/red brome cover, occasional rabbitbrush
U	*SE*: Seeded-Non-Native; Seeded-Non-Native; native or introduced (crested wheatgrass, forage kochia) seed mix cover 5-20%
	Curlleaf Mountain Mahogany 1062
A	*Early;* 0-20 yrs; <70% cover of mountain mahogany <3m high; other shrubs (snowberry, rabbitbrush) and grasses may be present
B	*Mid*1-*Closed*: 60-150 yrs; 30-70% cover of mountain mahogany 5-10m high, other shrubs (snowberry, rabbitbrush, big sagebrush, bitterbrush, black sagebrush) abundant
C	*Mid*1-*Open*: 20-60 yrs; 10-30% cover mountain mahogany and other shrubs, 0-5m
D	*Late*1-*Open*: 150+ yrs; 10-30% cover of mountain mahogany, 5-25m; big sagebrush, black sagebrush, bitterbrush; grasses abundant; occasional ponderosa pine possible
E	*Late*1-*Closed*: 150+ yrs 30-60% cover of mountain mahogany 5-25m; 5-10% cover of pinyon-juniper; snowberry may be common; occasional ponderosa pine possible
	Gambel Oak/Mixed Mountain Brush
A	*Early:* 0-4 years – *to be described*
B	*Mid1-Closed*: 5-19 years – *to be described*
C	*Mid2-Closed:* 20-80 years – *to be described*
D	*Late-Closed*: 80-500 years – *to be described*
U	TE: Tree-encroached – *to be described*
U	ES: Early shrub – *to be described*
	Limber-Bristlecone Pine Woodland 1020
A	*Early*: 0-10% limber and bristlecone pine cover 0-5m high, abundant mineral soil or talus cover; sparse ground cover; 0-99 yrs
B	*Mid1-Open*: 11-30% limber and bristlecone pine cover 5-10m high, abundant mineral soil or talus cover; sparse ground cover; 100-249 yrs
C	*Late1-Open*; very old trees; 11-30% limber and bristlecone pine cover 5-25m high, abundant mineral soil or talus cover; sparse ground cover; >250 yrs
	Mixed Conifer 1052
A	*Early*; 0-29yrs; 0-15% cover of tree/shrub/grass; <5m; 0-29 yrs
B	*Mid*1-*closed*; 30-99yrs; 35-100% cover of conifers <24m; 30-99 yrs
C	*Mid*1-*open*; 31-99yrs; 0-35% cover of conifers <24m; 30-99 yrs
D	*Late*1-*open*; 100-999yrs; 0-35% cover of conifers 25-49m; >100 yrs
E	*Late*1-*closed*; 100-999yrs; 35-100% cover of conifers 25-49m; >100 yrs
U	AG: Annual-Grass: saplings plus >10% annual grass cover
U	TA: Tree-Annual-Grass: Any class A-E plus >5% annual grass cover
	Mixed Salt Desert Scrub 1081
A	*Early*: 0-5 yrs; 0-20% cover of young saltbushes <0.5m
B	*Mid1*-open: 5+ yrs; 20-30% cover of saltbush and winterfat <0.5m
C	*Mid*2-open; 5-60 yrs; 20-30% cover budsage <0.25m with young saltbush growing
U	*SA*: Shrub-Annual-Grass; 20-30% cover of saltbush or other shrubs <0.5m, 0-20% cheatgrass cover
U	*AG*: Annual-Grass; 10-40% cover of cheatgrass

Appendix 2. Descriptions of vegetation classes of biophysical settings for the Dixie and Fishlake National Forests.

Class Code	Class abbreviation and brief description
	Montane Chaparral
A	*Early*: 0-9 yrs
B	*Late-closed*: 10-500 yrs
	Montane Sagebrush Steppe 1126
A	*Early*: 0-12 yrs: 0-10% canopy of mountain sage/mountain brush; 10-80% grass/forb cover
B	*Mid--open*: 13-38 yrs; 11-30% cover of mountain sage/mountain brush; >50% herbaceous cover
C	*Mid--closed*: 38+ yrs; 31-50% cover of mountain sage/mountain brush; 25-50% herbaceous cover, <10% conifer sapling cover
D	*Late-open*: 80-129 yrs; 10-30% cover conifer <5m for PJ and <10m for mixed conifers; 25-40% cover of mountain sage/mountain brush; <30% herbaceous cover
E	*Late-closed*: 130+ yrs; 31-80% conifer cover (lower for PJ, greater for mixed conifers) 10-25m; 6-20% shrub cover; <20% herbaceous cover
U	*ES*: *Early*-Shrub;20-50% cover rabbitbrush species
U	*TE*: Tree-Encroached; 31-80% conifer cover 10-25m; <5% shrub cover; <5% herbaceous cover
U	*DP*: Depleted; 20-50% cover of mountain sage/mountain brush; <5% herbaceous cover; <10% conifer sapling cover
U	*SAP*: Shrub-Annual-Grass-Perennial-Grass; 21-50% cover of mountain sage/mountain brush; >5% cover of native grass; 5-10% cheatgrass cover; <10% conifer sapling cover
U	*AG*: Annual-Grass; 10-30% cover of cheatgrass
U	TA: Tree-Annual-Grass: Tree-encroached (see TA above) plus >5% annual grass
U	SA: Shrub-Annual-Grass: SAP (see above) but <5% cover of native grass
	Montane-Subalpine Riparian 1154
A	*Early*: 0-50% cover of cottonwood, willow, Wood's rose <3m; carex present; 0-5 yrs
B	*Mid*1-*open*: 31-100% cover of cottonwood, aspen, willow, Wood's rose <10m; 5-20 yrs;
C	*Late*1-*closed*; 31-100% cover of cottonwood, alder, aspen, willow 10-24m; >20 yrs
U	*SFE*: Shrub-Forb-Encroached; 10-50% cover of Wood's rose in open areas or under tree canopy
U	*EXF*: Exotic-Forbs; 20-100% cover of exotic forbs (knapweed, tall whitetop, purple loosestrife), salt cedar, or Russian olive
U	*DES*: Desertification: Entrenched river/creek with 10-50% cover of upland shrubs (e.g., big sage)
U	TE: Tree-Encroached
U	EW: Elk wallow
	Pinyon-Juniper 1019
A	*Early-open*: 0-30% herbaceous cover, charred stumps and trunks
B	*Mid*1-*open*: 11-30% cover big sagebrush, black sagebrush, or bitterbrush <1.0m, 10-40% herbaceous cover
C	*Mid*2-*open*; 11-20% cover of young (<100 yrs old) pinyon and/or juniper <5m, 10-20% shrub cover, <20% herbaceous cover
D	*Late*1-*open*: old growth, 21-60% cover of pinyon and/or juniper <5m-9m, 10-40% shrub cover, <20% herbaceous cover
U	*TA*: Tree-Annual-Grass; 20-60% cover of pinyon and/or juniper <5m-9m, 10-40% shrub cover, <20% cheatgrass cover
U	*AG*: Annual-Grasses; 5-30% cheatgrass cover

Appendix 2. Descriptions of vegetation classes of biophysical settings for the Dixie and Fishlake National Forests.

Class Code	Class abbreviation and brief description
U	*SE:* Seeded-Non-Native; native or non-native (crested wheatgrass, forage kochia) seed mix cover 5-20%
	Ponderosa Pine 1054
A	*Early*: 0-60% cover of shrub/grass; conifer seedlings can be abundant <5m; 0-39yrs
B	*Mid*1-*closed*: 31-60% cover of ponderosa pine, Douglas-fir, and white fir 5-10m; dense shrub cover possible; 40-159yrs
C	*Mid*1-*open*: 0-30% cover of ponderosa pine (dominant), Douglas-fir, and white fir 5-10m; abundant shrub and grass cover; 40-159yrs
D	*Late*1-*open*: 0-30% cover of ponderosa pine (dominant), Douglas-fir, and white fir 11--50m; abundant shrub and grass cover; >160 yrs
E	*Late*1-*closed*: 31-80% cover of ponderosa pine, Douglas-fir, and white fir 11-50m; mountain snowberry common; >160 yrs
U	AG: Annual-Grass: saplings plus >10% annual grass cover
U	TA: Tree-Annual-Grass: Any class A,B,C plus >5% annual grass cover
	Stable Aspen 1011
A	*Early*; 0-100% cover of aspen <5m tall; 0-9 yrs
B	*Mid*1-*closed*; 40-99% cover of aspen <5-10m; 10-39 yrs
C	*Late*1-*closed*; 40-99% cover of aspen 10-25m; few conifers in mid-story; >39 yrs
D	*Late*1-*open*; 0-39% cover of aspen 10-25 m; 0-25% conifer cover 10-25 m; >99 yrs
U	*DP-Open*: 10-50% cover of older aspen 10-25m; no or little aspen regeneration; few conifers in mid-story
U	*NAS(No Aspen)-all*: Very few aspen stems present; dead clone of aspen, dead boles may be visible on the ground; 5-50% cover of mountain sagebrush/mountain shrub; <50% herbaceous cover
U	*Uncharacteristic*: includes several uncharacteristic NAS classes as observed in montane sagebrush steppe biophysical setting (see 1126)
	Subalpine Meadow
A	*Early*: 0-20 years
B	*Late-closed*: 10-300 years
	Spruce-Fir 1056
A	*Early*: 0-100% cover of spruce seedling/shrub/grass <5m; 0-39 yrs
B	*Mid*1-*closed*: 40-100% cover of spruce and aspen 5-24m; 40-129yrs
C	*Mid*1-*open*: 0-40% cover of spruce 5-24m pole size; ; 40-129yrs
D	*Late*1-*closed*: 40-100% cover of spruce 25-49m; >129 yrs
	Wyoming-Basin Big Sagebrush upland 1080up
A	*Early*: 0-20 yrs; 10-25% herbaceous cover, <10% cover of rabbitbrush species, <5% cover of basin or Wyoming big sagebrush
B	*Mid--open*: 20-60 yrs; 11-20% cover of basin or Wyoming big sagebrush, 10-25% herbaceous cover
C	*Late*1-*closed:* 60-100yrs; 20-40% cover of basin or Wyoming big sagebrush; 10-20% native herbaceous cover
D	*Late*2-*open*: 100-150 yrs; 0-15% pinyon or juniper sapling <5m tall, 10-25% cover of basin or Wyoming big sagebrush; <15% native herbaceous cover
E	*Late*2-*closed*: 150+ yrs; 21-50% pinyon or juniper cover <10m tall, <10% cover of basin or Wyoming big sagebrush; ~5% native herbaceous cover

Appendix 2. Descriptions of vegetation classes of biophysical settings for the Dixie and Fishlake National Forests.

Class Code	Class abbreviation and brief description
U	*SAP*: Shrub-Annual-Grass-Perennial-Grass; 10-30% basin or Wyoming big sagebrush <0.5m, 5-10% cover cheatgrass, 5-20% cover native grasses, scattered pinyon-juniper saplings may be present
U	*SA*: Shrub-Annual-Grass; 10-30% basin or Wyoming big sagebrush <0.5m, 10-30% cover cheatgrass, scattered pinyon-juniper saplings may be present, native grasses rare
U	*AG*: Annual-Grass; 10-40% cover of cheatgrass
U	*TA*: Tree-Annual-Grass; 11-60% cover of trees 5-9m, <20% cheatgrass cover
U	*ES*: Early-Shrub; 0-40% cover rabbitbrush species
	Tall Forbs
A	*Early*: 0-4 years
B	*Mid-closed*: 5-9 years
C	*Late-closed*: 10-300 years
U	US: Uncharacteristic shrubs
U	UA: Uncharacteristic forbs

Appendix 3. Description of ecological model dynamics for the Powell Ranger District.

Non-spatial state-and-transition models of ecological systems were created with the software Vegetation Dynamics Development Tool (VDDT from ESSA Technologies, Ltd.; Barrett, 2001; Beukema *et al*., 2003; Forbis *et al*., 2006). In VDDT, succession and disturbance are simulated in a semi-Markovian framework. Each vegetation state has one possible deterministic transition based on time in the state (usually succession) and several possible probabilistic transitions (natural and management). Each of these transitions has a new destination state and probability associated with it. Based on the timing of the deterministic transition and the probabilities of the stochastic transitions, at each time step a polygon may remain the same, undergo a deterministic transition based on elapsed time in the current state or undergo a probabilistic transition based on a random draw (for example, replacement fire). Model parameters (succession duration and disturbance rates) are presented in Appendix 4.

Ecological System State-and-Transition Models

TNC created 18 state-and-transition models from ecological systems mapped by LANDFIRE and the USFS Dixie National Forest. Two ecological systems were obtained from lumping:
i) Gambel oak and mountain shrub to form Gambel Oak–Mixed Mountain Brush, and ii) black sagebrush and low sagebrush to form Black/Low Sagebrush. Appendix 2 presents the different states, phases, and their abbreviations for each ecological system.

Although each model represented a distinct system, 17 models were all located on the same VDDT project page (i.e., Uber model) to allow for seamless system conversions (for example, loss of aspen to mixed conifer) and future climate change effect modeling. The only system not on the Uber page was montane-subalpine riparian. Moreover, models were developed from existing Great Basin templates from TNC but substantially modified using VDDT modeling notes and disturbance files from the 2005 attempted Fishlake Forest Plan revisions (models from the Fishlake National Forest applied directly to the Dixie National Forest.

All models had at their core the LANDFIRE reference condition represented by some variation around the A-B-C-D-E classes (Table 2). Essentially, this meant that models had an early development class and mid-development and/or late-development classes. Mid- and late-development classes may be expressed as open or closed canopy. Grass-forb meadow, a form of alpine turf, and chaparral were two-box models that contained the early and late-development class. The A-E class models simply represented succession from usually herbaceous vegetation to increasing woody species dominance where the dominant woody vegetation might be shrubs or trees. Aspen (three types) and curlleaf mountain mahogany started as woody dominated early-development vegetation, not herbaceous vegetation.

For the estimation of the natural range of variability (Table 2), only the A-E components of models were needed. However, for the models to also reflect the effects of management, we added uncharacteristic vegetation classes that represented different states that only exist because of direct or indirect human activity. As a general rule, LANDFIRE did not map different kinds of uncharacteristic classes, but we incorporated them in the models. For shrublands, typical uncharacteristic classes included:

- Sagebrush and mixed salt desert shrublands with <5% (less productive vegetation) or <10% (more productive vegetation) cover of herbaceous understory (*Depleted* shrubland = *DP*) that was created by historic livestock grazing, perhaps prior to the Taylor Grazing Act;
- Shrublands with >5% cover of cheatgrass with >5% cover of native grass (*Shrub-Annual Grass-Perennial Grass= SAP*) or • 5% cover of native grass (*Shrub-Annual Grass = SA*);
- Sagebrush shrubland where pinyon and juniper encroachment has been sufficiently long that native grass cover was <5% (less productive vegetation) or <10% (more productive vegetation), sagebrush skeletons were common, and trees were mostly conical and generally <125 years old (*Tree-Encroached = TE*);
- Either tree-encroached shrubland, or late-development pinyon-juniper, curlleaf mountain mahogany, mixed conifer, or ponderosa pine woodlands with >5% cheatgrass cover (*Tree-Annual Grass = TA*);
- Annual grasslands were the dominant cover is cheatgrass at >10% cover (*Annual Grass = AG*) and generally the result of burning any vegetation class containing cheatgrass;
- Shrublands of black and Wyoming big sagebrush, and montane sagebrush steppe invaded by non-native thistle species (*Cirsium* spp.).
- Shrubland dominated by early succession shrubs, such as rabbitbrush (*Early-Shrub = ES*), caused by excessive grazing; and
- Shrublands that was seeded with introduced species, such as crested wheatgrass (*Agropyron cristatum*), that may have various native shrub and herbaceous cover (*Seeded = SD*).

Riparian systems harbored more peculiar uncharacteristic vegetation classes. A common class reflecting historic grazing was the dominance of riparian corridors by native forbs and shrub species unpalatable to domestic sheep and cattle (*Shrub-Forb-Encroached = SFE*). Dense midstory of Wood's rose is a classic example. This vegetation class often set the stage to entrenchment of stream banks or rivulets where livestock or elk access to water chronically persist, although entrenchment could also be triggered by water diversions and creation of water retention ponds. The consequence of entrenchment was a drop of the water table, leading to a moist or wet system becoming a sub-xeric shrubland (*Desertification = DE*). Entrenched banks follow sagebrush dynamics, which we greatly simplified in the riparian model, with a possibility for pinyon and juniper encroachment (*Tree-Encroached = TE*). Similarly, pinyon and juniper can heavily encroach the late-succession reference class, usually because of missed fire cycles and lack of high intensity flood events, thus creating the *Pinyon-Juniper* (*PJ*) class. All wet to moist classes are also prone to invasion by exotic forbs (*Exotic Forbs = EF*), such as tall whitetop (*Lepidium latifolium*) and different thistle species. The same wet to moist classes can also be transformed into *Elk Wallows* (EW) through intensive elk activity. A final class that is not mappable by remote sensing is *Fenced* (*FD*) vegetation. In the model, all three succession classes can be fenced, and become fenced exotic forbs if invaded by such species. Fenced succession classes are not considered uncharacteristic, whereas the fenced exotic forb class is uncharacteristic. Another subtlety of the riparian systems was the allocation of the first two years of the early-succession class to point bar dynamics and establishment of cottonwood and willow seedlings.

Aspen/spruce-fir, aspen-mixed conifer, and aspen woodland were ecological systems with unique uncharacteristic vegetation classes that led to the loss of clones. Aspen woodland clones that were dominated by old trees and moderately to widely open canopies with minimal aspen recruitment were considered depleted stands, often called decadent aspen (*Depleted = DP*).

Excessive herbivory from past and current uses coupled with lack of fire were generally the causes of depletion of aspen clones. If intense herbivory and lack of disturbance continued, aspen cloned died and became montane sagebrush steppe (transition to another model). The pathway of clone loss for aspen with conifers (subalpine or mixed) was very different. With lack of fire or other disturbances that removed conifers, or persistent excessive herbivory that killed resprouts, aspen became dominated by spruce and subalpine fir in the subalpine version or by various mixed conifers (Douglas-fir, white fir, and subalpine fir) in the montane zone. Continued dominance by conifers eventually resulted with death of the clone and a permanent establishment of either a spruce-fir or mixed conifer forest, respectively composed of four or five succession classes.

Four conifer forest systems were modeled: limber-bristlecone pines (dry type with potentially ancient trees) spruce-fir (Engelmann spruce and subalpine fir), mixed conifer (Douglas-fir, white fir, and subalpine fir), and ponderosa pine. Only mixed conifer and ponderosa pine have uncharacteristic classes, which are the same. Both mixed conifer and ponderosa pine are five-box models with one early succession phase and parallel closed (main pathway for mixed conifer) and open(main pathway for ponderosa pine) mid- and late-succession phases. These two forest types can support two additional uncharacteristic classes after invasion by cheatgrass: tree-annual grass and annual-grassland that we discussed earlier. Spruce-fir is composed of four boxes; the early-, mid-, and late-succession closed classes form the main linear pathway, with a mid-succession open class resulting from stand thinning. The limber-bristlecone pine model is linear, slow growing three-box model. The late-succession class can be ancient.

Another ancient system was blackbrush, found in small areas. Although its uncharacteristic classes (*Annual-Grassland*, *Shrub-Annual-Grass*, and *Tree-Annual-Grass*) were described above for shrublands, we used three reference classes, as opposed to LANDFIRE's two-box model, to represent mesic blackbrush. Mesic blackbrush supports pinyon and juniper in the late-succession class. The first two classes corresponded to the generic LANDFIRE version better representing thermic blackbrush at lower elevations.

Natural Disturbances

In all models, any disturbance was quantified by a rate expressed as a probability per year. This rate is the inverse of the return interval of a disturbance or a frequency of spatial events. For example, a mean fire return interval of 100 years is equal to a rate of 0.01/year (0.01 = 1/100). The probability/year rate is used in VDDT because it has the very convenient property of being additive, whereas return intervals are not additive. This rate was further multiplied by a proportion that partitioned the main rate in terms of success and failure outcomes, allocation of resources to realize different management objectives, or extent of application (for example, 5% of the ecological system was grazed at a rate of 1.0/year – livestock grazed every year, thus the return interval is 1 year). The rate that was ultimately used was the probability/year multiplied by proportions of allocation. Any rate, which is generally based on return intervals, is converted to a spatial draw per year as a necessary time for space substitution. Although VDDT is a non-spatial simulation software, the underlying process imitates temporal rates with virtual pixel draws. To pursue the fire return interval example, a probability/year of 0.01 means that 1 out of every 100 pixels on average receives fire within a year. Temporal multipliers described in the main text can be used to modify how many pixels are selected per year.

Fire was the primary stochastic disturbance in all vegetation types, except in limber-bristlecone pine, montane-subalpine riparian, and mixed salt desert scrub (Young and Sparks 2002). The duration of mean fire return intervals generally decreased with soil productivity or moisture (Table A3-1). The mean fire return intervals represented natural fire regimes without external influences from temporal multipliers. Replacement fire restarted the succession clock to age zero within the reference condition, which was labeled the *early development* or *BPS-A* class (a phase of the reference condition). The *early development* class represented a native condition of shrubland with a dominant cover of usually herbaceous species dominated by perennial cool-season bunch grasses and few shrubs. Replacement fire in vegetation classes that already experienced a threshold transition also caused a threshold transition to less desirable vegetation classes, such as *annual grassland*, *early shrub*, *montane sagebrush steppe (for aspen woodland), or exotic forb* (Tausch *et al*., 1993; Frelich and Reich, 1998; Tausch and Nowak, 1999; Anderson and Inouye, 2001). Mixed severity fire was a combination of canopy thinning fire (for example, from closed to opened canopy) and surface fire. Surface fire caused no transition, although it prevented in growth of fire-sensitive woody species. Both mixed severity and surface fire were only prevalent in forested systems.

Table A3-1. Mean fire return intervals of ecological systems.

Ecological System	Mean Fire Return Interval (years)[1]
Aspen-Mixed Conifer	53
Aspen/Spruce-Fir	75
Aspen Woodland	110
Blackbrush	770
Black-Low Sagebrush	165
Chaparral	50
Curlleaf Mountain Mahogany	113
Grass-Forb Meadow	160
Limber-Bristlecone Pine	344
Mixed Conifer	102
Mixed Salt Desert Scrub	>1,000
Montane Sagebrush Steppe	50
Montane-Subalpine Riparian	72
Mountain Shrub	30
Pinyon-Juniper Woodland	285
Ponderosa Pine	23
Spruce-Fir	181
Wyoming Big Sagebrush-upland	115

1. The inverse of mean fire return interval is the probability/year used in VDDT models. The mean Fire Return Interval was obtained by simulating the reference condition for 200 years and 5 replicates, and verifying that class percentages had stabilized. Simulations conducted without temporal multipliers. Different values would be obtained with temporal multipliers.

Another widespread natural disturbances in almost all models was *drought* or *insect/disease outbreaks* that cause stand replacing events (generally 10% of times) or stand thinning (90% of times). These two disturbances were generally different sides of the same coin: in most cases *drought* created tree and shrub mortality under the assumption that prolonged and decreased soil moisture weakened plants that might ultimately be killed by insects or disease. Therefore, we did not double-count mortality. In the case of aspen and mixed conifer, *insect/disease outbreak* was used because it played a distinctive role that was more prominent than *drought* for natural resource managers. A *drought* and *insect/disease outbreak* return interval rate of every 178 years (a rate of 0.0056/year) was used based on the frequency of severe drought intervals estimated by Biondi *et al*. (2007) from 2,300 years of western juniper (*Juniperus occidentalis)* tree ring data from the Walker River drainage of eastern California and western Nevada. Although we recognized that droughts may be more common than every 178 years, severe droughts, which were >7-year drought events with consecutive far-below average soil moisture (narrow tree rings), killed naturally drought resistant shrubs and trees. For vegetation classes in the reference condition, drought or insect/disease outbreak induced mortality either caused a transition to the early-development class, or a transition to the previous succession class or a reversal of woody succession within the same vegetation class.

