Sage-Grouse Conservation Forecasting for
Barrick's Bank Study Area and Deep South Expansion Project
Plan of Operations Study Area

Report to Barrick Gold of North America,
The Bureau of Land Management, and
The Fish and Wildlife Service

Louis Provencher 2014, © The Nature Conservancy

Clockwise from top left: Shipley Meadow; Simpson Park Range looking onto Roberts Mountains; Spring flowers in low sagebrush and montane sagebrush steppe; Roberts Mountains sagebrush

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May 2017

Recommended citation:
Provencher L, Badik K, Anderson T, Munn L, Cameron M. 2017. Sage-Grouse conservation forecasting for Barrick's Bank Study Area and Deep South Expansion Projects Plan of Operations Study Area. Report by The Nature Conservancy in Nevada to Barrick Gold Corp., Elko, NV, Version 1.0. The Nature Conservancy, Reno, NV.

In the event substantive errors are found, readers can obtain an errata slip by contacting the Nevada Chapter of TNC through liz.munn@tnc.org, 775-322-4990.

Executive Summary

Introduction

The sagebrush biome in the Great Basin supports a diverse range of plant and animal species as well as important resource-dependent human communities. Conserving sagebrush habitat in Nevada for the benefit of wildlife and people is a priority for The Nature Conservancy (TNC) in Nevada. As such, TNC has long recognized the importance of businesses and sustainable economic development as critical to successful conservation. Based on these foundational principles, TNC in North America has pursued mitigation as a key strategy for achieving gains for conservation. The Nevada Chapter of TNC is uniquely suited to support mitigation through a new application of the well-developed, Landscape Conservation Forecasting™ tool (Low et al. 2010, Provencher et al. 2013). This quantitative tool, when paired with the University of Nevada, Reno's (UNR), Greater sage-grouse (*Centrocercus urophasianus*, hereafter GSG) habitat suitability model has been dubbed the Sage-Grouse Conservation Forecasting tool. This methodology has become the scientific underpinnings of Barrick Nevada Sage-Grouse Bank Enabling Agreement (Barrick Nevada Sage-Grouse Bank Enabling Agreement 2015), a mitigation mechanism which seeks to achieve a net conservation gain for GSG while providing increased regulatory certainty for future mining growth.

This report details the methodological steps to create vegetation maps, build spatially defined state-and-transition simulation models and their components, and estimate habitat gains and losses for greater sage-grouse for a specific set of simulations on the Bank and Plan of Operations Study Areas. These results can be used by the Department of the Interior and Barrick to help achieve the objectives of the Bank Enabling Agreement (BEA).

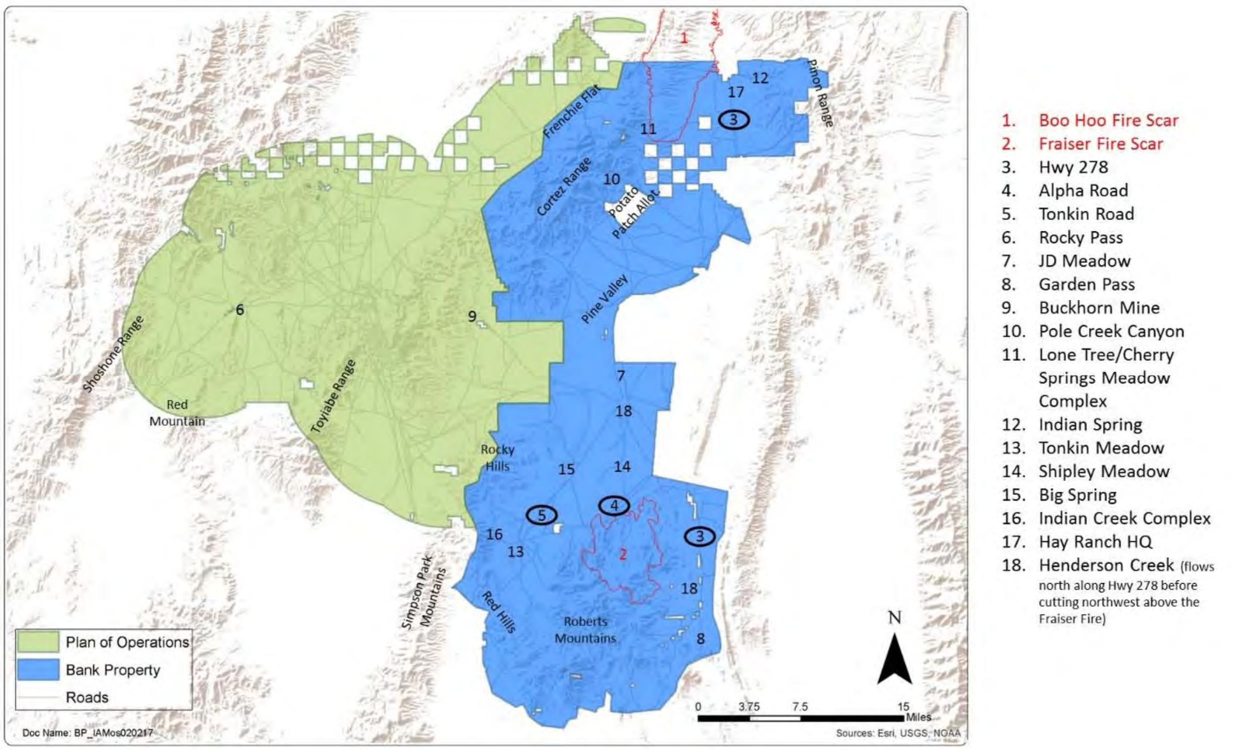
For the purposes of this project, TNC and Barrick developed two distinct "study areas" that are immediately adjacent to each other, the "Bank Study Area" and the "Plan of Operations Study Area." The Bank Study Area encompasses, 424,124 acres (171,637 hectares) and the Plan of Operations Study area encompasses 324,885 acres (46,412 hectares).

The Bank Study Area overlaps with parts of the Barrick-owned JD, Hay, and Dean Ranches from approximately the western alluvial fans of the Cortez Range (Frenchie Flat and Crescent Valley) to Highway 278 to the east and the Roberts Mountains to the south in Elko, Eureka, and Lander Counties (Executive Summary Figure 1). The area includes ranches owned and operated by other private entities. Restoration actions were simulated within the Bank Study Area to provide habitat uplift for GSG.

The Plan of Operations Study Area is primarily west of the Cortez Range and spans east to the higher slopes of the Shoshone Range and Dry Hills, and encompasses the northern tip of the Toiyabe Range, Red Mountains, and the northern part of Carico Valley (Executive Summary Figure 1).

All of the infrastructure proposed for the Deep South Expansion Project is contained within these two study areas. The vast majority of the proposed mining project lies within the Plan of Operations Study Area although a few Rapid Infiltration Basins lie within the Bank Study Area.

The direct and indirect impacts to GSG habitat due to proposed mining operations (also called the "proposed mine development") were based on the proposed Deep South Expansion Project which consists of new and expanded facilities at the Cortez Mine. The project includes expansion of existing pits and waste rock facilities, construction and operation of water management facilities, and construction and operation of additional ancillary facilities. The Cortez Hills underground mine would expand deeper than is currently authorized.



Executive Summary Figure 1: The Bank Study Area and Plan of Operations Study Area in central Nevada.

The results presented herein provide reason to be hopeful in the concept of mitigation as a powerful strategy for achieving sustainable economic growth, and, importantly in the west-wide effort to stop the decline of these precious landscapes.

Process and Methods

The Landscape Conservation Forecasting™ process for the Bank Study Area and Plan of Operations Study Area consists of five primary steps, although the implementation of some steps varied between areas:

1. Develop maps of potential vegetation types, termed ecological systems, and of current vegetation classes within each system, by conducting remote sensing of satellite imagery including extensive ground-truthing.
2. Refine computerized predictive state-and-transition ecological models for the ecological systems by updating TNC's Great Basin "library" of models, or by creating new models.
3. Determine current condition using metrics that match management questions. For the Barrick project, the primary metric was GSG habitat suitability, and more specifically the per-capita population growth rate (λ). Therefore, estimate current suitability of habitat for GSG using demographically-based metrics of habitat suitability and Functional Area (currency of mitigation estimated using cumulative pixel-based habitat suitability).

4. Use the computerized ecological models to forecast anticipated future condition of vegetation and habitat suitability for the GSG and of ecological systems, under custodial management.
5. Use the computerized ecological models to forecast anticipated future condition of vegetation and habitat suitability for GSG, and of ecological systems, under alternative "active" management scenarios (suites of specific actions or treatments).

Using the methodology described above, an iterative modeling approach, and input from many experts, a final suite of scenarios was established for final analysis and reporting. Fire, an important ecological disturbance on this landscape, proved responsible for a great deal of variability in modeling outcomes. As a result, Barrick and TNC chose to model all scenarios with and without fire. The intent of this decision was to give managers the ability to begin to separate the effect of fire on GSG habitat suitability for greater sage-grouse from other modeled disturbances and management actions. The scenarios can be summarized as follows:

- Plan of Operations Study Area – CUSTODIAL (with and without fire) – models expected changes to vegetation due to ecological processes. Includes all currently authorized mining disturbances.
- Plan of Operations Study Area – PROPOSED MINE DEVELOPMENT (with and without fire) - models expected changes to vegetation due to ecological processes. Includes all currently authorized mining disturbances as well as disturbances proposed for the Deep South Expansion Project.
- Bank Study Area – CUSTODIAL (with and without fire) - models expected changes to vegetation due to ecological processes without any restoration or preservation actions.
- Bank Study Area – FINAL (with and without fire) - models expected changes to vegetation due to ecological processes including significant investments in restoration and fuel breaks.

Using these scenarios as a base, TNC performed additional analyses to quantify the effects of certain specific management actions such as the preservation of certain privately held wet meadows.

Key Results and Conclusions

The TNC Model predicted a net conservation gain for GSG within the study area. This net gain included direct and indirect impacts to habitat from new infrastructure in the Plan of Operations Study Area and uplift provided by preservation and extensive restoration efforts for habitat in the Mitigation Area. TNC reached this conclusion by successfully coupling a complex state-and-transition simulation model supported by high-resolution vegetation maps and a private-public collaboration with a demographically-based GSG habitat suitability model. Reaching a net conservation gain required (1) transforming an academic and statistical habitat suitability model into an applied model and (2) expanding the tools of the well-established ST-Sim state-and-transition simulation software to allow for innovations in modeled fire behavior, grazing management, and spatially dynamic assignment of management priority based changing GSG vital rates. Next, we expand on important findings and assumptions.

A. Compared to the CUSTODIAL management scenario, the PROPOSED MINE DEVELOPMENT resulted in the loss of functional acres on the Plan of Operations Study Area. This loss of functional acres ranged over time from 572 to 606 without fire and from 529 to 572 with fire (Executive Summary Table 1).

B. The building of Rapid Infiltration Basins (RIBs) and supporting infrastructure in the Bank Study Area's Frenchie Flat added a peak loss of approximately 109 functional acres with and without fire (Executive Summary Table 1).

Executive Summary Table 1. Predicted loss of Functional Acres from scenarios conducted on the Bank and Plan of Operations Study Areas to model the effect of proposed mining operations on GSG Habitat. Functional Acre difference is the difference between a management scenario and its corresponding CUSTODIAL Scenario.

Scenario	Yr 0	Yr 5	Yr 10	Yr 15	Yr 20	Yr 25	Yr 30	Yr 35
PoO SA+NO FIRE FUNCTIONAL ACRE *Difference*	*572*	*574*	*575*	*576*	*579*	*595*	*606*	*604*
PoO SA+FIRE FUNCTIONAL ACRE *Difference*	*572*	*569*	*557*	*548*	*536*	*536*	*533*	*529*
BANK SA RIBS+FIRE FUNCTIONAL ACRE *difference*	*102*	*104*	*107*	*108*	*108*	*109*	*109*	*107*
BANK SA RIBS+NO FIRE FUNCTIONAL ACRE *difference*	*102*	*105*	*107*	*108*	*108*	*108*	*108*	*108*

C. Compared to the CUSTODIAL management scenario, restoration actions in the FINAL management scenario increased functional acres from 435 to 927 without fire and from 315 to 1,034 with fire (Executive Summary Table 2).

D. The condition of three currently intact wet meadows, Shipley, Tonkin, and Big Springs, was modeled in various states of degradation to explore how functional acres are impacted when these meadows are hummocked and invaded by exotic forbs. The HUMMOCK scenario predicted that preservation of these intact wet meadows led to an uplift of 367 functional acres at year 0 compared to CUSTODIAL with and without fire (Executive Summary Table 2). For the EXOTIC FORB scenario, preservation is predicted to have 668 more functional acres at year 0, with and without fire.

Executive Summary Table 2. Predicted gain of Functional Acres from scenarios conducted on the Bank Study Area to model the effect of restoration and preservation of important habitat. Functional Acre difference is the difference between a management scenario and its corresponding CUSTODIAL Management Scenario.

Scenario	Yr. 0	Yr. 5	Yr. 10	Yr. 15	Yr. 20	Yr. 25	Yr. 30	Yr. 35
BANK SA FINAL+FIRE FUNCTIONAL ACRE *difference*	*0*	*315*	*677*	*988*	*1,034*	*831*	*804*	*763*
BANK SA FINAL+NO FIRE FUNCTIONAL ACRE *difference*	*0*	*435*	*588*	*851*	*870*	*875*	*883*	*927*
BANK SA HUMMOCK+FIRE FUNCTIONAL ACRE *difference*	*367*	*347*	*310*	*289*	*272*	*281*	*276*	*266*
BANK SA HUMMOCK+NO FIRE FUNCTIONAL ACRE *difference*	*367*	*352*	*333*	*324*	*316*	*312*	*306*	*298*
BANK SA EXOTIC FORBS+FIRE FUNCTIONAL ACRE *difference*	*668*	*635*	*567*	*513*	*468*	*482*	*475*	*462*
BANK SA EXOTIC FORBS +NO FIRE FUNCTIONAL ACRE *difference*	*668*	*640*	*613*	*602*	*592*	*588*	*581*	*568*

E. With fire, a steady decline was observed in the CUSTODIAL management in the Bank Study Area (a similar pattern was observed in the Plan of Operation area); this reflects the scientific consensus that these systems are in decline primarily due to the fire-invasive weed cycle.

F. Large fires that occur in the last 10 years of a 35-year simulation explain most of the large decrease in habitat suitability and functional acres as recovery of nesting habitat after restoration is not possible (within the study period) and restoration actions were not deployed during the last 10 years of simulations. This is especially true for the active management scenario in the Bank Study Area.

G. Fire activity explained most of the variation among replicates per scenario.

H. Restoration of degraded GSG habitat was only accomplished on the Bank Study Area, though within the project boundary of Plan of Operation area restoration opportunities may exist far enough from planned impacts to improve GSG.

I. This project revealed a stark difference between single species management to increase GSG habitat suitability and traditional range improvement. Many actions that would be conducted to improve range condition, such as restoring depleted sagebrush into seedings, is detrimental to GSG nest-site selection and nest success in the short and intermediate terms, and, moreover, shift funding away from actions that directly increase habitat suitability. Despite the potential benefits for long-term habitat structure, any actions that remove sagebrush cover and create early-succession vegetation classes are detrimental to GSG nesting and were discouraged by the BLM during workshops.

J. The restoration of vegetation classes dominated by non-native annual species into seedings composed of mixed introduced and native grass species supplemented with planted native sagebrush and other shrubs in both big sagebrush, black, and low sagebrush ecological systems was perhaps the most important action to implement in proximity of leks and late-brood habitat as nesting habitat is the most limiting habitat in burned areas.

K. Restoration of degraded vegetation classes in wet meadows, or creation of irrigated pastures in otherwise degraded bottomland systems, that were isolated and distant from late-brood vegetation classes and systems, but sufficiently close to an active lek and nesting habitat, was an important contributor to increased habitat suitability.

L. Removal of trees in reference, tree-encroached, or wooded shrubland invaded by non-native annual species classes using a masticator with seeding or chainsaws was another important contributor to increased habitat suitability. Interestingly, fires naturally removed trees and, therefore, the ST-Sim software shifted treatments and budget allocation such that some burned areas were more cheaply treated as vegetation classes dominated by non-native annual species.

M. Because of the spatial dependence of GSG life history, the location of restoration actions was extremely important for success.

    - For chick survival, GSG habitat suitability increased most when management actions for late-brood habitat improvement were isolated from other late-brood habitat but near a nest site or a lek. In other words, restoring a wet meadow close to other wet meadows or high-elevation sagebrush would provide little habitat suitability uplift, whereas restoring a similar wet meadow isolated from other late-brood vegetation would greatly increase habitat suitability as long as quality nesting habitat was available.
    - Restoring vegetation dominated by non-native annual species was only valuable to enhancing nesting if management actions were conducted in proximity of a lek and late-brood rearing habitat.

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Report Guide

This section includes a glossary of commonly used terms, and some key concepts that readers may find helpful to interpret this document.

Glossary

Active Management		Scenarios in which actions occur that are different than the Custodial Management including further mine development, restoration actions, or change in management that leads to degradation.
Annual Species	Annual Spp	Any number of invasive annual species with similar ecological characteristics including cheatgrass, medusahead, mustard, etc.
Authorized Disturbance		Area within the Plan of Operations Study Area that has been previously authorized for disturbance, whether or not that disturbance has been realized.
Bank Enabling Agreement	BEA	Voluntary agreement between Barrick, the Fish and Wildlife Agency, and the Bureau of Land Management to achieve a net conservation gain for sage-grouse in a designated area of interest.
Bank Study Area	BSA	Eastern study area that, for this report, contains all forecast restoration and preservation efforts
Chick Survival	CS	The probability that at least one chick survives into adolescence.
Custodial		Scenario in which minimal management action takes place. Often thought of as the status quo and comparable to the "no-action" alternative in a NEPA application.
Deep South Expansion Project	DSEP	Proposed disturbances associated with mining activities analyzed in this report.
Exotic Forbs		Any number of invasive forbs such as thistles, halogeton, knapweed.
Female Survival	FS	The probability that a female survives the breeding and brood-rearing season.
Functional Area / Acre	FA	A unit of measurement which defines the value of a specific area, in this case acres, for greater sage-grouse in terms of their per-capita growth rate.
Lambda	λ	The per-capita growth rate of a species of interest - in this case greater sage-grouse.
Landscape Conservation Forecasting	LCF	TNC's methodology of combining remote sensed data and state-and-transition models to forecast future conditions on the landscape under alternate scenarios and analyze them based on various metrics.
Management Action		Any human intervention on the landscape including specific restoration actions, mine development, etc.

Natural Range of Variability	NRV	The relative amounts of reference classes that are expected to exist on the landscape under natural, pre-European settlement conditions.
Nest Site Selection	NSS	The probability of a greater sage-grouse hen initiating a nest in any given location.
Nest Success	NS	Given that a nest has been initiated, the probability that at least one chick survives the nesting period.
Non-Habitat		Vegetation systems that are not considered habitat for greater sage-grouse. For example, playas, salt desert, limber pine woodlands.
Plan of Operations Study Area	PoOSA	Western study area that, for this report, contains all.
Recipient Class		Vegetation classes that "receive" treated target classes. For example, if an acre of cheatgrass (U-A:Annual Spp) that is treated becomes a seeded class (U-A:SI), the seeded class is the "recipient" class.
Reference		Classes that are expected under natural disturbance regimes.
Replicate		A single iteration within a scenario. For this analysis, TNC used 10 replicates for every scenario.
Sage-grouse Conservation Forecasting	SGCF	a special case of Landscape Conservation Forecasting where the primary metric of interest is Greater Sage Grouse Habitat Suitability and thus, modelling is spatially explicit.
Scenario		A themed suite of actions (or lack thereof in the case of Custodial) that are input into the forecasting model for testing. In the ST-sim software, all scenarios are assigned a unique number.
ST-Sim		The freeware platform developed and maintained by ApexRMS used by TNC to conduct simulations.
Target Class		Vegetation classes that are the "target" for treatment. For example, if an acre of cheatgrass (U-A:Annual Spp) that is treated becomes a seeded class (U-A:SI), the cheatgrass is the "target" class.
Transition		Any event that causes a change in vegetation class including passage of time, ecological disturbances, human intervention through management actions, etc.
Unbranded, Unclaimed Horse		Horses on the landscape not managed by a federal or state agency.
Uncharacteristic Class	U	Classes that would not be expected under natural disturbance regimes, e.g. those that contain non-native invasive species.
Unified Ecological Departure	UED	A metric developed by TNC that measures the level to which a system has departed from it's natural range of variability.
Vegetation Class		The current vegetation found at a specific site including vegetation type, age, canopy cover, etc.

Vegetation System		The dominant potential vegetation types expected on the landscape under "natural," pre-European settlement conditions.
Wild Horse		Horses on the landscape under the jurisdiction of the Bureau of Land Management governed by the Wild and Free Roaming Horse Act (1976).

TNC's Class names:

All class names are defined in Appendix 1 along with descriptions of their associated vegetation. However, for the purposes of reading this report it can be helpful to become familiar with the basic shorthand. The letters before the colon indicate the whether the class is uncharacteristic ("U") or reference (no "U"), and what successional phase the class is in ("A"-"E"). The letters and terms after the colon are descriptors of some general vegetation characteristics. Thus, the class names can be thought of as:

[uncharacteristic/reference] – [successional phase] : [descriptor]

Examples

A:All	Reference – Successional Phase A : All types
B:Closed	Reference – Successional Phase B : Closed Canopy
U-A:SI	Uncharacteristic – Successional Phase A : Seeded with Introduced species
U-A:Annual Spp	Uncharacteristic – Successional Phase A : invasive Annual Species
U-E:TEA	Uncharacteristic – Successional Phase E : Tree Encroached e.g. Juniper OR Ann. species

TNC's System and Class Codes

All systems are given a 5-digit identifying code that is used in modeling. Likewise, all classes are given a 3 digit code. Class codes remain consistent across systems where applicable. For example, the class code 129 represents U-A:SI in all systems in which it exists including Basin Big Sagebrush Upland with Trees, Black Sagebrush, Low Sagebrush, etc. Thus, every pixel has an 8-digit code that identifies the vegetation (system and class) at that pixel.

Examples

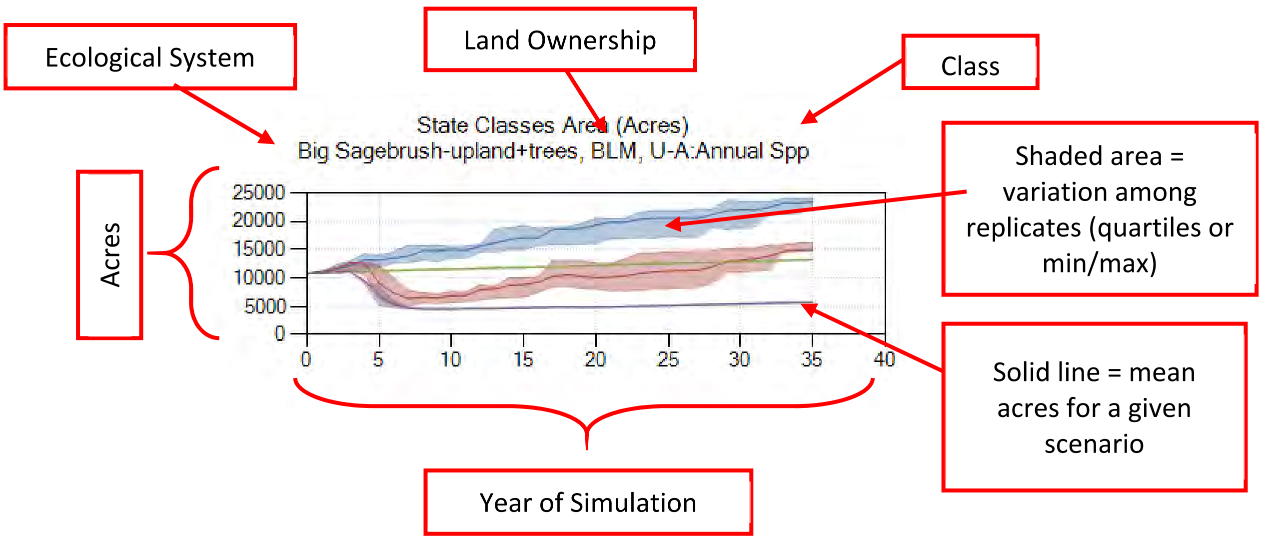
System 10804 = Basin Big Sagebrush Upland with Trees
System 11450 = Wet Meadow Montane

Class 129 = U-A:SI = Uncharacteristic – Succession Phase A : Seeded with Introduced species
Class 229 = U-B:SI = Uncharacteristic – Succession Phase B : Seeded with Introduced species

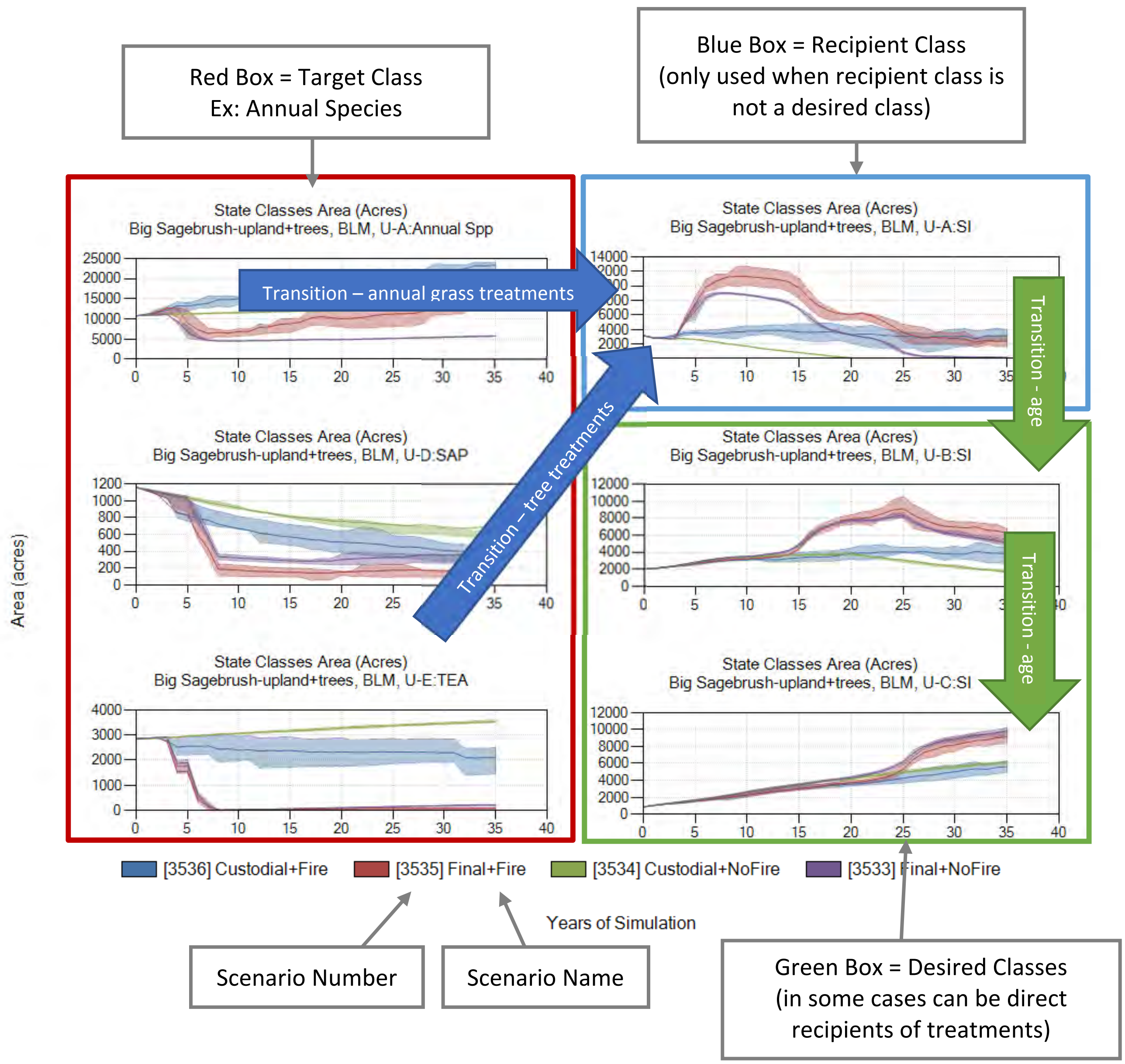
Code 10804129 = "Early-successional seeded class in the basin big sage system"

Interpreting ST-sim Graphic Outputs

The software ST-Sim outputs data in graphical form in a fixed format. These graphs are used substantially in the results section of this report. The second line of the graph title contains information about the data being presented in any given graph including the system, class, and land ownership. The unit of the y-axis is always acres. The unit of the x-axis is always time where 0=2014. Each color represents a different scenario and the colors remain consistent throughout the report. As scenarios are replicated 10 times, there is variability in the results. This variability is shown in shaded areas which depict either quartiles of min/max between replicates. The solid line depicts the mean. When very little variation exists, the shaded area can be hard to detect as in the purple and green scenarios below.



The complex interactions of treatments, disturbances, and time within an ecological system often require several graphs to depict. In this report, "target classes" or classes that require treatment are boxed in red (left side of example below). When treatments are successful, acres convert to the "recipient" class which in this report is depicted by both blue and green boxes. In many cases, the "recipient" class is a stepping stone to achieve better habitat for greater sage grouse, in this case, the graphs will be boxed in blue. As the treatments mature they will become the desired classes for greater sage grouse. In other cases, the desired class is a direct outcome of treatment. Either way, the desired classes will be boxed in green.



1. Introduction

Project Background and Agreement

The sagebrush biome in the Great Basin supports a diverse range of plant and animal species as well as important resource-dependent human communities. Conserving sagebrush habitat in Nevada for the benefit of wildlife and people is a priority for The Nature Conservancy (TNC) in Nevada. Similarly, TNC has long recognized the importance of businesses and sustainable economic development as critical to successful conservation. Based on these foundational principles, TNC has pursued mitigation as a key strategy for achieving gains for conservation. The Nevada Chapter of TNC is uniquely suited to support mitigation through a new application of the well-developed, Landscape Conservation Forecasting™ tool. This quantitative tool, when paired with the University of Nevada, Reno's (UNR), greater sage-grouse (*Centrocercus urophasianus*, hereafter GSG) habitat suitability model has become the scientific underpinnings of Barrick's Bank Enabling Agreement (BEA), a mitigation mechanism that seeks to achieve a net conservation gain for GSG, while providing increased regulatory certainty for future mining growth. This report details modeling results that can be used by the US Department of Interior (DOI) and Barrick to help achieve the objectives of the BEA.

A hundred years ago there were an estimated as many as 16 million GSG living across most western states (Federal Register 75 FR 13910). Current estimates suggest only 200,000 to 500,000 remain (Federal Register 75 FR 13910). GSG depend on different types of habitat and vegetation for food, nesting, and shelter from predators (Connelly et al. 2011). The decline of GSG is directly related to the loss of these habitats (Schoeder et al. 2004). In Nevada, habitat is being continuously lost, primarily due to historically large rangeland wildfires, invasive weeds, and conifer encroachment (U.S. Fish and Wildlife Service 2013). Incremental loss of habitat for a species, and especially for threatened and endangered species, can have a dramatic impact on a species' viability.

In 2010, GSG were determined to be warranted for protection, but precluded by other higher priorities under the Endangered Species Act (ESA, USFWS 2010). This decision lent focus and momentum to a west-wide effort to conserve and enhance habitat for the GSG. Across the species' range, Federal, State, Local, and private entities sought ways to provide assurance that GSG habitat would support viable populations for the long term. The agencies with jurisdiction over federally-managed habitat sought ways to minimize or cap disturbances while allowing for multiple uses on the landscape. This had a direct effect on many industries, including mining and ranching in Nevada. In September of 2015, the US Fish and Wildlife Service (FWS) decided not to list GSG as endangered in part due to these planned conservation actions, such as the BEA.

The FWS and US Bureau of Land Management (BLM) both have regulatory jurisdiction for maintaining the environmental integrity of the federal lands affected by mining. They are charged with ensuring that any economic activity on the land does not cause undue degradation of natural resources or threaten the viability of species. The challenge, therefore, is for the federal government and the affected companies to find balanced approaches that allow for both economic activity and protection of the environment. Meeting that challenge requires use of the best available science and the implementation of policies that allow for multiple uses.

Land management agencies and others have identified the mitigation hierarchy as a primary strategy for tackling this challenge not just in the United States, but around the world. Appropriate application of the mitigation hierarchy involves, first and foremost, avoiding and minimizing impacts as much as possible. For those impacts that are unavoidable, compensatory mitigation can be used to offset habitat degradation. To meet the goal of no net loss of habitat function through of compensatory mitigation, decision-makers need robust quantitative tools to evaluate gains and losses due to conservation and development. In Nevada, TNC is uniquely positioned to provide scientific rigor to federal and private decision-makers through the application of the Sage-Grouse Conservation Forecasting Tool.

Sage-Grouse Conservation Forecasting (SGCF) is a special case of Landscape Conservation Forecasting™ (LCF) created by TNC to help land managers design cost-effective strategies to restore ecological systems in large landscapes (Low et al. 2010, Provencher et al. 2013). As with LCF, Sage-Grouse Conservation Forecasting can be summarized by the "3 Ms": maps, models, and metrics. Traditionally, LCF's metrics measured the departure between the distribution of current vegetation classes in a single ecological system and the expected distribution under reference conditions. The nature of metrics of success have been expanded to include wildlife habitat suitability indices (e.g. desert tortoise in the Mojave Desert, Provencher et al. 2011, and Utah prairie dog and GSG in Utah's west desert, Provencher et al. 2015b). The focus on Greater Sage Grouse Metrics for this project merited changing the name to emphasize the management objectives.

Sage-Grouse Conservation Forecasting uses UNR's statistical demographic habitat suitability model as the metric to design restoration strategies to increase GSG habitat suitability compared to maintaining *status quo* (Custodial) management. The use of spatially-explicit habitat suitability models allows for a unit of measurement, functional area, and, in the case of this project, Functional Acre. Functional Acres can be totaled across the landscape and compared over time and between alternative scenarios. By comparing alternate future scenarios, TNC can quantify the improvements to GSG habitat of potential restoration actions as well as the impacts from increased infrastructure or habitat loss into the future.