Livestock grazing (*cattle-grazing* and *sheep-grazing*) was also widespread and implicitly modeled in all ecological systems, but not limber-bristlecone pine, spruce-fir, mixed conifer, pinyon-juniper, or chaparral. Workshop participants hypothesized that livestock grazing in the project area was based on best management practices and did not cause transitions between phases or states. But it was assumed that cattle and sheep grazing could reverse or accelerate woody succession depending on the age of the vegetation class and ecological system. Generally, livestock grazing will reverse woody succession in early succession but accelerate it in middle and late-succession classes. The rates of *cattle-grazing* and *sheep-grazing* were fixed through the area limit option as though they were treatments. Grazing rates were obtained from Chad Horman, the USFS range specialist for the Fishlake and Dixie National Forests, as grazable acres between • and 1 mile from a water source on slopes less than 10% (Table A3-2). (Livestock grazing at >1 mile from water was considered very light.) For ecological systems other than aspen, grazable acres were divided by 20 to correct for the 20 years of the simulation in a non-spatial setting (grazable acres always apply to the same geographic areas, but VDDT cannot account for spatial effects). Grazing in aspen systems was different because we used a time-since-disturbance function that forces the same pixels to be grazed in consecutive years; therefore, no correction was needed.

Livestock grazing was also expressed in two other forms: *excessive-herbivory* and *grazing-systems*. Whereas we hypothesized minimal effects of *cattle-grazing* and *sheep-grazing*, *excessive herbivory* was a special case with stronger effects between 0 and • mile from a water source. *Excessive-herbivory* represented the case where livestock grazing was concentrated and prolonged enough to cause either a transition to less desirable vegetation classes (for example, *Early Shrub* or loss of aspen clones) or very accelerated woody succession within a phase of the reference condition. Cattle and sheep primarily grazed herbaceous vegetation during the spring and summer; therefore they generally increased the cover of woody vegetation, which was equivalent to accelerating succession (West and Yorks, 2002; Beever, *et al*. 2003). Winter grazing by sheep in shrublands can reverse woody succession. Grazing rates were similarly

Table A3-2. Grazable acres of the Powell Ranger District and each ecological system. The distance of 0 to • mi from a water source represented the area of the *excessive-herbivory* parameter, whereas the area for the *cattle-grazing* or *sheep-grazing* rates were contained between • to 1 mi from water. Elk grazable acreage was assumed equal to that of *cattle-grazing*.

Ecological System[1,2]	Total area	Cattle • – 1 mi from water source	Sheep • – 1 mi from water source	Cattle 0 – • mi from water source	Sheep 0 – • mi from water source	Elk
Whole Ranger District	295,671	206,270	49,749	24,372	4,241	
Ponderosa Pine	102,760	37,245	5,780	3,502	292	37,245
Aspen/Spruce-Fir	43,003	15,586	2,419	1,465	122	15,586
Aspen/Mixed Conifer	41,310	14,973	2,324	1,408	117	14,973
Black/Low Sagebrush	30,420	11,026	1,711	1,037	86	11,026
Wyoming/Basin Big Sagebrush	21,142	7,663	1,189	720	60	7,663
Montane Sagebrush Steppe	16,633	6,029	936	567	47	6,029
Curlleaf Mountain Mahogany	13,747	4,982	773	468	39	4,982
Montane-Subalpine Riparian	12,449	4,512	700	424	35	4,512
Gambel Oak/Mixed Mtn Brush	10,044	3,640	565	342	29	3,640
Stable Aspen	4,103	1,487	231	140	12	1,487
Subalpine Meadow	60	22	3	2	0	22

1. Grazing rates were used unmodified in the simulation for all aspen systems.
2. Grazing rates for non-aspen systems were divided by 20.

derived from USFS grazable acres between 0 and • mile from water (Table A3-2). *Grazing-systems* (also called *cowboying*) was expressed in the model as a management action (associated to a budget) by which livestock operators actively move livestock away from wet or sensitive ecological systems to reduce their use. When grazing systems are used, especially in aspen systems, "normal" *cattle- grazing* and *sheep-grazing*, and *excessive-herbivory* of a virtual pixel are turned off, respectively, if and only if it grazing systems is not used for one year and three years.

Three other forms of herbivory included:

- *Native herbivory* where browsing by rodents and rabbits of mountain mahogany seedlings maintained the early development class (Arno and Wilson, 1986; Schultz *et al*., 1996; Ross, 1999);
- *Beaver-herbivory*, applied to montane-subalpine riparian, was considered a native disturbance that was more prevalent earlier in the history of Utah. *Beaver-herbivory* functioned as a rotating disturbance where beaver felled woody vegetation, left the creek reach, and only returned after substantial regrowth of aspen and willow had occurred, usually after 20-25 years. We assumed that the effect of beaver decreased from early- to later-development vegetation classes (as little as 1/1,000 if the late-development class); and
- *Wild Ungulate Grazing* that includes elk (primarily) and deer foraging of greater impact to aspen systems, Gambel oak/mountain shrub, and riparian corridors. For this project, we did not have estimates of elk herd size or foraging rates that would compare to livestock grazing

rates. Workshop participants agreed to set a fixed area limit for elk equal to the cattle grazing rate. It was obvious that more research is needed to firm up this key rate for future efforts.

Other widespread natural disturbances with pivotal roles in simulations were *tree-invasion* (i.e., pinyon-juniper encroachment) and *annual grass-invasion*. Pinyon and juniper encroachment of shrublands was a time-dependent process because seedlings required mature shrubs (we used between 40-100 years of succession), such as sagebrush and bitterbrush, for nurse plants. A standard rate of pinyon-juniper encroachment was 0.01/year (1 of 100 pixels per year) often starting in the late-development or uncharacteristic shrub-dominated vegetation classes of shrublands. We chose this rate because it approximately replicated encroachment levels proceeding in three phases of 50-year each discussed by Miller and Tausch (2001).

Cheatgrass invasion affected all shrublands, pinyon-juniper and mountain mahogany woodlands, and, to a lesser extent, mixed conifer and ponderosa pine forests. Invasion started in the early-development classes and rates varied among ecological systems and sometimes among vegetation classes. A low rate was 0.001/year (1 out of 1,000 pixels converted to a cheatgrass-invaded class per year) for mixed conifer, ponderosa pine, and pinyon-juniper and mountain mahogany woodlands. This base rate of 0.001/year was estimated from data of northwest Utah collected by the Utah Division of Wildlife Resources in black sagebrush semi-desert. Black sagebrush semi-desert is usually considered more resistant to cheatgrass invasion than Wyoming big sagebrush semi-desert. Because the BLM or USFS did not have similar data, we defaulted to the Utah data. Rates were five times higher, although still low for upland black sagebrush (higher precipitation zone than semi-desert), upland Wyoming big sagebrush, montane sagebrush steppe, and mixed salt desert scrub. The higher rates for these latter systems indicate greater susceptibility to cheatgrass because soils were more productive or, in the case of mixed salt desert scrub, were known to be susceptible. Blackbrush also experienced the rate of 0.005/year; however, red brome (*Bromus rubens*) and cheatgrass were invaders.

Sagebrush systems are not usually known to be invaded by exotic forbs, but workshop participants confirmed that black and Wyoming big sagebrush, and montane sagebrush steppe of the Dixie National Forest are increasingly invaded by thistles. Occurrences are not widespread; therefore the *Exotic-Forbs* disturbance rate was set very low at 0.001/year. Invasion occurred in many classes, except in the first two succession classes.

An important disturbance in montane-subalpine riparian was the invasion by exotic forbs (*exotic-invasion*) represented mainly by tall whitetop, knapweeds (*Centaurea* spp.), and thistles. Workshop participants agreed to a moderately high rate (0.01/year) as planning for a worst case scenario, although they did not feel that this was reflective of the current situation. Roadways, off-highway vehicles, and animals are usually the greatest vectors of exotic forbs.

Flooding was a disturbance restricted to montane-subalpine riparian. Three levels of *flooding* were 7-yr events (0.13/year) that killed or removed only herbaceous vegetation, 20-year events (0.05/year) that killed or removed shrubs and young trees, and 100-year events (0.01/year) that top-killed larger trees. Most flood events were stand replacing, but 20-year events in the late-development class thinned shrub and young trees without affected older trees. We also introduced a *low-flow-kill* disturbance that represented low flows from August and September that caused mortality of cottonwood and willow seedlings during the first two years of succession (we also introduced a *cottonwood-willow recruitment* disturbance also used in these years). The lower the late summer flows, the greater the mortality of seedlings.

<u>*Management Disturbances*</u>

Management activities included various mechanical treatments, prescribed burning, seeding, floodplain restoration, weed inventory, fencing, and herbicide (Appendix 5). Models contained more management activities than were actually employed in final simulations because we wanted to explore possibilities with workshop participants. The rate of application of each management action was set by the area limit function of VDDT that was reflective of management budgets and minimum treatments required to achieve objectives. Because area limits overrule rates, we generally used a default rate of 0.01 for all actions – we could have chosen another arbitrary rate; however, the proportional allocation of the area limit to different outcomes of the same management action was controlled by VDDT entries. Some outcomes represented failure rates for an action, such as when seeding failed and was replaced by cheatgrass. As a rule of thumb, management actions not followed by seeding were applied to reference states where the native perennial understory vegetation was present and was assumed to be releasable. In a few cases, canopy thinning actions were followed by native species seeding in black and Wyoming big sagebrush reference classes to purposefully increase plant diversity.

Most management actions applied to uncharacteristic states required seeding of native or, occasionally, introduced (crested wheatgrass) species because these states lost their native understory, and/or the understory was dominated by non-native exotic species. Herbicide Plateau® was also sprayed to control cheatgrass in addition to seeding. Chainsaw lopping or mastication of young pinyon and juniper trees was an exception as it did not require seeding and it was applied to both uncharacteristic and reference vegetation classes for the purpose of maintaining the openness of Greater sage-grouse habitat.

Controlled burning was a management option in many ecological systems, although its actual use was more limited, including lower elevation black sagebrush and Wyoming big sagebrush to convert late-development into early-development vegetation. We decided that an average of 30% of the burn perimeter contained unburned areas. Cost per unit area increased with smaller burns. Aerial ignition were used for roadless areas.

Fencing was used in montane-subalpine riparian and the early-succession aspen classes. The sole purpose of fencing was to make an area inaccessible to livestock grazing and elk browse for a temporary period of up to 9 years while palatable vegetation grew. In riparian systems, all reference classes could be fenced for protection from livestock and elk foraging. Moreover, alternative water delivery systems would be supplied if fencing resulted in livestock losing access to drinking water.

Weed inventory, *exotic-invasion*, and *weed control* were coupled and complex control activities for *exotic forbs* in montane-subalpine riparian. The most worrisome potential weeds were tall whitetop and thistles; while tall whitetop remains nearly undetected in the project area, different thistle species are present and occurrences are increasing. The starting point for weed management was a visit to all creeks of the project area on a rotational basis. Initially, a rotation period of 25 years (500 acres per year for about 12,500 acres) was proposed between visits based on current efforts. If a pixel was not selected for *weed inventory* for a period of five consecutive years, *exotic invasion* occurred at a rate 0.01/year. This meant that a full pixel equivalent to a 30-meter LandSat pixel was converted to *exotic forbs* (weeds are present although they may not initially dominate the pixel). *Exotic control*, which was achieved with registered herbicides, was applied to the *exotic forb* class to create early-, mid-, and late- development vegetation in equal amount; however, we assumed that herbicide treatments failed 40% of times and vegetation remained in *exotic forb*. If a pixel of *exotic forbs* remained untreated for 20 consecutive years, we assumed that it permanently escaped control methods and stayed *exotic forbs*.

The more peculiar and free management action applied to riparian system was to encourage the relocation of beaver by the Utah Division of Wildlife Resources to the Ranger District. Current beaver populations are low; however the Native American name for the southern portion of the District translates to Land of the Beaver. Beaver dams would elevate the water table, especially in entrenched reaches, increase water retention, and shift woody species to younger age classes. This action was accomplished by increasing the seldom used Transition Multiplier function of VDDT.

The largest class of restoration methods was thinning of vegetation, sometimes followed by herbicide application and/or seeding when applied in uncharacteristic vegetation classes. Thinning can be accomplished with several mechanical devices, prescribed fire, and herbicide. This group encompassed a long list of single or composite actions:

1. In forested systems and aspen, we used *Regeneration-Harvest*, *Partial-Harvest*, *Salvage (harvest)*, *Fecon + RxFire*, *Conifer-Removal*, and *Mechanical-Thinning*. *Conifer-Removal* and *Mechanical-Thinning* are specific to aspen management and result in transitions to either early succession or classes without conifer cover. *Mechanical-Thinning* was only used in late-succession aspen woodland (i.e., stable aspen). Other actions were deployed as standard forestry practices in spruce-fir, mixed conifer, and ponderosa pine. *Regeneration-harvest* was the removal of all trees and return to the early succession class. *Partial-harvest* could be accomplished in closed and open stands, but generally was used to open closed stands. *Partial-harvest* and canopy thinning are synonymous. *Salvage* was harvest of dead and mature standing trees. Many of these methods could generate revenues, although a large fraction of these never returned to the local Ranger District. The action *Fecon + RxFire* was used in ponderosa pine only to clear more fire sensitive conifers, such a subalpine fir and Douglas-fir, from closed classes and then burn the slash. The combined action removed conifer seedlings, saplings, and trees, and resulted in an open canopy. No revenue was generated.

2. In shrublands, included were *Chaining*, *Mechanical-Thinning (Dixie harrow) + Seed*, *Mechanical-Thinning (Dixie harrow) + NoSeed*, *Masticate-Trees*, *Mechanical-Saw*, *Chainsaw-Thinning*, *Herbicide-Spyke*, *Tree-Thin + Seed*, *RxFire + Seed*, *Tree-Thin + Herbicide + Seed*, *RxFire + Herbicide (Spyke) + Seed*, *Mow + Seed*, *Mow + Herbicide + Seed*, *Herbicide (Spyke) + Seed*, and *Herbicide-Plateau*. Actions that did not include herbicides or seed, with the exception of *Mechanical-Thinning (Dixie harrow) + Seed*, were only used in reference classes to create mostly mid-succession classes and, to a lesser degree, early-succession classes. When herbicide is added to the main thinning action, it was to control cheatgrass as woody cover was reduced; therefore, it was used in *Shrub-Annual-*

*Grass, Shrub-Annual-Perennial-Gras*s, *Tree-Annual-Grass*. If herbicide was not specified, vegetation classes were *depleted* and *tree-encroached* shrublands. Seed was also added to these actions because uncharacteristic classes required seeding. In the case of depleted shrublands, the herbicide Spyke® was used to thin sagebrush followed by seeding. When trees were present, the preferred method for their removal was mastication with a Fecon® device mounted on small tractors. Sometimes, chaining and prescribed fire were also used. The use of mastication alone was used in all late-succession classes, whereas herbicide and seed were supplemented in the uncharacteristic classes *tree-annual-grass* and *tree-encroached.* Chaining and prescribed fire were used in a similar fashion. The herbicide Plateau® was used in two cases. One was to control cheatgrass in shrub-annual-perennial-grass, thus causing a return to the mid- and late-succession reference classes. The second was the application of the herbicide followed by seed applied in *annual-grasslands*.

3. In riparian systems, only *Mechanical-Thinning* and *RxFire + Herbicide* were used for thinning. *Mechanical-thinning* was used to remove pinyon and juniper that encroached incised river banks or the upslope edges of the late-succession class. *RxFire + Herbicide* only applied to the reduction of the vegetation class dominated by shrubs and forbs unpalatable to livestock (*Shrub-Forb-Encroached*). Without herbicide, most unpalatable species will vigorously resprout.

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
Aspen/Spruce-Fir												
Avalanches	ASC-A	CL	ASC-A	CL	0	9	0	9999	0.13	0.05	-999	FALSE
Cattle-Grazing	ASC-A	CL	ASC-A	CL	2	9	1	9999	1	0.16	-1	FALSE
Excessive-Herbivory-Cattle	ASC-A	CL	SF-A	AL	2	9	3	9999	0.001	1	0	FALSE
Excessive-Herbivory-Sheep	ASC-A	CL	SF-A	AL	2	9	3	9999	0.001	1	0	FALSE
Fence.asc	ASC-A	CL	ASC-A	FD	0	9	0	9999	0.01	1	0	TRUE
Grazing-Systems.asc	ASC-A	CL	ASC-A	CL	0	9	0	9999	1	0.25	0	FALSE
Sheep-Grazing	ASC-A	CL	ASC-A	CL	2	9	1	9999	1	0.08	-2	FALSE
Wild-Ungulate-Grazing	ASC-A	CL	ASC-A	CL	0	9	0	9999	0.03	0.8	-999	FALSE
Wild-Ungulate-Grazing	ASC-A	CL	SF-A	AL	0	9	0	9999	0.03	0.2	0	FALSE
Avalanches	ASC-A	FD	ASC-A	CL	0	9	0	9999	0.13	0.05	0	FALSE
Avalanches	ASC-B	CL	ASC-A	CL	10	39	0	9999	0.13	0.05	0	FALSE
Cattle-Grazing	ASC-B	CL	ASC-B	CL	10	39	1	9999	1	0.16	1	FALSE
Excessive-Herbivory-Cattle	ASC-B	CL	ASC-B	CL	10	39	5	9999	0.001	1	5	FALSE
Excessive-Herbivory-Sheep	ASC-B	CL	ASC-B	CL	10	39	5	9999	0.001	1	5	FALSE
Grazing-Systems.asc	ASC-B	CL	ASC-B	CL	10	39	0	9999	1	0.25	0	FALSE
MixedFire	ASC-B	CL	ASC-B	CL	10	39	0	9999	0.001	1	-999	FALSE
ReplacementFire	ASC-B	CL	ASC-A	CL	10	39	0	9999	0.0167	1	0	FALSE
RxFire.asc	ASC-B	CL	ASC-A	CL	10	39	0	9999	0.01	0.7	0	FALSE
RxFire.asc	ASC-B	CL	ASC-B	CL	10	39	0	9999	0.01	0.3	0	FALSE
Sheep-Grazing	ASC-B	CL	ASC-B	CL	10	39	1	9999	1	0.08	1	FALSE
Wild-Ungulate-Grazing	ASC-B	CL	ASC-B	CL	10	39	0	9999	1	0.01	1	FALSE
Avalanches	ASC-C	OP	ASC-A	CL	40	169	0	9999	0.13	0.05	0	FALSE
Conifer-Removal.asc	ASC-C	OP	ASC-C	OP	40	169	0	9999	0.01	1	-999	FALSE
Insect/Disease	ASC-C	OP	ASC-B	CL	40	169	0	9999	0.0055	0.8	0	FALSE
Insect/Disease	ASC-C	OP	ASC-A	CL	40	169	0	9999	0.006	0.2	0	FALSE
ReplacementFire	ASC-C	OP	ASC-A	CL	40	169	0	9999	0.016	1	0	FALSE
RxFire.asc	ASC-C	OP	ASC-A	CL	40	169	0	9999	0.01	0.7	0	FALSE

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Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
RxFire.asc	ASC-C	OP	ASC-C	OP	40	169	0	9999	0.01	0.3	0	FALSE
Wild-Ungulate-Grazing	ASC-C	OP	ASC-C	OP	40	169	0	9999	1	0.01	2	FALSE
Avalanches	ASC-D	CL	ASC-A	CL	170	300	0	9999	0.13	0.05	0	FALSE
Conifer-Removal.asc	ASC-D	CL	ASC-C	OP	170	300	0	9999	0.01	1	0	FALSE
Insect/Disease	ASC-D	CL	ASC-C	OP	170	300	0	9999	0.0056	0.8	0	FALSE
Insect/Disease	ASC-D	CL	ASC-A	CL	170	300	0	9999	0.0055	0.2	0	FALSE
LosingClone	ASC-D	CL	SF-D	CL	250	300	0	9999	0.02	1	0	FALSE
Partial-Harvest.asc	ASC-D	CL	ASC-B	CL	170	300	0	9999	0.01	1	0	FALSE
Regen-Harvest.asc	ASC-D	CL	ASC-A	CL	170	300	0	9999	0.01	1	0	FALSE
ReplacementFire	ASC-D	CL	ASC-A	CL	170	300	0	9999	0.0067	1	0	FALSE
RxFire.asc	ASC-D	CL	ASC-A	CL	170	300	0	9999	0.01	0.8	0	FALSE
RxFire.asc	ASC-D	CL	ASC-D	CL	170	300	0	9999	0.01	0.2	0	FALSE
Wild-Ungulate-Grazing	ASC-D	CL	ASC-D	CL	170	300	0	9999	1	0.2	0	FALSE
Wild-Ungulate-Grazing	ASC-D	CL	ASC-D	CL	170	300	0	9999	1	0.01	3	FALSE
Aspen-Mixed Conifer												
Avalanches	ASM-A	AL	ASM-A	AL	0	9	0	9999	0.13	0.05	-999	FALSE
Cattle-Grazing	ASM-A	AL	ASM-A	AL	3	9	1	9999	1	0.16	-1	FALSE
Excessive-Herbivory-Cattle	ASM-A	AL	MC-A	AL	3	9	3	9999	0.001	1	5	TRUE
Excessive-Herbivory-Sheep	ASM-A	AL	MC-A	AL	3	9	3	9999	0.001	1	5	TRUE
Fence.asm	ASM-A	AL	ASM-A	FD	0	9	0	9999	0.01	1	0	TRUE
Grazing-Systems.asm	ASM-A	AL	ASM-A	AL	0	9	0	9999	1	0.25	0	FALSE
Sheep-Grazing	ASM-A	AL	ASM-A	AL	3	9	1	9999	1	0.08	-2	FALSE
Wild-Ungulate-Grazing	ASM-A	AL	MC-A	AL	0	9	0	9999	0.03	0.2	0	FALSE
Wild-Ungulate-Grazing	ASM-A	AL	ASM-A	AL	0	9	0	9999	0.03	0.8	-999	FALSE
Avalanches	ASM-A	FD	ASM-A	AL	0	9	0	9999	0.001	1	0	FALSE
Avalanches	ASM-B	CL	ASM-A	AL	10	39	0	9999	0.13	0.05	0	FALSE
Cattle-Grazing	ASM-B	CL	ASM-B	CL	10	39	1	9999	1	0.16	1	FALSE
Excessive-Herbivory-Cattle	ASM-B	CL	ASM-B	CL	10	39	5	9999	0.001	1	5	FALSE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
Excessive-Herbivory-Sheep	ASM-B	CL	ASM-B	CL	10	39	5	9999	0.001	1	5	FALSE
Grazing-Systems.asm	ASM-B	CL	ASM-B	CL	10	39	0	9999	1	0.25	0	FALSE
ReplacementFire	ASM-B	CL	ASM-A	AL	10	39	0	9999	0.025	1	0	FALSE
Sheep-Grazing	ASM-B	CL	ASM-B	CL	10	39	1	9999	1	0.08	1	FALSE
Wild-Ungulate-Grazing	ASM-B	CL	ASM-B	CL	10	39	0	9999	0.01	1	1	FALSE
Avalanches	ASM-C	CL	ASM-A	AL	40	79	0	9999	0.13	0.05	0	FALSE
Insect/Disease	ASM-C	CL	ASM-B	CL	40	79	0	9999	0.005	0.8	0	FALSE
Insect/Disease	ASM-C	CL	ASM-A	AL	40	79	0	9999	0.005	0.2	0	FALSE
MixedFire	ASM-C	CL	ASM-C	CL	40	79	0	9999	0.0067	1	-999	FALSE
Regen-Harvest.asm	ASM-C	CL	ASM-A	AL	40	79	0	9999	0.01	1	0	FALSE
ReplacementFire	ASM-C	CL	ASM-A	AL	40	79	0	9999	0.0167	1	0	FALSE
RxFire.asm	ASM-C	CL	ASM-A	AL	40	79	0	9999	0.01	0.7	0	FALSE
RxFire.asm	ASM-C	CL	ASM-C	CL	40	79	0	9999	0.01	0.3	0	FALSE
Wild-Ungulate-Grazing	ASM-C	CL	ASM-C	CL	40	79	0	9999	0.01	1	1	FALSE
AltSuccession	ASM-D	OP	ASM-E	CL	80	1079	100	9999	1	1	0	FALSE
Avalanches	ASM-D	OP	ASM-A	AL	80	1079	0	9999	0.13	0.05	0	FALSE
Conifer-Removal.asm	ASM-D	OP	ASM-C	CL	80	1079	0	9999	0.01	0.5	0	FALSE
Conifer-Removal.asm	ASM-D	OP	ASM-B	CL	80	1079	0	9999	0.01	0.5	0	FALSE
MixedFire	ASM-D	OP	ASM-C	CL	80	1079	0	9999	0.077	1	-999	FALSE
Partial-Harvest.asm	ASM-D	OP	ASM-C	CL	80	1079	0	9999	0.01	0.5	0	FALSE
Partial-Harvest.asm	ASM-D	OP	ASM-B	CL	80	1079	0	9999	0.01	0.5	0	FALSE
Regen-Harvest.asm	ASM-D	OP	ASM-A	AL	80	1079	0	9999	0.01	1	0	FALSE
ReplacementFire	ASM-D	OP	ASM-A	AL	80	1079	0	9999	0.0167	1	0	FALSE
RxFire.asm	ASM-D	OP	ASM-A	AL	80	1079	0	9999	0.01	0.7	0	FALSE
RxFire.asm	ASM-D	OP	ASM-D	OP	80	1079	0	9999	0.01	0.3	0	FALSE
Wild-Ungulate-Grazing	ASM-D	OP	ASM-D	OP	80	1079	0	9999	0.01	1	1	FALSE
Avalanches	ASM-E	CL	ASM-A	AL	100	300	0	9999	0.13	0.05	0	FALSE
Conifer-Removal.asm	ASM-E	CL	ASM-C	CL	100	300	0	9999	0.01	0.5	0	FALSE