In June of 2015, Sage-Grouse Conservation Forecasting became the scientific underpinnings of the Barrick Bank Enabling Agreement (BEA) signed between the Fish and Wildlife Service, the Bureau of Land Management, and Barrick. The BEA created an approved, scientifically robust, and novel landscape-scale mitigation process [1]:

> "This Bank Enabling Agreement sets forth the mechanism for: (1) establishment, use, operation, and maintenance of the Bank to compensate for impacts to the greater sage-grouse and sagebrush ecosystems with actions that produce a Net Conservation Gain; and (2) the establishment of the conservation Credit and Debit metrics using the Sage-Grouse Conservation Forecasting Methodology developed by The Nature Conservancy ("TNC") for calculating the Credits associated with Conservation Actions and the Debits associated with proposed mining or other associated activities ("TNC Methodology"). The Bank will provide for the preservation, restoration, and/or enhancement of sagebrush ecosystems by implementation of Projects to be

[1] http://www.blm.gov/style/medialib/blm/nv/wildlife__fishes/sage_grouse/barrick_nv_sage_grouse.Par.65037.File.dat/DOI-Barrick%20Sage%20Grouse%20Agreement%20March2015.pdf

> agreed upon among the Parties; management and maintenance of those ecosystems in accordance with this Bank Enabling Agreement and Project Plans ("Bank Plans"); and a methodology for accounting for Credits associated with implementation of the Projects, or portions thereof."

In the simplest sense, the BEA established an administrative and scientific methodology to dynamically (over decades) measure GSG mitigation debits from proposed mining (loss of habitat suitability) and mitigation credits (gain of habitat suitability) created from restoration and protection of habitat, and financial commitment to implement actions that will achieve net conservation gains for GSG in designated landscapes.

Project Area

For the purposes of this project, TNC and Barrick developed two distinct "Study Areas" that are immediately adjacent to each other. These will be referred to throughout the report as the "Bank Study Area" and the "Plan of Operations Study Area."

Barrick's Bank Study Area overlaps with parts of the Barrick-owned JD, Hay, and Dean Ranches from approximately the western alluvial fans of the Cortez Range (Frenchie Flat and Crescent Valley) to Highway 278 to the east and the Roberts Mountains to the south in Elko, Eureka, and Lander Counties (Figure 1). This study area also includes ranches owned and operated by other private entities. For this project, all actions taken to provide habitat uplift are taken in the Bank Study Area (also "Bank SA" in some places).

The Plan of Operations Study Area is primarily west of the Cortez Range up to about the higher slopes of the Shoshone Range and Dry Hills, and encompasses the northern tip of the Toiyabe Range, Red Mountains, and the northern part of Carico Valley (Figure 1). All simulations of proposed mining operations (also called the "Proposed Mine Development") were based on the currently proposed Deep South Expansion Project which consists of new and expanded facilities at the Cortez Mine. The project includes expansion of existing pits and waste rock facilities, construction and operation of water management facilities, and construction and operation of additional ancillary facilities. The Cortez Hills underground mine would expand deeper than is currently authorized.

The vast majority of the planned infrastructure associated with the Deep South Expansion Project is located in the "Plan of Operations Study Area" with the exception of a few Rapid Infiltration Basins (RIBs) that are located in the Bank Study Area. All planned infrastructure was buffered by a minimum of 5 miles including the above-mentioned RIBs to capture indirect effects of the planned mining operations. This buffering action dictated the size and shape of Plan of Operations Study Area. Modeled restoration actions were not buffered in this way and extend to the edges of the Bank Study Area where appropriate.

The boundaries of the two Study Areas do not always align with the administrative boundaries of the BEA (Figure 1). Three major differences can be observed: 1) the above-mentioned "buffer" on impacts extends the Plan of Operations Study Area beyond the BEA boundary to the west, 2) the Bank Study

Area includes other important habitat for sage grouse not included in the BEA to the south in the Roberts Mountains, 3) an area in the south-eastern corner of the Plan of Operations Study Area is considered available for restoration actions in the BEA but is not modeled as such for this report. This can be considered an area for future additional restoration actions.

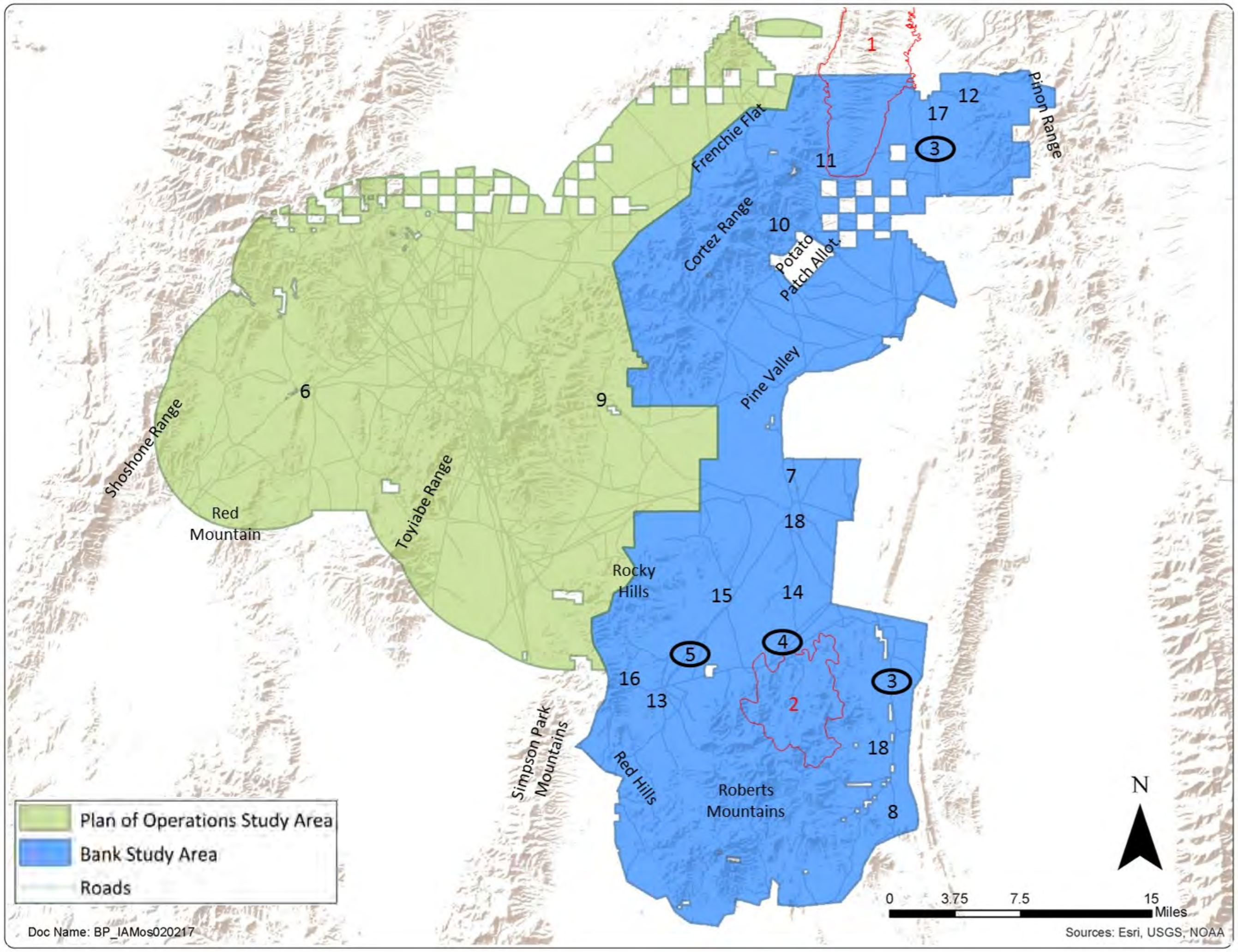
The project areas encompass, respectively, about 424,124 ac (171,637 ha) and 324,885 ac (46,412 ha) for the Bank Study Area and Plan of Operations Study Area. Each study area contains typical rangelands; however, the valley floor is substantially lower in the Plan of Operations Study Area than Bank Study Area (except near Mount Tenabo) and contains Barrick's active Cortez Hills and Pipeline mining operations. The Cortez Range, Simpson Park Range, Shoshone Range, Sulphur Spring Range, and Dry Hills are primarily volcanic and north-south trending, whereas the Roberts Mountains are dominated by carbonate rocks and have a circular landform.

The vegetation of both areas is zonal with wet and dry sodic to saline communities at the valley bottoms and the gradient of salt desert to big sagebrush shrublands distributed from middle and upper elevations. Pinyon and Utah juniper are present in all ranges except the Dry Hills; however, their densities increase towards the southern portion of all ranges. More mesic systems (e.g. aspen woodlands, patches of mountain shrub, and wet meadows) can be found on the slopes of all ranges. The most extensive upper-montane and subalpine ecological systems are found in the Roberts Mountains.

GSG is found in both project areas, but there are fewer leks in the Plan of Operations Study Area and extent of late-brood rearing habitat is much less. Both landscapes support other species of special concern, such as mule deer, golden eagle, and pygmy rabbit. Several creeks in the Bank Study Area supports introduced populations of Lahontan cutthroat trout.

This report details the methodological steps to create vegetation maps, build spatially defined state-and-transition simulation models and their components, and estimate habitat gains and losses for greater sage-grouse for a specific set of simulations on the Bank and Plan of Operations Study Areas. The intention is to present the information such that the DOI agencies and Barrick can utilize to implement actions and assess mitigation debits and credits.

The results presented herein provide reason to be hopeful in the concept of mitigation as a powerful strategy for achieving sustainable economic growth, and, importantly in the west-wide effort to stop the decline of these precious landscapes.



1. Boo Hoo Fire Scar
2. Fraiser Fire Scar
3. Hwy 278
4. Alpha Road
5. Tonkin Road
6. Rocky Pass
7. JD Meadow
8. Garden Pass
9. Buckhorn Mine
10. Pole Creek Canyon
11. Lone Tree/Cherry Springs Meadow Complex
12. Indian Spring
13. Tonkin Meadow
14. Shipley Meadow
15. Big Spring
16. Indian Creek Complex
17. Hay Ranch HQ
18. Henderson Creek (flows north along Hwy 278 before cutting northwest above the Fraiser Fire)

Figure 1. The Bank Study Area and Plan of Operations Study Area in central Nevada

2. Process and Methods

The Landscape Conservation Forecasting™ process for the Bank Study Area and Plan of Operations Study Area consists of five primary steps, although the implementation of some steps varied between areas:

1. Develop maps of potential vegetation types, termed ecological systems, and of current vegetation classes within each system, by conducting remote sensing of satellite imagery including extensive ground-truthing.
2. Refine computerized predictive state-and-transition ecological models for the ecological systems by updating TNC's Great Basin "library" of models, or by creating new models.
3. Determine current condition using metrics that match management questions. For the Barrick project, the primary metric was GSG habitat suitability, and more specifically the per-capita population growth rate (λ). Therefore, estimate current suitability of habitat for GSG using demographically-based metrics of habitat suitability and Functional Area (currency of mitigation estimated using cumulative pixel-based habitat suitability).[2]
4. Use the computerized ecological models to forecast anticipated future condition of vegetation and habitat suitability for the GSG and of ecological systems, under custodial management.
5. Use the computerized ecological models to forecast anticipated future condition of vegetation and habitat suitability for GSG, and of ecological systems, under alternative "active" management scenarios (suites of specific actions or treatments).

A diagram that displays the relationship of these six components to each other is presented in Figure 2, and the timeline of the project appears in Table 1 on the following page.

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[2] For LCF projects that are not primarily concerned with calculation of GSG mitigation debits and credits, the metric of Unified Ecological Departure (UED) measured the condition of each ecological system. UED was not used as a measure of success for this report.

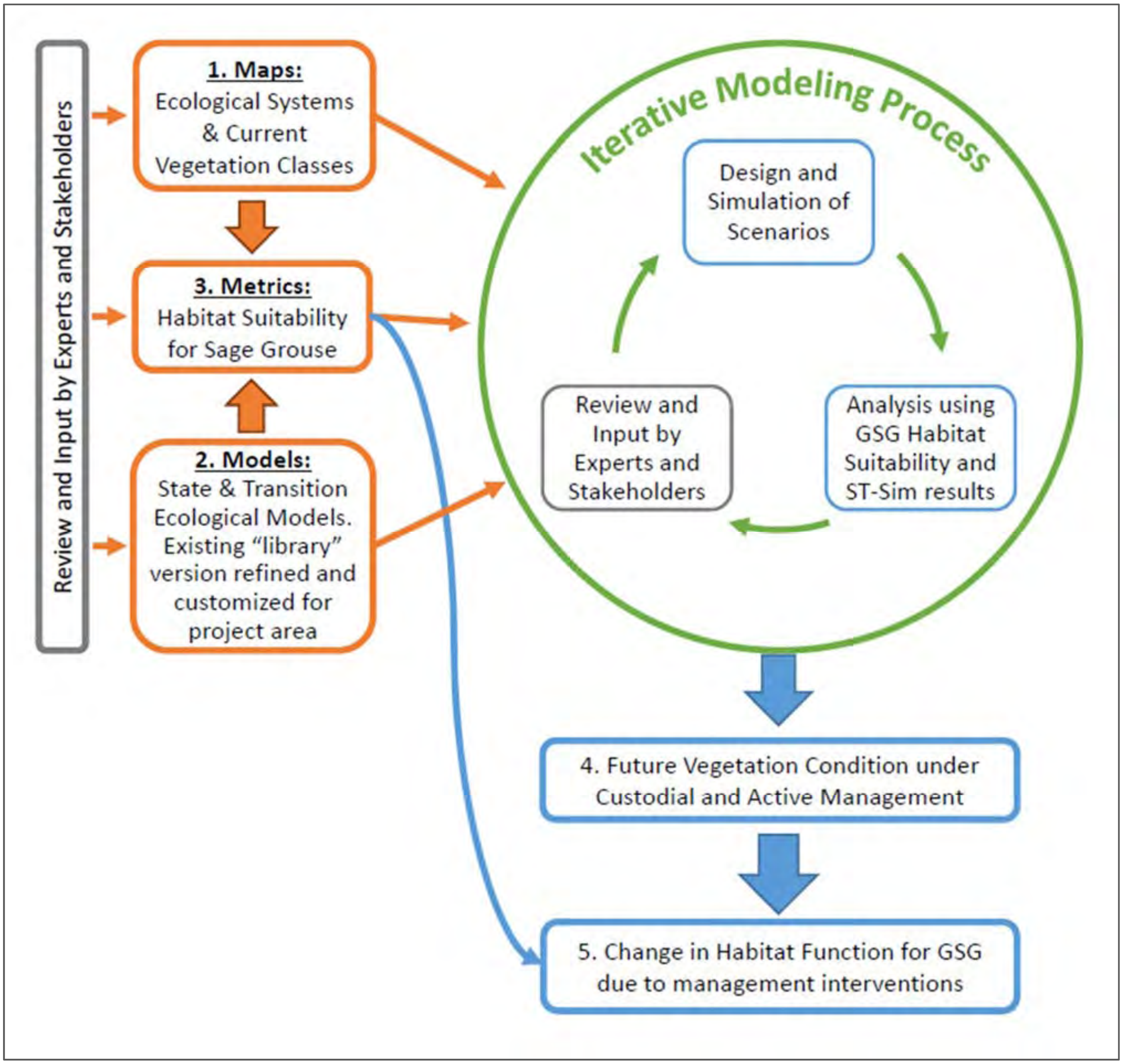

Figure 2: Diagram displaying the relationship of the Maps, Models, and Metrics as well as stakeholder and expert input in the TNC methodology. Numbers correspond to the descriptions on the previous page.

Table 1: TNC Project Timeline

	2013			2014				2015				2016				2017	
	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
Admin Set-Up	■	■	■	■	■												
Remote Sensing Bank Study Area					■	■	■	■									
Remote Sensing Plan of Operations Study Area									■	■	■		■		■		
Accuracy Assessment														■			
Modeling & Workshops					■	■	■	■	■	■	■	■	■				
Habitat Suitability Equation Building & Estimation								■	■	■	■	■	■	■	■		
Final Report														■	■	■	■
Outreach to Regulators			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

The TNC Methodology has always relied heavily on engaging experts and stakeholder partners to (i) provide transparency to the SGCF (or LCF™) process, (ii) elicit valuable feedback and new information from experts for model improvement, and (iii) attempt to increase understanding and acceptance of the SGCF (or LCF™) process from various agencies and other stakeholders. For this project, input was solicited through contracts with subject matter experts, two formal management workshops, and informal adaptive management meetings and communications. More details about these inputs can be found in Appendix 10 and within relevant parts of this section.

Vegetation Mapping

The fundamental elements of vegetation mapping are the distributions of:

1. Ecological systems, and
2. Current vegetation classes within each ecological system.

Ecological systems, also known as biophysical settings (Rollins 2009, LANDFIRE 2010; Low et al. 2010), are dominant *potential* vegetation types expected in the physical environment (geology-soil-landform-climate) under "natural" disturbance regimes. Thus, ecological systems are fundamentally abiotic units, NOT units of current vegetation. Each ecological system supports (expresses) a particular kind of dominant vegetation, and is named by its dominant vegetation. Ecological systems are essentially single or grouped ecological sites from the Natural Resource Conservation Service (NRCS) soil surveys. The NRCS defines an ecological site as "a distinctive kind of land with specific physical characteristics that differs from other kinds of 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). Unfortunately, order III soil surveys are too coarse to allow unambiguous mapping of ecological systems at each map pixel.

Within each ecological system, current vegetation classes are based on factors such as:

- Successional stages – early to mid to late.
- Vegetation canopy – open versus closed.
- Reference (native) versus Uncharacteristic vegetation or site characteristics – defined later in the subsection titled **Predictive Ecological Models**.

It is important to understand that a vegetation class label or attribute is *meaningless* unless it is associated with an ecological system. A customized process was used to map the project areas' ecological systems, and their component vegetation classes, as described below.

Definition and Description of Vegetation Prior to Mapping

Draft descriptions were compiled of ecological systems and their component vegetation classes that were believed to occur on the Bank Study Area and Plan of Operations Study Area, based on an inventory of ecological sites from the different NRCS soil surveys, and vegetation descriptions from different sites in the Great Basin (Appendix 1). The crosswalk to NRCS ecological sites is found in Appendix 2. The primary source of draft descriptions was from a previous project for the TS-Horseshoe Ranch, owned and operated by Elko Land and Livestock LLC, which is immediately north of the Bank Study Area. Adjustments to the vegetation descriptions continued throughout remote sensing and subsequent modeling.

Remote Sensing Analysis and Ground-Truthing

Spatial Solutions, Inc. was contracted by TNC to conduct vegetation mapping via interpretation of satellite imagery of the project area, which started on June 26, 2014 for the Bank Study Area and June 23, 2015, for the Plan of Operations Study Area. Remote sensing was conducted from new Spot6 (Spot 7 became available in 2016) 1.5-m resolution multi-spectral satellite imagery captured on June 8, 2014 for the Bank Study Area, and on June 14, 2015 for the initial Plan of Operations Study Area and archival imagery from May 30, 2016 and new imagery from June 25, 2016 for the expanded Plan of Operations Study Area. Moreover, freely available 1-m resolution NAIP imagery was used to assist interpretation of the 1.5-m multi-spectral imagery. The imagery was clipped to the boundary defined by Barrick staff and was not buffered outward. Private inholdings were part of the imagery, but private inholdings not belonging to Barrick were excluded from field surveys and mapping (i.e., removed from the imagery used in the field).

TNC sent descriptions of ecological systems and vegetation classes (see above) to Spatial Solutions. Spatial Solutions used these data to develop an unsupervised[3] vegetation classification of the selected satellite imagery, which was to be ground-truthed via fieldwork in June 26-July 23 and October 13-18, 2014 for the Bank Study Area, from June 23-July 11 and October 19-23, 2015 for original Plan of Operations Study Area, and from June 23-29, 2016 for expanded Plan of Operations Study Area. A chartered helicopter was used to interpret vegetation of the Bank Study Area on June 30, July 1, July 21 and October 15-19, 2014, from July 7-8 for the original Plan of Operations Study Area (including area of indirect effects), and June 27, 2016 for the expanded Plan of Operations Study Area.

Spatial Solutions used the software Imagine® from Leica Geosystems to conduct an iterative unsupervised classification of 1.5x1.5-m Spot6/7 imagery for the two landscapes. The unsupervised classification of the satellite imagery was used to interpret rasters and is described in Provencher et al. (2008, 2009) and Low et al. (2010). Draft raster layers were created of ecological systems and current vegetation classes with similar spectral characteristics (combinations of blue, green, red, and near infrared reflectance).

The goal of this field work was to visit all unique spectral class signatures (i.e., representing all of the systems and classes present) and document their vegetation and site features via rapid ("cruising") observations obtained from driving (either stopping or cruising), hiking, and helicopter flying. Each rapid road/hiking observation point included the identity of the ecological system and its vegetation class, and two geo-referenced photographs (landscape context and site) for use in future analysis. Additional comments about vegetation and topography were added to the data if time allowed. Prior to 2012, TNC utilized formal training plots, where the cover values of dominant species and cover types were recorded, which were supplemented with rapid observations. TNC and Spatial Solutions eventually replaced formal training plots with rapid observations, finding that a large number (e.g., 10,000) of rapid geo-referenced observations was far more valuable than a small number of formal training plots (e.g., 60-100 at most) given the short duration of field surveys. Thus, the Bank Study Area and the Plan of Operations Study Area, respectively, were covered by +7,800 observations and +9,300 observations. The portability of ruggedized computers, with GPS reception and Imagine® software running live, enabled the two field workers to map vegetation accurately by simply going within the boundary of spectral signatures, or by viewing them from a distance with binoculars (or via helicopter) in more difficult terrain.

A draft geo-layer of ecological systems and vegetation classes was spot-verified, and more observations were collected from data-poor areas, during a second field trip. The primary activity of the first field trip was to provide the vast majority of road, helicopter, and hiking observations. About 10 days were spent in each landscape during the first field trip. The second field trip was focused on areas that we were

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[3] In unsupervised classification, the image processing software classifies an image based on natural groupings of the spectral properties of the pixels, without the analyst specifying how to classify any portion of the image. This is in contrast to supervised classification, in which the analyst defines "training sites" – areas in the map that are known to be representative of a particular land cover type – for each land cover type of interest to guide the assignment of classes to each pixel.

unable to access during the first field trip, as well from areas already visited where more data were needed.

This final field trip allowed Spatial Solutions to complete final maps of ecological systems and their current vegetation classes, which were delivered to TNC on March 6, 2015, for the Bank Study Area. Final map delivery for the Plan of Operations Study Area was completed in three sequential efforts as proposed mine developments were added: January 18, 2016 for the Goldrush-Crescent Valley component, September 21, 2016 for the Dean Ranch and Filippini C-Ranches component, and November 10, 2016 for the Carico Valley and Frenchie Flat component.

Upon receipt of the ecological system and vegetation class rasters, the first step was to cross-walk Spatial Solutions' field coding to the nomenclature used in the state-and-transition models. The classification rasters originally had landcover systems and classes coded together in one field; however, ST-Sim is unable to utilize the data in this format. Therefore, the first step was to export the raw classified raster as an attribute table and added five new fields: SYS_NAME, SYS_CODE, CLA_NAME, CLA_CODE, and SYSxCLA. The original codes were crosswalked to ST-SIM appropriate codes, including corrections and reinterpretation of Spatial Solutions' classification if the names did not exist in ST-SIM. Utilizing a Python script, we added the new attribute table to the original raster creating a new 1.5m raster with the ST-SIM codes. We converted a shapefile of roads into raster format and combined it with the 'clean' 1.5-m raster.

The second step was to resample (i.e., make coarser) the 1.5-m resolution of Spot6 to a more manageable resolution. The 1.5-m spatial resolution resulted in a large number of pixels. This amount of data presents capacity challenges in processing and storing data both in the ST-Sim environment as well as for the habitat suitability estimation software. Therefore, to keep computer memory and processing in a reasonable timeframe, a multi-step resampling was necessary. We determined that 60-m was an acceptable resolution that retained characteristics of the landscape while reducing data processing.

We implemented a rule-based approach of resampling to ensure that small but important ecological systems would not be absorbed into the surrounding pixels during the resampling process. This included systems that are important to sage-grouse use as well as systems critical for non-native species management such as wet meadows. A set of priority rules was developed in order to determine how the different ecological systems (numerical code) and classes (name code; see Appendix 1-A) would be retained from 1.5-m to the final 60-m raster:

1. Preserve pixels of local and paved roads (10032)
2. Preserves pixels of inactive mines (10061)
3. Preserve pixels of agriculture (10070)
4. Preserve pixels of aspen (10110) in all vegetation classes at the expense of wet meadows (11450); furthermore, older depleted aspen classes (U-D:Depleted > U-B:Depleted, see Appendix 1_A for all descriptions) are preserved over all other vegetation classes in decreasing importance of succession age.
5. Preserve pixels of wet meadow-montane (11450) at the expense of other wet and upland system pixels. Within this system, the following classes are prioritized in decreasing order of importance: U-C:Exotic Forbs > U-B:Exotic Forbs > U-A:Exotic Forbs > U-C:Hummocked > U-B:Hummocked > U-A:Hummocked > U-A:Annual Spp > U-C:Desertified > U-C:Shrb-Frb Encr > U-B:Shrb-Frb Encr > U-A:Shrb-Frb Encr > B:Closed > C:Open > A:All.

6. Preserve pixels subalpine-upland grassland (11400) at the expense of surrounding upland pixels (mostly montane sagebrush steppe (11260), but not montane wet meadows (11450) pixels. Prioritize pixels in decreasing order of importance: C:Open > A:All > B:Closed.
7. Preserve pixels of exotic forbs (U-A:Exotic Forb) or exotic forbs and trees (U-A:Exotic-Forbs-Tree) in the following sequence of decreasing importance order for ecological systems: montane riparian (11540) > basin wildrye-montane (10801) > saline meadow (11451) > greasewood (11530) > four-wing saltbush (10811) > mountain shrub (11060) > winterfat (10812) > montane big sagebrush-subalpine (11261, U-A:Early-Shrub instead as exotic forbs are mostly absent from this system) > montane big sagebrush-upland (11260) > black sagebrush (10791) > mixed salt desert (10810). Early-succession exotic forb classes have higher resampling priority that later succession ones.
8. Preserve pixels of exotic Forbs (U-B:Exotic Forb) or exotic forbs and trees (U-B: Exotic-Forbs-Tree) in the following sequence of decreasing importance order for ecological systems: montane riparian (11540) > big sagebrush upland with trees (10804) > greasewood (11530) > mixed salt desert (10810). Mid-succession exotic forb classes have higher resampling priority that later succession ones
9. Preserve pixels of exotic forbs (U-C:Exotic Forb) or inset exotic forbs and trees (U-B:Inset-EFT) in the following sequence of decreasing importance order for ecological systems: basin wildrye-montane (10801) > montane riparian (11540).
10. Preserve pixels of hummocked classes (U-A:Hummocked) in the following sequence of decreasing importance order for ecological systems: montane riparian (11540) > saline meadow (11451) > inset montane riparian (U-A:Inset-HU).
11. Preserve pixels of moist floodplain (11541) mid-succession closed class (B:Willow) before pixels of montane riparian (11540) early-succession willow class (A:Willow).
12. The remaining pixels are subject to the implementation of the majority rule of ArcGIS.

To speed up the time it takes to process the raster into a usable format we used a Python script to direct ArcGIS 10.2.2, which also minimized human entry errors. A Python script (Appendix 3) was used to implement the following steps:

1. Implement a table of ranked ecological systems and classes paired with the updated raster including roads.
2. Extract priority classes with a ranking greater than 0 and perform block statistics (maximum) with a 60-m window. This was then resampled at a 60-m resolution.
3. Resample the entire raster (including the systems with a ranking greater than 0) at a 60-m resolution using majority filter.
4. Mosaic the resampled priority classes onto the resampled entire landscape to make the final 60-m raster.

While the impacts of vehicular sound on lekking behavior is well documented (Holloran 2005, Blickley et al. 2012, Patricelli et al. 2013), less is known about how noise from vehicles impact other aspects of GSG life history (though see Lyon and Anderson 2003). Whereas exact mechanism of impact is understudied, GSG are likely affected by vehicular traffic (e.g. sound disturbance, collisions, and altered predatory behavior; Sedinger pers. comm.). Given this relationship, special attention was given to roads. Spatial Solutions mapped two-track roads as barren, county maintained roads as roads-local, and paved roads as roads-paved. However, we found that Spatial Solutions' labeling of roads was not 100% consistent.

Although we kept the two-track roads as barren because they do not affect sage-grouse, we used external mapped road layers to force the designation of county-maintained dirt roads as "roads-local" and the few paved roads as "roads-paved." Then both local and paved roads were unified as local roads because the noise from both road types can equally affect male sage-grouse lekking. Roads were corrected at the end of the resampling processing on the 60-m raster. The resulting systems and classes raster layers provided the base vegetation rasters for the model.

The last iteration in the final draft map of current vegetation classes was used to calculate draft sage-grouse habitat suitability and unified ecological departure scores (defined farther below). The final vegetation maps and metric scores were reviewed at the project's first "management" workshop held November 17-19, 2015.

A number of difficulties were encountered during remote sensing. The following challenges and solutions were dealt with:

1. The most difficult mapping was in burned areas where no standing shrub vegetation remained. Although the vegetation class was relatively easy to determine (most often a monoculture of non-native annual species or a mix of native grasses and non-native annual species), the identification of ecological systems in thoroughly burned areas was the primary challenge because no standing woody vegetation is available to identify. When burned areas are large enough, several distinct ecological systems may have been present before the burn. The best method for classifying these areas required comparing to adjacent unburned areas at the same elevations and in the same watershed, and walking the burn to find remnant live or dead shrubs to assign dominant species to the ecological system. In addition, we relied on NRCS soil surveys and map units composed of single ecological sites (uncommon situation) to help assign ecological systems to large fires dominated primarily by annual species. Due to the challenge of classifying these areas, smaller ecological systems could have been missed in burn scars.
2. Large areas of the Bank Study Area and Plan of Operations Study Area support intermixed low and black sagebrush (shrubs of the two species were observed growing side by side), which we had never encountered before, although areas of pure low or black sagebrush were also encountered (e.g., the clay soils north and west of the Buckhorn mine support pure low sagebrush communities). NRCS's shallow clay loam for the Simpson Park Range is described as containing equal amounts of both species in the same soil unit. Moreover, we observed low sagebrush invaded by conifers as black sagebrush is in these mixed sites, which we had rarely encountered elsewhere where heavy clay soils are unhospitable to tree roots. Elsewhere, geology and soil types cause the two communities to be spatially segregated. Spectrally, it was impossible to distinguish between low and black sagebrush in such close proximity. Our first reaction was to lump both ecological systems as "dwarf sagebrush," but pure low sagebrush areas that did not appear to support trees could not be included in this lumped group because we would have predicted tree invasion when, in reality, it does not appear to happen. Therefore, lumping black and low sagebrush was not helpful. We decided to keep communities distinct and commit large amounts of field observations to areas of intermixed black and low sagebrush. When both species were completely intermixed, we assumed, based on observations, that lower and higher elevation communities, respectively, were primarily black sagebrush and low sagebrush. We predicted that this issue would be a source of errors during the accuracy assessment though these errors are not important to sage-grouse habitat suitability assessments. Although the accuracy assessment was >80% accurate for low and black

sagebrush, the greatest source of errors was low sagebrush being confused with black sagebrush, which we considered acceptable given NRCS's site description (Appendix 11).

3. Distinguishing among saline meadow, greasewood, pickleweed, four-wing saltbush, degraded basin wildrye bottomland, and big sagebrush semi-desert is spectrally difficult due to soil reflectance and very time-consuming because ecological systems were inter-mingled in a complex manner due to very small changes in elevation and fine sediment accumulation causing complete community changes. The two easiest of these difficult systems was basin wildrye bottomland and saline meadows because the abundant grass reflected more infrared. Basin wildrye when in its grass phase exhibits an infra-red signature and texture due to the tall grass that is distinctive, however, degraded basin wildrye that has been converted to bare ground or is dominated by shrubs due to heavy livestock grazing is difficult to map because it can be confused for degraded mixed salt desert, big sagebrush semi-desert, or greasewood. Greasewood flats were distinct due to their very white and high soil reflectance, except where they blended into saline meadows or pickleweed where greasewood, rabbitbrush, and/or basin big sagebrush plants have slightly encroached during dry periods. Patches of four-wing saltbush are difficult to detect, unless in large areas, because they blend in completely with the surrounding greasewood, mixed salt desert, or degraded basin wildrye bottomland. Big sagebrush semi-desert will follow low-gradient shallow washes that enter the greasewood zone. Therefore, this community often had a distinct linear shape; however, these community attributes were similar to those of shrub-encroached basin wildrye bottomland at lower elevations. We found that true degraded basin wildrye has denser shrub cover and will still support isolated clumps of basin wildrye. Mapping of these features took more time than mapping anything else despite an abundance of driving, hiking, and helicopter observations. None of these systems are GSG habitat.

4. It can be difficult to separate the widespread big sagebrush upland (i.e., Wyoming big sagebrush upland) from the montane sagebrush steppe (the primary indicator species is mountain big sagebrush) at their ecotone, especially if the area burned. Our first approach at separating the two systems was to determine the elevation of the ecotonal transition while driving roads and trails climbing in elevation and using that elevation as the first guess for splitting these two systems in other areas not visited. If the ecotonal transition could not be positively identified in other areas due to lack of field observations and fire, an arbitrary cutoff at 6,500 feet of elevation was used. Because the elevation cutoff was generic for unvisited areas, we knew this would cause mapping errors, albeit acceptable ones, during the accuracy assessment (see Appendix 11 for accuracy assessment methodology).

5. Mountain shrub is difficult to tease apart from montane sagebrush steppe. The two causes of this difficulty are that mountain shrub species are naturally found in montane sagebrush steppe communities, sometimes in high cover than in a pure mountain shrub community, and that more mesic occurrence of mountain big sagebrush nestled in snow bowls could be spectrally similar to mountain shrub. The first problem makes the field identification of mountain shrub ambiguous. We resolved to adopt a clearer description of mountain shrub communities that required >10% mountain shrub species and <10% of big sagebrush species cover when unburned. The second problem required field observations, often obtained by helicopter, to determine if the spectral signature was mountain big sagebrush with a lush understory of basin wildrye or mule-ears, or true mountain shrub.

Contributions from Expert and Stakeholder Partners on Maps

Expert and stakeholder opinion was one tool used to validate the mapping product. In the first workshop, TNC presented the base vegetation maps for review by people familiar with the landscape. A full day was dedicated to reviewing these maps in as much detail as the participants required. TNC used ArcGIS to isolate systems and classes of interest for the workshop participants to discuss and check the vegetation maps against their field knowledge. The result of this discussion was that participants were familiar with the quality of the mapping product and expressed confidence moving forward with it as the base map for the modelling platform. See Appendix 10 for more details of the expert stakeholder workshops.

Predictive Ecological Models

The SGCF (or LCF^{TM}) process includes the simulation of management scenarios using state-and-transition predictive models for each ecological system (reviewed in Daniel and Frid 2012 and Provencher et al. 2015). 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). Examples of state-and-transition models are shown in Forbis et al. (2006) for mountain big sagebrush from eastern Nevada and in Provencher et al. (2015) for Wyoming big sagebrush upland gravelly loam in Utah and buffelgrass (*Cenchus ciliaris*) in Arizona.

To build the full suite of state-and-transition models for this project, TNC modified models from TNC projects completed with Newmont Mining Corp. (Provencher et al. 2016), the BLM Cedar City Field Office (Provencher et al. 2015), Dixie National Forest (Tuhy et al. 2014), Great Basin National Park (Provencher et al. 2013), and NDOW's Revised Wildlife Action Plan (Wildlife Action Plan Team 2012).

Different boxes in the model belong either to: (a) different *states*, or (b) 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. Unlike thresholds, relatively reversible changes (e.g., fire, flooding, drought, insect outbreaks, and others) operate between phases *within* a state. In the TNC parlance, vegetation *classes* include *states* and *phases* because we follow the LANDFIRE terminology (Rollins 2009) and the simulation software cannot distinguish between states and phases (Daniel and Frid 2012), therefore all *phases* are *classes*, but not all *classes* are *phases*.

Predictive models for ecological systems include several different types of vegetation classes: reference and uncharacteristic. The classes of pre-settlement vegetation are considered to be each ecological system's core succession *reference* classes. At their core, therefore, all models have the reference condition represented by some variation around the A-B-C-D-E reference classes originally developed by LANDFIRE (see Table A7-2; Rollins 2009). The A-E classes typically represent succession, usually from herbaceous vegetation to increasing woody species dominance, either shrubs or trees. Said another way, the A-E classes are different (successional) *phases* within a single reference *state*.

Natural Range of Variability

The Natural Range of Variability (NRV) for each ecological system is the relative amount (percentage) of each vegetation class that would be expected to occur in an ecological system under its *reference* condition, i.e., under natural disturbance regimes and current climate (Hann and Bunnell 2001; Provencher et al. 2007, 2008; Rollins 2009). Understanding the NRV serves two purposes. First, and most relevant for the worked reported in this document, each ecological state-and-transition model must reach a credible NRV, based on expected NRV from the literature, when simulating reference conditions. This allows us to check model assumptions (e.g. fire return intervals, succession pathways, etc.). Second, the calculation of current or future condition (or "ecological health") of each ecological system based on ecological departure requires NRV. While, ecological departure was not the focus of this project, TNC tracked unified ecological departure and it is reported in Appendix 7.

NRV was calculated from results obtained from state-and-transition simulation models using the software ST-Sim within the Syncrosim platform (www.apexrms.com, www.syncrosim.com; Daniel and Frid 2012). The NRV is obtained by simulating models for 500 to 1,000 years without any post-settlement European disturbances or uncharacteristic classes and obtain the proportion of reference classes per ecological system. The NRV (reference) percentages of vegetation classes for each ecological system derived from the model are found in Table 1 in Appendix 7.

Uncharacteristic Classes

The current landscape contains vegetation classes (in many ecological systems) that would not be expected under natural disturbance regimes, and thus would not have been present in reference conditions (for example, a shrubland invaded by non-native annual species). These non-reference classes are termed uncharacteristic classes (designated with an "U:"). In addition to modeling reference conditions, therefore, predictive models also include the full range of uncharacteristic classes in the project area. The two main categories of uncharacteristic classes comprise vegetation or site conditions that result from:

(1) Disturbances beyond what would be considered "natural," whether caused by human actions or not; examples include invasion/dominance by non-native grasses, depleted understories of shrublands, incised/entrenched riparian areas, etc.; or
(2) Purposeful actions by land managers to manipulate or alter vegetation to meet specific management objectives, such as seedings with non-native species to provide forage for livestock and wildlife.

A complete list of model classes, their ages, and successional pathways appears in Appendix 4A.

Probabilistic Transitions

Predictive models for ecological systems also include arrows ("transitions") among classes that represent several types of pathways including:

1. Vegetation succession or simply a change in vegetation structure/composition due to the passage of time is generally modeled as a deterministic transition (but can be modeled probabilistically);
2. Disturbances that can be represented by probabilistic events:
    i. Natural ecological processes, such as fire or flooding;
    ii. Uncharacteristic disturbances, such as annual grass invasion or livestock grazing; and
    iii. Active management treatments, such as mechanical thinning or prescribed fire.

To develop the predictive ecological models used in this project, existing state-and-transition simulation models in the TNC library were revised to reflect decisions regarding the project's ecological systems and vegetation classes that were made in the first workshop. Models were constructed and run using the modeling software ST-Sim (www.apexrms.com, www.syncrosim.org; Daniel and Frid 2012). A complete list of model parameter values (probabilistic transitions) appears in Appendix 4B.

Spatial Parameters Generated for Modeling

In past LCF™ projects, non-spatial modeling was generally conducted because there were no explicit spatial questions that justified the increased computational demand of spatial modeling. Because we report here on species habitat suitability, where a species' fitness depends on the proximity of landscape features, spatial modeling was required for the SGCF process. Spatial modeling was also required to represent (a) the grazing systems defined by the spatial distribution of livestock, wild horses, and domestic unbranded horses (i.e. feral horses) by allotments and pastures, and the distance from water sources (all provided by Barrick), and (b) to constrain management zones with various spatial rasters.

ST-Sim allows for spatial modelling using the rasters of ecological systems, their vegetation classes, and land ownership as inputs. When current condition rasters are coupled with the state-and-transition models supplied to ST-Sim simulation of spatially explicit results are possible. From the simulated rasters, we can estimate future spatial metrics for our species of interest.

In order to create alternative future rasters of vegetation using ST-Sim's spatial modeling, additional data are required to more realistically model ecological and management processes. There are six types of data needed: Size distribution, spread distribution, patch prioritization, spatial multipliers, direction multipliers, and dynamic habitat suitability.

Size Distribution

The first set of additional spatial data consists of the spatial frequency distributions for all natural and management disturbances (i.e. probabilistic transitions; Appendix 4B). These distributions define the percentage of occurrence for a disturbance of a certain size (area; Table 2). For example, based on federal fire occurrence data from 1980 to 2014 and the Monitoring Trends in Burn Severity (MTBS) data from 1984 to 2014 for each landscape, we determined that 51% of fires were less than 1 acre, 16% of fires were between 1+ and 10 acres, 21% were between 10+ and 1,000 acres, 9% were between 1,000+ and 10,000 acres, 3% were between 10,000+ and 500,000 acres. In addition to the size distribution, no priority was given to any fire size interval realization relative to others (e.g., position large fires first, which are more difficult to place in fragmented landscapes, then other fire sizes). Finally, some disturbances receive no size distributions if they are spatially managed, such as livestock and horses, or the disturbance is believed to be random.

Table 2. Percent occurrence of ecological and management probabilistic transitions (i.e. disturbance) for various acreage sizes. For management actions, the size distribution indicates the minimum and maximum areas of implementation for any one event (e.g., contractor application) as it is often not possible for a contractor to profitably apply a treatment below a certain area and an application too large may not be feasible in one year. Actions not listed here have no size constraints in the model.

Probabilistic Transition	Area of Disturbance (Acres)	Percent Occurrence
AerialSeed+Masticate+Plateau	200+ to 1,500	100
AllFire	1	51
	1+ to 10	16
	10+ to 1,000	21
	1,000+ to 10,000	9
	10,000+ to 500,000	4
Aroga-Outbreak	1	90
	1+ to 100	10
AS-Invasion	1	99
	1+ to 10	1
Chainsaw-Thinning	10+ to 1,000	100
Competition	1	100
Entrenchment	1 to 10	100
Exotic-Control	1 to 100	100
Exotic-Invasion	1 to 1	90
	1+ to 10	10
Flooding	1 to 500	100
Floodplain-Recovery	1	100
Herbicide-Plateau+Seed+Shrub-Planting	1+ to 5,000	100
Insect/Disease	1	90
	1+ to 10	10
LosingClone	1	90
	1+ to 10	10
Severe Drought	1 to 100	95
	100+ to 50,000	5
Small-Tree-Lopping	200+ to 5,000	100
Weed-Inventory+Spot-Treat	1 to 5,000	100

Spread Distribution

The spread distribution applied only to the spread of non-native annual grasses (i.e., cheatgrass), exotic forb species, and native trees into shrublands (i.e. pinyon-juniper encroachment) from an infested source pixel into nearby or distant pixels. Note that ST-Sim also creates a few random invasion events beyond the distances specified by the spread distribution. For annual grasses, 99.9% of dispersal was within 5 m of a pixel (which was 60 x 60 m calculated from pixel centers), and the remaining 0.1% were within 30 m (i.e., the adjacent pixel). For exotic forbs, the frequencies and distances were, respectively, 99.9% and 0.1% for 1 m and 30 m. For pinyon or juniper encroachment into shrublands, the frequencies and distances were, respectively, 99.99% and 0.01% for 10 m and 30 m. Model results were most sensitive to the spread distribution specifications. A slight increase in the spread distance can profoundly increase the area invaded by the end of the simulation.

Patch Prioritization

Patch prioritization was only used to define the size of an exotic forb patch that would first be targeted for treatment. Actions were prioritized to first treat the smallest patches of exotic forbs, and then move to the next larger patches.

Spatial Multipliers

Spatial multiplier rasters were used either to enhance or to constrain natural or managed disturbances. We used four types of spatial multipliers that control the locations of (i) livestock and horse grazing, (ii) management exclusion areas, (iv) static fuel breaks, and (iii) dynamic management actions (Table 3). Unless noted each layer was generated for both the Bank Study Area and Plan of Operations Study Area.

Table 3: Summary of rasters created to support spatial simulations

Spatial layer	Purpose	Origin	Associated Figure
Base Mapping			
Classes	Identifies the vegetation classes per ecological system	Spatial Solutions remote sensing	*not shown*
Systems	Identifies the ecological systems	Spatial Solutions remote sensing	Figure 13, Figure 14
Livestock and Horse Grazing			
Four grazing management rasters for: Early-spring, late-spring, summer, and fall seasons grazing pastures	Identifies the relativized AUMs (heads of cattle pro-rated to months of use and pasture area, converted to AUMs, and divided by cumulative AUMs of each ranch to relativized pasture-level AUM partitioning) of cattle on the ranches in early-spring, late-spring, summer, and fall seasons for a current (baseline or custodial) system.	Barrick, BLM, and TNC	Figure 3, Figure 4
Cattle grazing on Slopes	Identifies the probability of cattle grazing on increasingly steeper slopes. No constraints on horses.	Digital Elevation Model (DEM) downloaded from EPA website	*not shown*
Horse Management Areas	Identifies the wild horse management areas overlapping project area and relativized by AUMs (as done with cattle except no season of use).	BLM and TNC	Figure 5

Spatial layer	Purpose	Origin	Associated Figure
Cattle Grazing: Distance to water in summer *Bank Study Area only.*	To identify areas with the greatest probability for grazing by cattle in summer	Calculated from water sources provided by Barrick	Figure 6
Cattle Grazing: Distance to water in early-spring, late-spring, and fall	To identify areas with the greatest probability early-spring, late-spring, and fall season of use based on the distance to water.	Calculated from water sources provided by Barrick	Figure 6
Horse Grazing; Distance to Water in Summer for Horses applied to entire year (most limiting and damaging effects)	To identify areas with the greatest probability for grazing by horses in summer based on the distance from water. Assumes no water constraints during cooler seasons.	Calculated from water sources provided by Barrick	Figure 6
Fuel Breaks			
"Custodial" Fuel Breaks	Location of existing fuel breaks and roads that may act as fuel breaks.	BLM, TNC	Figure 7
"Extended" Fuel Breaks *Bank Study Area only*	Identifies potential fuel breaks that could be implemented to minimize catastrophic fires on the landscape. Combined BLM's FIAT, Barrick private lands, and expanded fuel breaks created by Barrick and TNC. Includes all major roads.	BLM, Barrick, and TNC	Figure 8
Steep Slopes			
Slopes >15 degrees *Bank Study Area only*	Identifies areas of slopes of greater than 15%, which restricts certain mechanical restoration treatments. (eg: range drills cannot typically operate on slopes >15%)	DEM downloaded from EPA website	Figure 10
Slopes > 30 degrees *Bank Study Area only*	Identifies areas of slopes of greater than 30%, which restricts mechanical restoration treatments. (eg: masticators cannot typically operate on slopes >30%)	DEM downloaded from EPA website	*not shown*
Management Control Rasters			
Land Ownership / Management	Defines land management in model to allow for differential treatment plans. Categories include areas of Barrick-owned private land, BLM land, and BLM land in the South Roberts Allotment.	Barrick	Figure 9
South Buckhorn Exclusion *Bank Study Area only*	Further refined areas available for treatment based on management control. Prevented actions in a part of the South Buckhorn Allotment that is not under Barrick management.	Barrick	Figure 10

Spatial layer	Purpose	Origin	Associated Figure
Frenchie Flat Exclusion *Bank Study Area only*	All actions were prevented in the exterior part of Frenchie Flat	Barrick and TNC	Figure 10
JD Meadow Irrigation *Bank Study Area only*	Irrigation of an area in the greasewood system to create an irrigated pasture within the basin wildrye system.	Barrick	Figure 10
Wet Meadow Exclusion *Bank Study Area only*	Wet meadow restoration and maintenance actions were limited to only wet meadows in strategic areas	Barrick and TNC	Figure 10

Livestock and Horse Grazing
Spatial rasters limited early-spring (April 1 to May 15), late-spring (May 16 to June 30), summer (July 1 to September 30), and fall (October 1 to Marsh 30) cattle grazing to certain pastures within allotments under custodial management (i.e., baseline; Figure 3 for the Bank Study Area and Figure 4 for the Plan of Operations Study Area). Two classifications of horses were used for this project. Horses that are managed by the BLM under the Wild and Free Roaming Horse Act were considered "wild" horses. Horses that exist on these lands that are not managed under this Act were considered "unbranded, unclaimed" horses. The rasters defining where these different classifications can be seen in Figure 5.

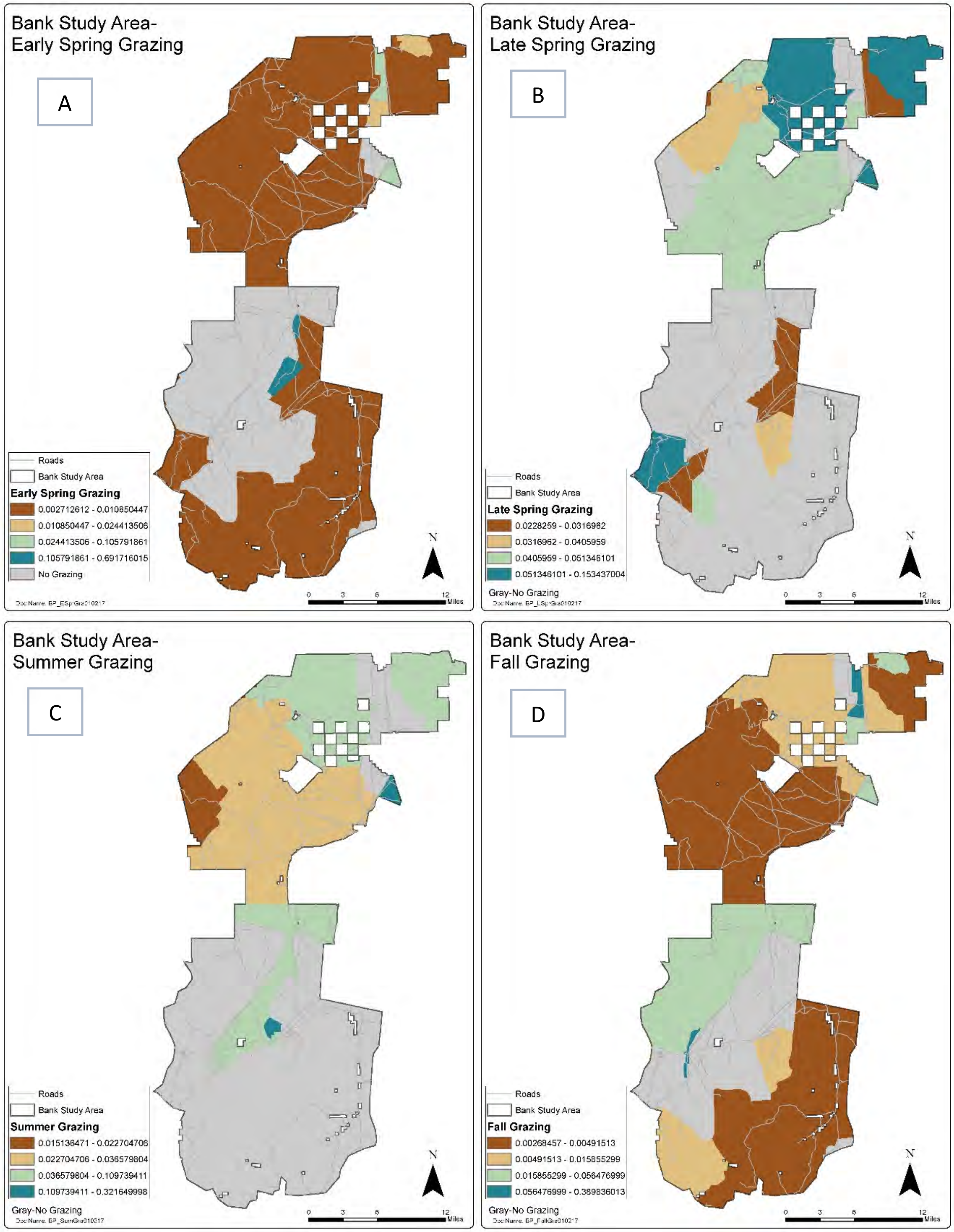


Figure 3: Grazed pastures for the early-spring (A: April 1 to May 15), late-spring (B: May 16-June 30), summer (C: July 1 to September 30), and fall (D: October 1 to March 30) season of use for Bank Study Area. Scale indicates intensity of grazing based on permitted AUMs, length of time in a given allotment or pasture, and size of a given allotment or pasture.

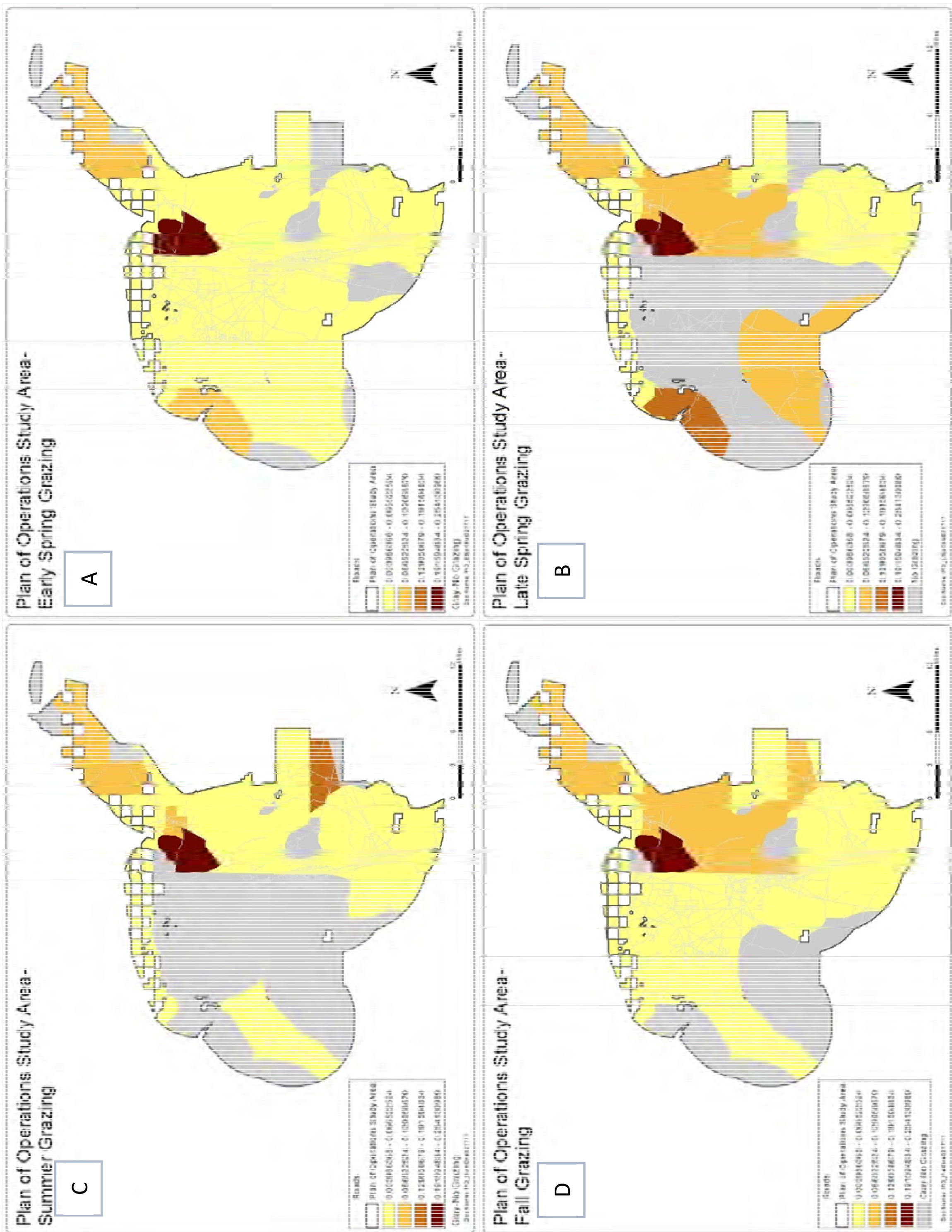


Figure 4: Grazed pastures for the early-spring (A: April 1 to May 15), late-spring (B: May 16-June 30), summer (C: July 1 to September 30), and fall (D: October 1 to March 30) for the Plan of Operations Study Area. Scale indicates intensity of grazing based on permitted AUMs, length of time in a given allotment or pasture, and size of a given allotment or pasture.

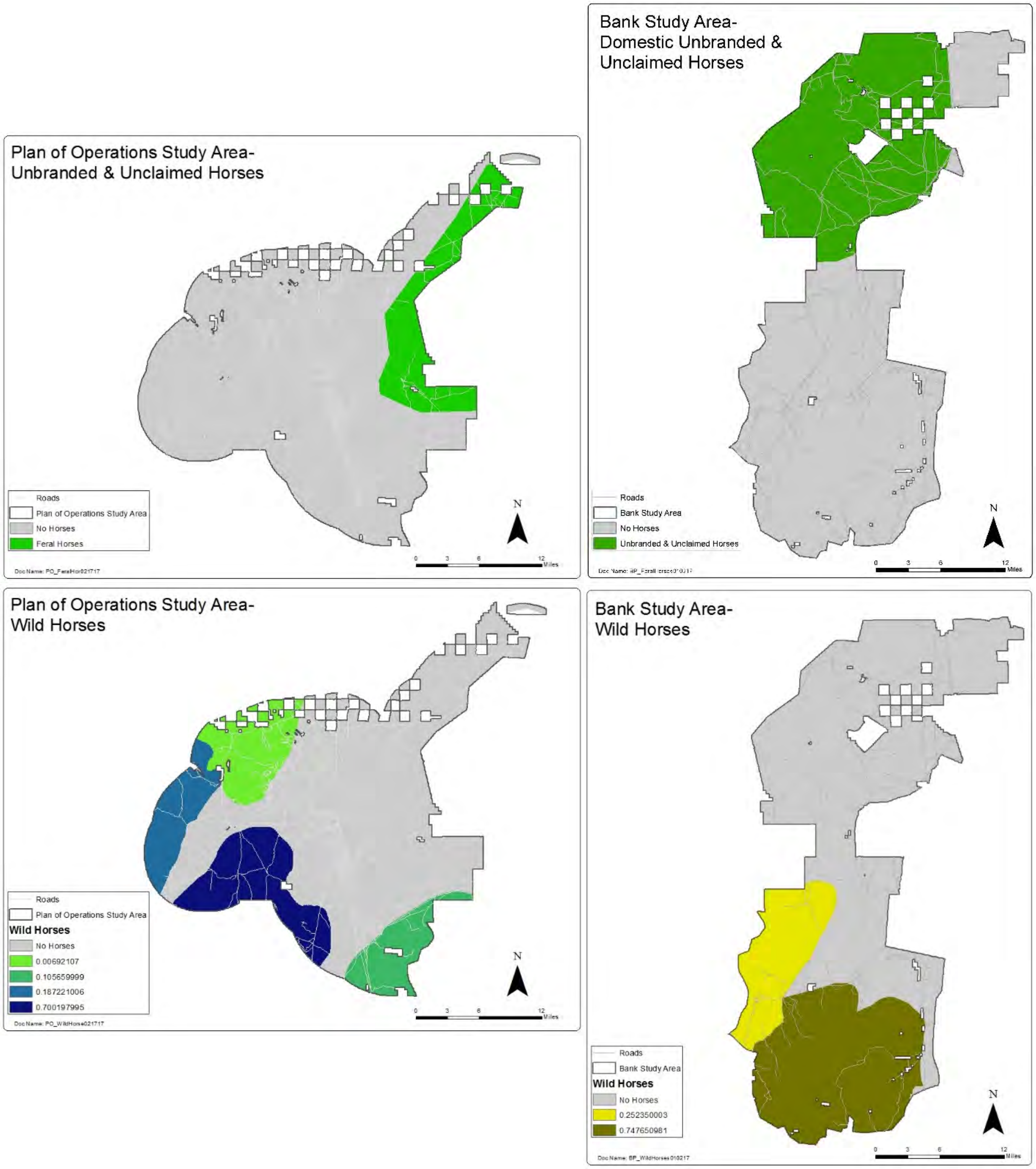


Figure 5: Areas grazed by wild horses and domestic unbranded and unclaimed horses in the Bank Study Area and Plan of Operations Study Area. Scale indicates intensity of grazing based on permitted AUMs, length of time in a given allotment or pasture, and size of a given allotment or pasture.

Furthermore, grazing intensity was jointly controlled by the distance from water sources and slope that varied between the summer (late-season grazing when many plants have begun to senesce and animals experience heat) and all others seasons (early-season grazing season when moisture is present in the vegetation or when animals stay cool during the day) (Table 4; Figure 6)

Cattle generally prefer to graze on shallower slopes; however, the effect of slopes is also seasonal. During the spring and fall grazing, spatial multiplier values were: 0.75× from 0% to 9% slopes; 0.18× from >9% to 19% slopes; 0.05× from >19% to 29% slopes; 0.02× from >29% to 39% slopes; 0× on slopes >39% slopes (Ganskopp and Vavra 1987). During the summer season of use, cattle appear to use steeper slopes characterized by more productive mountain big sagebrush communities: 1× for slopes <50% and 0× for slopes ≥50%. Discussions with experts revealed that horses are able to travel on steeper terrain thus we assumed horses are not constrained by slope.

Table 4. Effect of distance from a water source on the grazing rate of cattle and horses used in the ST-Sim transition pathways.

Cattle		
Distance (mi)	Summer Grazing Spatial Multiplier	Spring & Fall Grazing Spatial Multiplier
0.0 to 0.5	1.0	1.0
>0.5 to 1.0	0.9	1.0
>1.0 to 1.5	0.5	0.8
>1.5 to 2	0.1	0.5
>2.0 to 2.25	0.05	0.3
>2.25 to 2.5	0.0	0.3
>2.5 to 3.0	0.0	0.1
>3.0 to 4.0	0.0	0.03
>4.0	0.0	0.0
Horses		
Distance (mi)	Summer Grazing Spatial Multiplier	
0.0 to 0.25	1.25	Not used
>0.25 to 1.2	1.2	Not used
>1.2 to 1.25	0.65	Not used
>1.25 to 6.5	0.35	Not used
>6.5 to 9.0	0.21	Not used
>9.0	0.0	Not used

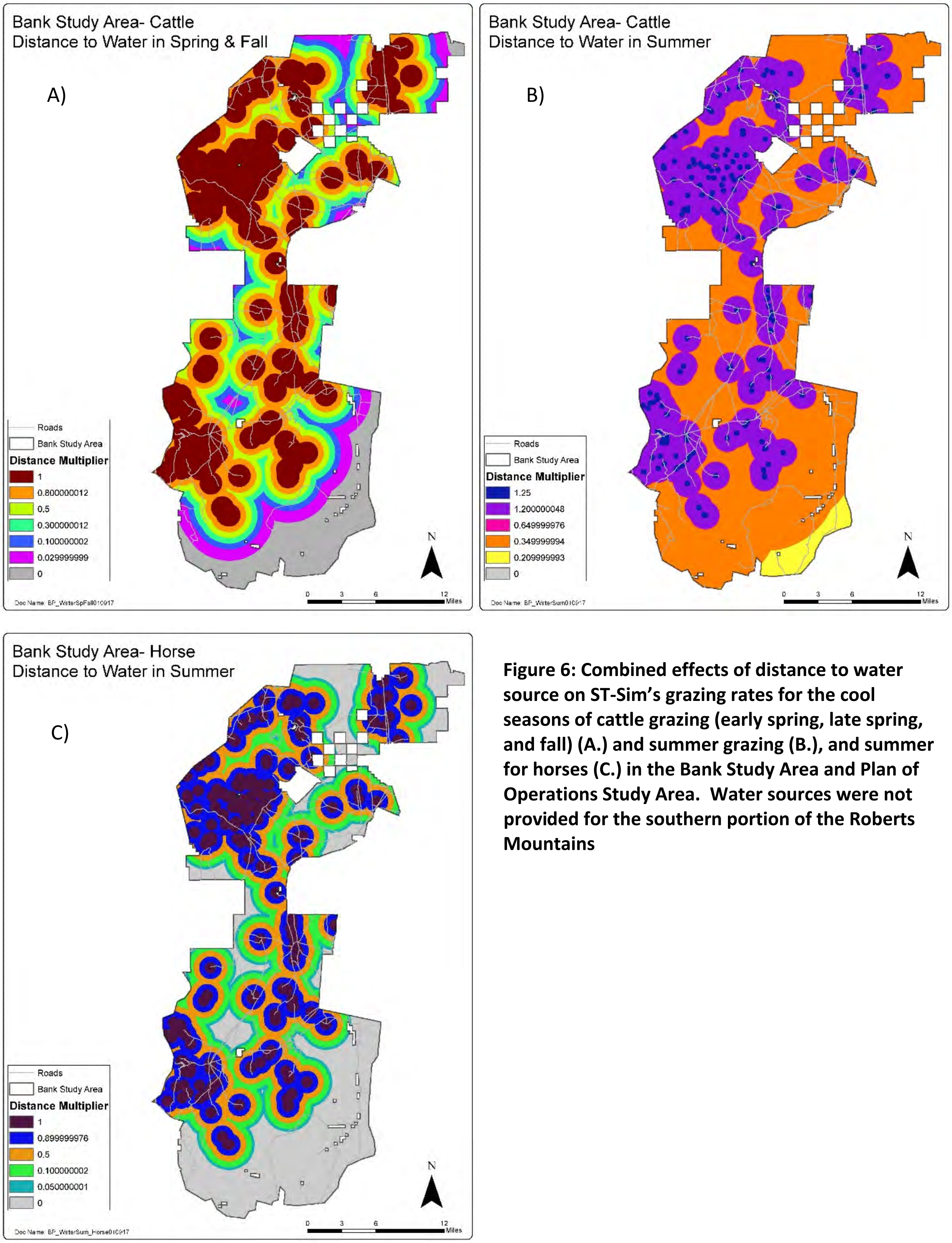


Figure 6: Combined effects of distance to water source on ST-Sim's grazing rates for the cool seasons of cattle grazing (early spring, late spring, and fall) (A.) and summer grazing (B.), and summer for horses (C.) in the Bank Study Area and Plan of Operations Study Area. Water sources were not provided for the southern portion of the Roberts Mountains

Fire-Suppression Effects of Roads and Fuel Breaks

All pixels that were classified as “Roads-Local” were assigned a low fire-return interval in both Study Areas (Figure 7 depicts these pixels for the Bank Study Area). These local road pixels (i.e. non-two track roads, such as county maintained road and paved roads) were given a value of 0.00195. This replacement fire rate was specified in ST-Sim as a probability per year because local roads are considered an ecological system (two-track roads were classified as the vegetation that existed between the tire tracks). As roads are known to impede fire spread, this value produces a very poorly permeable (i.e. very resistant) barrier to fire. To obtain this rate, we calculated from prior ST-Sim simulations the average overall probability per year of fire in the low to middle elevations where roads are mostly found. This rate was 0.011/year (equivalent to a 91-yr. mean fire return interval). Expert opinion suggested that in the absence of a fire suppression crew, a county-maintained road is likely to stop 20-50% of fires under average fire weather (Sandy Gregory, Nevada State Office of Bureau of Land Management, pers. comm.) Therefore, the frequency rate was multiplied by the median of that suggested range: 0.011 × 0.35 = 0.0039. Assuming ground fire crews will get to roads in approximately one hour, coming from either Battle Mountain, Eureka, or Elko, the crew is 50% likely to stop a fire at the road (i.e. there is a 50% probability of fire jumping the road): 0.0039 × 0.5 = 0.00195/year. We recognize that road material does not burn itself, but the vegetation around a road changes the likelihood that a fire will jump a road. Also, note that our roads are pixelated on the map, such that, real roads are more likely to stop fires.