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Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
Conifer-Removal.asm	ASM-E	CL	ASM-B	CL	100	300	0	9999	0.01	0.5	0	FALSE
Insect/Disease	ASM-E	CL	ASM-D	OP	100	300	0	9999	0.0056	1	0	FALSE
LosingClone	ASM-E	CL	MC-E	CL	250	300	0	9999	0.02	1	0	FALSE
MixedFire	ASM-E	CL	ASM-D	OP	100	300	0	9999	0.077	0.1	0	FALSE
Partial-Harvest.asm	ASM-E	CL	ASM-C	CL	100	300	0	9999	0.01	0.5	0	FALSE
Partial-Harvest.asm	ASM-E	CL	ASM-B	CL	100	300	0	9999	0.01	0.5	0	FALSE
Regen-Harvest.asm	ASM-E	CL	ASM-A	AL	100	300	0	9999	0.01	1	0	FALSE
ReplacementFire	ASM-E	CL	ASM-A	AL	100	300	0	9999	0.0167	0.9	0	FALSE
RxFire.asm	ASM-E	CL	ASM-A	AL	100	300	0	9999	0.01	1	0	FALSE
Wild-Ungulate-Grazing	ASM-E	CL	ASM-E	CL	100	300	0	9999	0.01	1	1	FALSE
Aspen Woodland												
Avalanches	ASP-A	CL	ASP-A	CL	0	9	0	9999	0.132	0.05	-999	FALSE
Cattle-Grazing	ASP-A	CL	ASP-A	CL	0	9	1	9999	1	0.16	1	FALSE
Excessive-Herbivory-Cattle	ASP-A	CL	MSu-A	AL	0	9	3	9999	0.001	1	5	TRUE
Excessive-Herbivory-Sheep	ASP-A	CL	MSu-A	AL	0	9	3	9999	0.001	1	0	TRUE
Grazing-Systems.asp	ASP-A	CL	ASP-A	CL	0	9	0	9999	1	0.25	1	FALSE
ReplacementFire	ASP-A	CL	ASP-A	CL	0	9	0	9999	0.0067	1	-999	FALSE
Sheep-Grazing	ASP-A	CL	ASP-A	CL	0	9	1	9999	1	0.08	-2	FALSE
Wild-Ungulate-Grazing	ASP-A	CL	ASP-A	CL	0	9	0	9999	0.002	0.8	-999	FALSE
Wild-Ungulate-Grazing	ASP-A	CL	MSu-A	AL	0	9	0	9999	0.002	0.2	0	FALSE
Avalanches	ASP-B	CL	ASP-A	CL	10	39	0	9999	0.13	0.05	0	FALSE
Cattle-Grazing	ASP-B	CL	ASP-B	CL	10	39	1	9999	1	0.16	1	FALSE
Excessive-Herbivory-Cattle	ASP-B	CL	ASP-B	CL	10	39	5	9999	0.001	1	5	FALSE
Excessive-Herbivory-Sheep	ASP-B	CL	ASP-B	CL	10	39	5	9999	0.001	1	5	FALSE
Grazing-Systems.asp	ASP-B	CL	ASP-B	CL	10	39	0	9999	1	0.25	0	FALSE
ReplacementFire	ASP-B	CL	ASP-A	CL	10	39	0	9999	0.0067	1	0	FALSE
Sheep-Grazing	ASP-B	CL	ASP-B	CL	10	39	1	9999	1	0.08	1	FALSE
Wild-Ungulate-Grazing	ASP-B	CL	ASP-B	CL	10	39	0	9999	0.002	1	0	FALSE