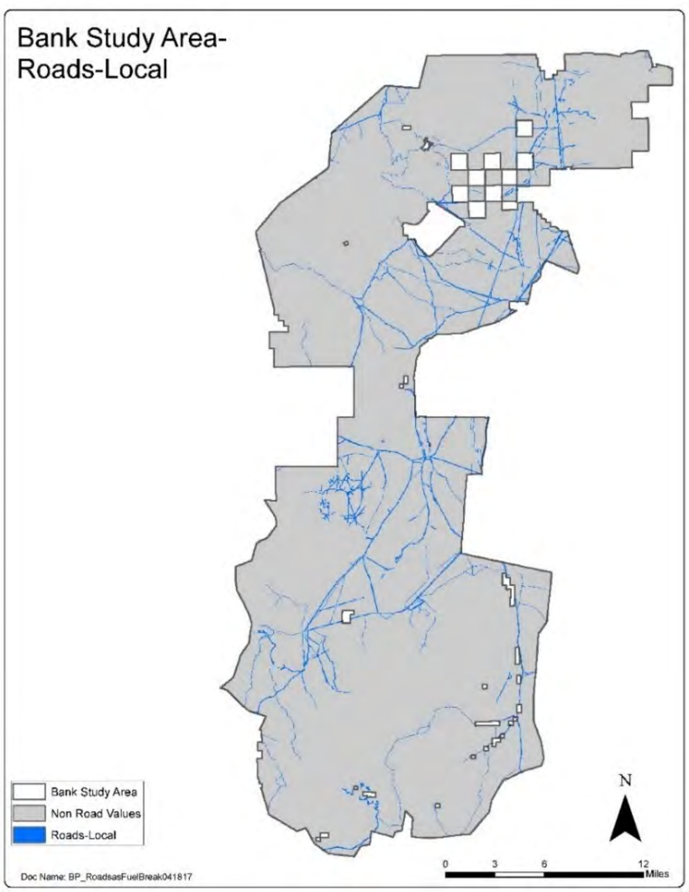


Figure 7: Pixels classified as Roads-Local in the Bank Study Area.

TNC also generated a raster of possible fuel breaks for the Bank Study Area based on existing BLM fuel breaks and additional ones we propose in areas near, and mostly upwind, of critical sage-grouse habitat (Figure 8). TNC assumed the use of introduced species (e.g. forage kochia), which generally perform better than native species as fuel breaks (Maestas et al. 2016). Fuel breaks were designed to follow existing roads and two-tracks to avoid further habitat fragmentation. The raster suppressed fire probability within the proposed fuel beaks, which were generally two 60-m pixels wide. Fire rates outside of the fuel break pixels were unchanged. As fire is known to jump fuel breaks under extreme fire weather (Maestas et al. 2016), absolute fuel breaks were not modeled. The fire suppression effect of these fuel breaks varied based on whether they were along a narrow (two-track, which were identified using the BLM Road polyline layer) or wide (county-maintained, "bladed," or paved) existing road:

(a) For fuel breaks along two-track roads, we assumed that fire will jump such a fuel break about 50% of the time in the early fire season and 70% of the time in the late fire season (average of 60%). Furthermore, longer response time by fire suppression crews were assumed in more difficult/remote terrain, so fires will be extinguished only 10% of times (i.e., fire will jump the fuel break along two-tracks 90% of the time). Thus, the raster value for suppressing fire used for fuel breaks along two-track roads is $0.6 \times 0.9 = 0.54$. For example, fire in montane sagebrush steppe with an average fire return interval of 75 years, would experience a realized fire probability of $1/75 \times 0.54 = 0.0072$. If low sagebrush is present, then the rate will be lower.

(b) Fuel breaks along local roads (i.e. non-two-track roads) were given a raster value of 0.000165, simulating a highly efficient fuel break (Maestas et al. 2016). To obtain this value, the fire probability for local roads (0.011) was multiplied by the median likelihood that a fire would jump a fuel break adjacent to a road in the absence of a fire suppression crew (median= 7.5%, range =5% to 10%, S. Gregory, pers. comm.): $0.011 \times 0.075 = 0.000825$. This rate was then modified by the likelihood that a fire suppression crew would be able to extinguish a fire that reaches a fuel break. Although fire crews are likely to take at least one hour to get to the fuel break, the fuel break would slow fire spread enough to decrease likelihood of a fire jumping the fuel break to 20% (thus, fires would be stopped 80% of the time): $0.000825 \times 0.2 = 0.000165$.

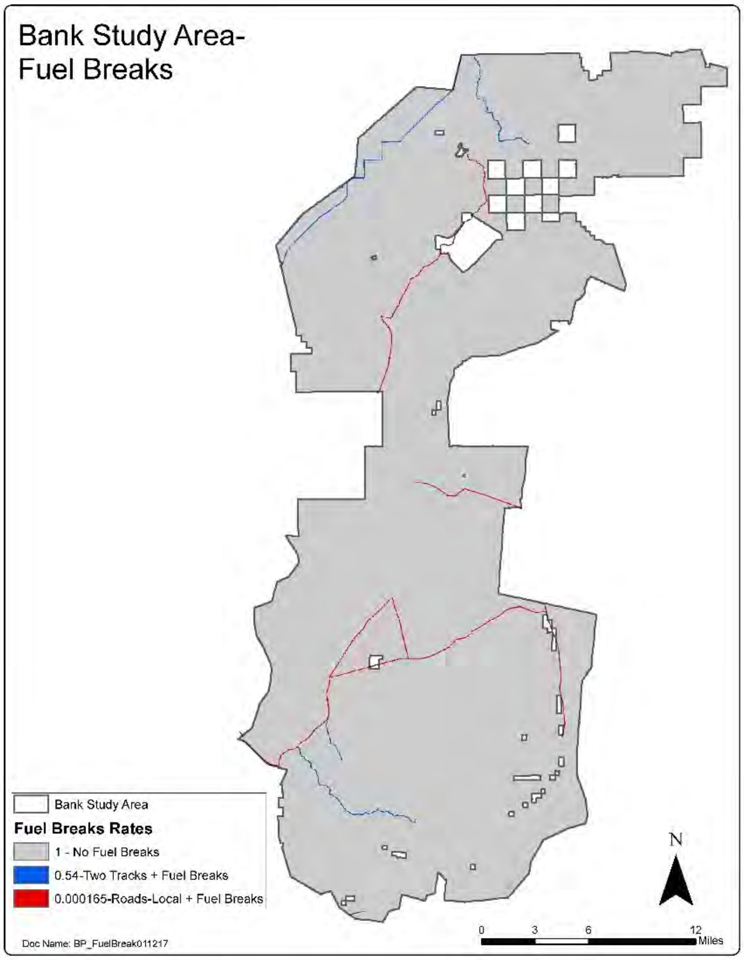


Figure 8: Modeled fuel breaks.

Steep Slopes

Discussion with experts in current restoration techniques informed the development of rasters that constrained management actions in the models. According to various practitioners, range drills (equipment used for drill-seeding) could not generally be used on slopes greater than 15%. Similarly, masticators, (used for controlling encroached stands of trees) could generally not be used on slopes greater than 30%. Using a digital elevation model, TNC developed two rasters – one of slopes greater than 15% and one of slopes greater than 30% - that were used to constrain these specific actions. Figure 9A shows the raster of slopes greater than 15%.

Management Control

- Land Ownership Profile - As Barrick was interested in exploring different implementation rates on their privately held land and the publicly held over which they have some management influence, TNC developed a Land Ownership Profile Map. This map (Figure 9B) defined three areas: 1) Barrick's privately held land within the Bank Area, 2) Public Land over which Barrick has some management influence, and 3) Public land included in the Bank Study Area over which Barrick has no management influence – namely in the southern portion of the Robert's

Mountains. This layer has not been developed for the Plan of Operations Study Area to date as no restoration actions were planned.

- South Buckhorn Exclusion – This raster prevented actions in part of the South Buckhorn Allotment (Figure 10A). This was created at the bequest of Barrick, who does not control all the grazing in this common allotment and this represents a refinement of the above-mentioned Land Ownership Profile. The exclusion zone includes low elevations systems and wet meadows in Pine Valley extending from the eastern toe of the central Cortez to Hwy 278. A significant portion of this exclusion area is not GSG habitat.
- JD Meadow Irrigation Area - this raster defines a narrowly defined area in the greasewood system that, through irrigation, would convert to pastures in the basin wildrye system (Figure 10B). This is a special case action meant to only be applied to the JD Meadow. The point of diversion for the water is between Shipley Meadow and the JD Meadows. This layer restricts the software to place the irrigation treatment only to the desired area.
- Frenchie Flat Exclusion – this raster prevented actions in part of the South Buckhorn Allotment (Figure 10C). Much of Frenchie Flat is dominated by non-native annual species and would not be of high value to GSG even in a more restored condition. Moreover, BLM discouraged management in Frenchie Flats during the workshops. This exclusion zone was created to concentrate resources in other portions of the Bank Study Area, where restoration actions are likely to have a greater impact on GSG habitat suitability.
- Wet Meadow Exclusion – this raster limits wet meadow restoration and maintenance actions to only certain wet meadows (Figure 10D). This was done for two reasons. First, especially in the northern portion of the Bank Study Area, many of the wet meadows are in close proximity to other types of late brood habitat (see the Reporting Metric for description of late brood habitat and how it affects habitat suitability). The exclusion of wet meadows in this area frees up resources to be used on other areas where restoration actions are likely to have a greater impact, especially given the cost of meadow restoration. Secondly, a few meadows (e.g. Shipley) are currently managed as a riparian pasture and thus fenced already. Therefore, the need for fencing in those areas are likely unnecessary.

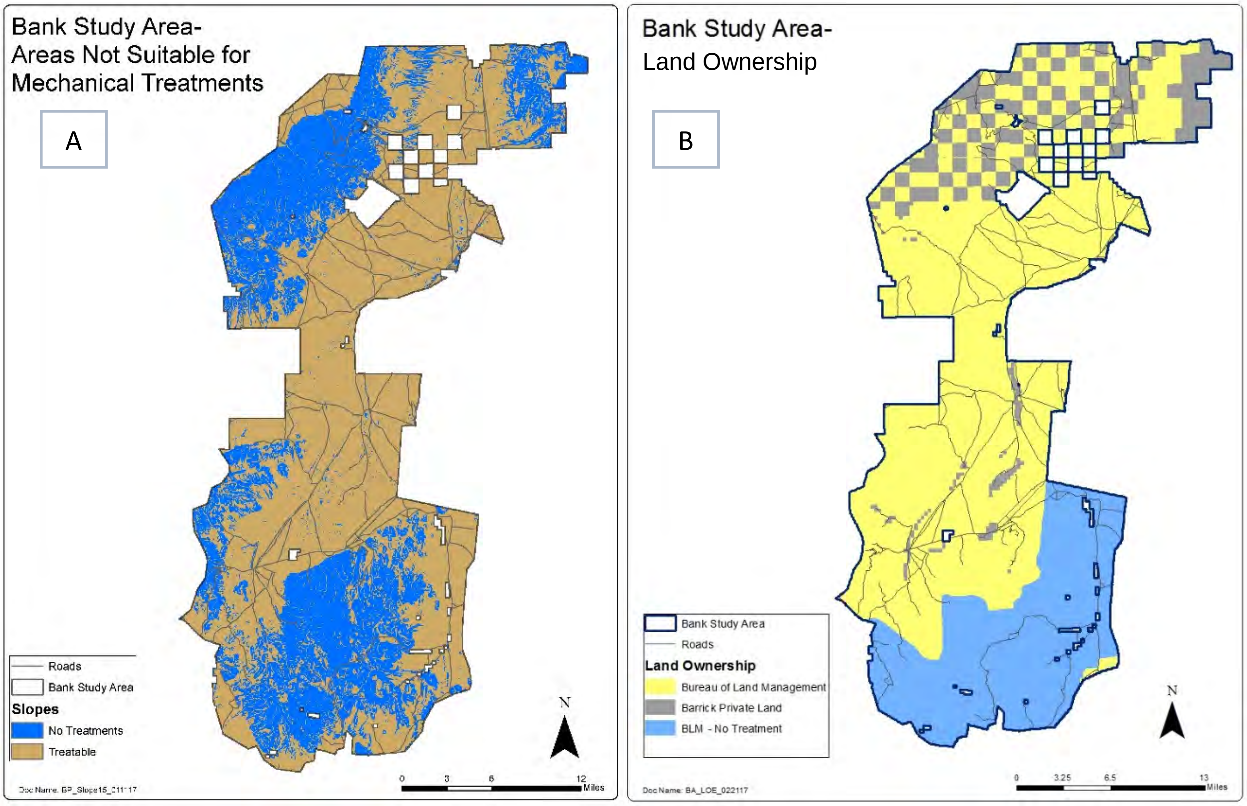


Figure 9: Rasters that constrain management actions. A) Areas where the slope is >15% and thus are not available for actions requiring rangeland drills. B) Land Ownership in the Bank Study Area where yellow depicts public land, and grey depicts private land controlled by Barrick. The area in light blue part, which contains both public and private land, was excluded from treatments as Barrick does not have grazing control of public lands.

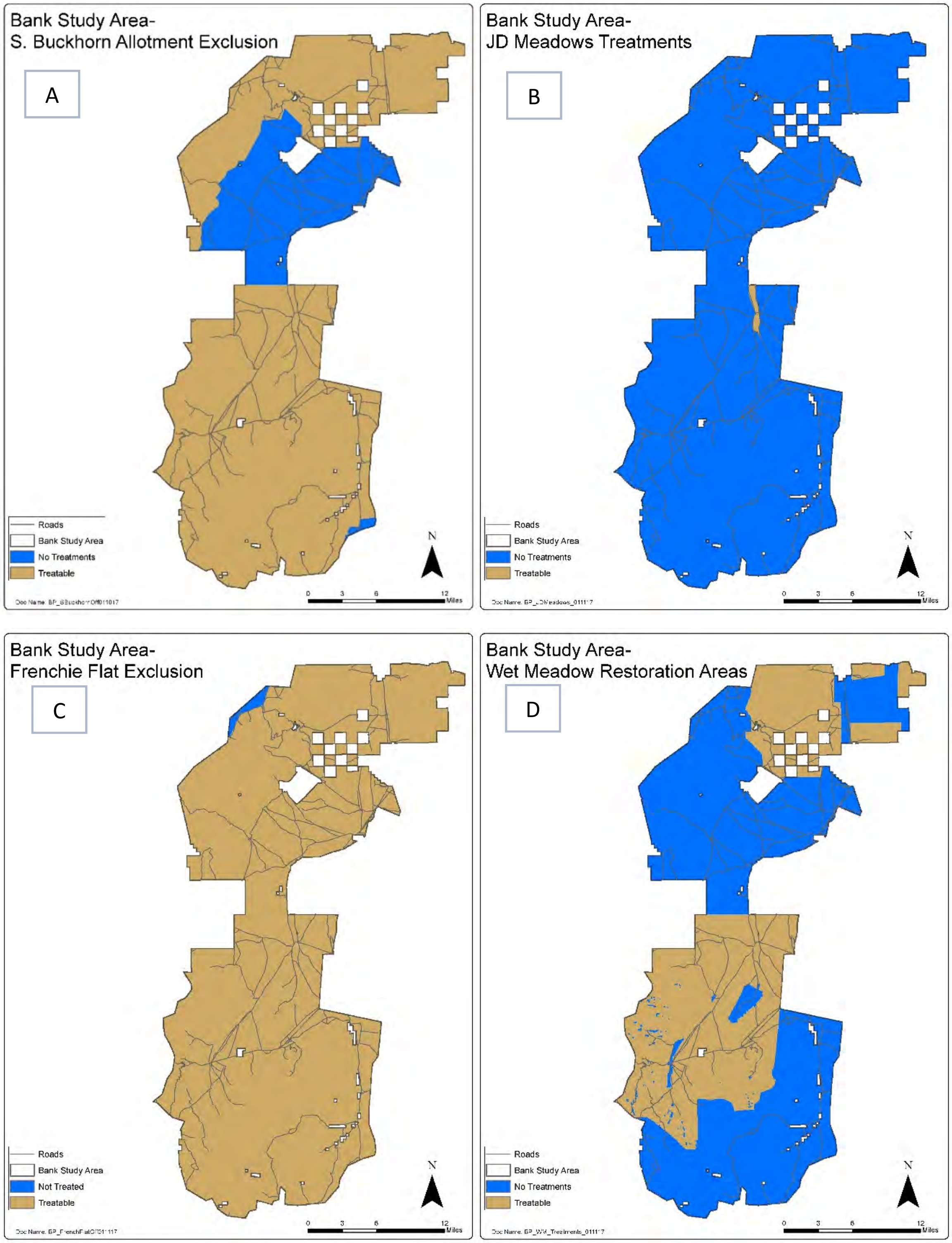


Figure 10: Rasters that constrain management actions for Banking Area: (A) Prevents treatments in the portion of the South Buckhorn Allotment not permitted to Barrick, and to prevent treatments in a mapping anomaly in the south east section of the Bank Study Area. (B) Allows irrigation of pastures only in the JD Meadows; (C) prevents treatments in a section of Frenchie Flat; (D) limits wet meadow restoration and maintenance actions to wet meadows in strategic areas.

Direction Multipliers

Direction multipliers governed the non-uniform direction of fire spread, primarily following southwest to northeast prevailing winds (i.e., 45 degrees). Table 5 shows the degree and the multiplicative factor of fire spread. For example, the likelihood of a fire spreading in a northeasterly direction (45°) is 7 times greater than in a westerly direction (270°). The distribution was determined through experimentally modeling fire spread to coarsely approximate true fire shapes for the area.

Table 5. Direction multipliers for fire spread of all types.

Direction (Degrees)	Multiplier
0	5.5
135	1.0
180	0.8
225	0.5
270	1.0
315	2.0
45	7.0
90	1.5

Dynamic Habitat Suitability Multiplier

The last spatial option used to constrain simulations was dynamic habitat suitability multiplier (DHS multiplier). The DHS multiplier functions by periodically sending the rasters of ecological systems and vegetation classes to R (R Core Team, 2014) to calculate part or all of sage-grouse habitat suitability (see *Habitat Suitability for Greater Sage-Grouse*). The output of the R analysis is used to concentrate restoration to increase the efficiency of management actions.

Management actions constrained by the DHS multiplier were: Herbicide-Plateau+seed+shrub-planting, chainsaw-thinning, and small tree-lopping. These were chosen as they directly impact nesting habitat and we believe that the most optimal late brood habitat improvements were implemented without the DHS multiplier. Nest-site selection was chosen as the seasonal component of habitat suitability to strategically focus implementation of certain management actions as this variable incorporates both vegetative components and other environmental factors. For a given year, the R script returns a binary (0.2, 1) raster to ST-Sim representing the areas where the selected management actions are more likely to be applied (i.e. a value of 1 indicates that a treatment is 5x more likely to be chosen for treatment than a pixel with a value of 0.2). Mid-range values of nest site selection were classified as "1" (mid-range was defined as less than 1 standard deviation from the greatest value observed and greater than 1 standard deviation from the lowest value observed). We reasoned that if a degraded pixel was generally surrounded by high quality habitat treating that pixel was likely to have a low return on investment compared to other sites with lower habitat suitability. Additionally, values with low nest site selection may not be improved by restoration actions due to the constraints of other environmental variables (e.g. elevation). The frequency for refreshing the binary raster was every 5 years (including year 0).

Accounting for Temporal Variability in Disturbances and Climate

The basic ST-Sim state-and-transition models incorporate by default stochastic disturbance rates that vary around a mean value associated with each vegetation class of each ecological system. This variability is simply caused by the drawing of random numbers to satisfy certain disturbance rates. For example, fire is a major disturbance factor for most ecological systems. These fire regimes have different rates (i.e., mean fire return interval) that are incorporated into the models for each ecological system's vegetation class where they are relevant. However, in real-world conditions the disturbance rates are likely to vary appreciably over time. While ST-Sim provides some level of default variability it is necessary to augment this variability to achieve a more accurate prediction of ecological processes. We have not included climate change trends in the simulations because their 35-year duration was not long enough to result in separation of temperature and precipitation trends relative to natural climate variability among Global Circulation Models and the historical trend (Collins et al. 2013).

Temporal multipliers were incorporated in the model-run replicates to simulate strong yearly variability for fire activity, climate-induced mortality and non-native species densification, insect and disease outbreaks, non-native species invasion rates, tree encroachment rate, loss of herbaceous understory, and flooding. Due to the extremely episodic nature of weather, fire, and flooding in the Great Basin, temporal multipliers have profound effects on model-run results (reporting variables). The Standard Precipitation Index (SPI), a monthly-based index based only on precipitation that is calculated from the probability of precipitation for any time scale (Mckee et al. 1993), was used for all climate derived variability, except for the temporal variability of flooding in riparian systems. For example, a very large area suitable for sage-grouse nesting could burn during a major fire year, which would then trigger major restoration actions to recover lost habitat suitability over decades, but that seeding could fail during an abnormal drought.

A temporal multiplier is a number in a yearly time series that multiplies a base disturbance rate in the state-and-transition models. For example, in 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, and a multiplier of three triples the likelihood of disturbance. In this example, if your original disturbance rate is $0.01 \cdot year^{-1}$ or 100-year mean fire return interval, a multiplier of zero would completely suppress fire in a given year and a multiplier of three would mean, $3 \times 0.01 \cdot year^{-1} = 0.03 \cdot year^{-1}$, or a 33-year mean fire return interval. A tripling of a fire rate means an approximate tripling of the area burned. Temporal multipliers can be obtained from data, statistical projections, mechanistic equations, and heuristic (i.e., curve fitting) equations. A more detailed explanation of temporal multipliers is presented in Appendix 5 and Provencher et al. (2015).

Contributions from Expert and Stakeholder Partners on Models

The critical elements of the model described above were reviewed and developed in cooperation with partners of this project. This was accomplished through (i) contracting experts to review ecological state-and-transition models (described above) (ii) the management workshops, and (iii) specific lines of inquiry with specific experts. The expert modelers contracted to review the state and transition models provided in-detail review of the box and arrow diagrams as well as the probabilistic transitions.

In the first management workshop, participants reviewed the expected Natural Range of Variability and the current percentage of reference classes in order to evaluate potential treatment options. In addition, discussions in both workshops covered critical modeling assumptions including fire return and expected size and the effects this has on the landscape as well as the effect of grazing on different ecological processes. See Appendix 10 for more information about the management workshops.

Finally, expert opinion was specifically sought for certain model assumptions, such as the effectiveness of different kinds of fuel breaks and further input on grazing.

Development of Management Objectives, Actions, and Scenarios: Iterative Modeling Process

Management objectives ultimately determine how the ST-Sim database will be structured as management scenarios whose actions (i.e., implemented treatments) are designed to reach stated objectives. Barrick with the assistance of TNC worked on three interrelated tasks toward achieving these purposes:

1) Development of a set of more-specific guiding *management objectives* consistent with the Department of Interior's Nevada-Barrick Bank Enabling Agreement[4], and BLM's multiple-use management;
2) Definition of comprehensive set of *management actions* per ecological system and per scenario, also known as a strategy, that Barrick, the BLM, and the FWS can implement; and
3) Development of various alternative *management scenarios*, i.e., combinations of management actions that have a similar theme.

Management Objectives

At workshops, participants reviewed proposed Barrick management objectives and conceptual strategies, which played an important role defining the type, cost and outcomes of management actions at the project's two management workshops. For this project all treatments were focused on improving habitat for greater sage-grouse, with the exception of a broad targeting of exotic forbs. The final management objectives and strategies are listed in the box below.

SGCF Management Objectives for the Banking Area

Objectives	Conceptual Strategies
▪ Manage to preserve critical SG habitat from wildfire and other disturbances.	▪ Implement and maintain appropriate fuel breaks to protect critical areas. ▪ Treat annual grasslands to achieve longer fire-return intervals ▪ Prevent expansion of non-native forbs and tree encroachment
▪ Optimize the increase in habitat suitability for greater sage-grouse.	▪ Maintain or restore vegetation classes that contribute to chick survival (especially near current/potential nesting) ➢ I.e. late-brood rearing habitat, focusing on wet meadows. ▪ "Do no harm" to higher-value nesting areas; no net loss of intact sagebrush (e.g., close to late-brood habitat). ▪ Treat vegetation classes that increase potential nesting areas (near leks and current/potential late-brood habitat). ▪ E.g., treating encroached PJ and annual grasslands

[4]http://www.blm.gov/style/medialib/blm/nv/wildlife___fishes/sage_grouse/barrick_nv_sage_grouse.Par.65037.File.dat/DOI-Barrick%20Sage%20Grouse%20Agreement%20March2015.pdf

▪ Maintain and/or improve overall ecological health of select systems according to collective priorities.	▪ Survey for and treat invasions of exotic forbs to prevent further spread.

Management Actions

Project workshop participants also identified various management actions (also termed treatments) toward achieving the management objectives for the two project areas and their ecological systems. The effectiveness of actions was tested using the predictive ecological models through a trial-and-error process. All management actions were fundamentally designed to improve average GSG habitat suitability within a 35-year simulation. It became apparent that there were financial and ecological tradeoffs between normal rangeland improvement actions and actions that only targeted classes of vegetation that directly improved average sage-grouse habitat suitability as predicted by the vital rates equations for habitat suitability. For example, restoring Wyoming big sagebrush with a depleted understory generally involves the removal of the sagebrush canopy before herbicide and seeding can be applied. However, according to the habitat suitability equations used, both a depleted and intact understory are used by sage-grouse for nesting. Thus, the costly action of restoring the site is not likely to increase the functional acres for sage-grouse in the model. Those same funds could be applied to other treatments that will increase habitat suitability more directly.

Initial sets of management actions were developed by participants in the project's model review workshop and first management workshop. A summary of these actions can be seen in Table 6. Each management action has a cost-per-acre figure associated with it, using various published sources as well as the local experience of agency staff and stakeholders. Similarly, the modelled actions often include a "failure rate" to reflect that some actions do not or only partially succeed at restoring a vegetation class, mirroring restoration in practice on the landscape. These failure rates were also adjusted based on field experience in this particular landscape. Only a handful of management actions were used to restore systems and vegetation classes identified by the sage-grouse habitat suitability equations (Appendix 6).

Table 6: Summary of treatments used in modeling including key assumptions important for managers to consider.

Objective(s)	Treatments	Specific Goal	Key Assumptions
Control Pinon-Juniper encroachment	AerialSeed+ Masticate+ Plateau	Remove trees from shrublands and create nesting habitat, and, to some extent, late-brood rearing habitat only at the higher elevations.	• Mixed introduced species (crested wheatgrass and or intermediate wheatgrass at higher elevations) and native grass and forb seed. Sagebrush and bitterbrush must be planted. Ratio of natives increases above Wyoming big sagebrush on upland soils. • Seeding must precede mastication for better incorporation of seed in soil. Herbicide can be sprayed later. • Masticator can be used on slopes up to 30%. Plateau will need to be spread aerially on steep slopes.
	Chainsaw-Thinning	Remove trees from shrublands and create nesting habitat.	• Work Crews with Chainsaws • Price based on felling, lopping, and scattering biomass
	Small-Tree-Lopping	Maintain nesting habitat	• Chainsaw. Simply drop small trees without lopping off lateral branches to reduce cost.
Treat annual grasslands to achieve greater resistance to fire and restore nesting function.	Herbicide-Plateau+ Seed+Shrub-Planting	Seed recently burned areas or areas dominated by non-native annual species to create nesting habitat, and, to some extent, late-brood rearing habitat only at the higher elevations.	• Spray Plateau before seeding to reduce competition during germination. • Mixed introduced species (crested wheatgrass and or intermediate wheatgrass at higher elevations) and native grass and forb seed. Sagebrush and bitterbrush must be planted. Ratio of natives increases above Wyoming big sagebrush on upland soils. • Rangeland drill can be used on slopes up to 15%. For the success assume, a Truax Roughrider rangeland drill was assumed (pers. comm., Mike Pellant)
Restore vegetation classes that contribute to chick survival.	Fence&Water-Delivery	Control livestock and horse access to wet meadows	• Fencing that will withstand horses as needed; • Piping and stock-tank for alternative water source outside fence perimeter
	Fence-Inspect &Maintain	Control livestock and horse access to wet meadows	• Inspect before maintenance
	Herbicide-Shrubs +Mow	Restore late-brood habitat in wet meadows	• Spray herbicides specific to native shrub or forbs and mow standing biomass if needed.

Create vegetation classes that contribute to chick survival.	Irrigation	Create late-brood rearing habitat close to leks.	• Introduced irrigated pasture grass species. • Proponent – driven action
Maintain ecological health of select systems	Weed-Inventory +Spot-Treat	Maintenance in in weed-prone areas.	• Visit sites and treat weeds as needed.
	Exotic-Control	Kill exotic noxious plant species.	• May involve wetland or riparian seed mix.
Mimic likely BLM post-fire actions	BLM-Fire-Rehab	Seed recently burned areas. Does not necessarily create nesting habitat because of seed mix and uncertainty about native shrub planting.	• BLM decides seed mix. • Aerial seeding on slopes >15% but seeding with rangeland drill at lower elevation for superior results. • High failure rate.

TNC then conducted computer simulations of the state-and-transition models to test and refine suites of actions for each of the selected ecological systems over a 35-year time horizon. Levels of treatment were tested to develop successful scenarios for sage-grouse (see below), while seeking to minimize cost.

Exploratory and Final Management Scenarios

Management scenarios represent common “themes” for grouping individual management actions (or lack of actions), so that the effectiveness of sets-of-actions can be better compared within and across ecological systems. Two types of analyses were done to test the effects of management actions on sage grouse (1) dynamic simulations (2) “stamping” of specific management changes into the dynamic simulation results.

Dynamic Simulations

Plan of Operations Study Area

Scenarios are simpler in the Plan of Operations Study Area as the goal was to compare *status quo* conditions (i.e., no new mine infrastructure) to conditions where mine infrastructure development was proposed. As fire is a major ecological process that can mask the impact of transitions, such as management, the same scenarios were simulated with fire and without fire.

Bank Study Area

Although a FINAL active management scenario and a CUSTODIAL (control) scenario were simulated for this report, a series of exploratory scenarios were first conducted to better understand how ecological processes and management strategies impacted response variables, including sage-grouse habitat suitability. These scenarios were designed to answer the following questions:

- What is the effect of actions implemented only on Private Land?
- What is the “supply curve” of habitat uplift based on increasing levels of investment?
- What is the effect of fuel breaks?
- How does the presence of fire affect treatments and habitat suitability?

- What is the best approach for modeling horses on this landscape given our limited ability to predict management and their effect on ecological processes?

Several conclusions emerged from these past results that guided model improvements and the development of final scenarios:

1. Supply-curve analysis showed that restoration of wet meadows and non-native annual species grasslands on Barrick private land and BLM-managed land were saturated at *relatively* low levels of investment (wet meadow treatments in the TNC model are assumed to be inherently expensive). Additional funding only accelerated the date of complete restoration (for example, by year 6 instead of year 12), but not the amount restored. Therefore, the lower levels of investments were retained for the final scenario.
2. Restoration of shrublands encroached with trees (with or without cheatgrass present in the understory) to seedings of mixed introduced and native species (i.e., aerial-seed+masticate+shrub-planting), which was primarily implemented at the highest level of investment after other actions were fully implemented, kept increasing with additional investments because this action was underfunded compared to the area that could be treated and benefit sage-grouse. This action was not a priority in shrublands because of its higher cost compared to seeding in non-native annual species grasslands.
3. Simulations where fire-suppression effects from grazing were programmed to be relatively high showed a noticeable change in fire occurrence in the Cortez Range with and without this grazing pressure. This was correlated in large part to the presence or absence of unbranded and unclaimed horses. In these exploratory scenarios, less grazing implied more fine fuels, thus more fire, in early and middle succession classes with non-native annual species, but not in late succession classes where fire spread is determined by canopy to canopy proximity. This assumption proposed by stakeholders during workshops was built in the early and mid-succession shrubland classes invaded by non-native annual species during the early-spring and fall seasons of use.

   The relationship between fire and grazing was revised in the model in response to a workshop on targeted grazing held by BLM in Reno, NV and consultation with rangeland management experts. Suppression of fire is likely to occur when targeted grazing (the application of high stocking rates of livestock in confined areas to reduce fine fuels) is applied to a site. However, under the stocking rates in the modeled grazing regime, this fire suppression effect is unlikely especially during years with above average precipitation when herbaceous biomass dramatically increases. Therefore, the effect of cattle grazing on fire suppression was not included in the final model.

   In contrast to this, it was believed that the current numbers of domestic unbranded and unclaimed horses could achieve fire suppression in some portion of the Banking Area (e.g. Frenchie Flat). Experts at the workshop confirmed that the fire-suppression effect will only last one year, and not the two years we had originally modeled. Therefore, the duration of the fire suppression effect was reduced from 2 to 1 year in the model. As a result of model adjustments, the spatial distribution of fires (i.e. where fires were likely to start) was more comparable between the CUSTODIAL and FINAL MANAGEMENT scenarios.
4. Comparing simulations with and without fire regardless of investment levels revealed that large fire years experienced after the 20th year in some replicates caused the greatest decrease in

average sage-grouse habitat suitability through loss of nesting habitat. This effect on sage-grouse habitat suitability was confounded with the effect of grazing on fire suppression (see above). Burnt sagebrush shrublands cannot generally succeed into nesting habitat with only 10 years of recovery.