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Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
AltSuccession	ASP-C	CL	ASP-D	OP	40	300	100	9999	0.33	1	0	FALSE
Avalanches	ASP-C	CL	ASP-A	CL	40	300	0	9999	0.13	0.05	0	FALSE
Cattle-Grazing	ASP-C	CL	ASP-C	CL	40	300	1	9999	1	0.16	1	FALSE
Excessive-Herbivory-Cattle	ASP-C	CL	ASP-C	CL	40	300	5	9999	0.001	1	5	FALSE
Excessive-Herbivory-Sheep	ASP-C	CL	ASP-C	CL	40	300	5	9999	0.001	1	5	FALSE
Grazing-Systems.asp	ASP-C	CL	ASP-C	CL	40	300	0	9999	1	0.25	0	FALSE
Insect/Disease	ASP-C	CL	ASP-A	CL	40	300	0	9999	0.0055	0.2	0	FALSE
Insect/Disease	ASP-C	CL	ASP-C	CL	40	300	0	9999	0.0056	0.8	0	FALSE
Mechanical-Thinnng.asp	ASP-C	CL	ASP-A	CL	40	300	0	9999	0.01	1	0	FALSE
ReplacementFire	ASP-C	CL	ASP-A	CL	40	300	0	9999	0.0067	1	0	FALSE
RxFire.asp	ASP-C	CL	ASP-A	CL	40	300	0	9999	0.01	0.7	0	FALSE
RxFire.asp	ASP-C	CL	ASP-C	CL	40	300	0	9999	0.01	0.3	0	FALSE
Sheep-Grazing	ASP-C	CL	ASP-C	CL	40	300	1	9999	1	0.08	1	FALSE
SurfaceFire	ASP-C	CL	ASP-C	CL	40	300	0	9999	0.002	1	0	FALSE
Avalanches	ASP-D	OP	ASP-A	CL	100	300	0	9999	0.13	0.05	0	FALSE
Cattle-Grazing	ASP-D	OP	ASP-D	OP	100	300	1	9999	1	0.16	1	FALSE
Excessive-Herbivory-Cattle	ASP-D	OP	ASP-U	DP	100	300	5	9999	0.001	1	0	TRUE
Excessive-Herbivory-Sheep	ASP-D	OP	ASP-U	DP	100	300	5	9999	0.001	1	0	TRUE
Grazing-Systems.asp	ASP-D	OP	ASP-D	OP	100	300	0	9999	1	0.25	0	FALSE
Insect/Disease	ASP-D	OP	ASP-C	CL	100	300	0	9999	0.003	1	0	FALSE
LosingClone	ASP-D	OP	ASP-U	DP	150	300	0	9999	0.0067	1	0	TRUE
Mechanical-Thinnng.asp	ASP-D	OP	ASP-A	CL	100	300	0	9999	0.01	1	0	FALSE
MixedFire	ASP-D	OP	ASP-C	CL	100	300	0	9999	0.002	1	0	FALSE
ReplacementFire	ASP-D	OP	ASP-A	CL	100	300	0	9999	0.018	1	0	FALSE
RxFire.asp	ASP-D	OP	ASP-A	CL	100	300	0	9999	0.01	0.7	0	FALSE
RxFire.asp	ASP-D	OP	ASP-D	OP	100	300	0	9999	0.01	0.3	0	FALSE
Sheep-Grazing	ASP-D	OP	ASP-D	OP	100	300	1	9999	1	0.08	1	FALSE
Wild-Ungulate-Grazing	ASP-D	OP	ASP-D	OP	100	300	0	9999	0.002	1	3	FALSE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
Avalanches	ASP-U	DP	ASP-A	CL	100	500	0	9999	0.13	0.3	0	FALSE
Avalanches	ASP-U	DP	MSu-A	AL	100	500	0	9999	0.13	0.2	0	FALSE
Cattle-Grazing	ASP-U	DP	ASP-U	DP	100	500	1	9999	1	0.16	2	FALSE
Drought	ASP-U	DP	ASP-A	CL	100	300	0	9999	0.006	0.1	0	FALSE
Drought	ASP-U	DP	MSu-B	OP	100	300	0	9999	0.0056	0.45	0	FALSE
Drought	ASP-U	DP	MSu-C	CL	100	300	0	9999	0.0056	0.45	0	FALSE
Excessive-Herbivory-Cattle	ASP-U	DP	MSu-B	OP	100	500	5	9999	0.001	0.5	0	FALSE
Excessive-Herbivory-Cattle	ASP-U	DP	MSu-C	CL	100	500	5	9999	0.001	0.5	0	FALSE
Excessive-Herbivory-Sheep	ASP-U	DP	MSu-B	OP	100	500	5	9999	0.001	0.7	0	FALSE
Excessive-Herbivory-Sheep	ASP-U	DP	MSu-C	CL	100	500	5	9999	0.001	0.3	0	FALSE
Grazing-Systems.asp	ASP-U	DP	ASP-C	CL	100	500	0	9999	1	0.22	0	FALSE
Grazing-Systems.asp	ASP-U	DP	ASP-U	DP	100	500	0	9999	1	0.03	0	FALSE
Insect/Disease	ASP-U	DP	ASP-A	CL	100	300	0	9999	0.003	0.7	0	FALSE
Insect/Disease	ASP-U	DP	MSu-B	OP	100	300	0	9999	0.0033	0.15	0	FALSE
Insect/Disease	ASP-U	DP	MSu-C	CL	100	300	0	9999	0.0033	0.15	0	FALSE
LosingClone	ASP-U	DP	MSu-A	AL	200	300	0	9999	0.01	1	0	FALSE
Mechanical-Thinnng.asp	ASP-U	DP	ASP-A	CL	100	500	0	9999	0.01	0.7	0	FALSE
Mechanical-Thinnng.asp	ASP-U	DP	MSu-A	AL	100	500	0	9999	0.01	0.3	0	FALSE
ReplacementFire	ASP-U	DP	ASP-A	CL	100	300	0	9999	0.02	0.7	0	FALSE
ReplacementFire	ASP-U	DP	MSu-A	AL	100	300	0	9999	0.02	0.3	0	FALSE
RxFire.asp	ASP-U	DP	ASP-A	CL	100	500	0	9999	0.01	0.7	0	FALSE
RxFire.asp	ASP-U	DP	MSu-A	AL	100	500	0	9999	0.01	0.3	0	FALSE
Sheep-Grazing	ASP-U	DP	ASP-U	DP	100	300	1	9999	1	0.08	3	FALSE
Wild-Ungulate-Grazing	ASP-U	DP	ASP-U	DP	100	300	0	9999	0.002	1	3	FALSE
Blackbrush												
AG-Invasion	BB-A	OP	BB-U	AG	0	19	0	9999	0.005	1	0	TRUE
AG-Invasion	BB-A	OP	BB-U	SA	20	200	0	9999	0.005	1	0	TRUE
Cattle-Grazing	BB-A	OP	BB-U	SA	0	200	0	9999	1	0.16	1	FALSE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
ReplacementFire	BB-A	OP	BB-A	OP	0	200	0	9999	0.0001	1	-999	FALSE
AG-Invasion	BB-B	CL	BB-U	SA	200	999	0	9999	0.005	1	0	TRUE
ReplacementFire	BB-B	CL	BB-A	OP	200	999	0	9999	0.0015	1	0	FALSE
Tree-Invasion	BB-B	CL	BB-C	OP	400	999	0	9999	0.005	1	0	FALSE
AG-Invasion	BB-C	OP	BB-U	TA	400	999	0	9999	0.005	1	0	TRUE
Drought	BB-C	OP	BB-C	OP	400	999	0	9999	0.0056	0.9	3	FALSE
Drought	BB-C	OP	BB-B	CL	400	999	0	9999	0.0057	0.07	0	FALSE
Drought	BB-C	OP	BB-A	OP	400	999	0	9999	0.0067	0.03	0	FALSE
Mechanical-Thinnng.bb	BB-C	OP	BB-A	OP	400	999	0	9999	0.01	1	0	FALSE
ReplacementFire	BB-C	OP	BB-A	OP	400	999	0	9999	0.002	1	0	FALSE
Tree-Encroachment	BB-C	OP	BB-U	TA	600	999	0	9999	0.005	1	0	TRUE
Herbicide+Seed.bb	BB-U	AG	BB-A	OP	0	3	0	9999	0.01	0.5	0	FALSE
Herbicide+Seed.bb	BB-U	AG	BB-U	AG	0	3	0	9999	0.01	0.5	0	FALSE
ReplacementFire	BB-U	AG	BB-U	AG	0	999	0	9999	0.1	1	-999	FALSE
Drought	BB-U	SA	BB-U	SA	20	999	0	9999	0.0056	0.95	-999	FALSE
Drought	BB-U	SA	BB-U	AG	20	999	0	9999	0.006	0.05	0	FALSE
Herbicide+Seed.bb	BB-U	SA	BB-B	CL	20	999	0	9999	0.01	0.5	0	FALSE
Herbicide+Seed.bb	BB-U	SA	BB-U	SA	20	999	0	9999	0.01	0.5	0	FALSE
ReplacementFire	BB-U	SA	BB-U	AG	20	999	0	9999	0.002	1	0	FALSE
Tree-Invasion	BB-U	SA	BB-U	TA	400	999	0	9999	0.005	1	0	FALSE
Drought	BB-U	TA	BB-U	TA	400	999	0	9999	0.0056	0.9	-999	FALSE
Drought	BB-U	TA	BB-U	AG	400	999	0	9999	0.006	0.1	0	FALSE
ReplacementFire	BB-U	TA	BB-A	OP	400	999	0	9999	0.002	0.5	0	FALSE
ReplacementFire	BB-U	TA	BB-U	AG	400	999	0	9999	0.002	0.5	0	FALSE
Tree-Thin+Hrbx+Seed.bb	BB-U	TA	BB-A	OP	400	999	0	9999	0.01	0.5	0	FALSE
Tree-Thin+Hrbx+Seed.bb	BB-U	TA	BB-U	AG	400	999	0	9999	0.01	0.5	0	FALSE
Black-Low Sagebrush												
AG-Invasion	BS-A	AL	BS-U	SAP	10	24	0	9999	0.001	1	0	TRUE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
AG-Invasion	BS-A	AL	BS-U	AG	0	9	0	9999	0.0001	1	0	FALSE
Cattle-Grazing	BS-A	AL	BS-A	AL	0	24	0	9999	1	0.16	1	FALSE
Drought	BS-A	AL	BS-A	AL	0	24	0	9999	0.0056	1	-1	FALSE
Excessive-Herbivory-Cattle	BS-A	AL	BS-U	ES	10	24	0	9999	0.001	1	0	FALSE
Excessive-Herbivory-Sheep	BS-A	AL	BS-U	ES	10	24	0	9999	0.001	1	0	FALSE
ReplacementFire	BS-A	AL	BS-A	AL	0	24	0	9999	0.004	1	-999	FALSE
Sheep-Grazing	BS-A	AL	BS-A	AL	0	24	0	9999	1	0.08	-1	FALSE
AG-Invasion	BS-B	OP	BS-U	SAP	25	119	0	9999	0.005	1	0	TRUE
Cattle-Grazing	BS-B	OP	BS-B	OP	25	119	0	9999	1	0.16	1	FALSE
Drought	BS-B	OP	BS-B	OP	25	119	0	9999	0.0056	0.5	-999	FALSE
Drought	BS-B	OP	BS-A	AL	25	119	0	9999	0.0056	0.5	0	FALSE
Excessive-Herbivory-Cattle	BS-B	OP	BS-U	ES	25	119	0	9999	0.001	1	0	FALSE
Excessive-Herbivory-Sheep	BS-B	OP	BS-U	ES	25	119	0	9999	0.001	1	0	FALSE
ReplacementFire	BS-B	OP	BS-A	AL	25	119	0	9999	0.0067	1	0	FALSE
Sheep-Grazing	BS-B	OP	BS-B	OP	25	119	0	9999	1	0.08	-1	FALSE
AG-Invasion	BS-C	OP	BS-U	SAP	120	300	0	9999	0.005	1	0	TRUE
Cattle-Grazing	BS-C	OP	BS-C	OP	120	300	0	9999	1	0.16	1	FALSE
Drought	BS-C	OP	BS-C	OP	120	300	0	9999	0.0056	0.75	-999	FALSE
Drought	BS-C	OP	BS-B	OP	120	300	0	9999	0.0056	0.25	0	FALSE
Excessive-Herbivory-Cattle	BS-C	OP	BS-U	DP	120	300	0	9999	0.001	1	0	FALSE
Excessive-Herbivory-Cattle	BS-C	OP	BS-U	DP	120	300	0	9999	0.001	1	0	FALSE
Exotic-Forb.bs	BS-C	OP	BS-U	EF	120	300	0	9999	0.001	1	0	TRUE
Herbicide-Spyke.bs	BS-C	OP	BS-B	OP	120	300	0	9999	0.01	1	0	FALSE
Masticate-Trees.bs	BS-C	OP	BS-C	OP	120	300	0	9999	0.01	1	-999	FALSE
Mechanical-Thinning.bs	BS-C	OP	BS-B	OP	120	300	0	9999	0.01	0.6	0	FALSE
Mechanical-Thinning.bs	BS-C	OP	BS-C	OP	120	300	0	9999	0.01	0.4	-999	FALSE
ReplacementFire	BS-C	OP	BS-A	AL	120	300	0	9999	0.0067	1	0	FALSE
RxFire.bs	BS-C	OP	BS-A	AL	120	300	0	9999	0.01	0.7	0	FALSE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
RxFire.bs	BS-C	OP	BS-C	OP	120	300	0	9999	0.01	0.3	0	FALSE
Sheep-Grazing	BS-C	OP	BS-C	OP	120	300	0	9999	1	0.08	1	FALSE
Tree-Invasion	BS-C	OP	BS-D	OP	120	149	0	9999	0.001	1	0	FALSE
Tree-Invasion	BS-C	OP	BS-D	OP	150	300	0	9999	0.005	1	0	FALSE
AG-Invasion	BS-D	OP	BS-U	TA	121	500	0	9999	0.005	1	0	TRUE
Drought	BS-D	OP	BS-D	OP	121	500	0	9999	0.0056	0.75	5	FALSE
Drought	BS-D	OP	BS-C	OP	121	500	0	9999	0.0056	0.25	0	FALSE
Masticate-Trees.bs	BS-D	OP	BS-C	OP	121	200	0	9999	0.01	1	0	FALSE
Mechanical-Thinning.bs	BS-D	OP	BS-A	AL	121	199	0	9999	0.01	0.2	0	FALSE
Mechanical-Thinning.bs	BS-D	OP	BS-B	OP	121	199	0	9999	0.01	0.6	0	FALSE
Mechanical-Thinning.bs	BS-D	OP	BS-C	OP	121	199	0	9999	0.01	0.2	0	FALSE
Mechanical-Thinning.bs	BS-D	OP	BS-B	OP	200	500	0	9999	0.01	0.9	0	FALSE
Mechanical-Thinning.bs	BS-D	OP	BS-A	AL	200	500	0	9999	0.01	0.1	0	FALSE
ReplacementFire	BS-D	OP	BS-A	AL	121	500	0	9999	0.0067	1	0	FALSE
RxFire.bs	BS-D	OP	BS-A	AL	121	500	0	9999	0.01	0.7	0	FALSE
RxFire.bs	BS-D	OP	BS-D	OP	121	500	0	9999	0.01	0.3	0	FALSE
Tree-Encroachment	BS-D	OP	BS-U	TE	170	219	0	9999	0.005	1	0	TRUE
Tree-Encroachment	BS-D	OP	BS-U	TE	220	269	0	9999	0.01	1	0	TRUE
Tree-Encroachment	BS-D	OP	BS-U	TE	270	300	0	9999	0.02	1	0	TRUE
Exotic-Forb.bs	BS-U	AG	BS-U	EF	0	300	0	9999	0.001	1	0	FALSE
Herbicide+Seed.bs	BS-U	AG	BS-U	SD	0	3	0	9999	0.01	0.5	0	FALSE
Herbicide+Seed.bs	BS-U	AG	BS-U	AG	0	3	0	9999	0.01	0.5	0	FALSE
ReplacementFire	BS-U	AG	BS-U	AG	0	300	0	9999	0.1	1	-999	FALSE
Drought	BS-U	DP	BS-U	DP	26	300	0	9999	0.0056	0.9	-999	FALSE
Drought	BS-U	DP	BS-U	ES	26	300	0	9999	0.006	0.1	0	FALSE
Exotic-Forb.bs	BS-U	DP	BS-U	EF	26	300	0	9999	0.001	1	0	TRUE
Herbicide+Seed.bs	BS-U	DP	BS-U	DP	26	300	0	9999	0.01	0.8	0	FALSE
Herbicide+Seed.bs	BS-U	DP	BS-B	OP	26	119	0	9999	0.01	0.2	0	TRUE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
Herbicide+Seed.bs	BS-U	DP	BS-C	OP	120	300	0	9999	0.01	0.2	0	TRUE
Masticate-Trees.bs	BS-U	DP	BS-U	DP	120	200	0	9999	0.01	1	-999	FALSE
Mow+Seed.bs	BS-U	DP	BS-U	DP	26	300	0	9999	0	0.5	0	FALSE
ReplacementFire	BS-U	DP	BS-U	ES	26	300	0	9999	0.0067	1	0	FALSE
RxFire+Seed.bs	BS-U	DP	BS-U	SD	26	300	0	9999	0.01	0.35	0	FALSE
RxFire+Seed.bs	BS-U	DP	BS-U	ES	26	300	0	9999	0.01	0.35	0	FALSE
RxFire+Seed.bs	BS-U	DP	BS-U	DP	26	300	0	9999	0.01	0.3	0	FALSE
Sheep-Grazing	BS-U	DP	BS-U	DP	26	300	0	9999	1	0.08	-1	FALSE
Tree-Invasion	BS-U	DP	BS-U	TE	120	300	0	9999	0.005	1	0	FALSE
Herbicide-Noxious-Weeds.ws	BS-U	EF	BS-A	AL	0	24	0	9999	0.01	1	0	TRUE
Herbicide-Noxious-Weeds.ws	BS-U	EF	BS-B	OP	25	119	0	9999	0.01	1	0	TRUE
Herbicide-Noxious-Weeds.ws	BS-U	EF	BS-C	OP	120	300	0	9999	0.01	1	0	TRUE
ReplacementFire	BS-U	EF	BS-U	EF	0	300	0	9999	0.0067	1	0	FALSE
ReplacementFire	BS-U	ES	BS-U	ES	0	300	0	9999	0.0067	1	-999	FALSE
Cattle-Grazing	BS-U	SA	BS-U	SA	10	300	0	9999	1	0.16	1	FALSE
Drought	BS-U	SA	BS-U	SA	10	300	0	9999	0.0056	0.9	-999	FALSE
Drought	BS-U	SA	BS-U	AG	10	300	0	9999	0.006	0.1	0	FALSE
Exotic-Forb.bs	BS-U	SA	BS-U	EF	10	300	0	9999	0.001	1	0	TRUE
Herbicide+Seed.bs	BS-U	SA	BS-U	SD	10	24	0	9999	0.01	0.2	0	TRUE
Herbicide+Seed.bs	BS-U	SA	BS-U	SA	10	300	0	9999	0.01	0.8	0	FALSE
Herbicide+Seed.bs	BS-U	SA	BS-B	OP	25	119	0	9999	0.01	0.2	0	TRUE
Herbicide+Seed.bs	BS-U	SA	BS-C	OP	120	300	0	9999	0.01	0.2	0	TRUE
Masticate-Trees.bs	BS-U	SA	BS-U	SA	120	200	0	9999	0.01	1	-999	FALSE
Mow+Hrbx+Seed.bs	BS-U	SA	BS-U	SD	10	300	0	9999	0	0.5	0	FALSE
ReplacementFire	BS-U	SA	BS-U	AG	10	300	0	9999	0.01	1	0	FALSE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
RxFire+Hrbx+Seed.bs	BS-U	SA	BS-U	SD	10	300	0	9999	0.01	0.35	0	FALSE
RxFire+Hrbx+Seed.bs	BS-U	SA	BS-U	AG	10	300	0	9999	0.01	0.35	0	FALSE
RxFire+Hrbx+Seed.bs	BS-U	SA	BS-U	SA	10	300	0	9999	0.01	0.3	0	FALSE
Sheep-Grazing	BS-U	SA	BS-U	SA	10	300	0	9999	1	0.08	-1	FALSE
Tree-Invasion	BS-U	SA	BS-U	TA	120	300	0	9999	0.005	1	0	FALSE
Cattle-Grazing	BS-U	SAP	BS-U	SAP	10	49	0	9999	1	0.16	1	FALSE
Cattle-Grazing	BS-U	SAP	BS-U	SA	50	300	0	9999	1	0.16	0	TRUE
Drought	BS-U	SAP	BS-U	SAP	10	300	0	9999	0.0056	0.9	-999	FALSE
Drought	BS-U	SAP	BS-U	AG	10	300	0	9999	0.006	0.05	0	FALSE
Drought	BS-U	SAP	BS-A	AL	10	300	0	9999	0.006	0.05	0	FALSE
Excessive-Herbivory-Cattle	BS-U	SAP	BS-U	SA	10	300	0	9999	0.001	1	0	TRUE
Excessive-Herbivory-Cattle	BS-U	SAP	BS-U	SA	10	300	0	9999	0.001	1	0	TRUE
Exotic-Forb.bs	BS-U	SAP	BS-U	EF	10	300	0	9999	0.001	1	0	TRUE
Herbicide-Plateau.bs	BS-U	SAP	BS-U	SD	10	24	0	9999	0.01	0.7	0	TRUE
Herbicide-Plateau.bs	BS-U	SAP	BS-U	SAP	10	300	0	9999	0.01	0.3	0	FALSE
Herbicide-Plateau.bs	BS-U	SAP	BS-B	OP	25	119	0	9999	0.01	0.7	0	TRUE
Herbicide-Plateau.bs	BS-U	SAP	BS-C	OP	120	300	0	9999	0.01	0.7	0	TRUE
Masticate-Trees.bs	BS-U	SAP	BS-U	SAP	120	200	0	9999	0.01	1	-999	FALSE
Natural-Recovery	BS-U	SAP	BS-B	OP	12	49	15	9999	0.001	1	0	TRUE
Natural-Recovery	BS-U	SAP	BS-C	OP	50	300	15	9999	0.001	1	0	TRUE
ReplacementFire	BS-U	SAP	BS-U	AG	10	300	0	9999	0.0067	0.95	0	FALSE
ReplacementFire	BS-U	SAP	BS-A	AL	10	300	0	9999	0.006	0.05	0	FALSE
Sheep-Grazing	BS-U	SAP	BS-U	SAP	10	49	0	9999	1	0.08	-1	FALSE
Sheep-Grazing	BS-U	SAP	BS-U	SA	50	300	0	9999	1	0.08	0	TRUE
Tree-Invasion	BS-U	SAP	BS-U	TA	120	300	0	9999	0.005	1	0	FALSE
Cattle-Grazing	BS-U	SD	BS-U	SD	3	500	0	9999	1	0.16	1	FALSE
Natural-Recovery	BS-U	SD	BS-A	AL	0	24	0	9999	0.1	1	0	TRUE
Natural-Recovery	BS-U	SD	BS-B	OP	25	119	0	9999	0.1	1	0	TRUE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
Natural-Recovery	BS-U	SD	BS-C	OP	120	500	0	9999	0.1	1	0	TRUE
ReplacementFire	BS-U	SD	BS-U	SD	0	500	0	9999	0.002	1	-999	FALSE
Sheep-Grazing	BS-U	SD	BS-U	SD	3	500	0	9999	1	0.08	-1	FALSE
Drought	BS-U	TA	BS-U	AG	121	300	0	9999	0.0056	1	0	FALSE
ReplacementFire	BS-U	TA	BS-U	AG	121	300	0	9999	0.0067	1	0	FALSE
RxFire+Hrbx+Seed.bs	BS-U	TA	BS-U	SD	121	300	0	9999	0.01	0.35	0	FALSE
RxFire+Hrbx+Seed.bs	BS-U	TA	BS-U	AG	121	300	0	9999	0.01	0.35	0	FALSE
RxFire+Hrbx+Seed.bs	BS-U	TA	BS-U	TA	121	300	0	9999	0.01	0.3	0	FALSE
Tree-Thin+Hrbx+Seed.bs	BS-U	TA	BS-U	SD	121	300	0	9999	0.01	0.5	0	FALSE
Tree-Thin+Hrbx+Seed.bs	BS-U	TA	BS-U	TA	121	300	0	9999	0.01	0.5	0	FALSE
AG-Invasion	BS-U	TE	BS-U	TA	121	300	0	9999	0.005	1	0	TRUE
Drought	BS-U	TE	BS-U	TE	121	300	0	9999	0.0056	0.5	-999	FALSE
Drought	BS-U	TE	BS-U	ES	121	300	0	9999	0.0056	0.5	0	FALSE
ReplacementFire	BS-U	TE	BS-U	ES	121	300	0	9999	0.0067	1	0	FALSE
RxFire+Seed.bs	BS-U	TE	BS-U	SD	121	300	0	9999	0.01	0.35	0	FALSE
RxFire+Seed.bs	BS-U	TE	BS-U	ES	121	300	0	9999	0.01	0.35	0	FALSE
RxFire+Seed.bs	BS-U	TE	BS-U	TE	121	300	0	9999	0.01	0.3	0	FALSE
Tree-Thin+Seed.bs	BS-U	TE	BS-U	SD	121	300	0	9999	0.01	0.5	0	FALSE
Tree-Thin+Seed.bs	BS-U	TE	BS-U	ES	121	300	0	9999	0.01	0.5	0	FALSE
Chaparral												
ReplacementFire	CH-A	OP	CH-A	OP	0	9	0	9999	0.02	1	-999	FALSE
ReplacementFire	CH-B	CL	CH-A	OP	10	500	0	9999	0.02	1	0	FALSE
Grass-Forb Meadow (alpine turf)												
Cattle-Grazing	GFM-A	AL	GFM-A	AL	3	20	0	9999	1	0.16	1	FALSE
ReplacementFire	GFM-A	AL	GFM-A	AL	0	20	0	9999	0.002	1	-999	FALSE
RxFire.gfm	GFM-A	AL	GFM-A	AL	0	20	0	9999	0.01	0.7	-999	FALSE
RxFire.gfm	GFM-A	AL	GFM-A	AL	0	20	0	9999	0.01	0.3	0	FALSE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
Sheep-Grazing	GFM-A	AL	GFM-A	AL	3	20	0	9999	1	0.08	-1	FALSE
Snow-Deposition	GFM-A	AL	GFM-A	AL	0	20	0	9999	0.01	1	-999	FALSE
Wild-Ungulate-Grazing	GFM-A	AL	GFM-A	AL	0	20	0	9999	1	0.03	2	FALSE
Cattle-Grazing	GFM-B	CL	GFM-B	CL	21	500	0	9999	1	0.16	1	FALSE
Drought	GFM-B	CL	GFM-B	CL	21	500	0	9999	0.0056	1	-999	FALSE
ReplacementFire	GFM-B	CL	GFM-A	AL	21	39	0	9999	0.02	1	0	FALSE
ReplacementFire	GFM-B	CL	GFM-A	AL	40	59	0	9999	0.01	0.01	0	FALSE
ReplacementFire	GFM-B	CL	GFM-A	AL	60	500	0	9999	0.002	1	0	FALSE
RxFire.gfm	GFM-B	CL	GFM-A	AL	21	500	0	9999	0.01	0.7	0	FALSE
RxFire.gfm	GFM-B	CL	GFM-B	CL	21	500	0	9999	0.01	0.3	0	FALSE
Sheep-Grazing	GFM-B	CL	GFM-B	CL	21	500	0	9999	1	0.08	-2	FALSE
Wild-Ungulate-Grazing	GFM-B	CL	GFM-B	CL	21	500	0	9999	1	0.03	2	FALSE
Limber-Bristlecone Pine												
Drought	LB-A	AL	LB-A	AL	0	99	0	9999	0.0056	1	-5	FALSE
ReplacementFire	LB-A	AL	LB-A	AL	0	99	0	9999	0.001	1	-999	FALSE
SurfaceFire	LB-A	AL	LB-A	AL	0	99	0	9999	0.001	1	0	FALSE
ReplacementFire	LB-B	OP	LB-A	AL	100	249	0	9999	0.001	1	0	FALSE
SurfaceFire	LB-B	OP	LB-B	OP	100	249	0	9999	0.002	1	0	FALSE
ReplacementFire	LB-C	OP	LB-A	AL	250	999	0	9999	0.001	1	0	FALSE
SurfaceFire	LB-C	OP	LB-C	OP	250	999	0	9999	0.002	1	0	FALSE
Mixed Conifer												
Drought	MC-A	AL	MC-A	AL	0	34	0	9999	0.0056	1	-999	FALSE
Mechanical-Thinning.mc	MC-A	AL	MC-A	AL	0	34	0	9999	0.01	1	5	TRUE
ReplacementFire	MC-A	AL	MC-A	AL	0	34	0	9999	0.008	1	-999	FALSE
RxFire.mc	MC-A	AL	MC-A	AL	0	34	0	9999	0.01	1	0	FALSE
Salvage.mc	MC-A	AL	MC-A	AL	0	34	0	9999	0.01	1	0	FALSE
AG-Invasion	MC-B	CL	MC-U	TA	35	104	0	9999	0.0001	1	0	TRUE
Insect/Disease	MC-B	CL	MC-C	OP	35	104	0	9999	0.01	1	0	TRUE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
Mechanical-Thinning.mc	MC-B	CL	MC-C	OP	35	104	0	9999	0.01	1	0	TRUE
MixedFire	MC-B	CL	MC-C	OP	35	104	0	9999	0.0016	1	0	TRUE
Partial-Harvest.mc	MC-B	CL	MC-C	OP	35	104	0	9999	0.01	1	0	FALSE
ReplacementFire	MC-B	CL	MC-A	AL	35	104	0	9999	0.01	1	0	FALSE
RxFire.mc	MC-B	CL	MC-C	OP	35	104	0	9999	0.01	0.5	0	TRUE
RxFire.mc	MC-B	CL	MC-A	AL	35	104	0	9999	0.01	0.2	0	TRUE
RxFire.mc	MC-B	CL	MC-B	CL	35	104	0	9999	0.01	0.3	0	TRUE
AG-Invasion	MC-C	OP	MC-U	TA	35	105	0	9999	0.0001	1	0	TRUE
AltSuccession	MC-C	OP	MC-B	CL	35	105	70	9999	1	0.33	0	TRUE
Insect/Disease	MC-C	OP	MC-C	OP	35	105	0	9999	0.01	1	0	FALSE
Mechanical-Thinning.mc	MC-C	OP	MC-C	OP	35	105	0	9999	0.01	1	15	FALSE
Partial-Harvest.mc	MC-C	OP	MC-C	OP	35	105	0	9999	0.01	1	10	FALSE
ReplacementFire	MC-C	OP	MC-A	AL	35	74	0	9999	0.0068	0.5	0	FALSE
ReplacementFire	MC-C	OP	MC-A	AL	75	105	0	9999	0.005	1	0	FALSE
RxFire.mc	MC-C	OP	MC-C	OP	35	105	0	9999	0.01	0.53	1	TRUE
RxFire.mc	MC-C	OP	MC-C	OP	35	105	0	9999	0.01	0.3	0	FALSE
RxFire.mc	MC-C	OP	MC-A	AL	35	105	0	9999	0.01	0.17	0	TRUE
SurfaceFire	MC-C	OP	MC-C	OP	35	74	0	9999	0.0068	0.5	-999	FALSE
SurfaceFire	MC-C	OP	MC-C	OP	75	105	0	9999	0.0017	1	0	FALSE
AG-Invasion	MC-D	OP	MC-U	TA	105	999	0	9999	0.0001	1	0	TRUE
AltSuccession	MC-D	OP	MC-E	CL	105	999	70	9999	1	1	0	TRUE
Insect/Disease	MC-D	OP	MC-C	OP	105	149	0	9999	0.001	1	0	FALSE
Insect/Disease	MC-D	OP	MC-C	OP	150	999	0	9999	0.005	1	0	FALSE
Partial-Harvest.mc	MC-D	OP	MC-C	OP	105	149	0	9999	0.01	1	0	FALSE
Partial-Harvest.mc	MC-D	OP	MC-C	OP	150	999	0	9999	0.01	0.33	0	FALSE
Partial-Harvest.mc	MC-D	OP	MC-D	OP	150	999	0	9999	0.01	0.67	0	FALSE
ReplacementFire	MC-D	OP	MC-A	AL	105	149	0	9999	0.005	1	0	FALSE
ReplacementFire	MC-D	OP	MC-A	AL	150	999	0	9999	0.0007	1	0	FALSE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
RxFire.mc	MC-D	OP	MC-A	AL	105	149	0	9999	0.01	0.25	0	FALSE
RxFire.mc	MC-D	OP	MC-D	OP	105	149	0	9999	0.01	0.75	0	FALSE
RxFire.mc	MC-D	OP	MC-A	AL	150	999	0	9999	0.01	0.1	0	FALSE
RxFire.mc	MC-D	OP	MC-D	OP	150	999	0	9999	0.01	0.9	0	FALSE
SurfaceFire	MC-D	OP	MC-D	OP	105	149	0	9999	0.0017	1	0	FALSE
SurfaceFire	MC-D	OP	MC-D	OP	150	999	0	9999	0.0063	1	0	FALSE
Insect/Disease	MC-E	CL	MC-C	OP	105	999	0	9999	0.005	1	0	FALSE
MixedFire	MC-E	CL	MC-D	OP	105	999	0	9999	0.0017	1	0	FALSE
Partial-Harvest.mc	MC-E	CL	MC-D	OP	105	999	0	9999	0.01	1	0	TRUE
Regen-Harvest.mc	MC-E	CL	MC-A	AL	150	999	0	9999	0.01	1	0	FALSE
ReplacementFire	MC-E	CL	MC-A	AL	105	999	0	9999	0.01	1	0	FALSE
RxFire.mc	MC-E	CL	MC-A	AL	105	999	0	9999	0.01	0.5	0	FALSE
RxFire.mc	MC-E	CL	MC-D	OP	105	999	0	9999	0.01	0.5	0	TRUE
ReplacementFire	MC-U	AG	MC-U	AG	0	999	0	9999	0.1	1	-999	FALSE
Insect/Disease	MC-U	TA	MC-U	TA	35	999	0	9999	0.0056	1	0	FALSE
MixedFire	MC-U	TA	MC-U	AG	35	999	0	9999	0.0151	0.75	0	FALSE
MixedFire	MC-U	TA	MC-U	TA	35	999	0	9999	0.0152	0.25	0	FALSE
Natural-Recovery	MC-U	TA	MC-E	CL	50	999	10	9999	0.01	1	0	TRUE
ReplacementFire	MC-U	TA	MC-U	AG	35	999	0	9999	0.0056	1	0	FALSE
Curlleaf Mountain Mahogany												
Cattle-Grazing	MM-A	AL	MM-A	AL	3	19	0	9999	1	0.11	1	FALSE
Excessive-Herbivory-Cattle	MM-A	AL	MM-A	AL	3	19	0	9999	0.001	1	5	FALSE
Excessive-Herbivory-Sheep	MM-A	AL	MM-A	AL	3	19	0	9999	0.001	1	-20	FALSE
NativeGrazing	MM-A	AL	MM-A	AL	0	19	0	9999	0.02	1	-999	FALSE
ReplacementFire	MM-A	AL	MM-A	AL	0	19	0	9999	0.002	1	-999	FALSE
Sheep-Grazing	MM-A	AL	MM-A	AL	3	19	0	9999	1	0.08	-20	FALSE
Wild-Ungulate-Grazing	MM-A	AL	MM-A	AL	0	19	0	9999	0.02	1	-999	FALSE
Cattle-Grazing	MM-B	OP	MM-B	OP	20	59	0	9999	1	0.11	1	FALSE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
Excessive-Herbivory-Cattle	MM-B	OP	MM-B	OP	20	59	0	9999	0.001	1	5	FALSE
Excessive-Herbivory-Sheep	MM-B	OP	MM-B	OP	20	59	0	9999	0.001	1	-5	FALSE
NativeGrazing	MM-B	OP	MM-B	OP	20	59	0	9999	0.01	1	0	FALSE
ReplacementFire	MM-B	OP	MM-A	AL	20	59	0	9999	0.007	1	0	FALSE
Sheep-Grazing	MM-B	OP	MM-B	OP	20	59	0	9999	1	0.08	-1	FALSE
Wild-Ungulate-Grazing	MM-B	OP	MM-B	OP	20	59	0	9999	0.01	1	-60	FALSE
AltSuccession	MM-C	CL	MM-D	OP	60	149	0	9999	0.005	1	0	TRUE
ReplacementFire	MM-C	CL	MM-A	AL	60	149	0	9999	0.007	1	0	FALSE
Wild-Ungulate-Grazing	MM-C	CL	MM-C	CL	60	149	0	9999	0.001	1	-1	FALSE
AG-Invasion	MM-D	OP	MM-U	TA	60	999	0	9999	0.001	1	0	FALSE
AltSuccession	MM-D	OP	MM-E	CL	60	999	150	9999	1	1	0	TRUE
Cattle-Grazing	MM-D	OP	MM-D	OP	60	999	0	9999	1	0.11	1	FALSE
Excessive-Herbivory-Cattle	MM-D	OP	MM-D	OP	60	999	0	9999	0.001	1	5	FALSE
Excessive-Herbivory-Sheep	MM-D	OP	MM-D	OP	60	999	0	9999	0.001	1	-5	FALSE
ReplacementFire	MM-D	OP	MM-A	AL	60	999	0	9999	0.003	1	0	FALSE
Sheep-Grazing	MM-D	OP	MM-D	OP	60	999	0	9999	1	0.08	-1	FALSE
SurfaceFire	MM-D	OP	MM-D	OP	60	999	0	9999	0.025	1	0	FALSE
AG-Invasion	MM-E	CL	MM-U	TA	150	999	0	9999	0.001	1	0	TRUE
ReplacementFire	MM-E	CL	MM-A	AL	150	999	0	9999	0.002	1	0	FALSE
ReplacementFire	MM-U	AG	MM-U	AG	0	999	0	9999	0.1	1	-999	FALSE
ReplacementFire	MM-U	TA	MM-U	AG	150	999	0	9999	0.007	1	0	FALSE
Montane-Subalpine Riparian												
Beaver-Herbivory	MR-A	AL	MR-A	AL	0	4	0	9999	0.05	1	-1	FALSE
Cattle-Grazing	MR-A	AL	MR-A	AL	0	4	1	9999	1	0.16	-5	FALSE
Excessive-Herbivory	MR-A	AL	MR-U	SFE	0	4	5	9999	0.001	1	0	TRUE
Fence	MR-A	AL	MR-A	FD	1	4	0	9999	0.01	1	0	TRUE
Flooding-7yr	MR-A	AL	MR-A	AL	0	4	10	9999	0.13	1	-5	FALSE
Grazing-Systems	MR-A	AL	MR-A	AL	0	4	0	9999	1	0.25	0	FALSE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
Low-Flow-Kill	MR-A	AL	MR-A	AL	0	2	0	9999	0.1	1	-5	FALSE
Sheep-Grazing	MR-A	AL	MR-A	AL	0	4	1	9999	1	0.11	-5	FALSE
Weed-Inventory.mr	MR-A	AL	MR-A	AL	0	4	0	9999	0.25	1	0	FALSE
Wild-Ungulate-Grazing	MR-A	AL	MR-A	AL	0	4	0	9999	0.03	0.8	-999	TRUE
Wild-Ungulate-Grazing	MR-A	AL	MR-U	EW	0	4	0	9999	0.03	0.2	0	FALSE
Willow-Cottonwood-Recruit	MR-A	AL	MR-A	AL	0	1	0	9999	0.33	0.5	1	FALSE
Willow-Cottonwood-Recruit	MR-A	AL	MR-A	AL	0	1	0	9999	0.33	0.5	-1	FALSE
Beaver-Herbivory	MR-A	FD	MR-A	FD	0	4	0	9999	0.05	1	-1	FALSE
Flooding-20yr	MR-A	FD	MR-A	AL	0	4	10	9999	0.05	1	0	FALSE
Flooding-7yr	MR-A	FD	MR-A	FD	0	4	15	9999	0.13	1	-5	FALSE
Low-Flow-Kill	MR-A	FD	MR-A	FD	0	4	0	9999	0.1	1	-5	FALSE
Weed-Inventory.mr	MR-A	FD	MR-A	FD	0	4	0	9999	0.01	1	0	FALSE
Willow-Cottonwood-Recruit	MR-A	FD	MR-A	FD	0	1	0	9999	0.33	0.5	1	FALSE
Willow-Cottonwood-Recruit	MR-A	FD	MR-A	FD	0	1	0	9999	0.33	0.5	-1	FALSE
Beaver-Herbivory	MR-B	FD	MR-A	FD	5	19	0	9999	0.08	0.5	0	FALSE
Beaver-Herbivory	MR-B	FD	MR-B	FD	5	19	0	9999	0.08	0.5	-20	FALSE
Exotic-Invasion	MR-B	FD	MR-U	FEF	5	19	0	9999	0.01	1	0	TRUE
Flooding-20yr	MR-B	FD	MR-A	AL	5	19	10	9999	0.05	1	0	FALSE
ReplacementFire	MR-B	FD	MR-A	FD	5	19	0	9999	0.02	1	0	FALSE
Weed-Inventory.mr	MR-B	FD	MR-B	FD	5	19	0	9999	0.01	1	0	FALSE
Beaver-Herbivory	MR-B	OP	MR-A	AL	5	19	0	9999	0.04	1	0	FALSE
Beaver-Herbivory	MR-B	OP	MR-B	OP	5	19	0	9999	0.04	1	-20	FALSE
Cattle-Grazing	MR-B	OP	MR-B	OP	5	19	1	9999	1	0.16	-1	FALSE
Excessive-Herbivory	MR-B	OP	MR-U	SFE	5	19	5	9999	0.001	1	0	TRUE
Exotic-Invasion	MR-B	OP	MR-U	EF	5	19	5	9999	0.01	1	0	FALSE
Fence	MR-B	OP	MR-B	FD	5	19	0	9999	0.01	1	0	TRUE
Flooding-20yr	MR-B	OP	MR-A	AL	5	19	5	9999	0.05	1	0	FALSE
Grazing-Systems	MR-B	OP	MR-B	OP	5	19	0	9999	1	0.25	0	FALSE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
ReplacementFire	MR-B	OP	MR-A	AL	5	19	0	9999	0.02	1	0	FALSE
Sheep-Grazing	MR-B	OP	MR-B	OP	5	19	1	9999	1	0.08	-2	FALSE
Weed-Inventory.mr	MR-B	OP	MR-B	OP	5	19	0	9999	0.25	1	0	FALSE
Wild-Ungulate-Grazing	MR-B	OP	MR-U	SFE	5	19	0	9999	0.03	0.8	0	TRUE
Wild-Ungulate-Grazing	MR-B	OP	MR-U	EW	5	19	0	9999	0.03	0.2	0	FALSE
Beaver-Herbivory	MR-C	CL	MR-B	OP	20	300	0	9999	0.002	0.5	0	FALSE
Beaver-Herbivory	MR-C	CL	MR-C	CL	20	300	0	9999	0.002	0.5	-5	FALSE
Cattle-Grazing	MR-C	CL	MR-C	CL	20	300	0	9999	1	0.16	1	FALSE
Exotic-Invasion	MR-C	CL	MR-U	EF	20	300	5	9999	0.01	1	0	FALSE
Fence	MR-C	CL	MR-C	FD	20	300	0	9999	0.01	1	0	TRUE
Flooding-100yr	MR-C	CL	MR-A	AL	20	300	0	9999	0.01	1	0	FALSE
Flooding-20yr	MR-C	CL	MR-C	CL	20	300	5	9999	0.05	1	0	FALSE
Grazing-Systems	MR-C	CL	MR-C	CL	20	300	0	9999	1	0.25	0	FALSE
ReplacementFire	MR-C	CL	MR-A	AL	20	300	0	9999	0.02	1	0	FALSE
Sheep-Grazing	MR-C	CL	MR-C	CL	20	300	0	9999	1	0.08	1	FALSE
Tree-Invasion	MR-C	CL	MR-C	PJ	20	300	0	9999	0.01	1	0	FALSE
Weed-Inventory.mr	MR-C	CL	MR-C	CL	20	300	0	9999	0.25	1	0	FALSE
Wild-Ungulate-Grazing	MR-C	CL	MR-U	SFE	20	300	0	9999	0.03	0.75	0	TRUE
Wild-Ungulate-Grazing	MR-C	CL	MR-U	EW	20	300	0	9999	0.03	0.25	0	FALSE
Beaver-Herbivory	MR-C	FD	MR-B	FD	20	300	0	9999	0.002	0.5	0	FALSE
Beaver-Herbivory	MR-C	FD	MR-C	FD	20	300	0	9999	0.002	0.5	-5	FALSE
Exotic-Invasion	MR-C	FD	MR-U	FEF	20	300	0	9999	0.01	1	0	TRUE
Flooding-100yr	MR-C	FD	MR-A	AL	20	300	5	9999	0.01	1	0	FALSE
Flooding-20yr	MR-C	FD	MR-C	CL	20	300	10	9999	0.05	1	0	TRUE
ReplacementFire	MR-C	FD	MR-A	FD	20	300	0	9999	0.02	1	0	FALSE
Weed-Inventory.mr	MR-C	FD	MR-C	FD	20	300	0	9999	0.01	1	0	FALSE
Beaver-Herbivory	MR-C	PJ	MR-B	OP	20	301	0	9999	0.002	0.5	0	FALSE
Beaver-Herbivory	MR-C	PJ	MR-C	CL	20	301	0	9999	0.002	0.5	-5	FALSE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
Cattle-Grazing	MR-C	PJ	MR-C	PJ	20	301	0	9999	1	0.11	1	FALSE
Excessive-Herbivory	MR-C	PJ	MR-U	SFE	20	301	0	9999	0.001	1	0	TRUE
Exotic-Invasion	MR-C	PJ	MR-U	EF	20	301	0	9999	0.01	1	0	TRUE
Flooding-100yr	MR-C	PJ	MR-A	AL	20	301	10	9999	0.01	1	0	FALSE
Mechanical-Thinning	MR-C	PJ	MR-C	CL	20	301	0	9999	0.01	1	0	FALSE
ReplacementFire	MR-C	PJ	MR-A	AL	20	301	0	9999	0.02	1	0	FALSE
RxFire.mr	MR-C	PJ	MR-A	AL	20	301	0	9999	0.01	1	0	FALSE
Sheep-Grazing	MR-C	PJ	MR-C	PJ	20	301	0	9999	1	0.08	1	FALSE
Weed-Inventory.mr	MR-C	PJ	MR-C	PJ	20	301	0	9999	0.01	1	0	FALSE
Wild-Ungulate-Grazing	MR-C	PJ	MR-U	SFE	20	301	0	9999	0.03	0.75	0	TRUE
Wild-Ungulate-Grazing	MR-C	PJ	MR-U	EW	20	301	0	9999	0.03	0.25	0	FALSE
Beaver-Herbivory	MR-U	DE	MR-U	DE	0	300	0	9999	0.002	0.5	-5	FALSE
Beaver-Herbivory	MR-U	DE	MR-U	SFE	0	300	0	9999	0.002	0.5	0	TRUE
Cattle-Grazing	MR-U	DE	MR-U	DE	0	300	1	9999	1	0.16	1	FALSE
Floodplain-Enlargement.mr	MR-U	DE	MR-A	AL	0	300	0	9999	0.01	1	0	FALSE
Floodplain-Recovery	MR-U	DE	MR-A	AL	0	300	5	9999	0.001	1	0	FALSE
Floodplain-Restoration.mr	MR-U	DE	MR-A	AL	0	300	0	9999	0.01	1	0	FALSE
Grazing-Systems	MR-U	DE	MR-U	DE	0	300	0	9999	1	0.25	0	FALSE
ReplacementFire	MR-U	DE	MR-U	DE	0	300	0	9999	0.02	1	-999	FALSE
Sheep-Grazing	MR-U	DE	MR-U	DE	0	300	1	9999	1	0.08	1	FALSE
Tree-Invasion	MR-U	DE	MR-U	TE	100	300	0	9999	0.01	1	0	FALSE
Wild-Ungulate-Grazing	MR-U	DE	MR-U	EW	0	300	0	9999	0.03	0.2	0	FALSE
Wild-Ungulate-Grazing	MR-U	DE	MR-U	DE	0	300	0	9999	0.03	0.8	3	FALSE
Exotic-Control.mr	MR-U	EF	MR-B	OP	0	300	0	20	1	0.15	0	TRUE
Exotic-Control.mr	MR-U	EF	MR-U	EF	0	300	0	20	1	0.4	0	FALSE
Exotic-Control.mr	MR-U	EF	MR-A	AL	0	300	0	20	1	0.15	0	TRUE
Exotic-Control.mr	MR-U	EF	MR-C	CL	0	300	0	20	1	0.15	0	TRUE
Exotic-Control.mr	MR-U	EF	MR-U	SFE	0	300	0	20	1	0.15	0	TRUE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
ReplacementFire	MR-U	EF	MR-U	EF	0	300	0	9999	0.02	1	-999	FALSE
Exotic-Invasion	MR-U	EW	MR-U	EF	0	300	5	9999	0.01	1	0	FALSE
Natural-Recovery	MR-U	EW	MR-A	AL	0	300	10	9999	0.005	1	0	FALSE
Weed-Inventory.mr	MR-U	EW	MR-U	EW	0	300	0	9999	0.01	0.25	0	FALSE
Wild-Ungulate-Grazing	MR-U	EW	MR-U	EW	0	300	0	9999	0.03	1	-300	FALSE
Exotic-Control.mr	MR-U	FEF	MR-U	FEF	0	300	0	9999	0.01	0.4	0	FALSE
Exotic-Control.mr	MR-U	FEF	MR-A	FD	0	300	0	9999	0.01	0.15	0	TRUE
Exotic-Control.mr	MR-U	FEF	MR-B	FD	0	300	0	9999	0.01	0.15	0	TRUE
Exotic-Control.mr	MR-U	FEF	MR-C	CL	0	300	0	9999	0.01	0.15	0	TRUE
Exotic-Control.mr	MR-U	FEF	MR-U	SFE	0	300	0	9999	0.01	0.15	0	TRUE
Flooding-20yr	MR-U	FEF	MR-U	EF	0	300	10	9999	0.05	1	0	FALSE
ReplacementFire	MR-U	FEF	MR-U	FEF	0	300	0	9999	0.02	1	-999	FALSE
Beaver-Herbivory	MR-U	SFE	MR-U	SFE	0	300	0	9999	0.04	1	-999	FALSE
Cattle-Grazing	MR-U	SFE	MR-U	SFE	0	300	0	9999	1	0.16	1	FALSE
Entrenchment	MR-U	SFE	MR-U	DE	0	4	0	9999	0.05	1	0	FALSE
Entrenchment	MR-U	SFE	MR-U	DE	5	300	0	9999	0.01	1	0	FALSE
Exotic-Invasion	MR-U	SFE	MR-U	EF	0	300	5	9999	0.01	1	0	TRUE
Flooding-7yr	MR-U	SFE	MR-U	SFE	0	4	10	9999	0.13	1	-999	FALSE
Grazing-Systems	MR-U	SFE	MR-U	SFE	0	300	0	9999	1	0.25	0	FALSE
ReplacementFire	MR-U	SFE	MR-U	SFE	5	300	0	9999	0.02	1	-999	FALSE
RxFire+Herbicide.mr	MR-U	SFE	MR-A	AL	0	300	0	9999	0.01	1	0	TRUE
Sheep-Grazing	MR-U	SFE	MR-U	SFE	0	300	0	9999	1	0.08	2	FALSE
Weed-Inventory.mr	MR-U	SFE	MR-U	SFE	0	300	0	9999	0.25	1	0	FALSE
Wild-Ungulate-Grazing	MR-U	SFE	MR-U	SFE	0	300	0	9999	0.03	0.8	1	FALSE
Wild-Ungulate-Grazing	MR-U	SFE	MR-U	EW	0	300	0	9999	0.03	0.2	0	FALSE
Insect/Disease	MR-U	TE	MR-U	TE	100	300	0	9999	0.0056	0.5	-200	FALSE
Insect/Disease	MR-U	TE	MR-U	DE	100	300	0	9999	0.0056	0.5	0	FALSE
Mechanical-Thinning	MR-U	TE	MR-U	DE	100	300	0	9999	0.01	1	0	FALSE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
ReplacementFire	MR-U	TE	MR-U	DE	100	300	0	9999	0.02	1	0	FALSE
Gambel Oak-Mountain Shrub												
Cattle-Grazing	MSb-A	AL	MSb-A	AL	0	4	0	9999	1	0.11	1	FALSE
Drought	MSb-A	AL	MSb-A	AL	0	4	0	9999	0.0056	1	-999	FALSE
Excessive-Herbivory-Cattle	MSb-A	AL	MSb-U	ES	0	4	0	9999	0.001	1	0	FALSE
Excessive-Herbivory-Sheep	MSb-A	AL	MSb-U	ES	0	4	0	9999	0.001	1	0	FALSE
ReplacementFire	MSb-A	AL	MSb-A	AL	0	4	0	9999	0.0667	1	-999	FALSE
Sheep-Grazing	MSb-A	AL	MSb-A	AL	0	4	0	9999	1	0.08	2	FALSE
Wild-Ungulate-Grazing	MSb-A	AL	MSb-A	AL	0	4	0	9999	0.03	0.8	-999	FALSE
Wild-Ungulate-Grazing	MSb-A	AL	MSb-U	ES	0	4	0	9999	0.03	0.2	0	TRUE
Cattle-Grazing	MSb-B	CL	MSb-B	CL	5	19	0	9999	1	0.11	1	FALSE
Drought	MSb-B	CL	MSb-A	AL	5	19	0	9999	0.006	0.1	0	FALSE
Drought	MSb-B	CL	MSb-B	CL	5	19	0	9999	0.0056	0.9	-999	FALSE
Excessive-Herbivory-Cattle	MSb-B	CL	MSb-U	ES	5	19	0	9999	0.001	1	0	FALSE
Excessive-Herbivory-Sheep	MSb-B	CL	MSb-U	ES	5	19	0	9999	0.001	1	0	FALSE
MixedFire	MSb-B	CL	MSb-B	CL	5	19	0	9999	0.0067	1	-999	FALSE
ReplacementFire	MSb-B	CL	MSb-A	AL	5	19	0	9999	0.02	1	0	FALSE
Sheep-Grazing	MSb-B	CL	MSb-B	CL	5	19	0	9999	1	0.08	-1	FALSE
Wild-Ungulate-Grazing	MSb-B	CL	MSb-B	CL	5	19	0	9999	0.03	0.8	-1	FALSE
Wild-Ungulate-Grazing	MSb-B	CL	MSb-U	ES	5	19	0	9999	0.03	0.2	0	TRUE
Cattle-Grazing	MSb-C	CL	MSb-C	CL	20	80	0	9999	1	0.11	1	FALSE
Drought	MSb-C	CL	MSb-B	CL	20	80	0	9999	0.006	0.1	0	FALSE
Drought	MSb-C	CL	MSb-C	CL	20	80	0	9999	0.0056	0.9	-999	FALSE
Excessive-Herbivory-Cattle	MSb-C	CL	MSb-U	ES	20	80	0	9999	0.001	1	0	FALSE
Excessive-Herbivory-Sheep	MSb-C	CL	MSb-U	ES	20	80	0	9999	0.001	1	0	FALSE
MixedFire	MSb-C	CL	MSb-B	CL	20	80	0	9999	0.0067	1	0	FALSE
ReplacementFire	MSb-C	CL	MSb-A	AL	20	80	0	9999	0.025	1	0	FALSE
RxFire.msb	MSb-C	CL	MSb-A	AL	20	80	0	9999	0.01	1	0	FALSE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
Sheep-Grazing	MSb-C	CL	MSb-C	CL	20	80	0	9999	1	0.08	-1	FALSE
Wild-Ungulate-Grazing	MSb-C	CL	MSb-C	CL	20	80	0	9999	0.03	1	1	FALSE
Cattle-Grazing	MSb-D	OP	MSb-D	OP	80	300	0	9999	1	0.11	1	FALSE
Chainsaw-Thinning.msb	MSb-D	OP	MSb-B	CL	80	300	0	9999	0.01	1	0	FALSE
Drought	MSb-D	OP	MSb-C	CL	80	300	0	9999	0.006	0.1	0	FALSE
Drought	MSb-D	OP	MSb-D	OP	80	300	0	9999	0.0056	0.9	-999	FALSE
Excessive-Herbivory-Cattle	MSb-D	OP	MSb-D	OP	80	300	0	9999	0.001	1	5	FALSE
Excessive-Herbivory-Sheep	MSb-D	OP	MSb-D	OP	80	300	0	9999	0.001	1	5	FALSE
Mechanical-Thinnng.msb	MSb-D	OP	MSb-B	CL	80	300	0	9999	0.01	0.9	0	FALSE
Mechanical-Thinnng.msb	MSb-D	OP	MSb-A	AL	80	300	0	9999	0.01	0.1	0	FALSE
MixedFire	MSb-D	OP	MSb-C	CL	80	300	0	9999	0.0067	1	0	FALSE
ReplacementFire	MSb-D	OP	MSb-A	AL	80	300	0	9999	0.02	1	0	FALSE
RxFire.msb	MSb-D	OP	MSb-A	AL	80	300	0	9999	0.01	0.9	0	FALSE
RxFire.msb	MSb-D	OP	MSb-D	OP	80	300	0	9999	0.01	0.1	0	FALSE
Sheep-Grazing	MSb-D	OP	MSb-D	OP	80	300	0	9999	1	0.08	1	FALSE
Tree-Encroachment	MSb-D	OP	MSb-U	TE	150	199	0	9999	0.005	1	0	TRUE
Tree-Encroachment	MSb-D	OP	MSb-U	TE	200	249	0	9999	0.01	1	0	TRUE
Tree-Encroachment	MSb-D	OP	MSb-U	TE	250	300	0	9999	0.05	1	0	TRUE
Wild-Ungulate-Grazing	MSb-D	OP	MSb-D	OP	80	300	0	9999	0.03	1	1	FALSE
Natural-Recovery	MSb-U	ES	MSb-B	CL	5	19	10	9999	0.001	1	0	TRUE
Natural-Recovery	MSb-U	ES	MSb-C	CL	20	80	10	9999	0.001	1	0	TRUE
ReplacementFire	MSb-U	ES	MSb-U	ES	0	300	0	9999	0.02	1	-999	FALSE
Drought	MSb-U	TE	MSb-U	ES	106	300	0	9999	0.006	0.1	0	FALSE
Drought	MSb-U	TE	MSb-U	TE	106	300	0	9999	0.0056	0.9	-999	FALSE
ReplacementFire	MSb-U	TE	MSb-U	ES	106	300	0	9999	0.0067	1	0	FALSE
Tree-Thin+Seed.msb	MSb-U	TE	MSb-A	AL	106	300	0	9999	0.01	0.8	0	FALSE
Tree-Thin+Seed.msb	MSb-U	TE	MSb-U	ES	106	300	0	9999	0.01	0.2	0	FALSE
Mixed Salt Desert Scrub												

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
AG-Invasion	MSD-A	AL	MSD-U	AG	0	4	0	9999	0.005	1	0	FALSE
Cattle-Grazing	MSD-A	AL	MSD-A	AL	0	4	0	9999	1	0.16	1	FALSE
Sheep-Grazing	MSD-A	AL	MSD-A	AL	0	4	0	9999	1	0.08	-2	FALSE
Very-Wet-Year	MSD-A	AL	MSD-A	AL	0	4	0	9999	0.018	1	-999	FALSE
AG-Invasion	MSD-B	CL	MSD-U	SA	5	500	0	9999	0.005	1	0	TRUE
Cattle-Grazing	MSD-B	CL	MSD-B	CL	5	500	0	9999	1	0.16	0	FALSE
Drought	MSD-B	CL	MSD-C	OP	5	500	0	9999	0.0056	1	0	FALSE
Sheep-Grazing	MSD-B	CL	MSD-B	CL	5	500	0	9999	1	0.08	-2	FALSE
Very-Wet-Year	MSD-B	CL	MSD-A	AL	5	500	0	9999	0.05	1	0	FALSE
AG-Invasion	MSD-C	OP	MSD-U	SA	6	30	0	9999	0.005	1	0	TRUE
Drought	MSD-C	OP	MSD-C	OP	6	30	0	9999	0.0056	1	-999	FALSE
Sheep-Grazing	MSD-C	OP	MSD-C	OP	6	30	0	9999	1	0.08	-1	FALSE
Very-Wet-Year	MSD-C	OP	MSD-A	AL	6	30	0	9999	0.05	1	0	FALSE
Herbicide+Seed.msd	MSD-U	AG	MSD-U	SD	0	500	0	9999	0.01	0.5	0	FALSE
Herbicide+Seed.msd	MSD-U	AG	MSD-U	AG	0	500	0	9999	0.01	0.5	0	FALSE
ReplacementFire	MSD-U	AG	MSD-U	AG	0	500	0	9999	0.1	1	-999	FALSE
Mow+Hrbx+Seed.msd	MSD-U	SA	MSD-U	SD	5	500	0	9999	0.01	0.5	0	FALSE
Mow+Hrbx+Seed.msd	MSD-U	SA	MSD-U	AG	5	500	0	9999	0.01	0.5	0	FALSE
ReplacementFire	MSD-U	SA	MSD-U	AG	5	500	0	9999	0.025	1	0	FALSE
Sheep-Grazing	MSD-U	SA	MSD-U	SA	5	500	0	9999	1	0.08	-2	FALSE
Very-Wet-Year	MSD-U	SA	MSD-U	AG	5	500	0	9999	0.05	1	0	FALSE
AG-Invasion	MSD-U	SD	MSD-U	AG	0	4	0	9999	0.005	1	0	FALSE
AG-Invasion	MSD-U	SD	MSD-U	SA	0	4	0	9999	0.005	1	0	FALSE
Cattle-Grazing	MSD-U	SD	MSD-U	SD	3	300	0	9999	1	0.16	1	FALSE
Drought	MSD-U	SD	MSD-U	SD	0	4	0	9999	0.0056	1	-999	FALSE
Drought	MSD-U	SD	MSD-U	SD	5	300	0	9999	0.0056	1	-1	FALSE
Natural-Recovery	MSD-U	SD	MSD-A	AL	0	4	0	9999	0.001	1	0	TRUE
Natural-Recovery	MSD-U	SD	MSD-B	CL	5	300	0	9999	0.005	1	0	TRUE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
Sheep-Grazing	MSD-U	SD	MSD-U	SD	3	300	0	9999	1	0.08	-2	FALSE
Very-Wet-Year	MSD-U	SD	MSD-U	SD	0	300	0	9999	0.05	1	-999	FALSE
Montane Sagebrush Steppe - upland sites												
Cattle-Grazing	MSu-A	AL	MSu-A	AL	3	11	0	9999	0.01	0.8	1	FALSE
Cattle-Grazing	MSu-A	AL	MSu-A	AL	3	11	0	9999	0.01	0.2	0	FALSE
Excessive-Herbivory-Cattle	MSu-A	AL	MSu-U	ES	5	11	0	9999	0.001	1	0	FALSE
Excessive-Herbivory-Cattle	MSu-A	AL	MSu-A	AL	3	4	0	9999	0.001	1	5	FALSE
Excessive-Herbivory-Sheep	MSu-A	AL	MSu-A	AL	3	4	0	9999	0.001	1	5	FALSE
Excessive-Herbivory-Sheep	MSu-A	AL	MSu-U	ES	5	11	0	9999	0.001	1	0	FALSE
ReplacementFire	MSu-A	AL	MSu-A	AL	0	11	0	9999	0.0125	1	-999	FALSE
Sheep-Grazing	MSu-A	AL	MSu-A	AL	3	11	0	9999	1	0.08	2	FALSE
Cattle-Grazing	MSu-B	OP	MSu-B	OP	12	49	0	9999	1	0.16	1	FALSE
Excessive-Herbivory-Cattle	MSu-B	OP	MSu-U	ES	12	49	0	9999	0.001	1	0	TRUE
Excessive-Herbivory-Sheep	MSu-B	OP	MSu-U	ES	12	49	0	9999	0.001	1	0	TRUE
ReplacementFire	MSu-B	OP	MSu-A	AL	12	49	0	9999	0.025	1	0	FALSE
Sheep-Grazing	MSu-B	OP	MSu-B	OP	12	49	0	9999	1	0.08	-1	FALSE
Tree-Invasion	MSu-B	OP	MSu-D	OP	40	49	0	9999	0.01	1	0	FALSE
AG-Invasion	MSu-C	CL	MSu-U	SAP	50	300	0	9999	0.005	1	0	TRUE
Cattle-Grazing	MSu-C	CL	MSu-C	CL	50	300	0	9999	1	0.16	1	FALSE
Drought	MSu-C	CL	MSu-C	CL	50	300	0	9999	0.0056	0.9	-999	FALSE
Drought	MSu-C	CL	MSu-B	OP	50	300	0	9999	0.006	0.1	0	FALSE
Excessive-Herbivory-Cattle	MSu-C	CL	MSu-U	ES	50	300	0	9999	0.001	1	0	TRUE
Exotic-Forb.ms	MSu-C	CL	MSu-U	EF	50	300	0	9999	0.001	1	0	TRUE
Herbicide-Spyke.ms	MSu-C	CL	MSu-B	OP	50	300	0	9999	0.01	1	0	FALSE
Mechanical-Thinnng.ms	MSu-C	CL	MSu-B	OP	50	300	0	9999	0.01	0.9	0	FALSE
Mechanical-Thinnng.ms	MSu-C	CL	MSu-A	AL	50	300	0	9999	0.01	0.1	0	FALSE
Mow.ms	MSu-C	CL	MSu-A	AL	50	300	0	9999	0.01	1	0	FALSE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
ReplacementFire	MSu-C	CL	MSu-A	AL	50	300	0	9999	0.02	1	0	FALSE
RxFire.ms	MSu-C	CL	MSu-A	AL	50	300	0	9999	0.01	0.7	0	FALSE
RxFire.ms	MSu-C	CL	MSu-C	CL	50	300	0	9999	0.01	0.3	0	FALSE
Sheep-Grazing	MSu-C	CL	MSu-C	CL	50	300	0	9999	1	0.08	-1	FALSE
Tree-Invasion	MSu-C	CL	MSu-D	OP	50	300	0	9999	0.01	1	0	FALSE
AG-Invasion	MSu-D	OP	MSu-U	SAP	40	114	0	9999	0.005	1	0	FALSE
Cattle-Grazing	MSu-D	OP	MSu-D	OP	40	114	0	9999	1	0.16	1	TRUE
Drought	MSu-D	OP	MSu-C	CL	40	114	0	9999	0.0057	0.6	0	FALSE
Drought	MSu-D	OP	MSu-B	OP	40	114	0	9999	0.0057	0.3	0	FALSE
Drought	MSu-D	OP	MSu-D	OP	40	114	0	9999	0.006	0.1	-999	FALSE
Excessive-Herbivory-Cattle	MSu-D	OP	MSu-U	ES	40	114	0	9999	0.001	1	0	TRUE
Excessive-Herbivory-Sheep	MSu-D	OP	MSu-U	ES	40	114	0	9999	0.001	1	0	TRUE
Exotic-Forb.ms	MSu-D	OP	MSu-U	EF	40	114	0	9999	0.001	1	0	TRUE
Herbicide-Spyke.ms	MSu-D	OP	MSu-B	OP	40	114	0	9999	0.01	1	0	FALSE
Masticate-Trees.ms	MSu-D	OP	MSu-C	CL	40	114	0	9999	0.01	1	0	FALSE
Mechanical-Thinnng.ms	MSu-D	OP	MSu-B	OP	40	114	0	9999	0.01	0.8	0	FALSE
Mechanical-Thinnng.ms	MSu-D	OP	MSu-A	AL	40	114	0	9999	0.01	0.2	0	FALSE
ReplacementFire	MSu-D	OP	MSu-A	AL	40	114	0	9999	0.02	1	0	FALSE
RxFire.ms	MSu-D	OP	MSu-A	AL	40	114	0	9999	0.01	0.7	0	FALSE
RxFire.ms	MSu-D	OP	MSu-D	OP	40	114	0	9999	0.01	0.3	0	FALSE
Sheep-Grazing	MSu-D	OP	MSu-D	OP	40	114	0	9999	1	0.08	2	TRUE
Chaining.ms	MSu-E	CL	MSu-B	OP	115	300	0	9999	0.01	0.5	0	FALSE
Chaining.ms	MSu-E	CL	MSu-C	CL	115	300	0	9999	0.01	0.5	0	FALSE
Chainsaw-Thinning.ms	MSu-E	CL	MSu-A	AL	115	300	0	9999	0.01	1	0	FALSE
Drought	MSu-E	CL	MSu-B	OP	115	300	0	9999	0.006	0.1	0	FALSE
Drought	MSu-E	CL	MSu-E	CL	115	300	0	9999	0.0056	0.9	5	FALSE
Herbicide-Spyke.ms	MSu-E	CL	MSu-B	OP	115	300	0	9999	0.01	0.9	0	FALSE
Herbicide-Spyke.ms	MSu-E	CL	MSu-A	AL	115	300	0	9999	0.01	0.1	0	FALSE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
Masticate-Trees.ms	MSu-E	CL	MSu-B	OP	115	300	0	9999	0.01	0.5	0	FALSE
Masticate-Trees.ms	MSu-E	CL	MSu-A	AL	115	300	0	9999	0.01	0.5	0	FALSE
Mechanical-Thinnng.ms	MSu-E	CL	MSu-B	OP	115	300	0	9999	0.01	0.5	0	FALSE
Mechanical-Thinnng.ms	MSu-E	CL	MSu-A	AL	115	300	0	9999	0.01	0.5	0	FALSE
ReplacementFire	MSu-E	CL	MSu-A	AL	115	300	0	9999	0.013	1	0	FALSE
RxFire.ms	MSu-E	CL	MSu-A	AL	115	300	0	9999	0.01	0.7	0	FALSE
RxFire.ms	MSu-E	CL	MSu-E	CL	115	300	0	9999	0.01	0.3	0	FALSE
Tree-Encroachment	MSu-E	CL	MSu-U	TE	140	189	0	9999	0.005	1	0	TRUE
Tree-Encroachment	MSu-E	CL	MSu-U	TE	190	239	0	9999	0.01	1	0	TRUE
Tree-Encroachment	MSu-E	CL	MSu-U	TE	240	300	0	9999	0.02	1	0	TRUE
Exotic-Forb.ms	MSu-U	AG	MSu-U	EF	0	300	0	9999	0.001	1	0	FALSE
Herbicide+Seed.ms	MSu-U	AG	MSu-A	AL	0	3	0	9999	0.01	0.8	0	FALSE
Herbicide+Seed.ms	MSu-U	AG	MSu-U	AG	0	3	0	9999	0.01	0.2	0	FALSE
ReplacementFire	MSu-U	AG	MSu-U	AG	0	300	0	9999	0.1	1	-999	FALSE
AG-Invasion	MSu-U	DP	MSu-U	SA	50	300	0	9999	0.005	1	0	TRUE
Drought	MSu-U	DP	MSu-U	DP	50	300	0	9999	0.0056	0.9	-999	FALSE
Drought	MSu-U	DP	MSu-U	ES	50	300	0	9999	0.006	0.1	0	FALSE
Exotic-Forb.ms	MSu-U	DP	MSu-U	EF	50	300	0	9999	0.001	1	0	FALSE
Masticate-Trees.ms	MSu-U	DP	MSu-U	DP	50	300	0	9999	0.01	1	-999	FALSE
Mow+Seed.ms	MSu-U	DP	MSu-A	AL	50	300	0	9999	0.01	0.9	0	FALSE
Mow+Seed.ms	MSu-U	DP	MSu-U	ES	50	300	0	9999	0.01	0.1	0	FALSE
ReplacementFire	MSu-U	DP	MSu-U	ES	50	300	0	9999	0.02	1	0	FALSE
Sheep-Grazing	MSu-U	DP	MSu-U	DP	50	300	0	9999	1	0.08	-1	FALSE
Tree-Invasion	MSu-U	DP	MSu-U	TE	100	300	0	9999	0.01	1	0	FALSE
Herbicide-Noxious-Weeds.ms	MSu-U	EF	MSu-A	AL	0	11	0	9999	0.01	1	0	TRUE
Herbicide-Noxious-Weeds.ms	MSu-U	EF	MSu-B	OP	12	49	0	9999	0.01	1	0	TRUE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
Herbicide-Noxious-Weeds.ms	MSu-U	EF	MSu-D	OP	50	115	0	9999	0.01	0.5	0	TRUE
Herbicide-Noxious-Weeds.ms	MSu-U	EF	MSu-C	CL	50	114	0	9999	0.01	0.5	0	TRUE
Herbicide-Noxious-Weeds.ms	MSu-U	EF	MSu-C	CL	115	300	0	9999	0.01	1	0	TRUE
ReplacementFire	MSu-U	EF	MSu-U	EF	0	300	0	9999	0.02	1	-999	FALSE
Natural-Recovery	MSu-U	ES	MSu-B	OP	12	49	10	9999	0.0001	1	0	FALSE
Natural-Recovery	MSu-U	ES	MSu-C	CL	50	300	10	9999	0.0001	1	0	FALSE
ReplacementFire	MSu-U	ES	MSu-U	ES	0	300	0	9999	0.02	0.95	0	FALSE
ReplacementFire	MSu-U	ES	MSu-A	AL	0	300	0	9999	0.02	0.05	0	FALSE
Cattle-Grazing	MSu-U	SA	MSu-U	SA	50	300	0	9999	1	0.16	1	FALSE
Drought	MSu-U	SA	MSu-U	SA	50	300	0	9999	0.0056	0.9	-999	FALSE
Drought	MSu-U	SA	MSu-U	AG	50	300	0	9999	0.006	0.1	0	FALSE
Exotic-Forb.ms	MSu-U	SA	MSu-U	EF	50	300	0	9999	0.001	1	0	TRUE
Herbicide+Seed.ms	MSu-U	SA	MSu-C	CL	50	300	0	9999	0.01	0.7	0	TRUE
Herbicide+Seed.ms	MSu-U	SA	MSu-U	SA	50	300	0	9999	0.01	0.3	0	FALSE
Mow+Hrbx+Seed.ms	MSu-U	SA	MSu-A	AL	50	300	0	9999	0.01	0.9	0	FALSE
Mow+Hrbx+Seed.ms	MSu-U	SA	MSu-U	AG	50	300	0	9999	0.01	0.1	0	FALSE
ReplacementFire	MSu-U	SA	MSu-U	AG	50	300	0	9999	0.04	1	0	FALSE
Sheep-Grazing	MSu-U	SA	MSu-U	SA	50	300	0	9999	1	0.08	-1	FALSE
Tree-Invasion	MSu-U	SA	MSu-U	TA	100	300	0	9999	0.01	1	0	FALSE
Cattle-Grazing	MSu-U	SAP	MSu-U	SAP	50	76	0	9999	1	0.16	1	FALSE
Cattle-Grazing	MSu-U	SAP	MSu-U	SA	75	300	0	9999	1	0.16	0	FALSE
Drought	MSu-U	SAP	MSu-U	SAP	50	300	0	9999	0.0056	0.9	-999	FALSE
Drought	MSu-U	SAP	MSu-U	AG	50	300	0	9999	0.006	0.05	0	FALSE
Drought	MSu-U	SAP	MSu-A	AL	50	300	0	9999	0.006	0.05	0	FALSE
Excessive-Herbivory-Cattle	MSu-U	SAP	MSu-U	SA	50	300	0	9999	0.001	1	0	FALSE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
Excessive-Herbivory-Sheep	MSu-U	SAP	MSu-U	SA	50	300	0	9999	0.001	1	0	FALSE
Exotic-Forb.ms	MSu-U	SAP	MSu-U	EF	50	300	0	9999	0.001	1	0	TRUE
Herbicide-Plateau.ms	MSu-U	SAP	MSu-C	CL	50	300	0	9999	0.01	0.8	0	TRUE
Herbicide-Plateau.ms	MSu-U	SAP	MSu-U	SAP	50	300	0	9999	0.01	0.2	0	FALSE
Masticate-Trees.ms	MSu-U	SAP	MSu-U	SAP	50	300	0	9999	0.01	1	-999	FALSE
Natural-Recovery	MSu-U	SAP	MSu-C	CL	50	300	10	9999	0.001	1	0	TRUE
ReplacementFire	MSu-U	SAP	MSu-U	AG	50	300	0	9999	0.04	0.5	0	FALSE
ReplacementFire	MSu-U	SAP	MSu-A	AL	50	300	0	9999	0.04	0.5	0	FALSE
RxFire.ms	MSu-U	SAP	MSu-U	AG	50	300	0	9999	0.01	0.5	0	FALSE
RxFire.ms	MSu-U	SAP	MSu-A	AL	50	300	0	9999	0.01	0.5	0	FALSE
Sheep-Grazing	MSu-U	SAP	MSu-U	SAP	50	300	0	9999	1	0.08	-1	FALSE
Tree-Invasion	MSu-U	SAP	MSu-U	TA	100	300	0	9999	0.01	1	0	FALSE
AG-Invasion	MSu-U	SD	MSu-U	SAP	50	999	0	9999	0.001	1	0	TRUE
Cattle-Grazing	MSu-U	SD	MSu-U	SD	0	999	0	9999	1	0.16	1	FALSE
Excessive-Herbivory-Cattle	MSu-U	SD	MSu-U	ES	0	999	0	9999	0.001	1	0	FALSE
Excessive-Herbivory-Sheep	MSu-U	SD	MSu-U	ES	0	999	0	9999	0.001	1	0	FALSE
Natural-Recovery	MSu-U	SD	MSu-A	AL	5	11	0	9999	0.001	1	0	FALSE
Natural-Recovery	MSu-U	SD	MSu-B	OP	12	49	0	9999	0.005	1	0	FALSE
Natural-Recovery	MSu-U	SD	MSu-C	CL	50	999	0	9999	0.01	1	0	FALSE
ReplacementFire	MSu-U	SD	MSu-U	SD	0	999	0	9999	0.005	1	-999	FALSE
Sheep-Grazing	MSu-U	SD	MSu-U	SD	0	999	0	9999	1	0.08	-1	FALSE
Drought	MSu-U	TA	MSu-U	TA	100	300	0	9999	0.0056	0.9	-999	FALSE
Drought	MSu-U	TA	MSu-U	AG	100	300	0	9999	0.006	0.1	0	FALSE
ReplacementFire	MSu-U	TA	MSu-U	AG	100	300	0	9999	0.0085	1	0	FALSE
RxFire+Hrbx+Seed.ms	MSu-U	TA	MSu-A	AL	100	300	0	9999	0.01	0.7	0	FALSE
RxFire+Hrbx+Seed.ms	MSu-U	TA	MSu-U	AG	100	300	0	9999	0.01	0.3	0	FALSE
Tree-Thin+Hrbx+Seed.ms	MSu-U	TA	MSu-A	AL	100	300	0	9999	0.01	0.8	0	FALSE
Tree-Thin+Hrbx+Seed.ms	MSu-U	TA	MSu-U	AG	100	300	0	9999	0.01	0.2	0	FALSE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
AG-Invasion	MSu-U	TE	MSu-U	TA	100	300	0	9999	0.005	1	0	TRUE
Drought	MSu-U	TE	MSu-U	TE	100	300	0	9999	0.0056	0.9	-999	FALSE
Drought	MSu-U	TE	MSu-U	ES	100	300	0	9999	0.006	0.1	0	FALSE
ReplacementFire	MSu-U	TE	MSu-U	ES	100	300	0	9999	0.0085	1	0	FALSE
RxFire+Seed.ms	MSu-U	TE	MSu-A	AL	100	300	0	9999	0.01	0.8	0	FALSE
RxFire+Seed.ms	MSu-U	TE	MSu-U	ES	100	300	0	9999	0.01	0.2	0	FALSE
Tree-Thin+Seed.ms	MSu-U	TE	MSu-A	AL	100	300	0	9999	0.01	0.9	0	FALSE
Tree-Thin+Seed.ms	MSu-U	TE	MSu-U	ES	100	300	0	9999	0.01	0.1	0	FALSE
Pinyon-Juniper Woodland												
ReplacementFire	PJ-A	AL	PJ-A	AL	0	9	0	9999	0.005	1	0	FALSE
ReplacementFire	PJ-B	OP	PJ-A	AL	10	29	0	9999	0.005	1	0	FALSE
AG-Invasion	PJ-C	OP	PJ-U	TA	30	99	0	9999	0.001	1	0	TRUE
Drought	PJ-C	OP	PJ-B	OP	30	99	0	9999	0.006	0.1	0	FALSE
Drought	PJ-C	OP	PJ-C	OP	30	99	0	9999	0.0056	0.9	-999	FALSE
ReplacementFire	PJ-C	OP	PJ-A	AL	30	99	0	9999	0.005	1	0	FALSE
AG-Invasion	PJ-D	OP	PJ-U	TA	100	999	0	9999	0.001	1	0	TRUE
Drought	PJ-D	OP	PJ-D	OP	100	999	0	9999	0.0168	0.9	-999	FALSE
Drought	PJ-D	OP	PJ-C	OP	100	999	0	9999	0.0171	0.07	0	FALSE
Drought	PJ-D	OP	PJ-B	OP	100	999	0	9999	0.0167	0.03	0	FALSE
ReplacementFire	PJ-D	OP	PJ-A	AL	100	999	0	9999	0.002	1	0	FALSE
SurfaceFire	PJ-D	OP	PJ-D	OP	100	999	0	9999	0.001	1	0	FALSE
Herbicide+Seed.pj	PJ-U	AG	PJ-A	AL	0	999	0	9999	0.01	0.6	0	FALSE
Herbicide+Seed.pj	PJ-U	AG	PJ-U	AG	0	999	0	9999	0.01	0.4	0	FALSE
ReplacementFire	PJ-U	AG	PJ-U	AG	0	999	0	9999	0.1	1	-999	FALSE
Drought	PJ-U	TA	PJ-U	TA	100	999	0	9999	0.0056	0.9	-999	FALSE
Drought	PJ-U	TA	PJ-U	AG	100	999	0	9999	0.006	0.1	0	FALSE
ReplacementFire	PJ-U	TA	PJ-U	AG	100	999	0	9999	0.005	1	0	FALSE
Ponderosa Pine												