5. Fuel breaks appear to have minor effects at the scale of the entire landscape; however, fuel breaks interacting with local management actions increased average sage-grouse habitat suitability only when measured locally (as one would expect). Furthermore, fuel breaks only limited to FIAT sites and Barrick private lands had no effect on amount and size of fire compared to simulating without any fuel breaks. Also, we found that fuel breaks did not perform as expected at the landscape level because of the manner in which ST-Sim selects fire sizes and spreads fires. Our expectation was that fuel breaks would reduce the number of large fires because the fuel break raster we imposed broke up areas in which a large fire could be placed. Our expectation did not match simulated results as previous versions of the ST-Sim software attempt to place large fires in areas with sufficient acreage to meet the fire size distribution specified in the model. As a consequence, large fires tended to be located in unfragmented areas by fuel breaks, where sage-grouse habitat suitability was often highest. Because the fire size selection process of ST-Sim did not operate in the manner expected with fuel breaks, ApexRMS Inc. was asked to modify ST-Sim's code to add the option that a fire that was intended to be large, but failed to become large because of a fuel break, was considered a successful large event and, therefore, satisfied the fire size distribution although the simulated fire never spread to a large size.

As a result of these diagnostic scenarios, the input of many experts, and through consultation with Barrick, TNC opted for eight final scenarios for the Bank Study Area and Plan of Operations Study Area. To estimate changes in Functional Acres due to various management actions, the CUSTODIAL MANAGEMENT scenario was required and represented status quo management for fire suppression and grazing and no special actions, except BLM's burnt lands rehabilitation (Table 7). To capture potential loss of sage-grouse habitat in the Plan of Operations Study Area, a PROPOSED MINE DEVELOPMENT scenario was simulated with and without fire. The FINAL MANAGEMENT scenario contained management actions and strategies to achieve the highest average sage-grouse habitat suitability (with an exception made for exotic forb control). More specifically, TNC chose to retain management actions that would result achieve increases in GSG habitat, based on the landscape variables used in the habitat suitability equations (see below "Habitat Suitability for Greater Sage-Grouse and Functional Acres"). The implementation rates of restoration actions and their temporal sequences were achieved through an iterative process of increasing habitat suitability while trying to maintain yearly budget constraints. Additionally, the implementation rates were dependent on the amount of uncharacteristic vegetation classes affecting habitat suitability (see **Findings**). The sequencing of restoration actions considered several constraints:

1) Other than routine exotic species control and limited Emergency Stabilization and Rehabilitation after fires, the earliest start of any BEA-related actions on BLM lands would be on the fourth year (from 2015) to model NEPA processing;
2) Actions on Barrick's private lands could be initiated immediately (i.e., second year of simulations);
3) Actions that would more rapidly yield habitat suitability benefits (for example, wet meadow restoration and irrigation of the JD Meadow pastures) were prioritized earlier in simulations;

4) If funding remained for a year, seeding of classes dominated by non-native annual species would be implemented earlier than removal of trees in wooded shrubland followed by seeding; and
5) Implementation of actions in higher elevation montane sagebrush steppe could be delayed compared to lower elevation systems because ecological succession is more rapid and this sequencing of restoration actions allowed the more even spread of yearly funding.

Each of the four final management scenarios (BANK STUDY AREA – CUSTODIAL, BANK STUDY AREA – FINAL, PLAN OF OPERATIONS – CUSTODIAL, PLAN OF OPERATIONS – PROPOSED MINE DEVELOPMENT) were modeled with and without fire. Programmed management actions were the same in the runs with and without fire with the exception of those actions that relate directly to fire. In other words, fire, as a disturbance, was “turned off” in “No Fire” simulations. This simply consisted of assigning a value of zero to all fire types. The intent of this was to tease apart the variability in results caused by fire on the landscape and to help Barrick and DOI quantify the risk of fire on this landscape.

Replication of Simulations

The scenarios from Table 7 were simulated for each ecological system for 35 years using the ST-Sim state-and-transition modeling software. The 35-year duration of simulations was chosen prior to the first management workshop. This time horizon allowed sufficient succession time for post-disturbance/post-restoration recovery of greater sage-grouse nesting habitat and surpassed Barrick’s stated life-of-mine for the Deep South Expansion Project. Ten model replicates per scenario were chosen to capture large variation in ecological processes, such as fire activity and drought. An analysis conducted indicated that the explanatory power of increased replication did not appreciably improve between 5 and 10 replicates, and improved very little above 10 replicates (unpub. data). Additionally, two technical limitations justified using 10 replicates. These were: (a) computation limitations and simulation times encouraged the use of as few replicates and (b) more replicates would have required building new temporal multiplier series using a more automated and rigorous methodology, which was not available at the time of analysis.

The application of specific actions within management scenarios will be presented later in this report, in **Findings** under the section **Predicted Future Condition – Management Scenarios and Actions**.

Table 7. Descriptions of management scenarios for the Bank Study Area and Plan of Operations Study Area.

<table>
<tr><th>Study Area</th><th>Scenario Title</th><th>Fire</th><th>Goal</th><th>Natural disturbances other than Fire</th><th>Grazing Assump-tions</th><th>Management Actions</th></tr>
<tr><td rowspan="4">Plan of Operations Study Area</td><td rowspan="2">CUSTODIAL</td><td>Fire</td><td>Provide a "control" scenario that includes fire.</td><td rowspan="8">Natural disturbances were modeled the same in all scenarios.</td><td rowspan="8">Cattle, wild horses, and unclaimed unbranded horses were modeled the same in all scenarios. Specific grazing parameters are defined above.</td><td>• BLM Fire Rehab</td></tr>
<tr><td>No Fire</td><td>Provide a "control" scenario that does not include fire.</td><td>• none</td></tr>
<tr><td rowspan="2">PROPOSED MINE DEVELOPMENT</td><td>Fire</td><td>Measure the direct and indirect effects of the plan of operations on GSG as compared to the corresponding CUSTODIAL scenario.</td><td>• BLM Fire Rehab
• Plan of Operations direct and indirect effects</td></tr>
<tr><td>No Fire</td><td>Measure the direct and indirect effects of the plan of operations on GSG as compared to the corresponding CUSTODIAL scenario.</td><td>• Plan of Operations direct and indirect effects</td></tr>
<tr><td rowspan="4">Bank Study Area</td><td rowspan="2">CUSTODIAL</td><td>Fire</td><td>Provide a "control" scenario that includes fire</td><td>• BLM Fire Rehab
• No “enhanced” fuel breaks.</td></tr>
<tr><td>No Fire</td><td>Provide a "control" scenario that does not include fire.</td><td>• none</td></tr>
<tr><td rowspan="2">FINAL MANAGEMENT</td><td>Fire</td><td>Measure the direct and indirect effects of management actions for GSG as compared to the corresponding CUSTODIAL scenario.</td><td>• BLM Fire Rehab
• Significant investments in restoration and maintenance actions on public and private lands
• Enhanced fuel breaks</td></tr>
<tr><td>No Fire</td><td>Measure the direct and indirect effects of management actions for GSG as compared to the corresponding CUSTODIAL scenario.</td><td>• Significant investments in restoration actions on public and private lands</td></tr>
</table>

“Stamps” applied to the dynamic simulations

In order to estimate the change in habitat suitability and the resulting functional acres due to certain specific actions, we conducted three additional analyses: 1) functional acre loss due to the Proposed Plan of Operation, 2) functional acre loss due to the proposed rapid infiltration basins (RIBs) in the Bank Study Area, and 3) estimation of preservation on three privately held wet meadows. For all three analyses, post-hoc conversion of CUSTODIAL vegetation rasters for the Study Area of interest was conducted in R before habitat suitability was calculated (described below). In one case, analysis was also conducted using the FINAL+FIRE data. The system and class vegetation change was conducted for each replicate-timestep combination so that interpretation of the results could be done for all years simulated across all replicates.

The same general process was used for all three analyses. Areas of interest were converted to the desired condition by "stamping in" a different system and class than what was remoted sensed (e.g. converting "Big Sagebrush with trees" BpS pixels with "Mine-Active" pixels). First, a polygon of the vegetation change was converted to a raster with the same resolution and origin as the original vegetation raster. This is the "stamp". All pixels in the stamp are overlaid with the original vegetation raster. Pixels that overlap are reclassified in the original vegetation raster to the corresponding system and class classification desired.

Plan of Operations Study Area

For the impact of the Proposed Plan of Operation, two vegetation conversions were made. First for both the CUSTODIAL and PLAN OF MINE DEVELOPMENT scenarios, areas previously permitted for soil/vegetation disturbance were stamped in. These areas represent land Barrick was authorized to disturb prior to the Bank Enabling Agreement but has not had yet development. The same stamp was used for CUSTODIAL and PLAN OF MINE DEVELOPMENT scenarios (Figure 11). For the PLAN OF MINE DEVELOPMENT only, an additional stamp was used to model the proposed plan of operation development (Figure 11). For both the authorized and proposed development stamps, all pixels were reclassified to "Mine-Active" BpS and "U-A:Bare Ground" class. To assess the indirect impacts of mine development, a second raster was also created from the proposed mine development polygon. This represented the location of proposed infrastructure. The proposed infrastructure was combined with existing infrastructure to model the indirect impacts on NSS and NS, respectively (see Appendix 8 for description of method).

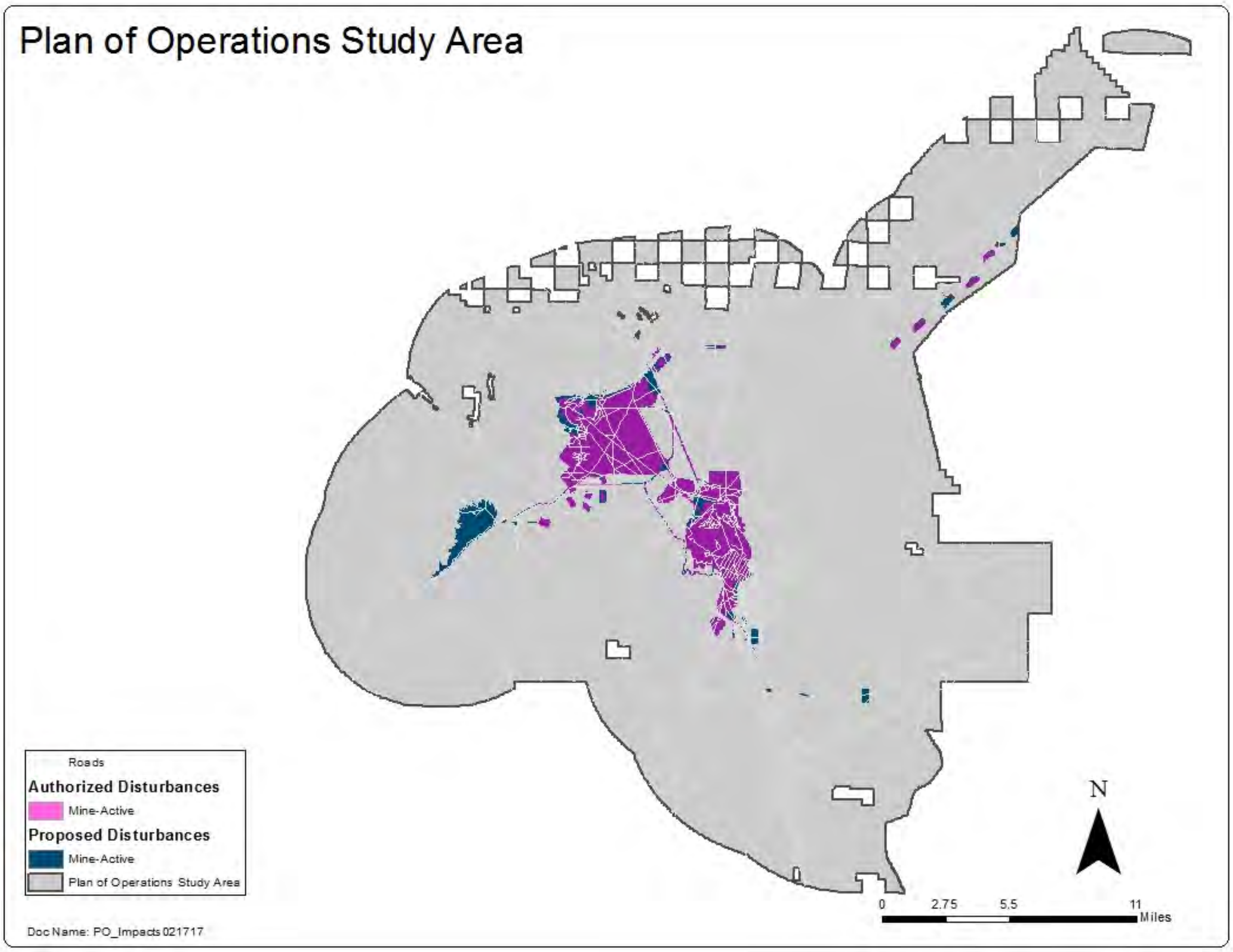


Figure 11: Spatial extent of Barrick's currently Authorized Disturbances and proposed additional disturbances of the Deep South Expansion Project Plan of Operations within the Plan of Operations Study Area.

Bank Study Area

A similar method of stamping in of proposed mine development was used for the estimation of the RIBs impact in the Bank Study Area. As with the assessment of the proposed mine development in the Plan of Operation Study Area, all pixels in the stamped area were converted to "Mine-Active" BpS and "U-A:Bare Ground" class. All proposed RIBs were located in the Frenchie Flat area, in the northwestern portion of the Study Area (Figure 12).

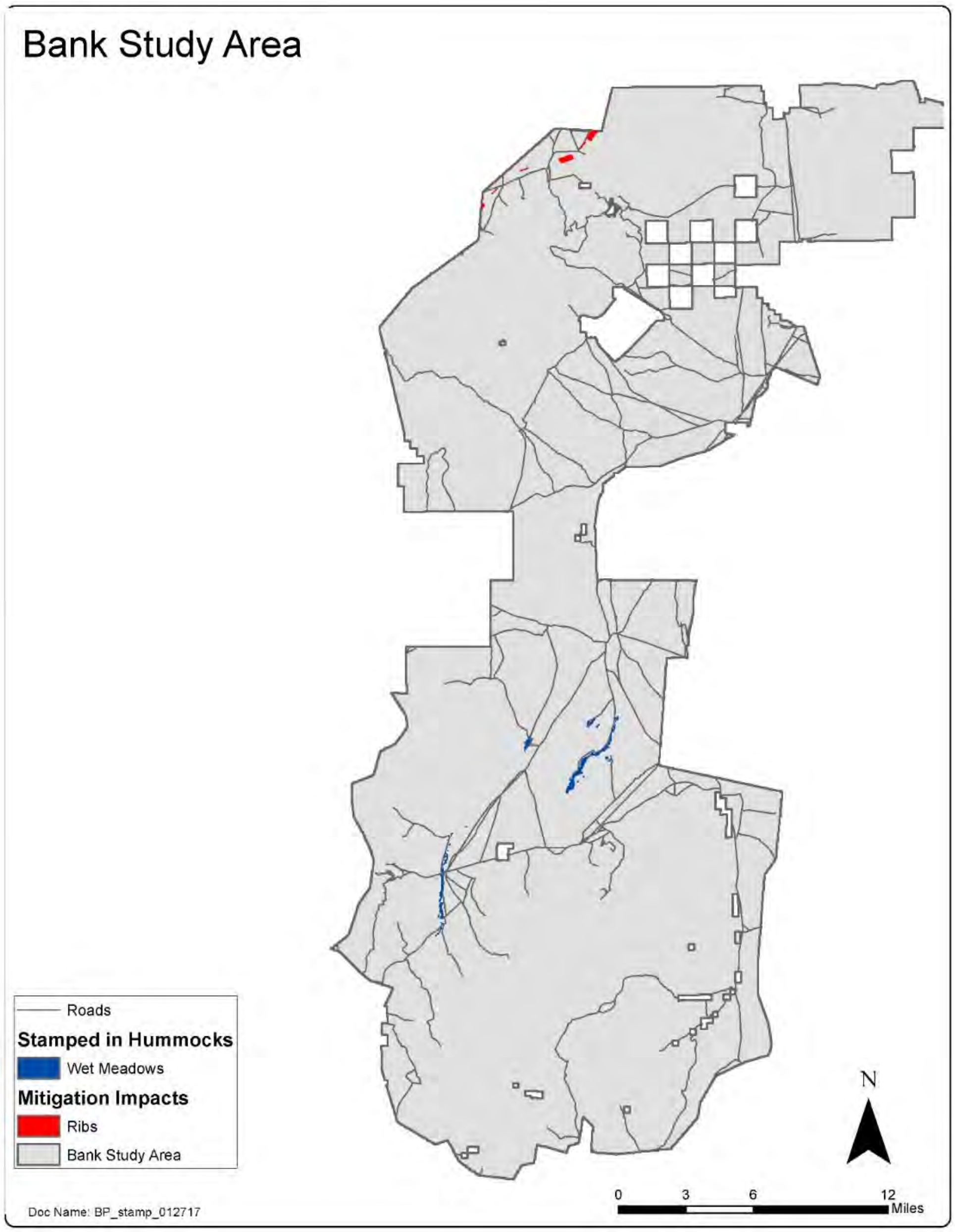


Figure 12: Spatial extent of the stamps used to calculate the influence of the RIBs and the privately held wet meadows on the JD Ranch. The "Hummock" stamp was used for both analysis of conversion to hummocking and to exotic forb-dominated pixels.

The last analysis was intended to assess the impact of preserving three privately held wet meadows on the JD Allotment: Shipley, Tonkin, and Big Springs Meadows (Figure 12). These meadows are currently in good condition and, due to proper grazing management within these areas, continue to be dominated by reference classes in the simulated future in all scenarios. Despite the meadows' current condition, poorly managed livestock grazing could convert these areas to uncharacteristic classes, with the most likely outcome being hummocking or, with more severe degradation, conversion to exotic forb-dominated sites. Whereas, hummocked wet meadows are usable by GSG, exotic forb-dominated meadows provide no habitat benefit to the birds. Separate analyses were conducted to compare the impact of hummocking these meadows in both the CUSTODIAL and FINAL scenarios. To explore impacts under a different, let plausible, threat, the same stamps were used to simulate conversion to exotic forb dominance. Unlike the previously described analyses, pixels in these meadows were maintained in the same BpS, "Wet Meadow-montane", but all pixels were reclassified to the "U-A:Hummocked" class or “U-A:Exotic Forbs”, respectively. This process of converting all pixels in these three meadows was done at each timestep. This means hummocked or exotic forb-dominated pixels did not transition to other classes (i.e. no natural recovery or further degradation).

Reporting Metrics

At a landscape level, the main reporting variable used for this project was an area based measure of average GSG habitat suitability termed Functional Area (converted to acres; defined below). GSG habitat suitability was based on the University of Nevada, Reno demographic model. Other measures were reported including simulated acres treated and the 35-year total cost of treatments.

Habitat Suitability for Greater Sage-Grouse and Functional Acres

In order to assess current and future habitat changes (including direct and indirect impacts of anthropogenic development) to GSG, habitat suitability and functional acres were estimated. The habitat suitability model used in this project was based on demographic data collected in the vicinity of, and in some cases within, the Bank and Proposed Plan of Operations Study Area boundaries. The resulting metric, λ (or Lambda), estimates the contribution of any given area to population growth of the species. When $\lambda = 1$, the population is assumed to be stable. Values above 1 indicate population growth and values below 1 indicate population declines. This demography-based habitat suitability model, as opposed an occupancy based model, allows for more direct translation of management actions to per-capita population growth of GSG. The habitat suitability results were then translated into a single functional acre score.

Data on GSG demography were collected as part of a long-term research program on greater GSG ecology from 2003-2012 in Eureka County, Nevada (Falcon-Gondor study area; see Gibson et al. 2013, Kane et al. *in prep*). The field data from that project were used to quantitatively describe the habitat requirements for four demographic parameters (i.e. life history stages): nest site selection (NSS), nest success (NS), chick survival (CS), and female survival (Appendix 8, Tables 8-1 and 8-2). While winter is an important season for GSG, we did not include winter habitat suitability as mortality tends to be low during that season (J. Sedinger, pers. comm.). Additionally, within the Eureka Co. study winter habitat was not limited, so it did not greatly impact demographic rates (J. Sedinger, pers. comm.). The four demographic parameters are defined as such:

1. Nest Site Selection (NSS): probability of an individual successfully initiating a nest. It is a function of elevation, slope, distance from the nearest lek, proportion of sagebrush classes surrounding a given pixel, and interactions among these variables. High NSS would be found at pixels that are at mid-elevations, moderate slopes, close to a lek, and have high sagebrush cover in the surrounding area. This parameter was further impacted by the presence of certain types of infrastructure (e.g. transmission lines, tall buildings, high use roads, etc.).
2. Nest Success (NS): probability that at least one chick will hatch from the nest and survive until brood rearing age and includes the likelihood that a female will initiate a new nest if her first one fails. This variable is a function of the proportion of grassland surrounding a pixel and the non-sagebrush shrub cover of vegetation classes used by GSG for nesting. The correlation of sagebrush cover to non-sagebrush cover was determined using field data from the Eureka Co. study. This statistical relationship was used to estimate non-sagebrush cover for each pixel. Pixels with high NS would be those with low levels of grasslands in the surrounding area and have high non-sagebrush shrub cover. This parameter was further impacted by the presence of certain types of infrastructure (e.g. transmission lines, tall buildings, high use roads, etc.).
3. Chick Survival (CS): probability that at least one chick from the brood will survive through the 6-week late brood rearing season. First, average daily distance moved was calculated as the distance from a potential nest site to the nearest pixel classified as late brood habitat. This variable was then used to calculate the weekly survival rates of the brood across brood rearing. Finally, CS was the product of the 6 weekly survival rates. High CS values were calculated for pixels close to brood rearing habitat (Appendix 8, Table 8-2). Additionally, the effect of degraded late brood rearing habitat was accounted for by penalizing CS values for pixels that are nearest to hummocked late-brood habitat.
4. Female Survival (FS): probability that a female will survive. Calculated based on monthly survival rates within the four seasons. Additionally, FS is dependent on NS and CS. Both NS and CS illustrate the trade-off that exists between reproductive success and female survival. This means areas where a female is more likely to successfully produce a nest or brood are areas of depressed female survival.

In addition to outputs from simulations other environmental spatial data were gathered for the calculation of the four demographic parameters. Rasters of slope and elevation were obtained from a National Elevation Dataset Digital Elevation Model (NED DEM; EPA). Lek locations were made available by the Nevada Department of Wildlife (NDOW). All rasters were standardized by subtracting the rasters mean and dividing by its standard deviation (unless otherwise noted), to obtain a raster with mean 0 and a standard deviation 1. Rasters were standardized to allow for comparison between the Barrick properties and the Eureka Co. dataset. We used the following general form of logistic regression equation with the corresponding coefficients and beta values to build our spatial models (Hosmer and Lemeshow 1989):

$$S= e^{((\beta0 + \beta1X1+\beta2X2 +\ldots+ \beta nXn)/ (1 + \exp (\beta0 + \beta1X1 + \beta2X2 +\ldots+ \beta nXn))}$$

where β_0 is the model intercept, β_i are the logistic regression coefficients (Appendix 8 Table 8-4), and X_i are the measured covariates.

The demographic parameters were used to model the per capita population growth rate (λ) as a function of the spatial variation in GSG demographic parameters to predict contributions of specific habitats to regional population dynamics (Kane et al. *in prep*). This process allows for the direct link between a pixel's demographic parameter values and its expected impact on GSG population. The calculation of λ (or Lambda) incorporates the fecundity and annual survival of females and the relative impact of NSS, NS, CS, and FS. Fecundity was estimated from the Eureka Co. data and assumed constant throughout the study period. It is important to note that λ is effectively weighted toward the lower values among the demographic parameters. For example, a pixel with relatively high values for NSS but low CS will have a lower λ as CS is given more weight at that pixel.

Once λ was calculated for each pixel, a single functional acre score was computed for each Study Area. Functional area (expressed as functional acres by managers, although units could also be hectares) is the sum over all pixels in a landscape of the product of the area of each pixel by the overall habitat suitability (scaled 0 to 1) of that pixel. It can also be calculated as the area of a pixel (all the same in a grid) multiplied by the sum of the overall habitat suitability (scaled 0 to 1) of each pixel in the landscape. By definition, functional area is always equal to or smaller than the size of the landscape. Functional area is calculated as:

$$FA = A * \Sigma_{i}= \lambda_i / \lambda_{max}$$

where A = area of pixel (units in acres for this application), λ_I is the λ for a pixel, and λ_{max} is the maximum λ found. To keep results from different replicates and scenarios comparable, λ_{max} was set at 2.0. This meant that $\lambda_i / \lambda_{max} = 0.5$ corresponds to a stable rate of $\lambda_I = 1$.

3. Findings

Current Condition

Ecological Systems

Twenty-four ecological systems, were mapped in the Bank Study Area (Table 8 and Figure 13). Twenty-five ecological systems were mapped in the Plan of Operations Study Area[5] (Table 9 and Figure 14). Specific acreage for each ecological system in the two Project Areas appear in Table 8 and Table 9. The largest system was big sagebrush on upland soils (i.e., Wyoming big sagebrush) across all ownership for both the Bank Study Area and Plan of Operations Study Area. This ecological system was also the most abundant system on BLM and Barrick's private lands in the Bank Study Area and on BLM in the Plan of Operation, whereas montane sagebrush steppe was the most abundant system in the South Roberts BLM Allotment, which tends to have higher elevations than the rest of the Bank Study Area. On the Bank Study Area, the second largest system by area and ownership was montane sagebrush steppe for BLM and Barrick Private and black sagebrush for the South Roberts BLM Allotment. The third largest system by area and ownership was low sagebrush on BLM and South Roberts BLM Allotment and greasewood for Barrick Private for the Bank Study Area. For the Plan of Operation, greasewood was the largest system on Barrick private land with mixed salt desert the second largest on the private and BLM lands. Montane sagebrush steppe and saline meadows were the third largest systems for private and BLM lands, respectively.

[5] The system "Pickleweed" was only found in the Plan of Operations Study Area.

Table 8. Ecological systems by ownership (acres) of the Bank Study Area based on 1.5-m Spot 6/7 satellite imagery. Imagery does not include a buffer around the project area. See Figure 9 left panel for associated map of land ownership.

	Land Ownership Profile	
System	**BLM (acres)**	**Private-Barrick (acres)**
Agriculture	122	370
Aspen Woodland	1,834	691
Badland	329	61
Barren-Rock-Mud	318	183
Basin Wildrye-bottomland	213	133
Basin Wildrye-montane	3,448	1,658
Big Sagebrush-upland+trees	121,342	24,575
Black Sagebrush	32,747	774
Curl-leaf Mountain Mahogany	7,240	133
Desert Wash	30	3
Four-Wing Saltbush	41	0
Greasewood	10,275	1,809
Limber Pine Woodland	660	0
Low Sagebrush	42,244	0
Mine-Inactive	1,140	89
Mixed Salt Desert	3,480	3
Moist Floodplain	93	0
Montane Riparian	994	506
Montane Sagebrush Steppe-Subalpine	3,288	0
Montane Sagebrush Steppe-Upland	102,960	11,891
Mountain Shrub	2,891	803
Pinyon-Juniper Woodland	17,751	215
Roads-Local	12,350	1,556
Saline Meadow	1,669	239
Subalpine-Upper Montane Grassland	205	65
Water	16	47
Wet Meadow-Montane	2,748	1,271
Wetland	1	0
Winterfat	244	0
Sub-Total	**370,671**	**47,074**
TOTAL	**417,745 acres**	

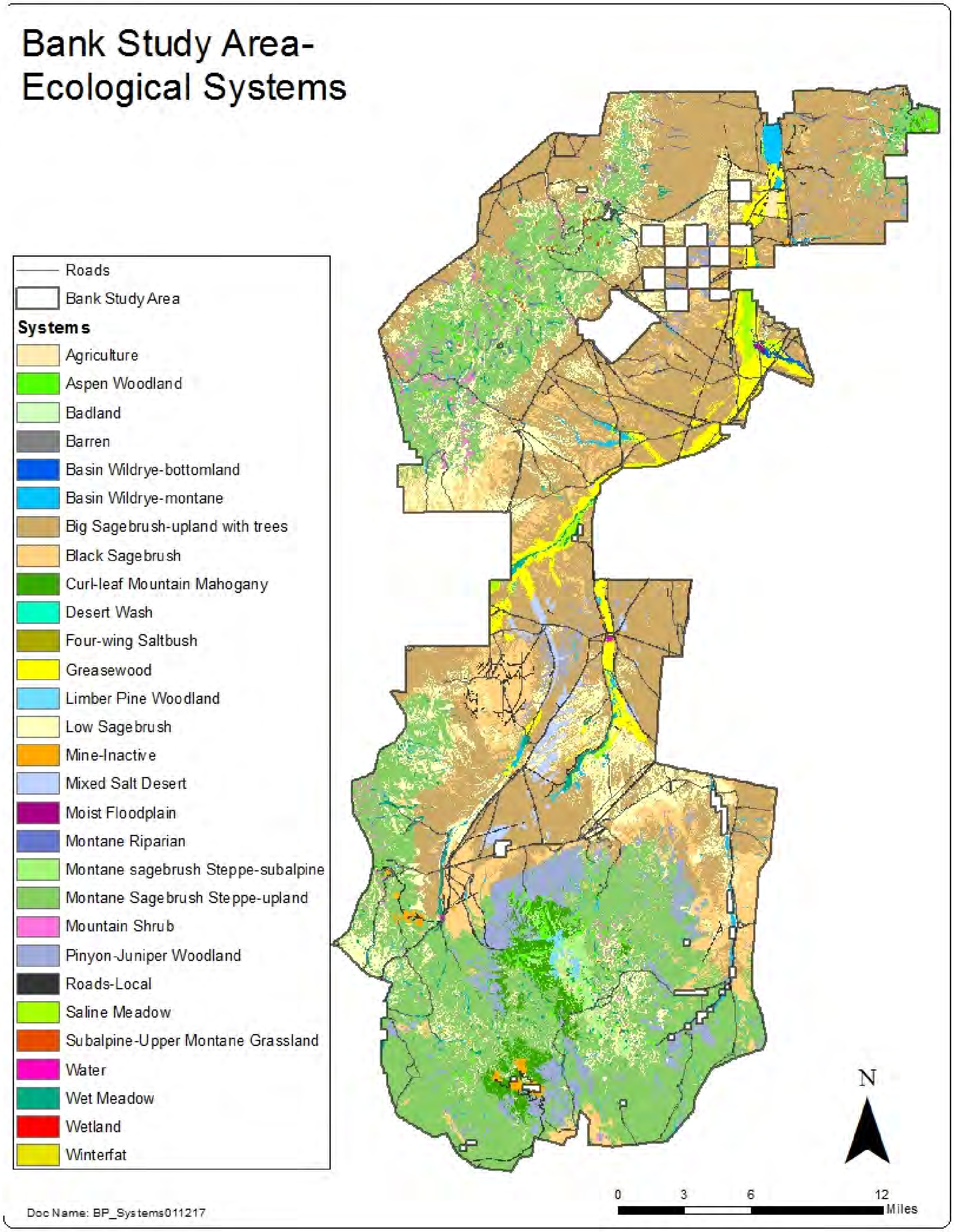


Figure 13. Ecological systems of the Bank Study Area.

Table 9. Ecological systems by ownership (acres) of the Plan of Operations Study Area based on 1.5-m Spot6/7 satellite imagery. Imagery does not include a buffer around the project area.

Ecological System	BLM (acres)	Private -Barrick (acres)
Agriculture	204	2466
Aspen Woodland	61	0
Badland	53	0
Barren-Rock-Mud	5,782	493
Basin Wildrye-bottomland	3,412	866
Basin Wildrye-montane	8,359	239
Big Sagebrush-semidesert	8,522	674
Big Sagebrush-upland+trees	93,766	1,334
Black Sagebrush	15,796	130
Curl-leaf Mountain Mahogany	1,407	273
Desert Wash	10	0
Four-Wing Saltbush	147	0
Greasewood	11,401	2,126
Limber Pine Woodland	147	6
Low Sagebrush	27,488	343
Mine-Active	11,312	1,142
Mine-Inactive	538	191
Mixed Salt Desert	60,558	1,825
Moist Floodplain	0	161
Montane Riparian	1,414	128
Montane Sagebrush Steppe-Upland	29,304	751
Mountain Shrub	3,186	45
Pickleweed	544	262
Pinyon-Juniper Woodland	7,183	200
Roads-Local	9,274	669
Roads-Paved	4,104	265
Saline Meadow	2,769	1,497
Water	440	73
Wet Meadow-Montane	1,368	77
Wetland	7	1
Winterfat	92	2
Sub-Total	**308,646**	**16,239**
TOTAL	**324,885 acres**	

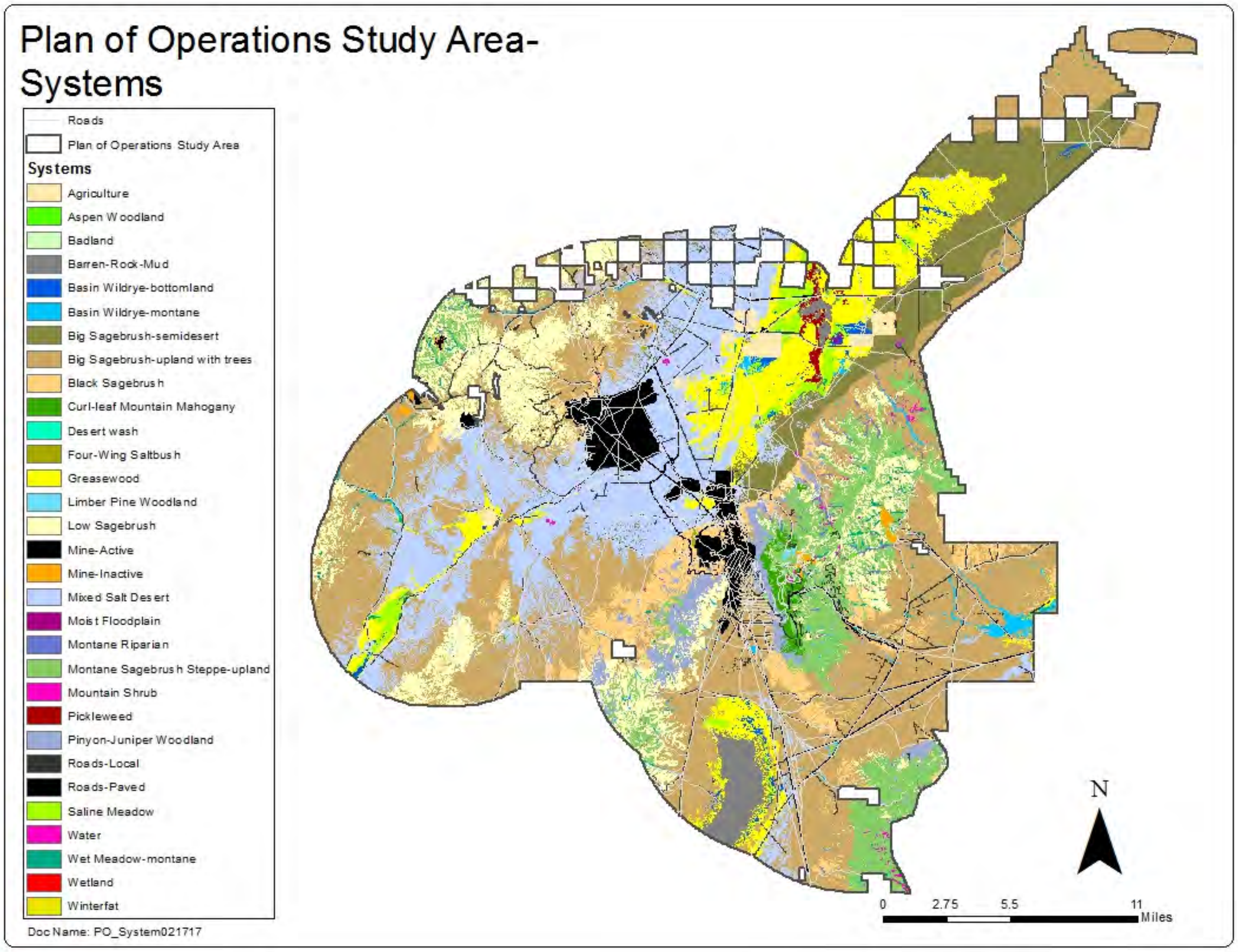


Figure 14. Ecological systems of the Plan of Operations Study Area based on Remote Sensing. Note that the as-built mine footprint differs from the currently authorized disturbance shown in Figure 11.

Current Condition

Greater Sage-Grouse: Habitat Suitability

Bank Study Area

Higher GSG nest site selection (values approaching 100%) occurred in areas closer to leks and with more consistent mature sagebrush cover (i.e., bluer areas on Figure 15). The majority of low nest-site selection areas had burned (for example, the BooHoo Fire to the north) or were non-habitat (for example, greasewood, see Appendix 8). Excluding values for non-habitat, the lowest value for nest-site selection was 6%. Several areas with adequate sagebrush cover had low nest site selection values because they were far from known leks, such as east of the JD Meadows. Areas of highest nest site selection were north, northwest, and southeast of Potato patch, between the Buckhorn mine and the Cottonwood Canyon road, west of the JD Meadows dipping into Huntington Creek, and the higher elevation benches of the Roberts Mountains.

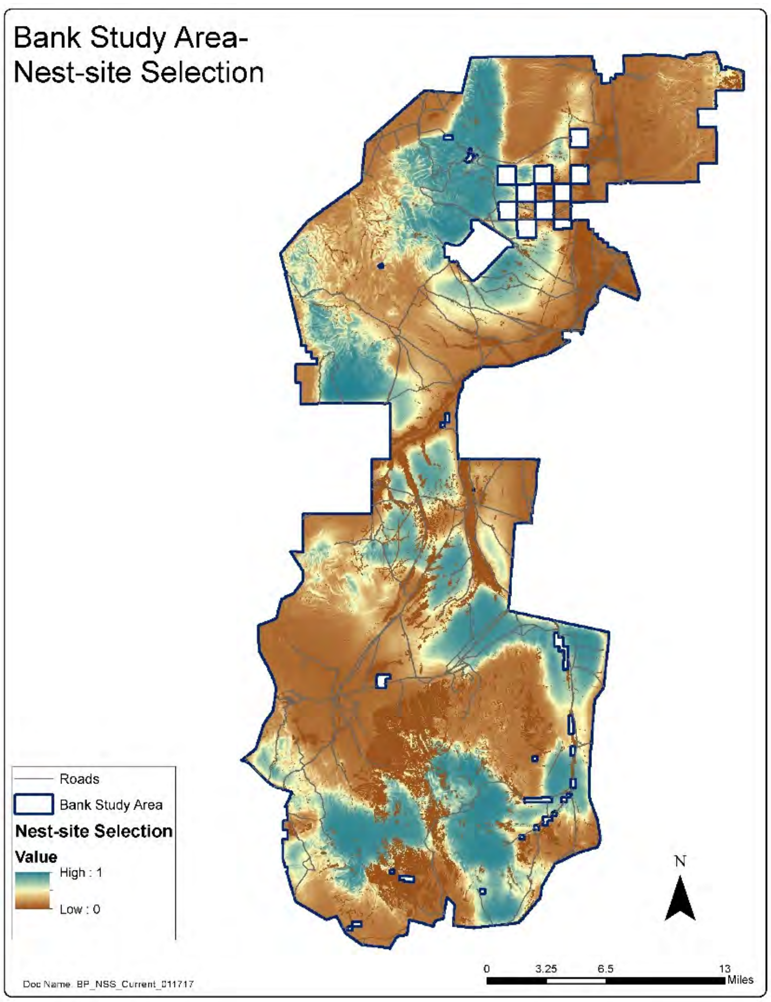


Figure 15. Spatial distribution of nest site selection values for sage-grouse in the Bank Study Area based on 2014 1.5-m Spot 6/7 satellite imagery.

Nest success ranged from 24% to 100% for habitat (Figure 16). The lowest values at 0% (shown in brick red) were non-habitat. Although many areas achieved moderate nest success (different shades of blue), lower nest success was clearly associated with early succession vegetation classes with low shrub cover, often where fire occurred. The highest values were observed north of the Buckhorn mine, in the triangle south of the JD Road and west of the Tonkin Road, and scattered in the Roberts Mountains.

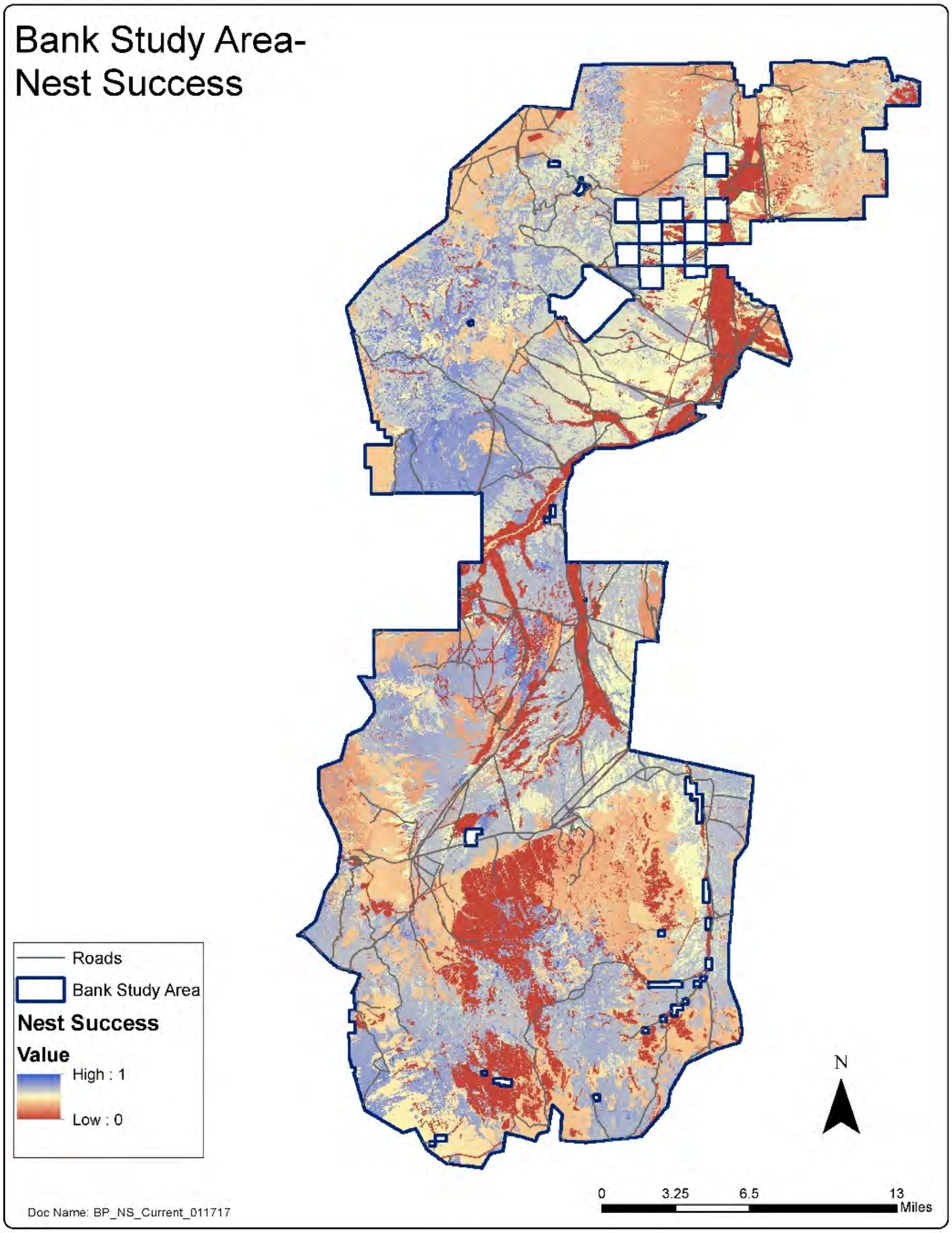


Figure 16. Spatial distribution of nest success values for sage-grouse in the Bank Study Area based on 2014 1.5-m Spot 6/7 satellite imagery.

Female survival was nearly the opposite of nest-site selection and nest success outside of non-habitat, which reflects the biological trade-off between a female's reproductive success and her individual survival (Blomberg et al. 2013, Figure 17). Highest values approaching 67% were generally found where nest success was lowest, which were burned areas. Lowest values (outside of non-habitat), which dipped to around 51%, were found in areas of high nest success. Non-habitat has a value of 0 and is shown in purple.

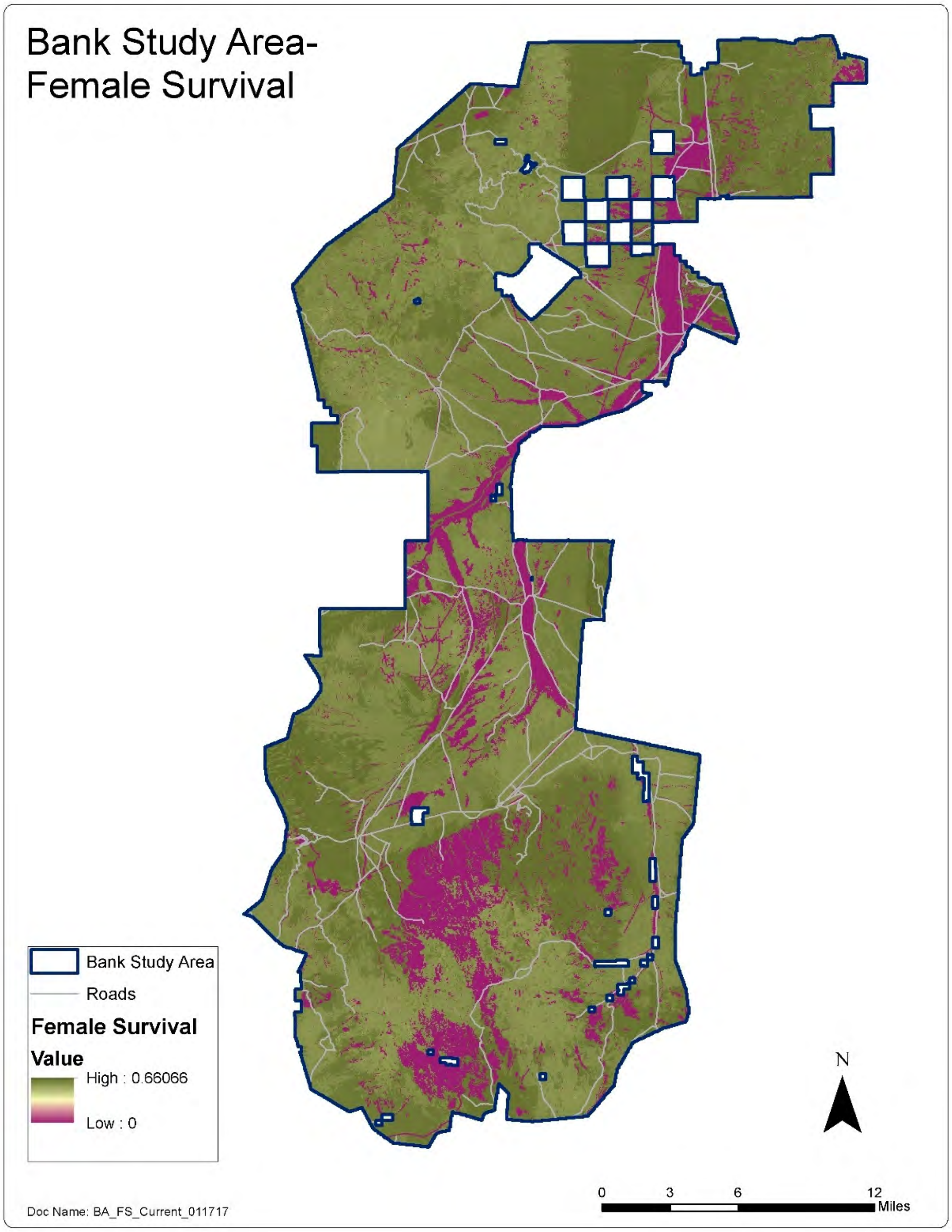


Figure 17. Spatial distribution of female success values for sage-grouse in the Bank Study Area based on 2014 1.5-m Spot 6/7 satellite imagery.

Chick survival was high (never exceeding 49%) in many areas because wet meadows and high-elevation shrub communities were located throughout the Bank Study Area (Figure 18). Chick survival only depends on the distance to these plant communities. The lowest values outside of non-habitat (17%) were in the central and narrow portion of the Bank Study Area that also contained the lowest elevations. The sharp lines in chick survival corresponded to the maximum distance, therefore sudden drop-off, chicks could travel to reach late-brood habitat. Non-habitat has a value of 0 and is shown in red.

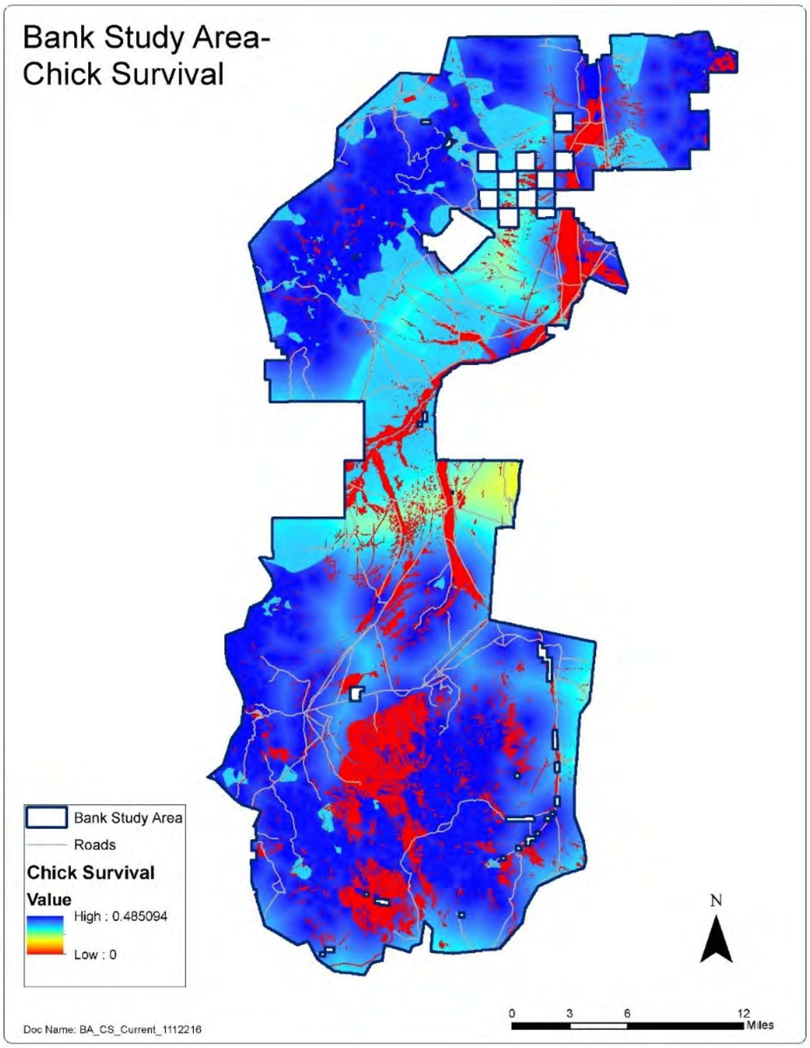


Figure 18. Spatial distribution of chick survival values for sage-grouse in the Bank Study Area based on 2014 1.5-m Spot 6/7 satellite imagery.

As discussed in the section on Methods, the per-capita population growth rate (λ) λ is a mathematical combination of the four previous parameters weighted toward the lowest value and represents a pixel's contribution to population growth of the species. Values of λ less than 1 indicate negative contribution to the population, values of 1 indicate no net loss or gain to the population, and values greater than 1 imply a positive contribution to the population. The spatial variation of λ matched closely the spatial distribution of nest site selection and rarely exceeded a value of 1.14 (Figure 19). The lowest value of λ outside non-habitat was 0.783.

Concentrations of good to great habitat can be seen in areas such as the Roberts Mountains, Pole Creek Watershed, and north of Buckhorn mine. Much of the landscape is poor habitat. There are two primary reasons for poor habitat on this landscape: (1) the habitat is not suitable for GSG due to naturally-occurring circumstances, or (2) the habitat is significantly degraded from what is useable by the bird. For example, areas along Highway 278 on the Hay Ranch that are low in elevation, near greasewood and salt-desert systems, and far from leks, and good nesting habitat are poor due to naturally occurring conditions. On the other hand, the BooHoo fire scar is an example of an area that could be good for GSG were it not degraded to an unusable class (annual species dominated). Non-habitat is shown in grey.

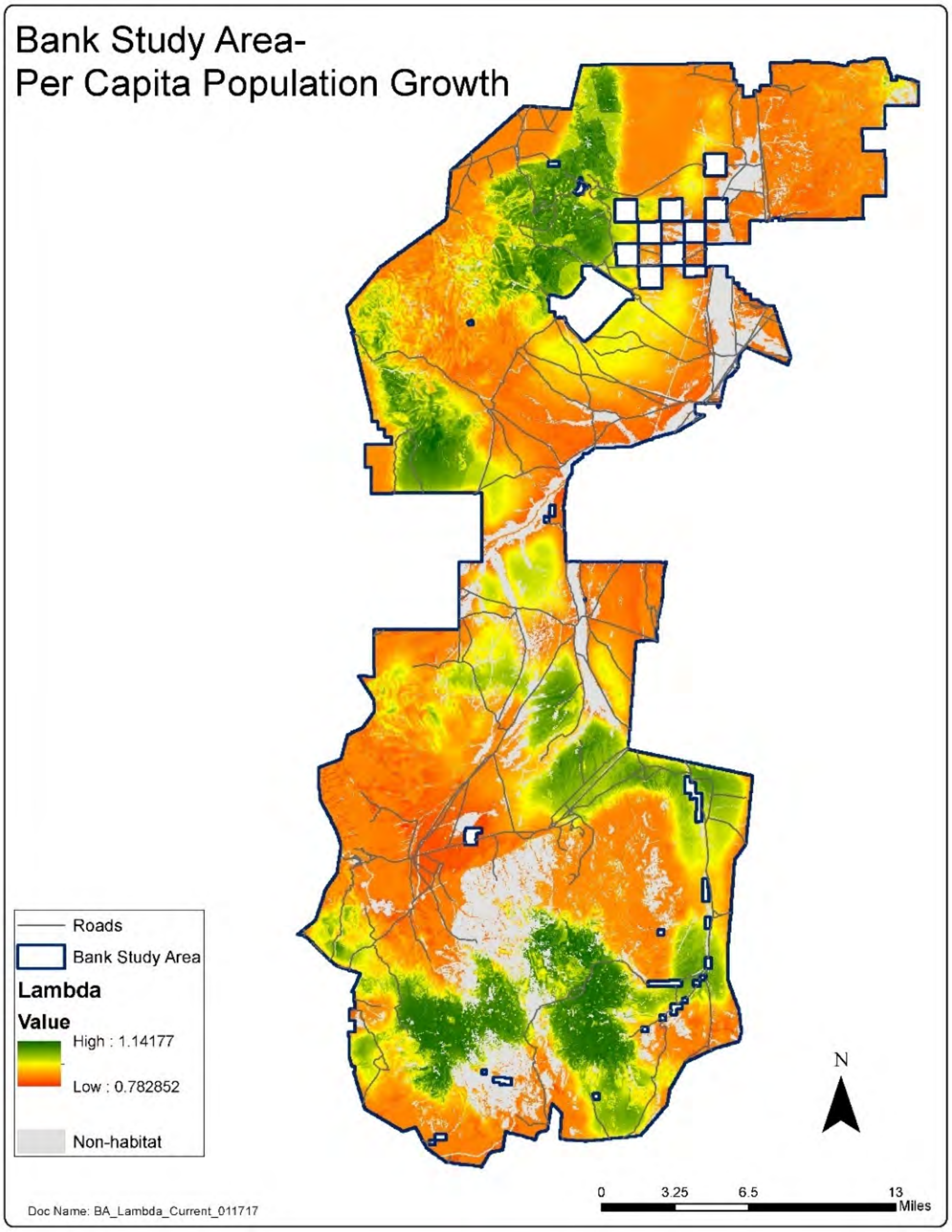


Figure 19. Spatial distribution of λ for sage-grouse in the Bank Study Area based on 2014 1.5-m Spot 6/7 satellite imagery.

Habitat suitability for the Plan of Operations Study Area reflected a greater proportion of lower elevation systems, including sagebrush semi-desert. Non-habitat (e.g., playa, greasewood, and mixed salt desert) dominated the southwest to northeast axis of the Plan of Operations Study Area. For nest-site selection, burned areas dominated by non-native annual species (lighter brown) had the lowest values for habitat (7%), whereas the west side of the Cortez Range, east side of Shoshone Range, northern tip of the Toiyabe Range, Red Mountain, and the upstream part of Pine Valley showed the highest values (Figure 20).

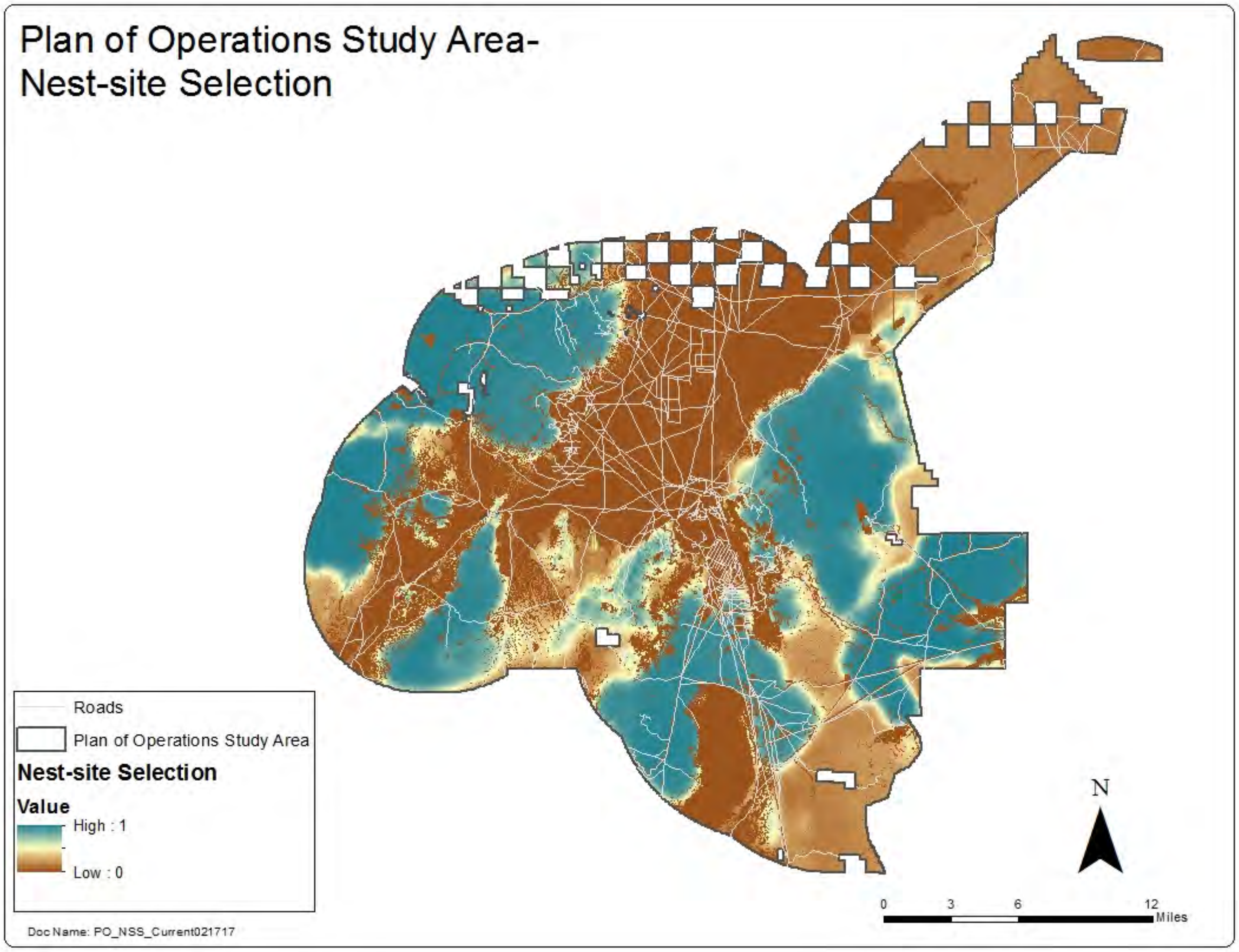


Figure 20. Spatial distribution of nest site selection for sage-grouse in the Plan of Operations Study Area based on 2015 and 2016 1.5-m Spot 6/7 satellite imagery.

There was a strong visual correlation between areas of higher nest-site selection (Figure 20) and nest success due to the presence of surrounding sagebrush cover (Figure 21). Nest success, however, was more fragmented due to many occurrences of small early-succession vegetation classes lowering nest success, sometimes down to 27% (Figure 21). In some areas, nest success approached 100%; however, these areas were more localized than the highest nest-site selection values. Much of the area is non-habitat and thus has a value of 0 and represented in brick red.

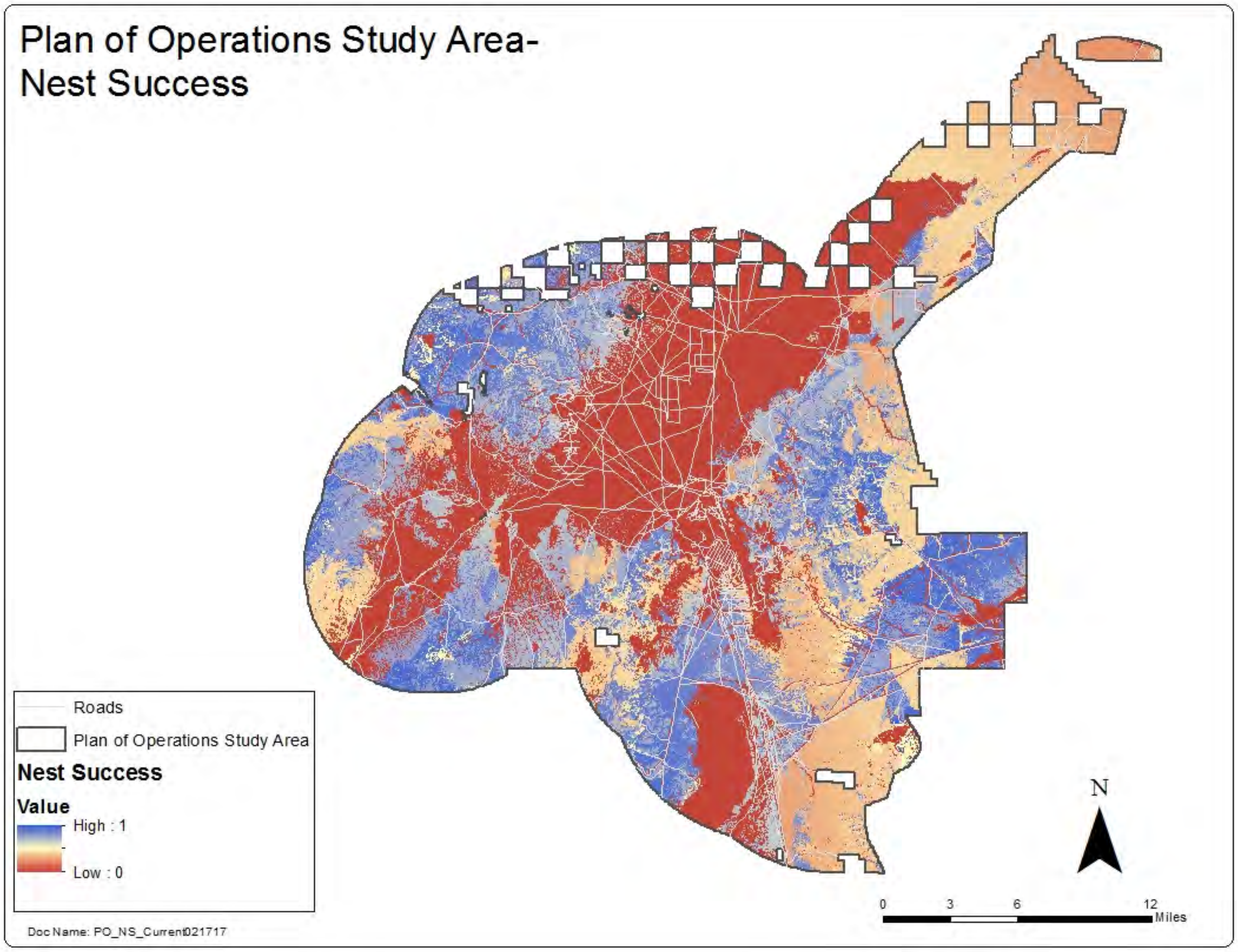


Figure 21. Spatial distribution of nest success for sage-grouse in the Plan of Operations Study Area based on 2015 and 2016 1.5-m Spot 6/7 satellite imagery.

Outside of non-habitat (purple areas), female survival was highest in burned areas dominated by non-native annual species (Figure 22). As previously noted, areas which positively contribute to reproductive success result in lower female survival because of the negative correlation between nest success and female survival. Unlike the previous two demographic rates, female survival never exceeded 0.67, and not lower than 0.52, and the difference between the best and worst nesting areas was small (Figure 22).

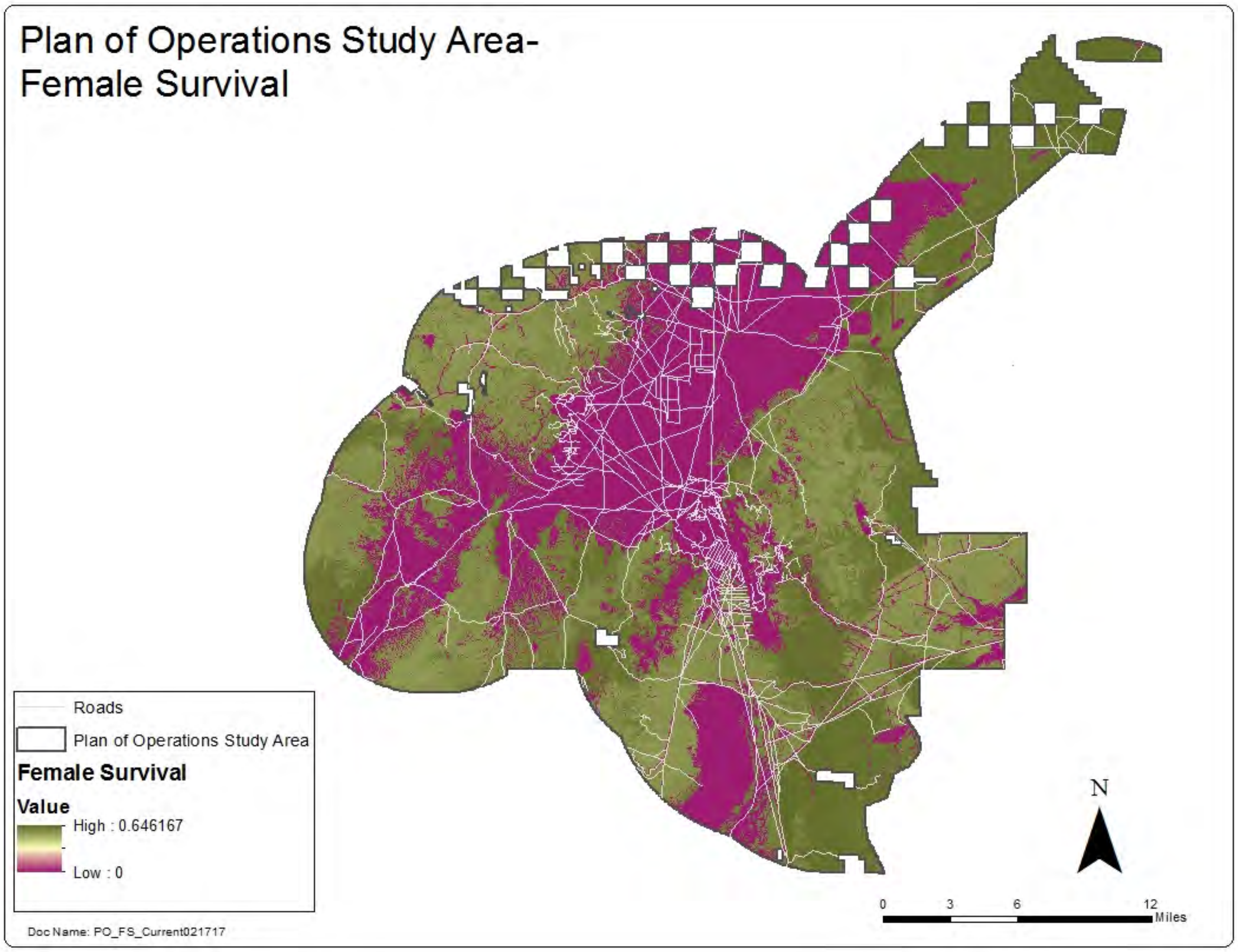


Figure 22. Spatial distribution of female survival values for sage-grouse in the Plan of Operations Study Area based on 2015 and 2016 1.5-m Spot 6/7 satellite imagery.