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
AltSuccession	PP-A	AL	PP-B	CL	0	39	38	9999	0.33	1	0	FALSE
Cattle-Grazing	PP-A	AL	PP-A	AL	0	39	0	9999	1	0.16	1	FALSE
Excessive-Herbivory-Cattle	PP-A	AL	PP-A	AL	0	39	0	9999	0.001	1	5	FALSE
Excessive-Herbivory-Sheep	PP-A	AL	PP-A	AL	0	39	0	9999	0.001	1	5	FALSE
ReplacementFire	PP-A	AL	PP-A	AL	0	39	0	9999	0.01	1	-999	FALSE
RxFire.pp	PP-A	AL	PP-A	AL	2	39	0	9999	0.01	0.5	1	TRUE
RxFire.pp	PP-A	AL	PP-A	AL	2	39	0	9999	0.01	0.5	0	FALSE
Salvage.pp	PP-A	AL	PP-A	AL	0	5	0	9999	0.01	1	0	FALSE
Sheep-Grazing	PP-A	AL	PP-A	AL	0	39	0	9999	1	0.08	-1	FALSE
AG-Invasion	PP-B	CL	PP-U	TA	40	159	0	9999	0.001	1	0	FALSE
Cattle-Grazing	PP-B	CL	PP-B	CL	40	159	0	9999	1	0.16	1	FALSE
Excessive-Herbivory-Cattle	PP-B	CL	PP-B	CL	40	159	0	9999	0.001	1	5	FALSE
Excessive-Herbivory-Sheep	PP-B	CL	PP-B	CL	40	159	0	9999	0.001	1	5	FALSE
Fecon-RxFire.pp	PP-B	CL	PP-C	OP	40	159	0	9999	0.01	1	0	TRUE
Insect/Disease	PP-B	CL	PP-C	OP	40	159	0	9999	0.005	1	0	FALSE
Mechanical-Thinning.pp	PP-B	CL	PP-C	OP	40	159	0	9999	0.01	1	0	TRUE
MixedFire	PP-B	CL	PP-C	OP	40	159	0	9999	0.04	1	0	TRUE
Partial-Harvest.pp	PP-B	CL	PP-C	OP	40	159	0	9999	0.01	1	0	TRUE
ReplacementFire	PP-B	CL	PP-A	AL	40	159	0	9999	0.0067	1	0	FALSE
RxFire.pp	PP-B	CL	PP-C	OP	40	159	0	9999	0.01	0.5	0	TRUE
RxFire.pp	PP-B	CL	PP-B	CL	40	159	0	9999	0.01	0.3	0	TRUE
RxFire.pp	PP-B	CL	PP-A	AL	40	159	0	9999	0.01	0.2	0	TRUE
Sheep-Grazing	PP-B	CL	PP-B	CL	40	159	0	9999	1	0.08	0	FALSE
AG-Invasion	PP-C	OP	PP-U	TA	40	159	0	9999	0.001	1	0	TRUE
AltSuccession	PP-C	OP	PP-B	CL	40	159	80	9999	0.33	1	0	TRUE
Cattle-Grazing	PP-C	OP	PP-C	OP	40	159	0	9999	1	0.16	1	FALSE
Excessive-Herbivory-Cattle	PP-C	OP	PP-C	OP	40	159	0	9999	0.001	1	5	FALSE
Excessive-Herbivory-Sheep	PP-C	OP	PP-C	OP	40	159	0	9999	0.001	1	5	FALSE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
Partial-Harvest.pp	PP-C	OP	PP-C	OP	40	159	0	9999	0.01	1	5	TRUE
ReplacementFire	PP-C	OP	PP-A	AL	40	159	0	9999	0.0003	1	0	FALSE
RxFire.pp	PP-C	OP	PP-C	OP	40	159	0	9999	0.01	0.7	1	TRUE
RxFire.pp	PP-C	OP	PP-C	OP	40	159	0	9999	0.01	0.3	0	FALSE
Sheep-Grazing	PP-C	OP	PP-C	OP	40	159	0	9999	1	0.08	-1	FALSE
SurfaceFire	PP-C	OP	PP-C	OP	40	159	0	9999	0.04	1	0	FALSE
AG-Invasion	PP-D	OP	PP-U	TA	160	500	0	9999	0.001	1	0	FALSE
AltSuccession	PP-D	OP	PP-E	CL	160	500	80	9999	0.33	1	0	TRUE
Cattle-Grazing	PP-D	OP	PP-D	OP	160	500	0	9999	1	0.16	1	FALSE
Excessive-Herbivory-Cattle	PP-D	OP	PP-D	OP	160	500	0	9999	0.001	1	5	FALSE
Excessive-Herbivory-Sheep	PP-D	OP	PP-D	OP	160	500	0	9999	0.001	1	5	FALSE
Insect/Disease	PP-D	OP	PP-C	OP	160	500	0	9999	0.005	1	0	FALSE
Partial-Harvest.pp	PP-D	OP	PP-C	OP	160	500	0	9999	0.01	1	0	FALSE
Regen-Harvest.pp	PP-D	OP	PP-A	AL	160	500	0	9999	0.01	1	0	FALSE
ReplacementFire	PP-D	OP	PP-A	AL	160	500	0	9999	0.0025	1	0	FALSE
RxFire.pp	PP-D	OP	PP-D	OP	160	500	0	9999	0.01	0.3	0	FALSE
RxFire.pp	PP-D	OP	PP-A	AL	160	500	0	9999	0.01	0.01	0	FALSE
RxFire.pp	PP-D	OP	PP-D	OP	160	500	0	9999	0.01	0.69	1	FALSE
Senescence	PP-D	OP	PP-C	OP	400	500	0	9999	0.01	1	0	FALSE
Sheep-Grazing	PP-D	OP	PP-D	OP	160	500	0	9999	1	0.08	-1	FALSE
SurfaceFire	PP-D	OP	PP-D	OP	160	500	0	9999	0.05	1	0	FALSE
AG-Invasion	PP-E	CL	PP-U	TA	160	500	0	9999	0.001	1	0	FALSE
Cattle-Grazing	PP-E	CL	PP-E	CL	160	500	0	9999	1	0.16	1	FALSE
Excessive-Herbivory-Cattle	PP-E	CL	PP-E	CL	160	500	0	9999	0.001	1	5	FALSE
Excessive-Herbivory-Sheep	PP-E	CL	PP-E	CL	160	500	0	9999	0.001	1	5	FALSE
Fecon-RxFire.pp	PP-E	CL	PP-D	OP	160	500	0	9999	0.01	1	0	TRUE
Insect/Disease	PP-E	CL	PP-D	OP	160	209	0	9999	0.005	1	0	FALSE
Insect/Disease	PP-E	CL	PP-D	OP	210	500	0	9999	0.01	1	0	FALSE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
Mechanical-Thinning.pp	PP-E	CL	PP-D	OP	160	500	0	9999	0.01	1	0	FALSE
MixedFire	PP-E	CL	PP-D	OP	160	500	0	9999	0.05	1	0	TRUE
Partial-Harvest.pp	PP-E	CL	PP-D	OP	160	500	0	9999	0.01	1	0	TRUE
Regen-Harvest.pp	PP-E	CL	PP-A	AL	160	500	0	9999	0.01	1	0	FALSE
ReplacementFire	PP-E	CL	PP-A	AL	160	209	0	9999	0.0067	1	0	FALSE
ReplacementFire	PP-E	CL	PP-A	AL	210	500	0	9999	0.005	1	0	FALSE
RxFire.pp	PP-E	CL	PP-E	CL	160	500	0	9999	0.01	0.3	0	FALSE
RxFire.pp	PP-E	CL	PP-A	AL	160	500	0	9999	0.01	0.35	0	FALSE
RxFire.pp	PP-E	CL	PP-E	CL	160	500	0	9999	0.01	0.35	10	FALSE
Senescence	PP-E	CL	PP-B	CL	400	500	0	9999	0.01	1	0	FALSE
Sheep-Grazing	PP-E	CL	PP-E	CL	160	500	0	9999	1	0.08	0	FALSE
Herbicide+Seed.pp	PP-U	AG	PP-A	AL	0	39	0	9999	0.01	0.8	0	FALSE
Herbicide+Seed.pp	PP-U	AG	PP-U	AG	0	39	0	9999	0.01	0.2	0	FALSE
ReplacementFire	PP-U	AG	PP-U	AG	0	39	0	9999	0.1	1	-999	FALSE
Cattle-Grazing	PP-U	TA	PP-U	TA	40	999	0	9999	1	0.1	1	FALSE
Excessive-Herbivory-Cattle	PP-U	TA	PP-U	TA	40	999	0	9999	0.001	1	5	FALSE
Excessive-Herbivory-Sheep	PP-U	TA	PP-U	TA	40	999	0	9999	0.001	1	5	FALSE
Insect/Disease	PP-U	TA	PP-U	TA	40	999	0	9999	0.005	0.9	0	FALSE
Insect/Disease	PP-U	TA	PP-U	AG	40	999	0	9999	0.005	0.1	0	FALSE
MixedFire	PP-U	TA	PP-U	TA	40	999	0	9999	0.04	0.75	0	FALSE
MixedFire	PP-U	TA	PP-U	AG	40	999	0	9999	0.04	0.25	0	FALSE
Natural-Recovery	PP-U	TA	PP-B	CL	40	159	30	9999	0.01	1	0	TRUE
Natural-Recovery	PP-U	TA	PP-E	CL	160	999	30	9999	0.01	1	0	TRUE
Partial-Harvest.pp	PP-U	TA	PP-U	TA	40	500	0	9999	0.01	1	-999	FALSE
ReplacementFire	PP-U	TA	PP-U	AG	40	999	0	9999	0.0067	1	0	FALSE
Sheep-Grazing	PP-U	TA	PP-U	TA	40	999	0	9999	1	0.08	1	FALSE
Tree-Thin+Hrbx+Seed.pp	PP-U	TA	PP-A	AL	40	500	0	9999	0.01	0.8	0	FALSE
Tree-Thin+Hrbx+Seed.pp	PP-U	TA	PP-U	AG	40	500	0	9999	0.01	0.2	0	FALSE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
Spruce-Fir												
Competition/Maintenance	SF-A	AL	SF-A	AL	11	39	0	9999	0.002	1	-10	FALSE
ReplacementFire	SF-A	AL	SF-A	AL	0	10	0	9999	0.0133	1	-999	FALSE
ReplacementFire	SF-A	AL	SF-A	AL	11	39	0	9999	0.005	1	-999	FALSE
Salvage.sf	SF-A	AL	SF-A	AL	0	3	0	9999	0.01	1	0	FALSE
Competition/Maintenance	SF-B	CL	SF-B	CL	40	129	0	9999	0.001	1	-10	FALSE
Insect/Disease	SF-B	CL	SF-C	OP	70	129	0	9999	0.002	1	0	FALSE
Partial-Harvest.sf	SF-B	CL	SF-A	AL	40	129	0	9999	0.01	1	0	FALSE
Partial-Harvest.sf	SF-B	CL	SF-C	OP	40	129	0	9999	0.01	1	0	TRUE
ReplacementFire	SF-B	CL	SF-A	AL	40	69	0	9999	0.005	1	0	FALSE
ReplacementFire	SF-B	CL	SF-A	AL	70	129	0	999	0.0025	1	0	FALSE
RxFire.sf	SF-B	CL	SF-A	AL	40	69	0	9999	0.01	0.5	0	FALSE
RxFire.sf	SF-B	CL	SF-A	AL	70	129	0	9999	0.01	0.5	0	FALSE
RxFire.sf	SF-B	CL	SF-B	CL	70	129	0	9999	0.01	0.5	-25	FALSE
RxFire.sf	SF-B	CL	SF-B	CL	40	69	0	9999	0.01	0.51	0	FALSE
SurfaceFire	SF-B	CL	SF-B	CL	70	129	0	9999	0.0025	1	0	FALSE
AltSuccession	SF-C	OP	SF-B	CL	40	129	60	9999	1	0.33	0	TRUE
Insect/Disease	SF-C	OP	SF-C	OP	70	129	0	9999	0.002	1	0	FALSE
Partial-Harvest.sf	SF-C	OP	SF-C	OP	40	129	0	9999	0.01	1	0	FALSE
Partial-Harvest.sf	SF-C	OP	SF-A	AL	40	129	0	9999	0.01	1	0	FALSE
ReplacementFire	SF-C	OP	SF-A	AL	40	69	0	9999	0.008	1	0	FALSE
ReplacementFire	SF-C	OP	SF-A	AL	70	129	0	9999	0.0072	1	0	FALSE
Salvage.sf	SF-C	OP	SF-C	OP	40	129	0	9999	0.01	1	0	FALSE
SurfaceFire	SF-C	OP	SF-C	OP	69	129	0	9999	0.0008	1	0	FALSE
Insect/Disease	SF-D	CL	SF-C	OP	130	500	0	9999	0.004	1	0	FALSE
Partial-Harvest.sf	SF-D	CL	SF-C	OP	130	500	0	9999	0.01	1	0	FALSE
Regen-Harvest.sf	SF-D	CL	SF-A	AL	130	500	0	9999	0.01	1	0	FALSE
ReplacementFire	SF-D	CL	SF-A	AL	130	500	0	9999	0.0036	1	0	FALSE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
RxFire.sf	SF-D	CL	SF-C	OP	130	500	0	9999	0.01	0.5	0	FALSE
RxFire.sf	SF-D	CL	SF-C	OP	130	500	0	9999	0.01	0.25	0	FALSE
RxFire.sf	SF-D	CL	SF-D	CL	130	500	0	9999	0.01	0.25	0	FALSE
Salvage.sf	SF-D	CL	SF-D	CL	130	500	0	9999	0.01	1	0	FALSE
Senescence	SF-D	CL	SF-C	OP	130	500	0	9999	0.002	1	0	FALSE
SurfaceFire	SF-D	CL	SF-D	CL	130	500	0	9999	0.0014	1	0	FALSE
Wyoming Big Sagebrush												
AG-Invasion	WS-A	AL	WS-U	SAP	10	19	0	9999	0.005	1	0	TRUE
Cattle-Grazing	WS-A	AL	WS-A	AL	3	19	0	9999	1	0.16	1	FALSE
Excessive-Herbivory-Cattle	WS-A	AL	WS-A	AL	3	4	0	9999	0.001	1	5	FALSE
Excessive-Herbivory-Cattle	WS-A	AL	WS-U	ES	5	19	0	9999	0.001	1	0	FALSE
Excessive-Herbivory-Sheep	WS-A	AL	WS-A	AL	3	4	0	9999	0.001	1	5	FALSE
Excessive-Herbivory-Sheep	WS-A	AL	WS-U	ES	5	19	0	9999	0.001	1	0	FALSE
ReplacementFire	WS-A	AL	WS-A	AL	0	19	0	9999	0.002	1	-999	FALSE
Sheep-Grazing	WS-A	AL	WS-A	AL	3	19	0	9999	1	0.08	-1	FALSE
AG-Invasion	WS-B	OP	WS-U	SAP	20	59	0	9999	0.001	1	0	TRUE
Cattle-Grazing	WS-B	OP	WS-B	OP	20	59	0	9999	1	0.16	1	FALSE
Excessive-Herbivory-Cattle	WS-B	OP	WS-U	ES	20	59	0	9999	0.001	1	0	FALSE
Excessive-Herbivory-Sheep	WS-B	OP	WS-U	ES	20	59	0	9999	0.001	1	0	FALSE
ReplacementFire	WS-B	OP	WS-A	AL	20	59	0	9999	0.01	1	0	FALSE
RxFire.ws	WS-B	OP	WS-A	AL	20	59	0	9999	0.01	0.7	0	FALSE
RxFire.ws	WS-B	OP	WS-B	OP	20	59	0	9999	0.01	0.3	0	FALSE
Sheep-Grazing	WS-B	OP	WS-B	OP	20	59	0	9999	1	0.08	-1	FALSE
AG-Invasion	WS-C	CL	WS-U	SAP	60	300	0	9999	0.005	1	0	TRUE
Cattle-Grazing	WS-C	CL	WS-C	CL	60	300	0	9999	1	0.16	1	TRUE
Chaining+Seed.ws	WS-C	CL	WS-B	OP	60	300	0	9999	0.01	0.9	0	FALSE
Chaining+Seed.ws	WS-C	CL	WS-A	AL	60	300	0	9999	0.01	0.1	0	FALSE
Drought	WS-C	CL	WS-B	OP	60	300	0	9999	0.006	0.1	0	FALSE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
Drought	WS-C	CL	WS-C	CL	60	300	0	9999	0.0056	0.9	-999	FALSE
Excessive-Herbivory-Cattle	WS-C	CL	WS-C	CL	60	300	0	9999	0.001	0.9	5	TRUE
Excessive-Herbivory-Cattle	WS-C	CL	WS-U	DP	60	300	0	9999	0.001	0.1	0	TRUE
Excessive-Herbivory-Sheep	WS-C	CL	WS-C	CL	60	300	0	9999	0.001	0.9	5	FALSE
Excessive-Herbivory-Sheep	WS-C	CL	WS-U	DP	60	300	0	9999	0.001	0.1	0	TRUE
Exotic-Forb.ws	WS-C	CL	WS-U	EF	60	300	0	9999	0.001	1	0	TRUE
Herbicide-Spyke.ws	WS-C	CL	WS-B	OP	60	300	0	9999	0.01	1	0	FALSE
Mechanical-Thinning.ws	WS-C	CL	WS-B	OP	60	300	0	9999	0.01	0.9	0	FALSE
Mechanical-Thinning.ws	WS-C	CL	WS-A	AL	60	300	0	9999	0.01	0.1	0	FALSE
Mechanical-Thinning+Seed.ws	WS-C	CL	WS-B	OP	60	300	0	9999	0.01	0.9	0	FALSE
Mechanical-Thinning+Seed.ws	WS-C	CL	WS-A	AL	60	300	0	9999	0.01	0.1	0	FALSE
ReplacementFire	WS-C	CL	WS-A	AL	60	300	0	9999	0.01	1	0	FALSE
RxFire.ws	WS-C	CL	WS-A	AL	60	300	0	9999	0.01	0.7	0	FALSE
RxFire.ws	WS-C	CL	WS-C	CL	60	300	0	9999	0.01	0.3	0	FALSE
Sheep-Grazing	WS-C	CL	WS-C	CL	60	300	0	9999	1	0.08	-1	FALSE
Tree-Invasion	WS-C	CL	WS-D	OP	100	300	0	9999	0.01	1	0	FALSE
AG-Invasion	WS-D	OP	WS-U	SAP	100	124	0	9999	0.005	0.5	0	FALSE
AG-Invasion	WS-D	OP	WS-U	TA	100	124	0	9999	0.005	0.5	0	FALSE
Cattle-Grazing	WS-D	OP	WS-D	OP	125	149	0	9999	1	0.16	1	TRUE
Chaining+Seed.ws	WS-D	OP	WS-A	AL	100	149	0	9999	0.01	0.1	0	FALSE
Chaining+Seed.ws	WS-D	OP	WS-B	OP	100	149	0	9999	0.01	0.9	0	FALSE
Drought	WS-D	OP	WS-C	CL	100	149	0	9999	0.0056	0.9	0	FALSE
Drought	WS-D	OP	WS-B	OP	100	149	0	9999	0.006	0.1	0	FALSE
Excessive-Herbivory-Cattle	WS-D	OP	WS-D	OP	100	149	0	9999	0.001	0.9	5	TRUE
Excessive-Herbivory-Cattle	WS-D	OP	WS-U	DP	100	149	0	9999	0.001	0.1	0	TRUE
Excessive-Herbivory-Sheep	WS-D	OP	WS-D	OP	100	149	0	9999	0.001	0.9	5	TRUE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
Excessive-Herbivory-Sheep	WS-D	OP	WS-U	DP	100	149	0	9999	0.001	0.1	0	TRUE
Exotic-Forb.ws	WS-D	OP	WS-U	EF	100	149	0	9999	0.001	1	0	TRUE
Herbicide-Spyke.ws	WS-D	OP	WS-B	OP	100	149	0	9999	0.01	1	0	FALSE
Masticate-Trees.ws	WS-D	OP	WS-C	CL	100	149	0	9999	0.01	1	0	TRUE
Mechanical-Thinning.ws	WS-D	OP	WS-B	OP	100	149	0	9999	0.01	0.9	0	FALSE
Mechanical-Thinning.ws	WS-D	OP	WS-A	AL	100	149	0	9999	0.01	0.1	0	FALSE
Mechanical-Thinning+Seed.ws	WS-D	OP	WS-A	AL	100	149	0	9999	0.01	0.1	0	FALSE
Mechanical-Thinning+Seed.ws	WS-D	OP	WS-B	OP	100	149	0	9999	0.01	0.9	0	FALSE
ReplacementFire	WS-D	OP	WS-A	AL	100	149	0	9999	0.01	1	0	FALSE
RxFire.ws	WS-D	OP	WS-A	AL	100	149	0	9999	0.01	0.7	0	FALSE
RxFire.ws	WS-D	OP	WS-D	OP	100	149	0	9999	0.01	0.3	0	FALSE
Sheep-Grazing	WS-D	OP	WS-D	OP	100	149	0	9999	1	0.08	1	FALSE
AG-Invasion	WS-E	CL	WS-U	TA	150	300	0	9999	0.005	1	0	FALSE
Chaining+Seed.ws	WS-E	CL	WS-B	OP	150	300	0	9999	0.01	0.5	0	FALSE
Chaining+Seed.ws	WS-E	CL	WS-A	AL	150	300	0	9999	0.01	0.5	0	FALSE
Drought	WS-E	CL	WS-E	CL	150	300	0	9999	0.0056	0.9	5	FALSE
Drought	WS-E	CL	WS-B	OP	150	300	0	9999	0.006	0.1	0	FALSE
Exotic-Forb.ws	WS-E	CL	WS-U	EF	150	300	0	9999	0.001	1	0	TRUE
Herbicide-Spyke.ws	WS-E	CL	WS-B	OP	150	300	0	9999	0.01	0.9	0	FALSE
Herbicide-Spyke.ws	WS-E	CL	WS-A	AL	150	300	0	9999	0.01	0.1	0	FALSE
Masticate-Trees.ws	WS-E	CL	WS-B	OP	150	300	0	9999	0.01	1	0	FALSE
ReplacementFire	WS-E	CL	WS-A	AL	150	300	0	9999	0.008	1	0	FALSE
RxFire.ws	WS-E	CL	WS-A	AL	150	300	0	9999	0.01	0.7	0	FALSE
RxFire.ws	WS-E	CL	WS-E	CL	150	300	0	9999	0.01	0.3	0	FALSE
Tree-Encroachment	WS-E	CL	WS-U	TA	200	249	0	9999	0.005	1	0	TRUE
Tree-Encroachment	WS-E	CL	WS-U	TA	250	300	0	9999	0.01	1	0	TRUE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
Cattle-Grazing	WS-U	AG	WS-U	AG	0	300	0	9999	1	0.16	1	FALSE
Exotic-Forb.ws	WS-U	AG	WS-U	EF	0	300	0	9999	0.001	1	0	TRUE
Herbicide-Plateau+Seed.ws	WS-U	AG	WS-U	SD	0	300	0	9999	0.01	0.6	0	FALSE
Herbicide-Plateau+Seed.ws	WS-U	AG	WS-U	AG	0	300	0	9999	0.01	0.4	0	FALSE
ReplacementFire	WS-U	AG	WS-U	AG	0	300	0	9999	0.1	1	-999	FALSE
Sheep-Grazing	WS-U	AG	WS-U	AG	0	300	0	9999	1	0.08	0	FALSE
AG-Invasion	WS-U	DP	WS-U	SA	60	300	0	9999	0.005	1	0	TRUE
Drought	WS-U	DP	WS-U	DP	60	300	0	9999	0.0056	0.9	-999	FALSE
Drought	WS-U	DP	WS-U	ES	60	300	0	9999	0.006	0.1	0	FALSE
Exotic-Forb.ws	WS-U	DP	WS-U	EF	60	300	0	9999	0.001	1	0	TRUE
Mow+Seed.ws	WS-U	DP	WS-U	SD	60	300	0	9999	0.01	0.6	0	FALSE
Mow+Seed.ws	WS-U	DP	WS-U	ES	60	300	0	9999	0.01	0.4	0	FALSE
ReplacementFire	WS-U	DP	WS-U	ES	60	300	0	9999	0.008	1	0	FALSE
Sheep-Grazing	WS-U	DP	WS-U	DP	60	300	0	9999	1	0.08	-1	FALSE
Tree-Invasion	WS-U	DP	WS-U	TA	60	300	0	9999	0.01	1	0	FALSE
Herbicide-Noxious-Weeds.ws	WS-U	EF	WS-A	AL	0	19	0	9999	0.01	1	0	TRUE
Herbicide-Noxious-Weeds.ws	WS-U	EF	WS-B	OP	20	59	0	9999	0.01	1	0	TRUE
Herbicide-Noxious-Weeds.ws	WS-U	EF	WS-C	CL	60	99	0	9999	0.01	1	0	TRUE
Herbicide-Noxious-Weeds.ws	WS-U	EF	WS-D	OP	100	149	0	9999	0.01	1	0	TRUE
Herbicide-Noxious-Weeds.ws	WS-U	EF	WS-C	CL	150	300	0	9999	0.01	1	0	TRUE
ReplacementFire	WS-U	EF	WS-U	EF	0	999	0	9999	0.008	1	0	FALSE
ReplacementFire	WS-U	ES	WS-U	ES	0	300	0	9999	0.01	1	-999	FALSE
Tree-Invasion	WS-U	ES	WS-U	TA	0	300	0	9999	0.005	1	0	FALSE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
Cattle-Grazing	WS-U	SA	WS-U	SA	22	300	0	9999	1	0.16	1	FALSE
Drought	WS-U	SA	WS-U	SA	22	300	0	9999	0.0056	0.9	-999	FALSE
Drought	WS-U	SA	WS-U	AG	22	300	0	9999	0.006	0.1	0	FALSE
Mow+Hrbx+Seed.ws	WS-U	SA	WS-U	SD	22	300	0	9999	0.01	0.6	0	FALSE
Mow+Hrbx+Seed.ws	WS-U	SA	WS-U	AG	22	300	0	9999	0.01	0.4	0	FALSE
ReplacementFire	WS-U	SA	WS-U	AG	22	300	0	9999	0.04	1	0	FALSE
Sheep-Grazing	WS-U	SA	WS-U	SA	22	300	0	9999	1	0.08	-1	FALSE
Tree-Invasion	WS-U	SA	WS-U	TA	22	300	0	9999	0.01	1	0	FALSE
Cattle-Grazing	WS-U	SAP	WS-U	SAP	21	59	0	9999	1	0.16	3	TRUE
Cattle-Grazing	WS-U	SAP	WS-U	SAP	60	300	0	9999	1	0.08	5	TRUE
Cattle-Grazing	WS-U	SAP	WS-U	SA	60	300	0	9999	1	0.08	0	FALSE
Drought	WS-U	SAP	WS-U	SAP	21	300	0	9999	0.0056	0.9	-999	FALSE
Drought	WS-U	SAP	WS-U	AG	21	300	0	9999	0.006	0.1	0	FALSE
Exotic-Forb.ws	WS-U	SAP	WS-U	EF	21	300	0	9999	0.001	1	0	TRUE
Herbicide-Plateau.ws	WS-U	SAP	WS-B	OP	21	59	0	9999	0.01	0.8	0	TRUE
Herbicide-Plateau.ws	WS-U	SAP	WS-C	CL	60	300	0	9999	0.01	0.8	0	TRUE
Herbicide-Plateau.ws	WS-U	SAP	WS-U	SAP	21	300	0	9999	0.01	0.2	0	FALSE
Natural-Recovery	WS-U	SAP	WS-C	CL	21	300	20	9999	0.001	1	0	FALSE
ReplacementFire	WS-U	SAP	WS-U	AG	21	300	0	9999	0.0133	0.9	0	FALSE
ReplacementFire	WS-U	SAP	WS-A	AL	21	300	0	9999	0.013	0.1	0	FALSE
Sheep-Grazing	WS-U	SAP	WS-U	SAP	21	300	0	9999	1	0.08	-1	FALSE
Tree-Invasion	WS-U	SAP	WS-U	TA	100	300	0	9999	0.01	1	0	FALSE
AG-Invasion	WS-U	SD	WS-U	AG	0	24	0	9999	0.005	1	0	TRUE
AG-Invasion	WS-U	SD	WS-U	SA	25	300	0	9999	0.005	1	0	TRUE
Cattle-Grazing	WS-U	SD	WS-U	SD	3	300	0	9999	1	0.16	1	TRUE
Natural-Recovery	WS-U	SD	WS-A	AL	0	19	5	9999	0.1	1	0	TRUE
Natural-Recovery	WS-U	SD	WS-B	OP	20	59	5	9999	0.1	1	0	TRUE
Natural-Recovery	WS-U	SD	WS-C	CL	60	300	5	9999	0.1	1	0	TRUE