Chick survival never exceeded 49% and was highest in the higher elevation mountain ranges and close to wet meadows at all elevations. Early- (i.e., burned) and mid-succession high elevation sagebrush and mountain shrub systems were high for chick survival (Figure 23). The lowest values were about 16%. Non-habitat has a value of 0 and is shown in red.

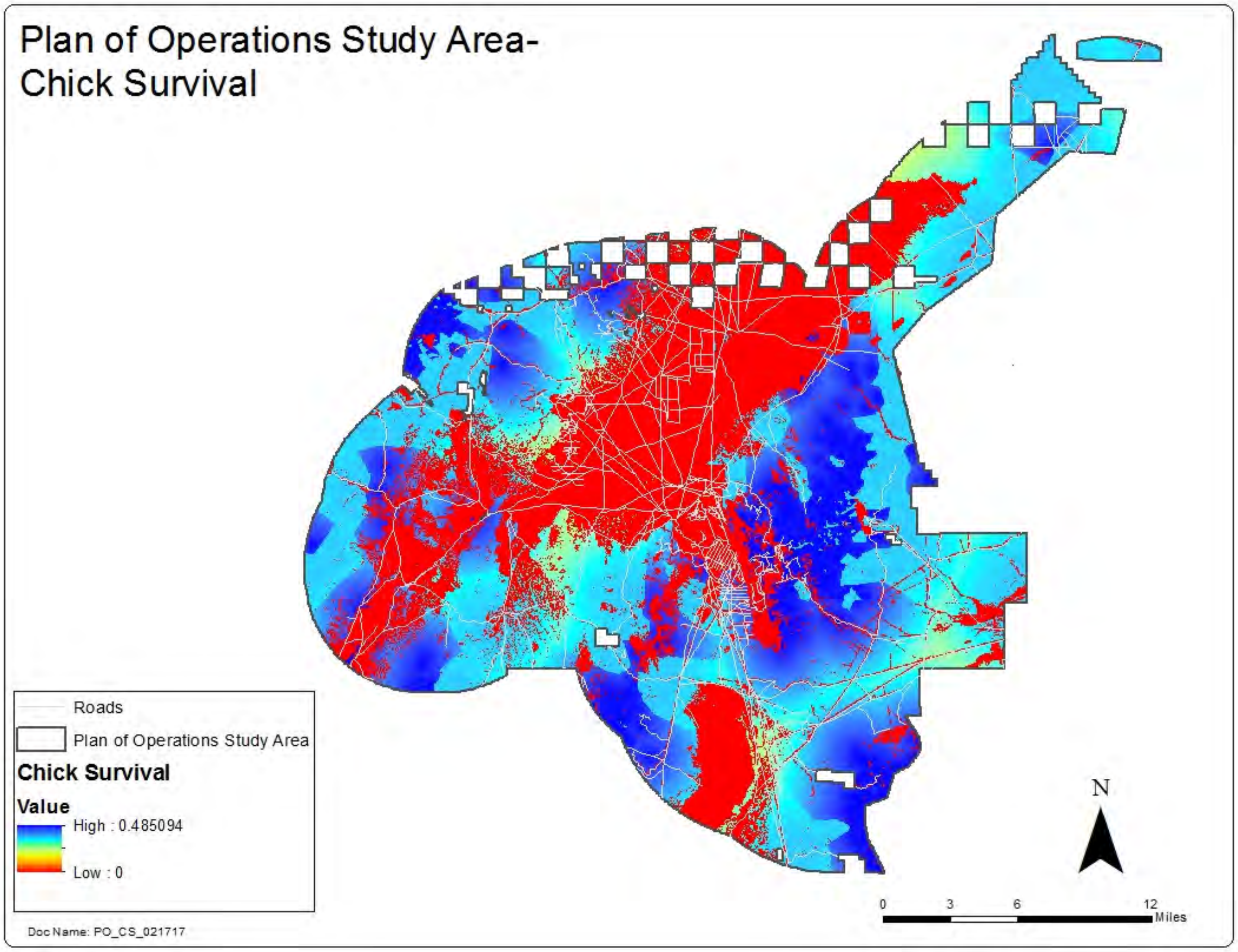


Figure 23. Spatial distribution of chick survival for sage-grouse in the Plan of Operations Study Area based on 2015 and 2016 1.5-m Spot 6/7 satellite imagery.

Per capita population growth rate (λ) closely resembled nest-site selection and nest success as cover of sagebrush is the most limiting feature in this well-burned landscape (Figure 24). Moreover, remaining adequate sagebrush also is spatially associated with the higher elevation late-brood habitat. The values of λ ranged from 0.785 and 1.174. Higher elevation areas tended to contain the highest λ values (Figure 24). The upstream portion of Pine Valley, which showed high nesting values, was only moderately contributing to overall population growth rate perhaps due to the extensive seedings in the valley. Non-habitat is shown in grey.

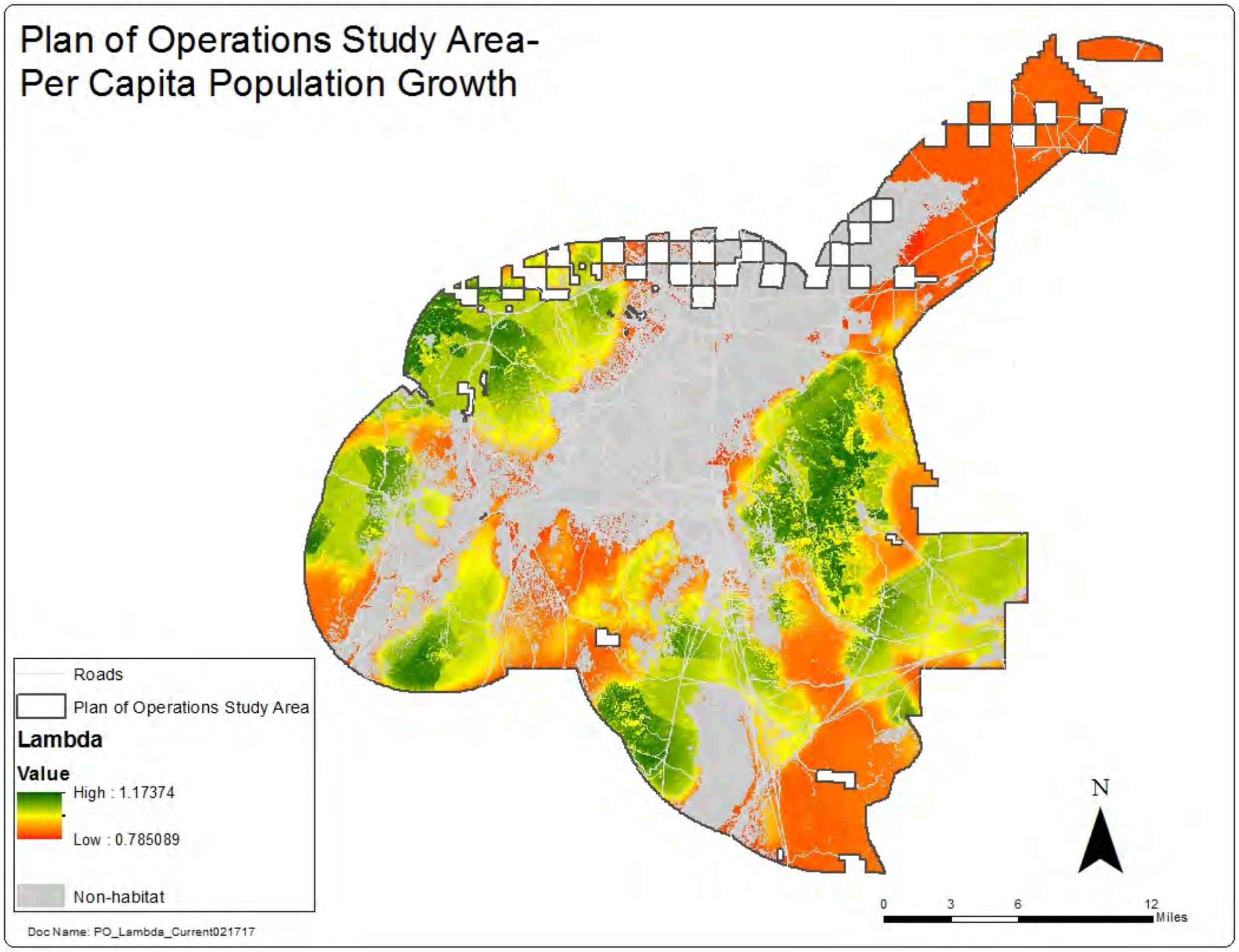


Figure 24. Spatial distribution of λ for sage-grouse in the Plan of Operations Study Area based on 2015 and 2016 1.5-m Spot 6/7 satellite imagery.

Predicted Future Conditions

Bank Study Area

Changes in Habitat Suitability for GSG due to management actions are calculated by comparing CUSTODIAL management habitat conditions (i.e. status quo management) to conditions obtained under active management. For the Plan of Operations Study Area, active management only involves mine infrastructure development. For the Bank Study Area, the active management was designed to increase GSG habitat suitability by focusing actions to improve the covariates for nest-site selection, nest success, and chick survival (Table A8-5). As such, conservation actions were limited to a few ecological systems: big sagebrush shrubland on upland soils, black sagebrush, low sagebrush, montane sagebrush steppe, and wet meadows (Table 10). In addition to these systems, artificial late-brood rearing habitat was created in the JD Meadows and exotic control was conducted in the montane riparian to limit the sources of exotic species as a good range management practice.

The primary vegetation classes targeted for restoration were monocultures of non-native annual species, late-succession wooded shrubland, tree-encroached shrublands, late-succession shrubland occupied by young conifers (a.k.a., Christmas tree phase), hummocked montane wet meadows, shrub-forb encroached montane wet meadows, montane wet meadows invaded by exotic species, and all classes of greasewood in the JD meadows owned by Barrick (Table 10). The classes of non-native annual species (U-A:Annual Spp) and tree-encroached or tree with annual species shrubland (U-D:TEA, U-E:TEA) were dominant in upland systems, whereas the hummocked class (U-A:Hummocked) was dominant in wet meadows.

Implicit in the simulated vegetation treatments were assumptions regarding the time associated with recovery and succession, including:

(1) the “Shrub-Planting” in the action termed “Herbicide-Plateau+Seed+Shrub-Planting” (and assumed in the action “AerialSeed+Masticate+Plateau”) was necessary for sagebrush and bitterbrush recoveries and shortened transition through the early-succession seeded class by 5 years, thus creating GSG nesting habitat 5 years faster;

(2) aerial seeding must precede mastication to incorporate seed in the soil in the action termed “AerialSeed+Masticate+Plateau”; and

(3) the “Seed” implied a mix of native and introduced species (crested wheatgrass or intermediate wheatgrass, and not forage kochia which can prevent sagebrush establishment). The proportion of native seed should increase with elevation, as seeding native species has increased success with increased site productivity.

Table 10. Area available in year 0 (t = 0) and average area treated by ecological system, ownership, action, and class on the Barrick's Bank Study Area for GSG Habitat Suitability. Treated area was summed over 35 years for the FINAL+FIRE scenario, as an illustration of current and future class areas, and spatial management exclusion zones. Class Area$_{t=0}$ represent the largest extent of acres available for a treatment at year 0; however, future fires, if present, created new treatment areas.

Owner-ship	Action	Class	Class Area$_{t=0}$ (Acres)	Avg. Area Treated Over 35 years (Acres)
Big Sagebrush-upland+trees				
BLM				
	AerialSeed+Masticate+Plateau			
		U-E:TEA	2,847	2,609
	Herbicide-Plateau+Seed+Shrub-Planting			
		U-A:Annual Spp	10,779	13,835
	Small-Tree-Lopping			
		D:Dense	0	713
		U-D:SA	0	1
		U-D:SAP	1,161	590
		U-D:SAP-Dense	0	9
Private-Barrick				
	AerialSeed+Masticate+Plateau			
		U-E:TEA	178	159
	Herbicide-Plateau+Seed+Shrub-Planting			
		U-A:Annual Spp	7,639	6,529
	Small-Tree-Lopping			
		D:Dense	0	35
		U-D:SAP	17	16
		U-D:SAP-Dense	0	0
Black Sagebrush				
BLM				
	AerialSeed+Masticate+Plateau			
		U-D:TEA	2,112	1,001
	Chainsaw-Thinning			
		D:Open	1,156	1,361
		U-D:TEA	2,112	681
Private-Barrick				
	Chainsaw-Thinning			
		D:Open	23	26
		U-D:TEA	17	17
	Herbicide-Plateau+Seed+Shrub-Planting			
		U-A:Annual Spp	2	44
Greasewood				
Private-Barrick				
	Irrigation			
		U-A:Bare Ground	0	1
		U-A:Exotic Forbs	189	84
		U-A:Pasture	469	469
Low Sagebrush				
BLM				
	AerialSeed+Masticate+Plateau			
		U-D:TEA	860	382

Owner-ship	Action	Class	Class Area$_{t=0}$ (Acres)	Avg. Area Treated Over 35 years (Acres)
	Chainsaw-Thinning			
		D:Open	713	385
		U-D:TEA	860	305
	Herbicide-Plateau+Seed+Shrub-Planting			
		U-A:Annual Spp	159	263
Private-Barrick				
	Chainsaw-Thinning			
		D:Open	4	22
		U-D:TEA	2	18
	Herbicide-Plateau+Seed+Shrub-Planting			
		U-A:Annual Spp	66	131
Montane Sagebrush Steppe-Upland				
BLM				
	AerialSeed+Masticate+Plateau			
		U-E:TEA	6,841	5,755
	Herbicide-Plateau+Seed+Shrub-Planting			
		U-A:Annual Spp	5,304	3,139
	Small-Tree-Lopping			
		D:Dense	0	0
		D:Open	881	432
		U-D:Depleted	93	20
		U-D:SA	0	6
		U-D:SAP	2,190	879
Private-Barrick				
	AerialSeed+Masticate+Plateau			
		U-E:TEA	39	27
	Herbicide-Plateau+Seed+Shrub-Planting			
		U-A:Annual Spp	517	67
	Small-Tree-Lopping			
		D:Open	5	5
		U-D:SAP	16	15
Wet Meadow-Montane				
BLM				
	Fence&Water-Delivery			
		A:All	0	5
		B:Closed	0	31
		U-A:Desertified	0	1
		U-A:Early Shrub	0	0
		U-A:Exotic Forbs	36	1
		U-A:Hummocked	920	27
		U-A:Shrb-Frb Encr	0	1
		U-B:Desertified	0	1
		U-B:Shrb-Frb Encr	108	9
		U-C:Depleted	0	2
		U-C:Desertified	17	0
		U-C:Shrb-Frb Encr	50	4
	Fence-Inspect&Maintain			
		A:All	9	9

Owner-ship	Action	Class	Class Area$_{t=0}$ (Acres)	Avg. Area Treated Over 35 years (Acres)
		B:Closed	86	86
		C:Open	1	1
		U-A:Desertified	1	1
		U-A:Early Shrub	0	0
		U-A:Exotic Forbs	0	0
		U-A:Hummocked	26	26
		U-A:Shrb-Frb Encr	1	1
		U-B:Desertified	2	2
		U-B:Early Shrub	0	0
		U-B:SAP	0	0
		U-B:Shrb-Frb Encr	12	12
		U-C:Depleted	3	3
		U-C:Desertified	0	0
		U-C:Shrb-Frb Encr	2	2
	Herbicide-Shrubs+Mow			
		U-A:Shrb-Frb Encr	1	1
		U-B:Shrb-Frb Encr	12	22
		U-C:Shrb-Frb Encr	2	22
	Weed-Inventory+Spot-Treat			
		A:All	9	17
		B:Closed	86	245
		C:Open	1	4
		U-A:Annual Spp	0	0
		U-A:Desertified	1	5
		U-A:Early Shrub	0	0
		U-A:Hummocked	26	330
		U-A:Shrb-Frb Encr	1	4
		U-B:Depleted	0	0
		U-B:Desertified	2	14
		U-B:Early Shrub	0	1
		U-B:SAP	0	1
		U-B:Shrb-Frb Encr	12	19
		U-C:Depleted	3	3
		U-C:Desertified	0	1
		U-C:SAP	0	0
		U-C:Shrb-Frb Encr	2	6
Private-Barrick				
	Fence&Water-Delivery			
		A:All	0	12
		B:Closed	0	244
		U-A:Desertified	0	1
		U-A:Exotic Forbs	0	3
		U-A:Hummocked	266	105
		U-A:Shrb-Frb Encr	0	2
		U-B:Exotic Forbs	2	0
		U-B:Shrb-Frb Encr	94	80
		U-C:Depleted	0	1
		U-C:Desertified	3	2

Owner-ship	Action	Class	Class Area$_{t=0}$ (Acres)	Avg. Area Treated Over 35 years (Acres)
		U-C:SAP	0	0
		U-C:Shrb-Frb Encr	2	6
	Fence-Inspect&Maintain			
		A:All	0	141
		B:Closed	0	1,899
		C:Open	0	11
		U-A:Desertified	0	4
		U-A:Early Shrub	0	1
		U-A:Exotic Forbs	2	5
		U-A:Hummocked	266	25
		U-A:SAP	0	0
		U-A:Shrb-Frb Encr	0	9
		U-B:Depleted	0	0
		U-B:Desertified	0	6
		U-B:Early Shrub	0	1
		U-B:Exotic Forbs	20	2
		U-B:SAP	0	0
		U-B:Shrb-Frb Encr	94	278
		U-C:Depleted	0	4
		U-C:Desertified	3	3
		U-C:Exotic Forbs	0	0
		U-C:SAP	0	1
		U-C:Shrb-Frb Encr	2	44
	Herbicide-Shrubs+Mow			
		U-A:Shrb-Frb Encr	0	1
		U-B:Shrb-Frb Encr	94	18
	Weed-Inventory+Spot-Treat			
		A:All	0	18
		B:Closed	0	249
		C:Open	0	1
		U-A:Annual Spp	0	0
		U-A:Desertified	0	2
		U-A:Early Shrub	0	0
		U-A:Hummocked	266	56
		U-A:SAP	0	0
		U-A:Shrb-Frb Encr	0	4
		U-B:Desertified	0	2
		U-B:Shrb-Frb Encr	94	20
		U-C:Depleted	0	0
		U-C:Desertified	3	0
		U-C:Shrb-Frb Encr	2	2

While montane riparian was not targeted for GSG habitat improvement, weed control and inventory were still conducted in this system due to the importance of riparian systems. Only classes already invaded by exotic forbs or trees received exotic control, whereas only classes not yet invaded or in the very early phase of invasion were inventoried for weeds or spot-sprayed, respectively (Table 11).

Table 11. Area available in year 0 (t = 0) and average area treated by ownership, action, and class on the Barrick's Bank Study Area of montane riparian. Treated area was summed over 35 years for the Final+Fire scenario, as an illustration of current and future class areas, and spatial management exclusion zones. "Na" indicates that the treatment was not necessary for that class. Class Area$_{t=0}$ represent the largest extent of acres available for a treatment at year 0.

Ownership	Class	Exotic-Control		Weed-Inventory+Spot-Treat	
		Area$_{t=0}$ of Class (Acres)	Area Treated Over 35 years (Acres)	Area$_{t=0}$ of Class (Acres)	Area Treated Over 35 years (Acres)
BLM					
	A-Willow:Closed	na	0	442	682
	B-Willow:Closed	na	0	144	45
	C-Cottonwood:Closed	na	0	2	0
	C-Willow:Closed	na	0	0	44
	U-A:Annual Spp	na	0	0	5
	U-A:Desertified	na	0	0	3
	U-A:Early Shrub	na	0	0	1
	U-A:Exotic Forb&Tree	0	32	na	0
	U-A:Incised-EFT	0	1	na	0
	U-A:Inset	na	0	22	70
	U-A:Inset-EFT	0	31	na	0
	U-A:Inset-SFE	na	0	0	3
	U-A:Shrb-Frb Encr	na	0	3	0
	U-B:Desertified	na	0	0	8
	U-B:Early Shrub	na	0	0	2
	U-B:Exotic Forb&Tree	6.2	12	na	0
	U-B:Incised-EFT	0	0	na	0
	U-B:Inset	na	0	11	31
	U-B:Inset-EFT	49	51	na	0
	U-B:Inset-SFE	na	0	14	15
	U-B:Shrb-Frb Encr	na	0	7	5
	U-C:Desertified	na	0	0	1
	U-C:Exotic Forb&Tree	0	1	na	0
	U-C:Shrb-Frb Encr	na	0	1	0
Private-Barrick					
	A-Willow:Closed	na	0	248	159
	B-Willow:Closed	na	0	142	8
	C-Cottonwood:Closed	na	0	2	1
	C-Willow:Closed	na	0	0	14
	U-A:Annual Spp	na	0	0	2
	U-A:Desertified	na	0	0	0
	U-A:Early Shrub	na	0	0	0
	U-A:Exotic Forb&Tree	12	42	na	0
	U-A:Incised-EFT		1	na	0
	U-A:Inset	na	0	8	7
	U-A:Inset-EFT		7	na	0
	U-B:Desertified	na	0	0	1
	U-B:Early Shrub	na	0	0	0

Ownership	Class	Exotic-Control		Weed-Inventory+Spot-Treat	
	U-B:Exotic Forb&Tree	6	10	na	0
	U-B:Incised-EFT		0	na	0
	U-B:Inset	na	0	4	4
	U-B:Inset-EFT	6	6	na	0
	U-B:Inset-SFE	na	0	0	1
	U-B:Shrb-Frb Encr	na	0	6	2
	U-C:Exotic Forb&Tree		4	na	0

Within agreed upon budgets, the highest priorities of the FINAL SCENARIO were to greatly reduce the non-native annual species class and degraded wet meadow classes (hummocked, invaded by exotic forb, and shrub-forb encroached) because they have a large effect on, respectively, nesting and chick survival, especially in the northern part of the Bank Study Area. Also of high priority to Barrick was the creation of late-brood rearing habitat in the form of irrigated pastures in the JD Meadows. As funding allowed, removal of young and older trees was the next priority as future nesting and, for higher elevations, brood-rearing habitat would be created. Moreover, obtaining mitigation credits earlier by front-loading planned restoration was preferable. Table 12 represented the *average* planned implementation rates in ST-Sim; however, realized implementation rates were frequently lower due to vegetation class availability and location, management constraints (for example, slopes >15%), and competing disturbances (for example, fire removing trees).

Table 12. Planned yearly implementation rates (acres) for different management actions by ecological system and year for the FINAL SCENARIO of Barrick's Bank Study Area. Planned rates do not equal realized rates because (i) other factors may reduce acres available for treatment (e.g. management constraints) and the planned rate is treated as average by ST-Sim, which can stochastically vary . For "Year of Simulation", the "→" indicates the implementation was maintained throughout the specified years.

			Planned Implementation Area (acres)	
Action	Ecological System	Year of Simulation	BLM	Private-Barrick
AerialSeed+Masticate+Plateau				
	Big Sagebrush-upland+trees			
		1→3	0	0
		4	1000	0
		5	0	240
		6	2000	160
		7	500	160
		8	500	0
		9→35	0	0
	Black Sagebrush			
		1→3	0	0
		4→8	500	0
		9→35	0	0
	Low Sagebrush			
		1→3	0	0
		4→6	500	0

Action	Ecological System	Year of Simulation	Planned Implementation Area (acres) BLM	Private-Barrick
		7→35	0	0
	Montane Sagebrush Steppe-Upland			
		1→4	0	0
		5	500	0
		6	2000	0
		7	2000	0
		8→10	2000	60
		11→35	0	60
Chainsaw-Thinning				
	Black Sagebrush			
		1	0	0
		2	0	100
		3	0	100
		4	500	100
		5	500	100
		6→8	500	0
		9→35	0	0
	Low Sagebrush			
		1→3	0	0
		4	400	0
		5	400	0
		6	0	0
		7	0	0
		8→11	0	40
		12→35	0	0
Exotic-Control				
	Montane Riparian			
		1→31	40	100
		32→35	0	0
	Wet Meadow-Montane			
		1	20	100
		2→31	20	40
		32	0	0
Fence&Water-Delivery				
	Wet Meadow-Montane			
		1	0	0
		2→4	0	440
		5	20	440
		6→8	20	260
		9→11	0	260
		12→35	0	0
Fence-Inspect&Maintain				
	Wet Meadow-Montane			
		1→9	0	0

Action	Ecological System	Year of Simulation	Planned Implementation Area (acres) BLM	Private-Barrick
		10	20	0
		11	0	4000
		12→15	0	0
		16	60	4000
		17→20	0	0
		21	0	4000
		22	60	0
		23→25	0	0
		26	0	4000
		27→30	0	0
		31	0	4000
		32→35	0	0
Herbicide-Plateau+Seed+Shrub-Planting				
	Big Sagebrush-upland+trees			
		1→2	0	0
		3	0	2860
		4	500	2860
		5	500	6440
		6	950	4000
		7	950	3480
		8→11	825	3480
		10	930	3480
		11	350	3480
		12→13	350	252
		14→15	0	252
		16	0	532
		17	0	180
		19→20	520	180
		21	1200	0
		22→35	0	0
	Black Sagebrush			
		1→5	0	0
		6→11	0	100
		12→35	0	0
	Low Sagebrush			
		1→4	0	0
		5→6	100	80
		7→11	0	80
		12→35	0	0
	Montane Sagebrush Steppe-Upland			
		1→3	0	0
		4	95	0
		5	80	640
		6→7	190	640

Action	Ecological System	Year of Simulation	Planned Implementation Area (acres) BLM	Private-Barrick
		8→9	250	640
		10	400	640
		11	1000	640
		12→21	0	0
		22→25	520	0
		26→35	0	0
Herbicide-Shrubs+Mow				
	Wet Meadow-Montane			
		1	0	0
		2→4	0	400
		5	5	400
		6→9	20	400
		10→14	0	400
		15→35	0	0
Irrigation				
	Greasewood			
		1	0	0
		2	0	1000
		3→4	0	1200
		5→35	0	0
Small-Tree-Lopping				
	Big Sagebrush-upland+trees			
		1	0	0
		2→5	0	80
		6→8	500	80
		9→11	0	80
		12→35	0	0
	Montane Sagebrush Steppe-Upland			
		1	0	0
		2→11	0	250
		12	700	0
		13→35	0	0
Weed-Inventory+Spot-Treat				
	Montane Riparian			
		1	40	16
		2→31	40	8
		32→35	0	0
	Wet Meadow-Montane			
		1	20	16
		2→35	20	8
		32	0	0
		33	0	8
		34→35	0	0

Average realized implementation rates were remarkably similar between the FINAL+FIRE and FINAL+NOFIRE within land ownership. The greatest differences were that (a) less trees were available and, therefore, fewer treed areas were treated when fire was present and (b) more burned areas dominated by non-native annual species were available and treated when fire was present (Table 13). These differences were more pronounced in the later years of implementation because the cumulative effect of fire was greater. In other words, fire helped restoration by removing wooded areas, but the price paid was the need to seed areas dominated by non-native annual species. Restoration activities in wet meadow and montane riparian appeared unaffected by fire (Table 13).

Table 13. Average yearly implementation rates (acres) for different management actions by ecological system and by year for the Final Scenario of Barrick's Bank Study Area. Years that were not shown have zero implementation for all scenarios. Notations: (1) X→Y, where X and Y are years and X<Y, means the implementation rate was maintained for all years from X to Y, and (2) A to B, where A < B, applies to the range of average realized implementation rates. N = 10 replicates. See Appendix 11 for an alternative formatting of this table.

			Ave. Realized Imp. Area (acres)			
			Final + Fire		Final + NoFire	
Action	Ecological System	Year of Simulation	BLM	Private-Barrick	BLM	Private-Barrick
AerialSeed+Masticate+Plateau						
	Big Sagebrush-upland+trees					
		4	1070	0	1061	0
		5	0	130	0	145
		6	1110	22	1269	13
		7	305	7	414	5
		8	123	0	242	0
	Black Sagebrush					
		4	461	0	494	0
		5	333	0	301	0
		6	145	0	280	0
		7	58	0	141	0
		8	3	0	10	0
	Low Sagebrush					
		4	218	0	290	0
		5	73	0	81	0
		6	91	0	122	0
	Montane Sagebrush Steppe-Upland					
		5	823	0	989	0
		6	2619	0	2783	0
		7	1627	0	2142	0
		8	595	27	837	39
		9	61	0	39	0
		10	31	0	53	0
		11	0	0	0	0
Chainsaw-Thinning						
	Black Sagebrush					

Action	Ecological System	Year of Simulation	Ave. Realized Imp. Area (acres) Final + Fire BLM	Final + Fire Private-Barrick	Final + NoFire BLM	Final + NoFire Private-Barrick
		2	0	41	0	41
		3	0	2	0	4
		4	477	0	520	0
		5	561	0	454	1
		6	500	0	500	0
		7	302	0	452	0
		8	201	0	279	0
	Low Sagebrush					
		4	351	0	320	0
		5	339	0	293	0
		8	0	30	0	35
		9	0	5	0	14
		10	0	7	0	8
		11	0	3	0	8
Exotic-Control						
	Montane Riparian					
		1	56	25	56	25
		2	21	11	24	10
		3→9	3 to 6	2 to	1 to 10	1 to 4
		10→35	2	1	2	1
	Wet Meadow-Montane					
		1	95	22	95	22
		2	43	10	42	10
		3	12	4	18	6
		4	10	4	7	4
		5→30	2 to 7	1 to 4	2 to 7	1 to 4
Fence&Water-Delivery						
	Wet Meadow-Montane					
		2	0	361	0	358
		3	0	93	0	96
		5	20	0	20	0
		6	20	1	20	1
		7	21	0	20	0
		8	21	0	21	0
		11	0	1	0	0
Fence-Inspect&Maintain						
	Wet Meadow-Montane					
		10	20	0	19	0
		11	0	487	0	487
		16	62	487	56	487
		21	0	487	0	487
		22	62	0	59	0
		26	0	487	0	487

Action	Ecological System	Year of Simulation	Ave. Realized Imp. Area (acres) Final + Fire BLM	Final + Fire Private-Barrick	Final + NoFire BLM	Final + NoFire Private-Barrick
		31	0	487	0	487
Herbicide-Plateau+ Seed+Shrub-Planting						
	Big Sagebrush-upland+trees					
		3	0	2310	0	2669
		4	2130	563	2217	509
		5	4380	1697	3325	1291
		6	2594	737	2078	697
		7	1387	374	974	218
		8	1005	257	326	81
		9	471	86	110	30
		10	172	62	50	18
		11	120	40	37	7
		12	98	19	40	8
		13	86	37	43	12
		14→18	0	45 to 81	0	10 to 13
		19	488	6	153	8
		20	429	6	52	7
		21	476	0	48	0
	Black Sagebrush					
		6→11	0	4 to 13	0	1 to 2
	Low Sagebrush					
		5	99	33	92	34
		6	164	27	95	21
		7	0	18	0	11
		8	0	24	0	7
		9	0	15	0	4
		10	0	9	0	4
		11	0	5	0	3
	Montane Sagebrush Steppe-Upland					
		4	85	0	94	0
		5	729	22	542	20
		6	942	18	695	13
		7	580	7	495	5
		8	391	13	210	3
		9	111	4	49	3
		10	28	2	22	2
		11	8	1	11	1
		22	172	0	111	0
		23	42	0	23	0
		24	30	0	12	0
		25	22	0	11	0
Herbicide-Shrubs+Mow						

Action	Ecological System	Year of Simulation	Ave. Realized Imp. Area (acres) Final + Fire BLM	Final + Fire Private-Barrick	Final + NoFire BLM	Final + NoFire Private-Barrick
	Wet Meadow-Montane					
		2	0	6	0	6
		3	0	5	0	4
		4	0	3	0	3
		5	6	2	5	2
		6	21	2	19	1
		7	15	1	18	1
		8	3	0	3	0
		9	1	0	1	0
		10	0	0	0	0
		11	0	0	0	0
		12→14	0	0	0	0
Small-Tree-Lopping						
	Big Sagebrush-upland+trees					
		2	0	51	0	52
		6	500	0	486	0
		7	413	0	451	0
		8	400	0	500	0
	Montane Sagebrush Steppe-Upland					
		2	0	20	0	21
		10	697	0	699	0
		11	327	0	491	0
		12	313	0	349	0
Weed-Inventory+Spot-Treat						
	Basin Wildrye-montane					
		1→35	3 to 22	0 to 7	4 to 17	0 to 9
	Moist Floodplain					
		1→35	1 to 3	0	1 to 3	0
	Montane Riparian					
		1→35	19 to 38	3 to 14	21-38	0 to 15
	Saline Meadow					
		1→35	12 to 23	0 to 5	11 to 25	0 to 7
	Wet Meadow-Montane					
		1→35	13 to 30	5 to 25	15 to 30	0 to 17

Change in Vegetation Classes

Below, we report three types of results to measure the success of restoration actions. First is the change in vegetation class acres due to restoration actions with CUSTODIAL results shown for comparison. These are aggregated by system. TNC's results database can produce non-spatial graphic results like the ones presented for each unique class and land ownership which would total well over 1500 graphs for the two Study Areas. As much of this data is unrelated to GSG habitat, and in the interest of keeping this report relatively short, only a selection of those results is shown here. These non-spatial results do not reveal the effect of restoration on changes to GSG Functional Acres as GSG habitat is spatially contextual and impacted by non-vegetative environmental variables (e.g. location of leks, slope, elevation, etc.). Therefore, the second set of results are the maps of λ and time series of Functional Acres. The third set of results are the maps showing the location and frequency of action implementation; these maps are useful to land managers as they delineate the most likely implementation areas of each action.