Appendix 4. Probabilistic transitions for biophysical systems of the Powell Ranger District. Output obtained from VDDT database.

Disturbance	From-Class	From-Structure	To-Class	To-Structure	Min-Age	Max-Age	TSD-Min	TSD-Max	Prob/yr	Prop.	Rel-Age	Keep-Rel-Age
ReplacementFire	WS-U	SD	WS-U	SD	0	300	0	9999	0.002	1	-999	FALSE
Sheep-Grazing	WS-U	SD	WS-U	SD	3	300	0	9999	1	0.08	-1	TRUE
Drought	WS-U	TA	WS-U	ES	125	300	0	9999	0.006	0.05	0	FALSE
Drought	WS-U	TA	WS-U	TA	125	300	0	9999	0.0056	0.9	-999	FALSE
Drought	WS-U	TA	WS-U	AG	125	300	0	9999	0.006	0.05	0	FALSE
ReplacementFire	WS-U	TA	WS-U	AG	125	300	0	9999	0.008	0.8	0	FALSE
ReplacementFire	WS-U	TA	WS-U	ES	125	300	0	9999	0.008	0.2	0	FALSE
Tree-Thin+Hrbx+Seed.ws	WS-U	TA	WS-U	SD	125	300	0	9999	0.01	0.6	0	FALSE
Tree-Thin+Hrbx+Seed.ws	WS-U	TA	WS-U	ES	125	300	0	9999	0.01	0.2	0	FALSE
Tree-Thin+Hrbx+Seed.ws	WS-U	TA	WS-U	AG	125	300	0	9999	0.01	0.2	0	FALSE

Appendix 5. Management strategies for focal ecosystems of the Powell District project area.

Ecological System	Management Action in Model	Management Action Description	From Class	To Class	Cost/ Acre	Comment
Aspen-Mixed Conifer	RxFire	Prescribed fire to increase early succession class	C, D, E	A	$120	30% remains in class, except 0% for E
Aspen-Mixed Conifer	Conifer removal	Remove merchantable & non-merchantable conifer except seedlings to prevent loss of aspen	D, E	B, C	$(50)	
Aspen-Mixed Conifer	Partial Harvest	Commercial harvest of trees (conifers & older aspen) resulting in a thinned aspen stand	D, E	B, C	$(200)	
Aspen-Mixed Conifer	Fence	Fencing to maintain early succession class	A	Fence-A	$40	
Aspen-Spruce Fir	RxFire	Prescribed fire to increase early succession class	B, C, D	A	$100	30% remains in class, except 20% for D
Aspen-Spruce Fir	Conifer removal	Remove merchantable & non-merchantable conifer except seedlings to prevent loss of aspen	C, D	B	$(50)	
Aspen-Spruce Fir	Partial Harvest	Commercial harvest of trees (conifers & older aspen) resulting in a thinned aspen stand	D	B	$(200)	
Black/Low Sagebrush	Mechanical Thinning	Harrow without seeding	C	B	$100	
Black/Low Sagebrush	Mechanical Thinning	Harrow with seeding added to create a more diverse understory	C	B	$180	No effect shows in model, but improves resulting understory in Class B
Black/Low Sagebrush	Tree-thin+herb+seed	Masticate tree encroached areas, with seeding	TE, TA	SD	$160	Split 50-50 between TE and TA in model runs
Black/Low Sagebrush	Masticate	Masticate "Christmas trees"	C	C	$80	No seed required.
Gambel Oak/Mixed Brush	Mechanical Thinning	Mechanically thin brush with trees with Fecon	D	A	$80	
Gambel Oak/Mixed Brush	Tree-thin+seed	Masticate plus seed	TE	A	$120	
Gambel Oak/Mixed Brush	RxFire	Prescribed fire to increase early succession class	All	A	$90	needs to be done in small blocks
Gambel Oak/Mixed Brush	Chainsaw thinning	Hand thin	D	B	$125	
Mixed Conifer	RxFire	Prescribed fire to increase open succession class	A, B, C, D, E	Open (and A to A)	$125	% remaining in class varies
Mixed Conifer	Mechanical Thinning	Thinning from below	Closed (B, E)	Open	$150	B to C, E to D
Mixed Conifer	Partial Harvest	Commercial harvest resulting in a more uneven aged forest	B, C, D, E	Varies	$(200)	

Appendix 5. Management strategies for focal ecosystems of the Powell District project area.

Ecological System	Management Action in Model	Management Action Description	From Class	To Class	Cost/ Acre	Comment
Mixed Conifer	Regen Harvest	Commercial harvest of majority of overstory; maintain seed trees	D, E	A	$(200)	
Mixed Conifer	Salvage	Salvage logging	A	A	$(200)	Dead snags either present or absent do not change class status; revenue generation
Montane Sagebrush Steppe	Chaining	Chain late-closed succession class to restore mid succession classes	E	B, C	$40	
Montane Sagebrush Steppe	Masticate	Masticate emerging conifers to prevent future tree encroachment and restore early succession classes	E	A, B	$80	
Montane Sagebrush Steppe	RxFire	Prescribed fire in late succession classes to restore early class	C, D, E	A	$50	
Montane Sagebrush Steppe	Herbicide-Spike	Apply herbicide-spyke for to prevent Early Shrubs	D, E	B	$70	
Montane-Subalpine Riparian	Weed Inventory	Periodic weed inventory	All Classes	n/a	$-	
Montane-Subalpine Riparian	Exotic Control	Spot treatment of invasive weeds (multiple treatments in a year)	EF	B	$50	40% remains in Exotic Forbs
Montane-Subalpine Riparian	Thinning	Thinning or fire for encroached trees	"PJ"	C	$150	
Montane-Subalpine Riparian		Beaver reintroduction	A, B, C, SFE	Maintain, or send back B & C	$-	Beaver herbivory is in model. Increased transition multiplier to reflect reintroduction.
Montane-Subalpine Riparian	RxFire+Herbicide	Fire or rose reduction followed by herbicide	SFE	A	$150	
Ponderosa Pine	RxFire	Prescribed fire to increase open succession class	A, B, C, D, E	Open (and A to A)	$100	% remaining in class varies
Ponderosa Pine	Mechanical Thinning	Thinning from below	Closed (B, E)	Open	$150	B to C, E to D
Ponderosa Pine	Partial Harvest	Commercial harvest of ponderosa pines resulting in a more open forest	B, C, D, E	Varies	$(200)	
Ponderosa Pine	Regen Harvest	Shelterwood harvest of majority of overstory; maintain seed trees	D, E	A	$(200)	
Ponderosa Pine	Fecon-Burn	Fecon machine thinning of conifers followed by prescribed fire	Closed (B, E)	Open	$175	E to D; B to C

Appendix 5. Management strategies for focal ecosystems of the Powell District project area.

Ecological System	Management Action in Model	Management Action Description	From Class	To Class	Cost/ Acre	Comment
Ponderosa Pine	Salvage	Salvage logging	A	A	$(200)	Dead snags either present or absent do not change class status; revenue generation
Wyoming/Basin Big Sagebrush	Masticate	Masticate "Christmas trees" with bobcat	D, E	C, B	$80	D to C; E to B
Wyoming/Basin Big Sagebrush	Herbicide-Spike	Apply herbicide-spike for to prevent P-J, Early Shrubs	E	A, B	$60	higher herbicide rate needed for PJ
Wyoming/Basin Big Sagebrush	Chaining+Seed	Seed with native-nonnative mix	C, D, E	A, B	$70	
Wyoming/Basin Big Sagebrush	Tree-thin+herb+seed	Masticate tree encroached areas, with seeding	TA	Seeded	$160	
Wyoming/Basin Big Sagebrush	Mow-herb-seed	Mow plus herbicide & seed to treat shrubs with annual grass	SA	Seeded	$220	
Wyoming/Basin Big Sagebrush	Herbicide-Plateau	Apply Plateau but not aerially to treat cheatgrass under shrubs	SAP	B, C	$50	
Wyoming/Basin Big Sagebrush	Plateau+Seed	Apply prescribed fire or Plateau to treat cheatgrass, plus seeding	AG	Seeded	$70	

Uncharacteristic Classes Codes for Dixie-Fishlake Models	
Annual grass	AG
Entrenched river, creek or meadow	DE
Depleted (of understory or aspen clone)	DP
Early shrubs (e.g. rabbitbrush)	ES
Exotic forbs	EF
Elk wallow	EW
Seeded	SD
Shrub-forb encroached	SFE
Shrubs with annual grass	SA
Shrubs with annual & perennial grass	SAP
Trees with annual grass	TA
Tree-encroached	TE

Appendix 6. Current acres by vegetation class, natural range of variability (NRV) and ecological departure (ED) calculations for biophysical settings on the Powell District.

Ponderosa Pine								
Class	**A**	**B**	**C**	**D**	**E**	**UE**	**UN**	**Total**
Acres in Class	17,078	7,683	38,568	19,462	16,864	3,105	-	102,759
NRV	7	3	43	46	1	0	0	100
Current % in Class	17	7	38	19	16	3	0	100
Ecological Departure								**32**

Aspen–Spruce-Fir								
Class	**A**	**B**	**C**	**D**	**E**	**UE**	**UN**	**Total**
Acres in Class	15,913	112	7,407	19,567	-	-	4	43,002
NRV	13	39	43	5	0	0	0	100
Current % in Class	37	0	17	46	0	0	0	100
Ecological Departure								**65**

Pinyon-Juniper								
Class	**A**	**B**	**C**	**D**	**E**	**UE**	**UN**	**Total**
Acres in Class	6,507	3,929	15,546	15,565	-	184	-	41,732
NRV	2	7	25	66	0	0	0	100
Current % in Class	16	9	37	37	0	0	0	100
Ecological Departure								**29**

Aspen–Mixed Conifer								
Class	**A**	**B**	**C**	**D**	**E**	**UE**	**UN**	**Total**
Acres in Class	10,392	1,827	953	10,914	16,740	117	366	41,310
NRV	17	42	35	4	2	0	0	100
Current % in Class	25	4	2	26	41	0	1	100
Ecological Departure								**71**

Mixed Conifer								
Class	**A**	**B**	**C**	**D**	**E**	**UE**	**UN**	**Total**
Acres in Class	5,689	1,422	743	6,462	18,985	53	-	33,354
NRV	28	35	7	5	26	0	0	100
Current % in Class	17	4	2	19	57	0	0	100
Ecological Departure								**46**

Black/Low Sagebrush								
Class	**A**	**B**	**C**	**D**	**E**	**UE**	**UN**	**Total**
Acres in Class	3,269	7,568	15,857	-	-	2,974	752	30,420
NRV	17	48	25	10	0	0	0	100
Current % in Class	11	25	52	0	0	10	2	100
Ecological Departure								**39**

Wyoming/Basin Big Sagebrush								
Class	**A**	**B**	**C**	**D**	**E**	**UE**	**UN**	**Total**
Acres in Class	1,711	162	3,223	4,867	8,870	1,931	378	21,141
NRV	16	28	41	6	9	0	0	100
Current % in Class	8	1	15	23	42	9	2	100
Ecological Departure								**61**

Montane Sagebrush Steppe								
Class	A	B	C	D	E	UE	UN	Total
Acres in Class	2,627	1,578	1,170	8,392	2,831	32	1	16,633
NRV	21	44	21	10	3	0	0	100
Current % in Class	16	9	7	50	17	0	0	100
Ecological Departure								55

Curlleaf Mountain Mahogany								
Class	A	B	C	D	E	UE	UN	Total
Acres in Class	7,089	540	167	2,871	3,075	5	-	13,747
NRV	8	11	13	17	51	0	0	100
Current % in Class	52	4	1	21	22	0	0	100
Ecological Departure								48

Montane-Subalpine Riparian								
Class	A	B	C	D	E	UE	UN	Total
Acres in Class	2,209	9,124	-	-	-	1,075	40	12,449
NRV	34	44	22	0	0	0	0	100
Current % in Class	18	73	0	0	0	9	0	100
Ecological Departure								38

Gambel Oak–Mixed Mountain Brush								
Class	A	B	C	D	E	UE	UN	Total
Acres in Class	2,910	1,605	1,164	3,045	-	1	1,320	10,044
NRV	9	33	50	7	0	0	0	100
Current % in Class	29	16	12	30	0	0	13	100
Ecological Departure								56

Stable Aspen								
Class	A	B	C	D	E	UE	UN	Total
Acres in Class	2,228	32	273	1,569	-	1	-	4,103
NRV	9	25	44	22	0	0	0	100
Current % in Class	54	1	7	38	0	0	0	100
Ecological Departure								61

Spruce-Fir								
Class	A	B	C	D	E	UE	UN	Total
Acres in Class	937	2	620	1,507	-	-	-	3,067
NRV	14	43	1	42	0	0	0	100
Current % in Class	31	0	20	49	0	0	0	100
Ecological Departure								43

Montane Chaparral								
Class	A	B	C	D	E	UE	UN	Total
Acres in Class	201	35	-	-	-	-	-	236
NRV	16	84	0	0	0	0	0	100
Current % in Class	85	15	0	0	0	0	0	100
Ecological Departure								69

Subalpine Meadow								
Class	A	B	C	D	E	UE	UN	Total
Acres in Class	53	8	-	-	-	-	-	60
NRV	11	89	0	0	0	0	0	100
Current % in Class	87	13	0	0	0	0	0	100
Ecological Departure								76

Mixed Salt Desert Scrub								
Class	**A**	**B**	**C**	**D**	**E**	**UE**	**UN**	**Total**
Acres in Class	-	1	27	-	-	18	-	46
NRV	17	76	7	0	0	0	0	100
Current % in Class	0	2	58	0	0	39	1	100
Ecological Departure								**91**

Limber-Bristlecone Pine								
Class	**A**	**B**	**C**	**D**	**E**	**UE**	**UN**	**Total**
Acres in Class	1	-	8	-	-	-	3	12
NRV	10	14	77	0	0	0	0	100
Current % in Class	6	0	65	0	0	0	29	100
Ecological Departure								**29**

Appendix 7. Strategy worksheets for ecological systems on the Powell District.

Strategy Worksheet | ***Ponderosa Pine*** | *103,000 acres*

Enter percentages from "Final Conditions" as a whole number

	Vegetation Class (describe) *type x in left box if high-risk*	NRV	Current Condtion	Minimum Mgmt - 20 yrs	Maximum Mgmt (no net cost)	Streamlined Mgmt	Fire Mgmt only	Timber Mgmt only	-
	A	7%	17%	12%	16%	13%	13%	15%	
	B	3%	7%	5%	4%	3%	4%	6%	
	C	43%	38%	44%	49%	47%	46%	48%	
	D	46%	19%	30%	25%	30%	30%	25%	
	E	1%	16%	5%	2%	3%	3%	3%	
x	AG		0%	1%	1%	1%	1%	1%	
x	TA		3%	3%	3%	3%	3%	3%	
	Note: Large stochastic fire event in model year 19 improves Min Mgmt outcomes								

	Current Condtion	Minimum Mgmt - 20 yrs	Maximum Mgmt (no net cost)	Streamlined Mgmt	Fire Mgmt only	Timber Mgmt only	-
Ecological Departure	32	16	21	16	16	21	-
High-Risk Classes	3	4	4	4	4	4	0
Vegetation Conversion							
Total Cost		$ -	$ (100,000)	$ 1,825,000	$ 3,100,000	$ (2,400,000)	$ -
Total Cost (out-of-pocket)			$ 3,500,000	$ 3,225,000			

Scenarios (enter name below)	Enter Notes: Transitions & Multipliers	RxFire	Mech Thinning	Partial harvest	Shelterwood Harvest	Fecon-Burn	Salvage Harvest
Minimum Mgmt - 20 yrs							
Maximum Mgmt (no net co		**800**	**400**	**350**	**350**	**200**	**200**
Streamlined Mgmt		**750**	**400**	**200**	**100**	**150**	**50**
Fire Mgmt only		**1200**				**200**	
Timber Mgmt only			**400**	**350**	**350**		**200**
Cost of Strategy (per acre)		$ 100	$ 150	$ (200)	$ (200)	$ 175	$ (200)
Number of Years		20	20	20	20	20	20

Enter Management Strategies, Number of Acres/Year, Costs & Number of Years

Appendix 7. Strategy worksheets for ecological systems on the Powell District.

Strategy Worksheet | ***Aspen–Spruce-Fir*** | *43,000 acres*

Enter percentages from "Final Conditions" as a whole number

	Vegetation Class (describe) *type x in left box if high-risk*	NRV	Current Condtion	Minimum Mgmt - 20 yrs	Maximum mgmt	Steamlined mgmt (5 yrs)	-	-	-
	A	13%	37%	18%	20%	20%			
	B	39%	0%	36%	40%	41%			
	C	43%	17%	11%	16%	15%			
	D	5%	46%	27%	16%	19%			
x	Spruce Fir - A & B		0%	2%	4%	3%			
x	Spruce Fir - C & D			5%	3%	3%			
	Note: Spruce fir classified as "high risk" due to conversion & loss of aspen								

Ecological Departure	**65**	**35**	**27**	**28**	**-**	**-**	**-**
High-Risk Classes	**0**	**7**	**7**	**6**	**0**	**0**	**0**
Vegetation Conversion	**0**						
Total Cost		$ -	$ (500,000)	$ (550,000)	$ -	$ -	$ -
Total Cost (out-of-pocket)			$ 150,000	$ 100,000			

	Enter Notes	Enter Management Strategies, Number of Acres/Year, Costs & Number of Years					
Scenarios (enter name below)	**Transitions & Multipliers**	RxFire	Conifer Removal	Partial Harvest	RxFire	Conifer Removal	Partial Harvest
Minimum Mgmt - 20 yrs							
Maximum mgmt		**75**	**250**	**100**			
Steamlined mgmt (5 yrs)					**200**	**1000**	**400**
Cost of Strategy (per acre)		$ 100	$ (50)	$ (200)	$ 100	$ (50)	$ (200)
Number of Years		20	20	20	5	5	5

Appendix 7. Strategy worksheets for ecological systems on the Powell District.

Strategy Worksheet | ***Aspen–Mixed Conifer*** *41,000 acres*

Enter percentages from "Final Conditions" as a whole number

	Vegetation Class (describe) *type x in left box if high-risk*	NRV	Current Condtion	Minimum Mgmt - 20 yrs	Maximum Mgmt	Steamlined Mgmt	-	Same & AUMs in half	-
	A	17%	25%	24%	31%	28%		28%	
	B	42%	4%	24%	41%	34%		35%	
	C	35%	2%	21%	18%	21%		21%	
	D	4%	26%	4%	1%	2%		2%	
	E	2%	41%	19%	3%	8%		8%	
x	Mixed Conifer - A & B		1%	5%	4%	6%		4%	
x	Mixed Conifer - D & E			3%	2%	2%		2%	
	Note: Mixed conifer classified as "high risk" due to conversion & loss of aspen								

	Current Condtion	Minimum Mgmt - 20 yrs	Maximum Mgmt	Steamlined Mgmt	-	Same & AUMs in half	-
Ecological Departure	71	32	21	24	-	23	-
High-Risk Classes	1	8	6	8	0	6	0
Vegetation Conversion							
Total Cost		$ -	$ 750,000	$ (520,000)	$ -	$ (520,000)	$ -
Total Cost (out-of-pocket)			$ 2,000,000	$ 480,000			

Scenarios (enter name below)	Enter Notes: Transitions & Multipliers	RxFire	Conifer Removal	Partial Harvest	Fencing		
Minimum Mgmt - 20 yrs							
Maximum Mgmt		500	250	250	1000		
Steamlined Mgmt		200	200	200	0		
Same & AUMs in half		200	200	200	0		
Cost of Strategy (per acre)		$ 120	$ (50)	$ (200)	$ 40		
Number of Years		20	20	20	20		

Enter Management Strategies, Number of Acres/Year, Costs & Number of Years

Appendix 7. Strategy worksheets for ecological systems on the Powell District.

Strategy Worksheet — ***Mixed Conifer*** — *33,000 acres*

Enter percentages from "Final Conditions" as a whole number

	Vegetation Class (describe) *type x in left box if high-risk*	NRV	Current Condtion	Minimum Mgmt - 20 yrs	Maximum Mgmt	Streamlined Mgmt	-	Fire Mgmt only	Timber Mgmt only
	A	28%	17%	22%	34%	32%		26%	36%
	B	35%	4%	13%	9%	10%		11%	10%
	C	7%	2%	9%	14%	12%		9%	14%
	D	5%	19%	11%	18%	17%		16%	16%
	E	26%	57%	46%	25%	29%		37%	25%
x	AG								
x	TA								
	Note: Large stochastic fire event in model								
	year 19 improves Min Mgmt outcomes								

	Current Condtion	Minimum Mgmt - 20 yrs	Maximum Mgmt	Streamlined Mgmt	-	Fire Mgmt only	Timber Mgmt only
Ecological Departure	46	27	26	24	-	25	25
High-Risk Classes	0	0	0	0	0	0	0
Vegetation Conversion							
Total Cost		$ -	$ (1,950,000)	$ (1,450,000)	$ -	$ 1,000,000	$ (3,500,000)
Total Cost (out-of-pocket)			$ 1,050,000	$ 850,000			

Scenarios (enter name below)	Enter Notes: Transitions & Multipliers	RxFire	Thin	Partial Harvest	Regen Harvest	Salvage	
Minimum Mgmt - 20 yrs							
Maximum Mgmt		300	100	500	200	50	
Streamlined Mgmt		250	75	400	150	25	
Fire Mgmt only		400					
Timber Mgmt only			100	600	300	50	
Cost of Strategy (per acre)		$ 125	$ 150	$ (200)	$ (200)	$ (200)	
Number of Years		20	20	20	20	20	

(Column group heading: Enter Management Strategies, Number of Acres/Year, Costs & Number of Years)

Appendix 7. Strategy worksheets for ecological systems on the Powell District.

Strategy Worksheet | ***Black/Low Sagebrush*** *30,000 acres*

Enter percentages from "Final Conditions" as a whole number

	Vegetation Class (describe) *type x in left box if high-risk*	NRV	Current Condtion	Minimum Mgmt - 20 yrs	Maximum Mgmt	Streamlined Mgmt	–	–	–
	A	17%	11%	13%	17%	15%			
	B	48%	25%	22%	41%	29%			
	C	25%	52%	38%	18%	31%			
	D	10%	0%	2%	1%	2%			
	SAP		5%	8%	8%	8%			
x	TE		1%	1%	1%	1%			
	ES		0%	2%	2%	2%			
x	AG		0%	2%	2%	2%			
x	SA		5%	6%	6%	6%			
x	TA		0%	1%	0%	0%			
x	DP		1%	3%	3%	3%			
x	EF		0%	1%	1%	1%			

	Current Condtion	Minimum Mgmt - 20 yrs	Maximum Mgmt	Streamlined Mgmt	–	–	–
Ecological Departure	39	38	23	29	-	-	-
High-Risk Classes	7	14	13	13	0	0	0
Vegetation Conversion							
Total Cost		$ -	$ 1,760,000	$ 560,000			
ROI (vs. Min. Mgmt)			9.1	17.9			

	Enter Notes	Enter Management Strategies, Number of Acres/Year, Costs & Number of Years					
Scenarios (enter name below)	**Transitions & Multipliers**	Harrow & Seed for more diverse understory (C & D to A & B)	Harrow No Seed (C to B)	Masticate Tree Encroached (and TA) + Seed	Masticate xmas trees (same as chainsaw lopping in model)	Harrow & Cheap Seed	
Minimum Mgmt - 20 yrs							
Maximum Mgmt		**400**		**50**	**100**		
Streamlined Mgmt			**200**	**25**	**50**		
Cost of Strategy (per acre)		$ 180	$ 100	$ 160	$ 80	$ 150	
Number of Years		20	20	20	20		

Appendix 7. Strategy worksheets for ecological systems on the Powell District.

Strategy Worksheet | ***Wyoming/Basin Big Sagebrush*** *21,000 acres*

Enter percentages from "Final Conditions" as a whole number

	Vegetation Class (describe) *type x in left box if high-risk*	NRV	Current Condtion	Minimum Mgmt - 20 yrs	Maximum Mgmt	Streamlined Mgmt	Streamlined plus	_	_
	A	16%	8%	12%	25%	20%	22%		
	B	28%	1%	7%	31%	20%	24%		
	C	41%	15%	12%	12%	13%	13%		
	D	6%	23%	10%	5%	7%	6%		
	E	9%	42%	35%	15%	24%	20%		
x	TA		1%	9%	0%	3%	1%		
	SAP		5%	4%	0%	1%	0%		
x	DP		1%	1%	1%	1%	1%		
x	SA		5%	2%	0%	1%	0%		
x	AG		0%	5%	4%	5%	5%		
x	ES		0%	2%	3%	3%	3%		
x	EF		0%	1%	1%	1%	1%		
	Seeded				2%	2%	3%		
	Ecological Departure		61	54	30	36	32	-	-
	High-Risk Classes		7	20	9	14	11	0	0
	Vegetation Conversion								
	Total Cost			$ -	$1,196,000	$ 598,000	$ 877,000		
	ROI (vs. Min. Mgmt)				29.3	40.1	35.3		

Scenarios (enter name below)	Enter Notes: **Transitions & Multipliers**	Chain+Seed	Spike	Masticate	RxFire or Plat+Seed	Tree thin+herb+seed	Plateau	Mow +Herb+ Seed
Minimum Mgmt - 20 yrs								
Maximum Mgmt		**100**	**100**	**150**	**100**	**100**	**100**	**40**
Streamlined Mgmt		**50**	**50**	**75**	**50**	**50**	**50**	**20**
Streamlined plus		**75**	**75**	**100**	**75**	**75**	**75**	**30**
Cost of Strategy (per acre)		$ 70	$ 40	$ 80	$ 70	$ 160	$ 50	$ 220
Number of Years		20	20	20	20	20	20	20

Enter Management Strategies, Number of Acres/Year, Costs & Number of Years

Appendix 7. Strategy worksheets for ecological systems on the Powell District.

Strategy Worksheet | *Montane Sagebrush Steppe* *17,000 acres*

Enter percentages from "Final Conditions" as a whole number

	Vegetation Class (describe) *type x in left box if high-risk*	NRV	Current Condtion	Minimum Mgmt - 20 yrs	Maximum Mgmt	Streamlined Mgmt	–	–	–
	A	21%	16%	19%	26%	22%			
	B	44%	9%	25%	41%	34%			
	C	21%	7%	8%	13%	11%			
	D	10%	50%	19%	8%	13%			
	E	3%	17%	18%	2%	9%			
x	AG			1%	1%	1%			
x	ES (high risk in Powell)			4%	4%	4%			
x	TA			0%	0%	0%			
x	DP			0%	0%	0%			
	SAP			2%	2%	2%			
x	SA			0%	0%	0%			
x	TE			2%	1%	2%			
x	EF			1%	1%	1%			

Ecological Departure	55	35	15	21	-	-	-
High-Risk Classes	0	8	7	8	0	0	0
Vegetation Conversion							
Total Cost		$ -	$ 480,000	$ 240,000			
ROI (vs. Min. Mgmt)			43.8	58.3			

Scenarios (enter name below)	Enter Notes: Transitions & Multipliers	Enter Management Strategies, Number of Acres/Year, Costs & Number of Years: RxFire	Herbicide-Spike (D & E)	Chaining (E)	Masticate Trees (E)		
Minimum Mgmt - 20 yrs							
Maximum Mgmt		100	100	100	100		
Streamlined Mgmt		50	50	50	50		
Cost of Strategy (per acre)		$ 50	$ 70	$ 40	$ 80		
Number of Years		20	20	20	20		

Appendix 7. Strategy worksheets for ecological systems on the Powell District.

Strategy Worksheet | ***Montane-Subalpine Riparian*** *12,000 acres*

Enter percentages from "Final Conditions" as a whole number

High-risk	Vegetation Class (describe) *type x in left box if high-risk*	NRV	Current Condtion	Minimum Mgmt - 20 yrs	Maximum Mgmt (no fencing)	Streamlined Mgmt	Scenario 4	Scenario 5	Beaver only
	A	34%	18%	2%	14%	13%			6%
	B	44%	73%	8%	46%	38%			20%
	C	22%	0%	29%	25%	23%			17%
x	DES		0%	2%	0%	1%			3%
x	EF		9%	24%	2%	8%			23%
x	SFE		0%	22%	2%	8%			20%
x	TE		0%	0%	0%	0%			0%
	EW		0%	9%	9%	8%			9%
x	PJ		0%	3%	1%	2%			2%

	Current Condtion	Minimum Mgmt - 20 yrs	Maximum Mgmt (no fencing)	Streamlined Mgmt	Scenario 4	Scenario 5	Beaver only
Ecological Departure	38	68	20	27	-	-	57
High-Risk Classes	9	51	5	19	0	0	48
Vegetation Conversion							
Total Cost		$ -	$ 1,060,000	$ 630,000	$ -	$ -	$ -
ROI (vs. Min. Mgmt)			88.7	115.9	-	-	-

Scenarios (enter name below)	Enter Notes: Transitions & Multipliers	Weed Inventory	Spot Treatment	Thinning	Beaver reintroduction	Fencing	Rose Treatment
Minimum Mgmt - 20 yrs	with only 10% of natural beaver herbivory; floods changed						
Maximum Mgmt (no fencin	beaver included at natural regime	500	250	20			250
Streamlined Mgmt	beaver included at natural regime	500	150	10			150
Scenario 4							
Scenario 5							
Beaver only	increase multiplier to natural regime						
Cost of Strategy (per acre)		$ -	$ 50	$ 150	$ -	$ 400	$ 150
Number of Years		20	20	20	20	20	20

"Enter Management Strategies, Number of Acres/Year, Costs & Number of Years" spans the strategy columns.

Appendix 7. Strategy worksheets for ecological systems on the Powell District.

Strategy Worksheet | ***Gambel Oak–Mxd Mtn Brush*** *10,000 acres*

Enter percentages from "Final Conditions" as a whole number

	Vegetation Class (describe) *type x in left box if high-risk*	NRV	Current Condtion	Minimum Mgmt - 20 yrs	Maximum mgmt	Streamlined	–	–	–
	A	9%	29%	16%	22%	20%			
	B	33%	16%	20%	38%	31%			
	C	50%	12%	26%	24%	26%			
	D	7%	30%	15%	4%	8%			
x	TE		11%	14%	0%	4%			
	ES		2%	10%	12%	12%			
	Note: Adjusted LANDFIRE data.								
	Allocated 70% of UN (TE) to Class D								

	Current Condtion	Minimum Mgmt - 20 yrs	Maximum mgmt	Streamlined	–	–	–
Ecological Departure	56	38	30	27	-	-	-
High-Risk Classes	11	14	0	4	0	0	0
Vegetation Conversion							
Total Cost		$ -	$ 381,000	$ 238,000			
ROI (vs. Min. Mgmt)			57.7	88.2			

	Enter Notes	Enter Management Strategies, Number of Acres/Year, Costs & Number of Years					
Scenarios (enter name below)	**Transitions & Multipliers**	Hand thin (D to B)	Thin+Seed (tree encroached)	RxFire	Mech thin (D ot A)		
Minimum Mgmt - 20 yrs							
Maximum mgmt		**30**	**70**	**50**	**30**		
Streamlined		**20**	**50**	**20**	**20**		
Cost of Strategy (per acre)		$ 125	$ 120	$ 90	$ 80		
Number of Years		20	20	20	20		