Big sagebrush shrubland on upland soils

In big sagebrush shrubland on upland soils system (a.k.a. Big Sagebrush-upland+trees), the primary targets were reduction of vegetation classes that were dominated by non-native annual species (U-A:Annual Spp), young conifers (U-D:SAP), and mature conifers (U-E:TEA). To accomplish these targets, each class received different restoration actions (Figure 25).

Tree removal activities were the most effective at lowering the targeted classes to nearly zero before the 10th year of simulations. Vegetation classes dominated by non-native annual species were rapidly reduced, but about 5,000 acres and 3,700 acres, respectively, for BLM-managed and Private-Barrick lands (Figure 25) remained after treatment. Land management exclusion areas prevented restoration of some non-native annual species dominated classes because the grazing allotment was not controlled by Barrick or the burned areas, even if treated, were too far away from leks to contribute to GSG habitat suitability.

By comparing results with fire to those without fire we can draw conclusions as to how fire, specifically, may affect vegetation classes in the future. For example, in Figure 25 – "State Classes Area (Acres): Big Sagebrush-upland+trees, BLM, U-E: TEA," the difference in CUSTODIAL scenarios suggests that fire reduced treed classes by at least 1,700 acres on BLM-managed classes. In Figure 25 – "State Classes Area (Acres): Big Sagebrush-upland+trees, BLM, U-A:Annual Spp," both scenarios that include fire exhibit an upward trajectory meaning Annual Species increase over time. For the active management scenario with fire, we see an initial reduction in Annual Species due to treatment, but an upward trend beginning around year 10, after treatment has ceased. In other words, the initial success of these treatments is impacted by the continued loss of sagebrush habitat to annual species over time, especially given the successional recovery period in this system. However, both with and without fire, the active management scenario still results in significantly less of the annual species class than the custodial.

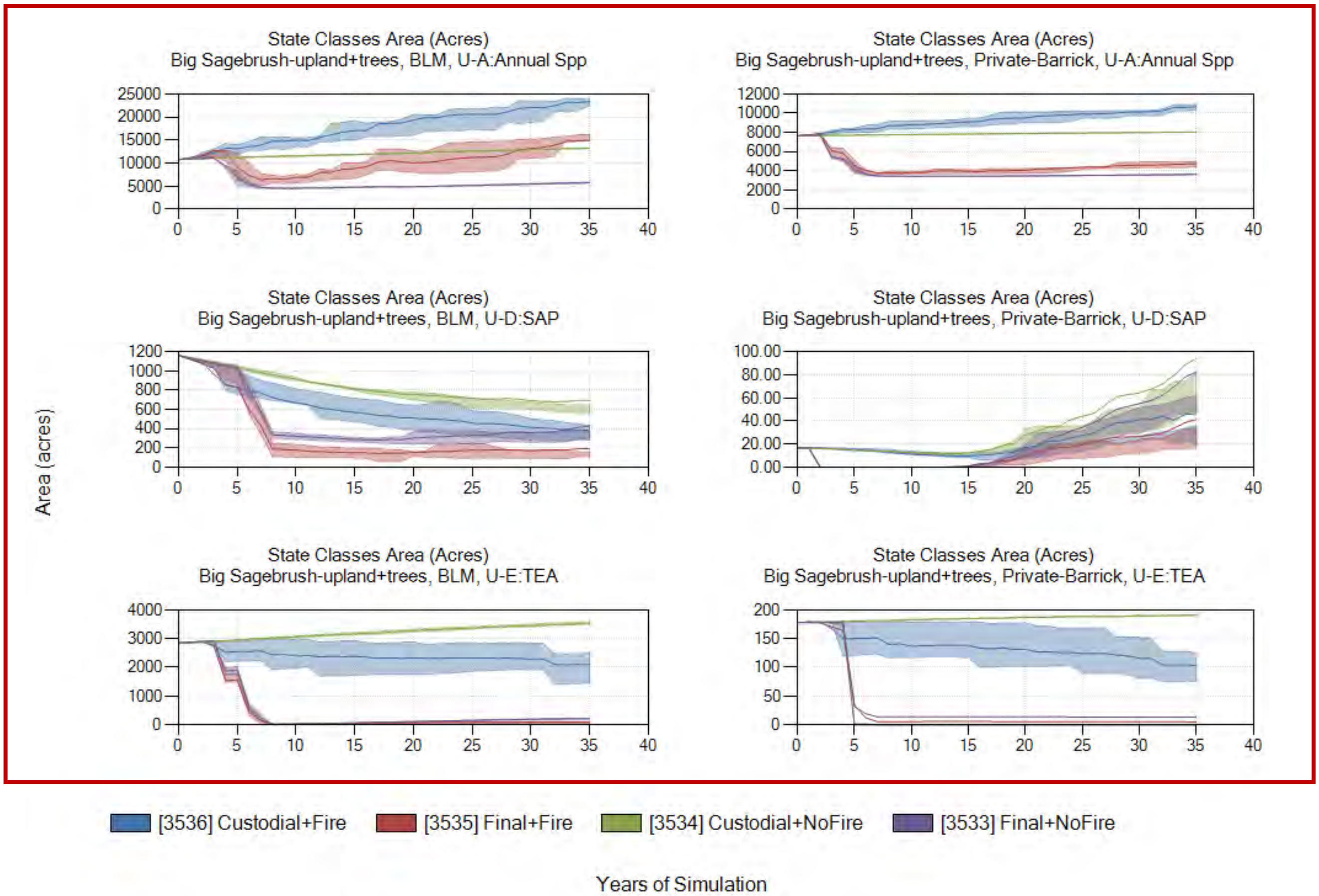


Figure 25. Big sagebrush shrubland on upland soils vegetation classes targeted for restoration on Barrick's Bank Study Area using ST-Sim simulations. Color bands are the 25% to 75% percentiles. N = 10 replicates.

Classes dominated by non-native annual species and mature conifers in big sagebrush shrubland on upland soils required mixed introduced and native species seeding, thus, when treated successfully, become a "seeded" class. The seeded classes are shown in Figure 26 in their three succession phases (U-A:SI → U-B:SI → U-C:SI). On BLM-managed lands, active management in the scenario with fire created approximately 4,500 acres of mature seeded class (i.e. U-C:SI) over the corresponding CUSTODIAL scenario. Without fire, active management led to about 3,000 acres created over the corresponding CUSTODIAL scenario. This difference is due to the increased occurrence of non-native annual species following fires and thus the increasing areas in need of restoration.

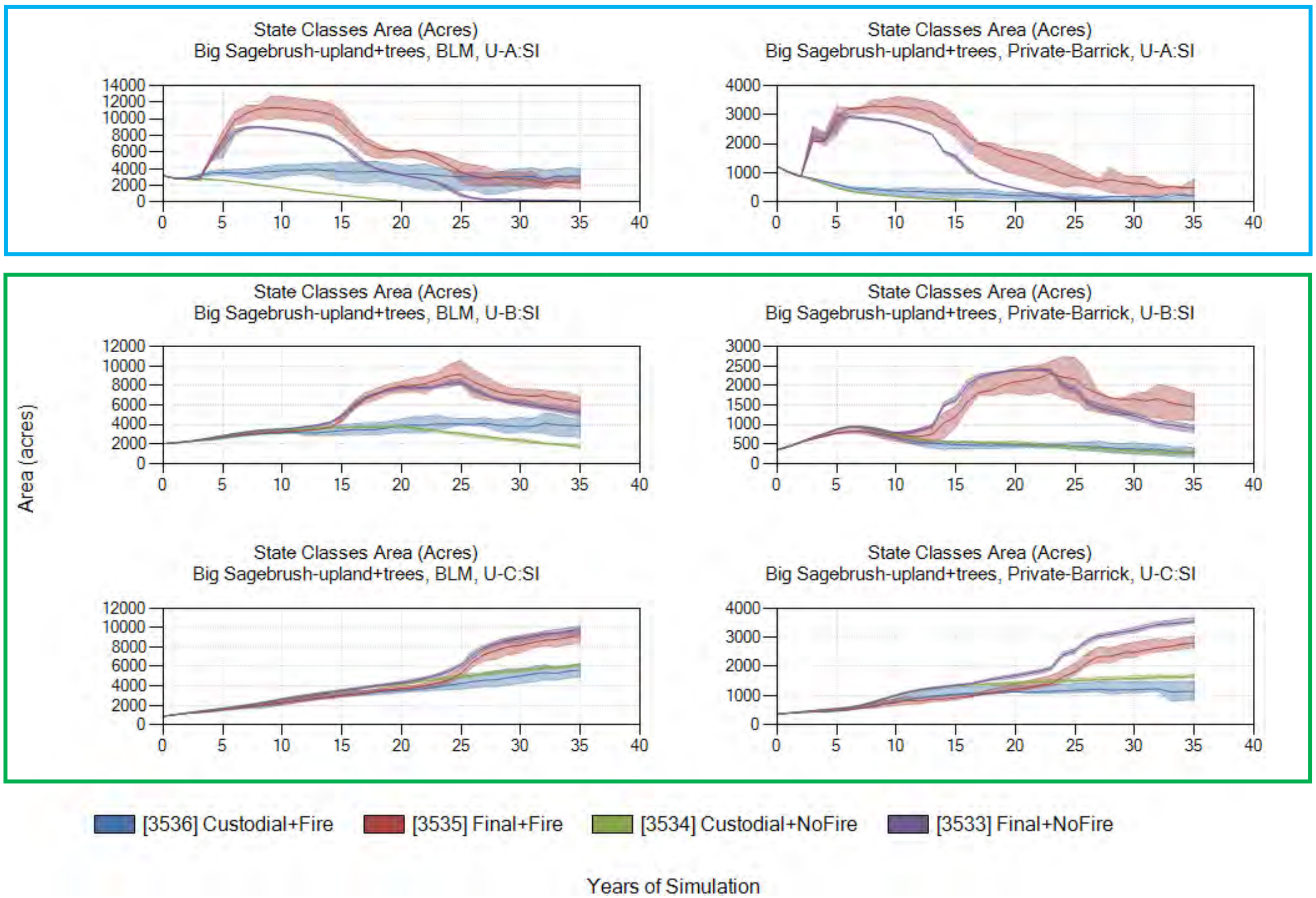


Figure 26. Big sagebrush shrubland on upland soils vegetation classes recipient of restoration actions with seeding on Barrick's Bank Study Area using ST-Sim simulations. Color bands are the 25% to 75% percentiles. N = 10 replicates.

Chainsaw lopping of small trees in big sagebrush shrubland resulted in recruitment of shrub-dominated classes (U-C:SA and U-C:SAP). This action is intended to slow down tree encroachment which leads to a complete loss of nesting habitat (Figure 27). Although hard to see, the small-tree lopping action resulted in about 1,000 acres more of shrubland without young trees compared to the CUSTODIAL+FIRE scenario on BLM-management lands with simulated fire and about 500 acres without fire on Barrick's private lands.

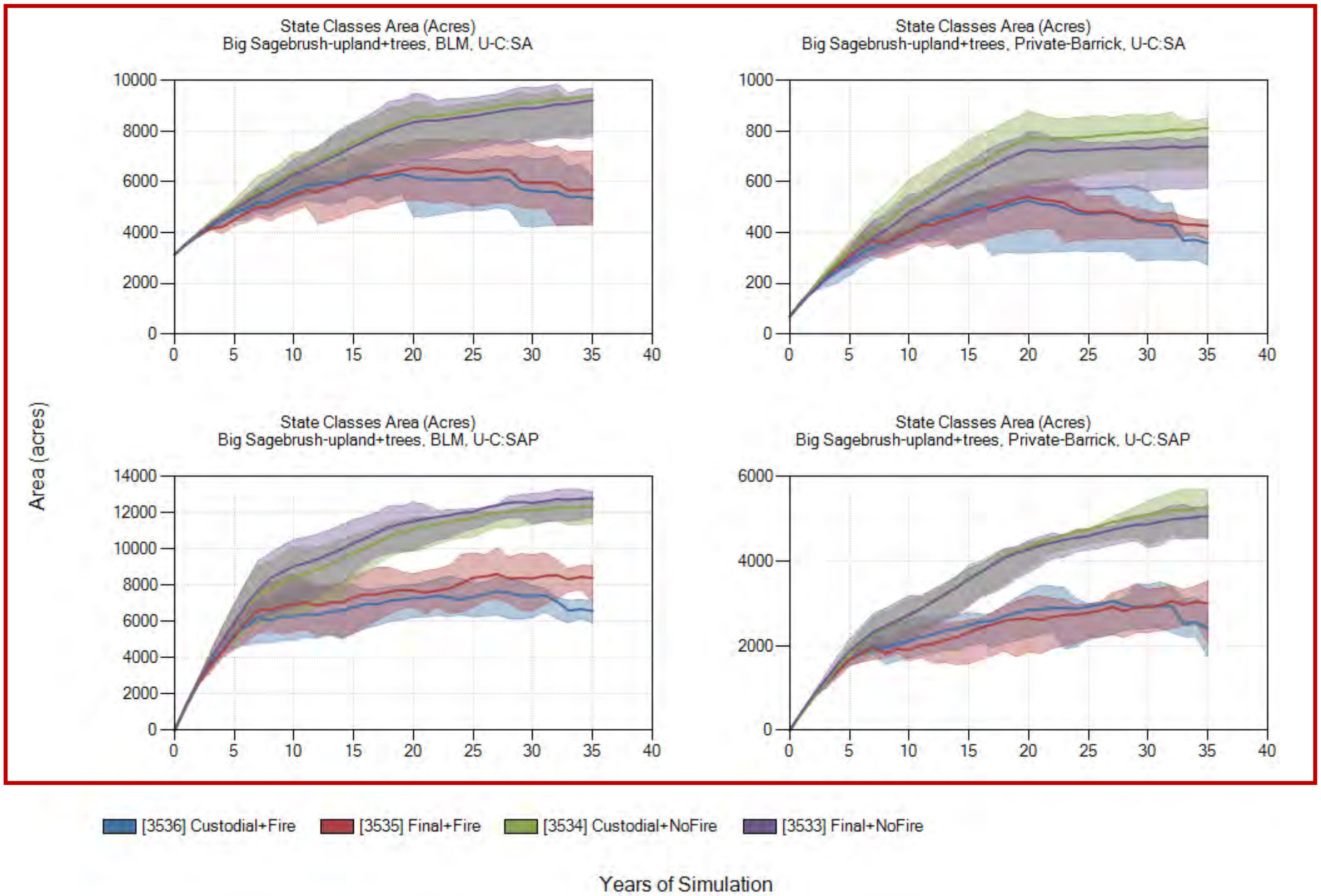


Figure 27. Big sagebrush shrubland on upland soils vegetation classes recipient of small-tree lopping on Barrick's Bank Study Area using ST-Sim simulations. Color bands are the 25% to 75% percentiles. N = 10 replicates.

Dwarf sagebrush systems (black and low sagebrush)

Dwarf sagebrush systems (black and low sagebrush) are lumped here as the state-and-transition models and restoration actions used were nearly identical. Three vegetation classes were targeted: large conifers were cut in the late-succession reference class (D:Open), the class dominated by non-native annual species was seeded and sprayed with herbicide (U-A:Annual Spp), and the class with large tree encroachment or invaded by annual species was seeded, masticated, and sprayed (U-D:TEA). Both actions of tree reduction resulted in sizable differences between the FINAL and CUSTODIAL scenarios (>1,500 acres with fire and >3,700 acres without fire on BLM-management lands, and proportionally smaller but consistent areas on Barrick-private lands). No treatment effect, however, was observable for non-native annual species on Barrick-private lands (

Figure **28**) which is due to the small amount of implementation of non-native annual species treatments that was also stopped after year 12 (Table 13).

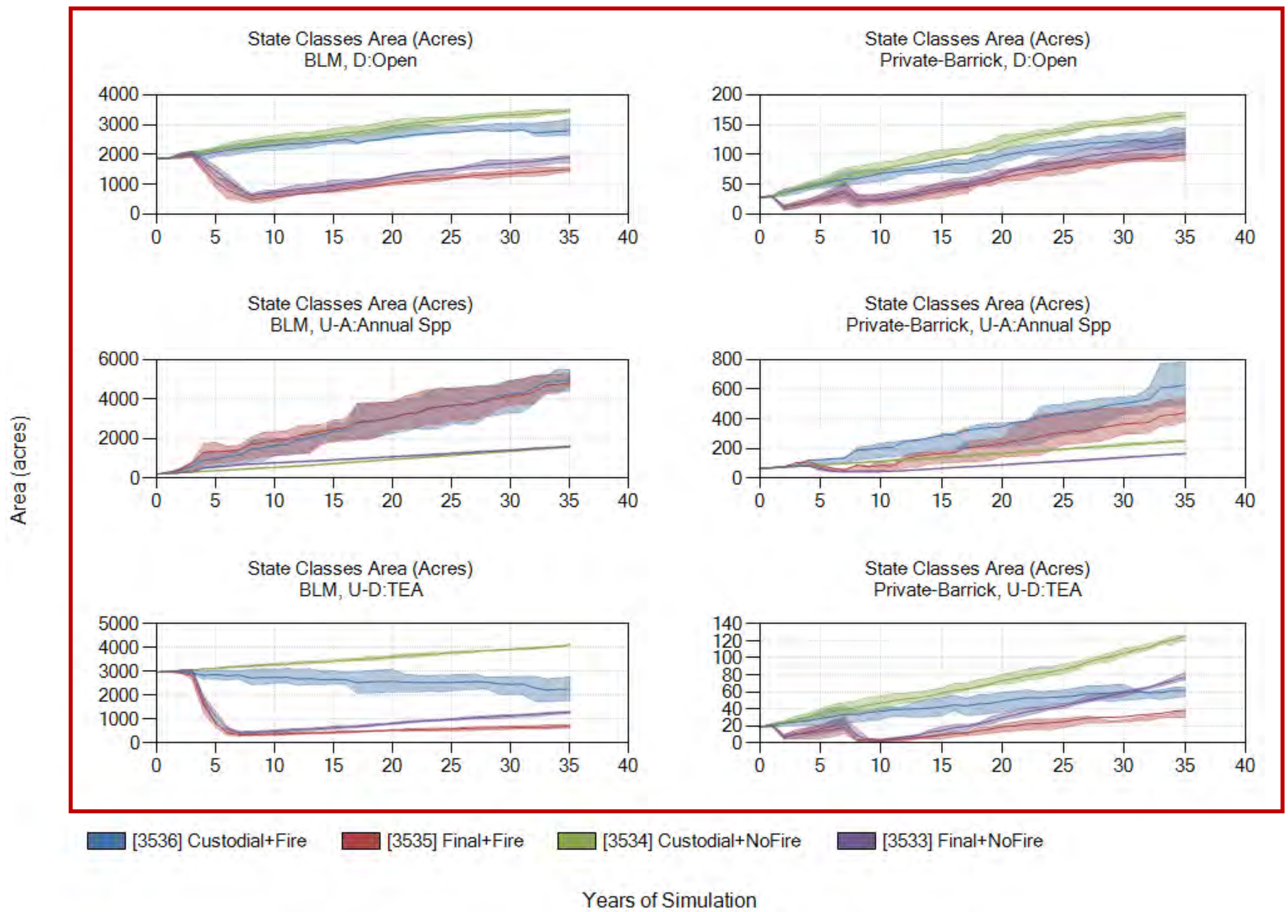


Figure 28. Dwarf sagebrush vegetation classes targeted for restoration on Barrick's Bank Study Area using ST-Sim simulations. Color bands are the 25% to 75% percentiles. N = 10 replicates.

The vegetation classes that were recipient of restoration actions reflected closely the area treated (

Figure 28; D:Open → B:Open and U-D:TEA → U-A:SI → U-B:SI). Compared to big sagebrush systems, seedings of dwarf sagebrush do not mature into the latest succession class during 35 years (U-C:SI) because recovery dynamics are too slow due to poor soils.

Similar to the big sagebrush uplands with tree system, we can draw conclusions as to how fire, specifically, may affect vegetation classes in the future. In

Figure 28– "State Classes Area (Acres): BLM, U-D: TEA," the difference in CUSTODIAL scenarios suggests that fire reduced treed classes by at least 1,700 acres on BLM-managed classes.

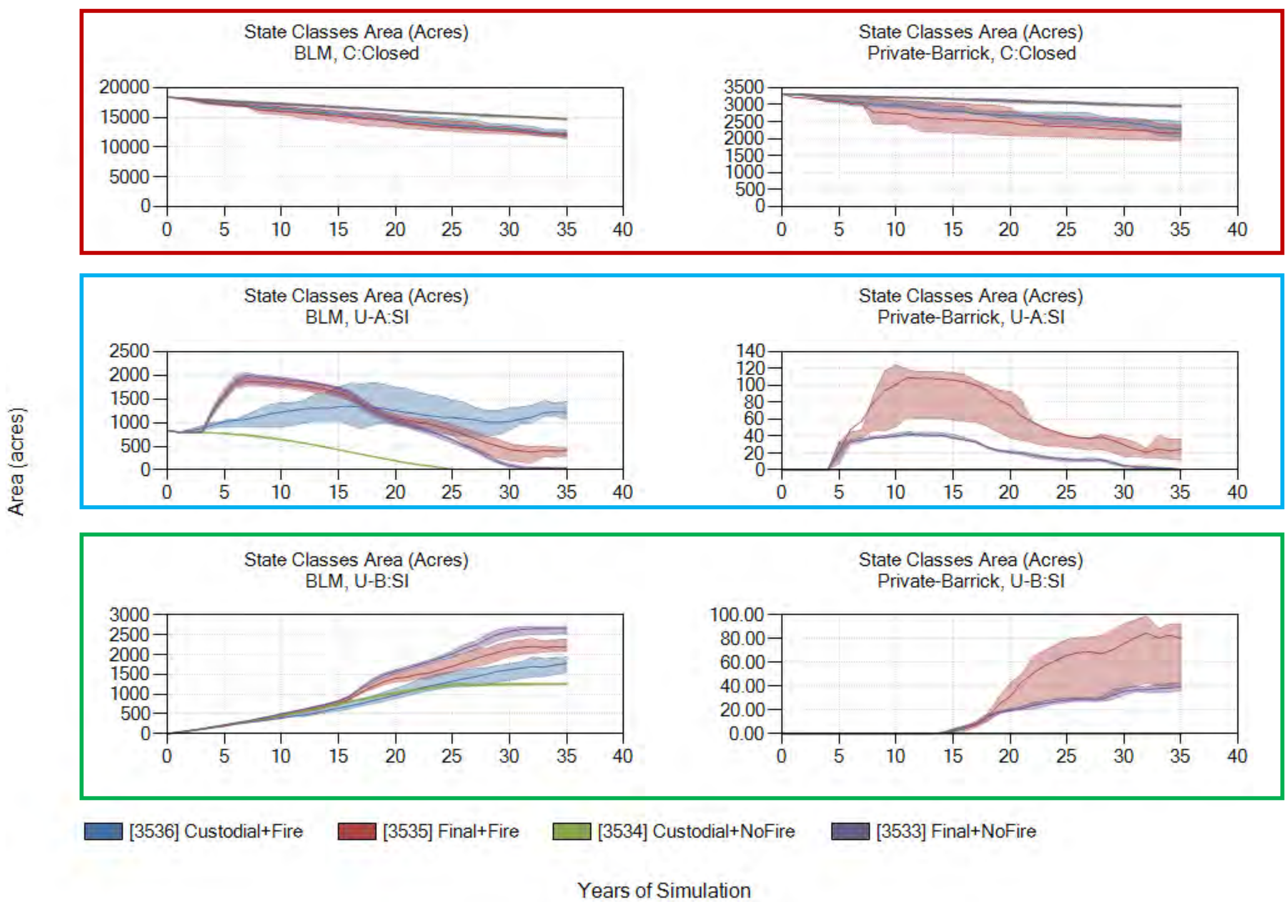


Figure 29. Dwarf sagebrush vegetation classes recipient of small-tree lopping on Barrick's Bank Study Area using ST-Sim simulations. Color bands are the 25% to 75% percentiles. N = 10 replicates.

Greasewood
Irrigation of and seeding pasture grasses in the greasewood system of the JD Meadow resulted in the creation of irrigated pasture within a basin wildrye bottomland system. This would create useable late-brood rearing habitat available to GSG in a strategic area and allow the continuation of livestock grazing. Importantly, in the model, irrigation causes the site to convert from a greasewood *system* to basin wildrye *system*. Further, TNC assumed that pasture grasses, *excluding* basin wildrye, would be used to create the artificial late-brood habitat. About 550 acres of JD's Meadow greasewood were converted using this method without any variation around implementation rates by year 4 of the simulations (Figure 30).

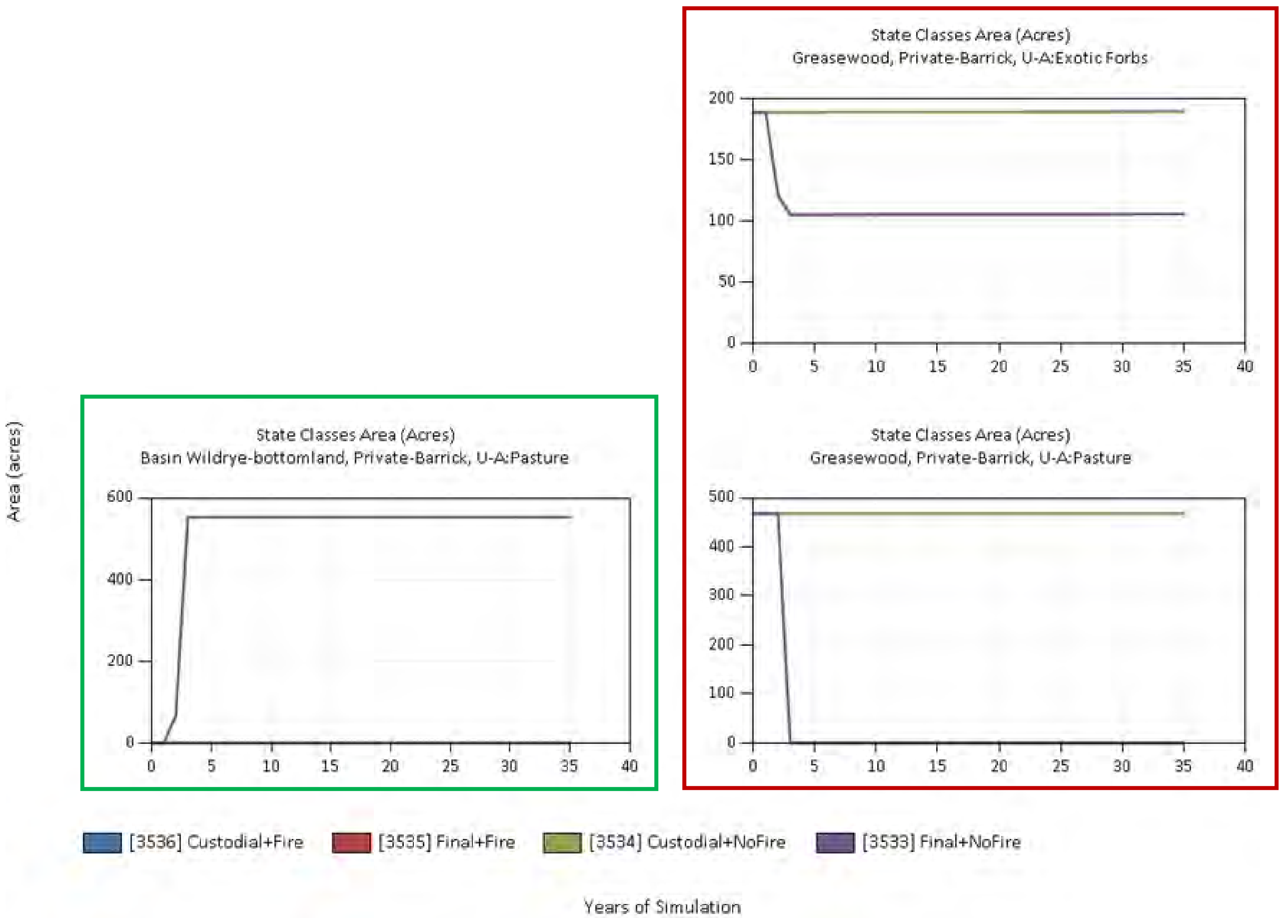


Figure 30. Greasewood and basin wildrye-bottomland vegetation classes targeted for restoration (greasewood) and recipient of restoration (basin wildrye-bottomland) on Barrick's Bank Study Area using ST-Sim simulations. Due to the narrow definition of this treatment, scenarios produced the exact same results with no variation with and without fire. As a result, the scenario lines are stacked and cannot be discerned in this graph.

Montane Sagebrush Steppe

The second largest system, is montane sagebrush steppe, which received the same treatments as big sagebrush shrubland to target classes of non-native annual species (U-A:Annual Spp), young conifers (U-D:SAP), and mature conifers with non-annual species or tree-encroached (U-E:TEA). Whereas only small differences were observed on Barrick's private lands due to treatments, these targeted classes occurred at low levels on Barrick lands (<30 acres for trees and none for non-native annual species), classes were shown to decrease, respectively, for the FINAL+FIRE and FINAL+NOFIRE scenarios by about 2,000 and 1,000 acres of non-native annual species, about 200 and 500 acres of young conifers, and 4,000 and 8,000 acres for the mature conifers, respectively (Figure 31).

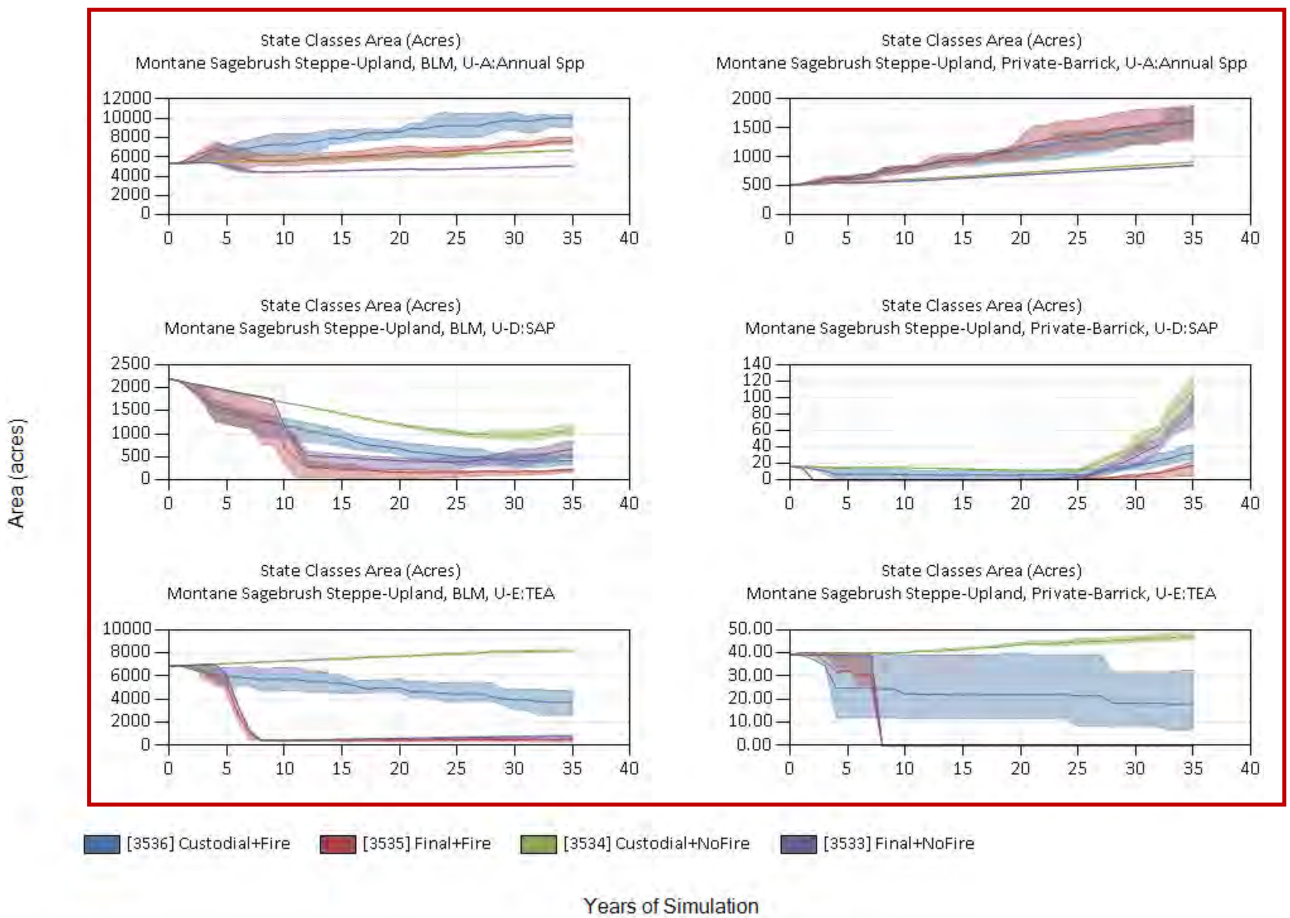


Figure 31. Montane sagebrush steppe vegetation classes targeted for restoration on Barrick's Bank Study Area using ST-Sim simulations. Color bands are the 25% to 75% percentiles. N = 10 replicates.

Recipient classes were combined by land ownership as the treated areas were very small on Barrick's private lands compared to those on BLM-managed lands. Across BLM and Barrick lands, for the FINAL+FIRE and FINAL+NOFIRE scenarios after 35 years, respectively, acres of vegetation gained due to restoration actions was 1,000 and 0 for the early-succession seeded class (U-A:SI), 0 and 700 for the mid-succession class (U-B:SI), 500 and 500 for the late-succession class with mixed non-native annual species and native species (U-C:SAP), and 3,000 and 6,500 for the late-succession seeded class (U-C:SI) (Figure 32). It is noteworthy that a large area of recruitment into the mid-succession seeded class, a late-brood rearing class, occurred around year 17 of the simulation and this result might help explain the highest peak in GSG functional acres when fire was present.

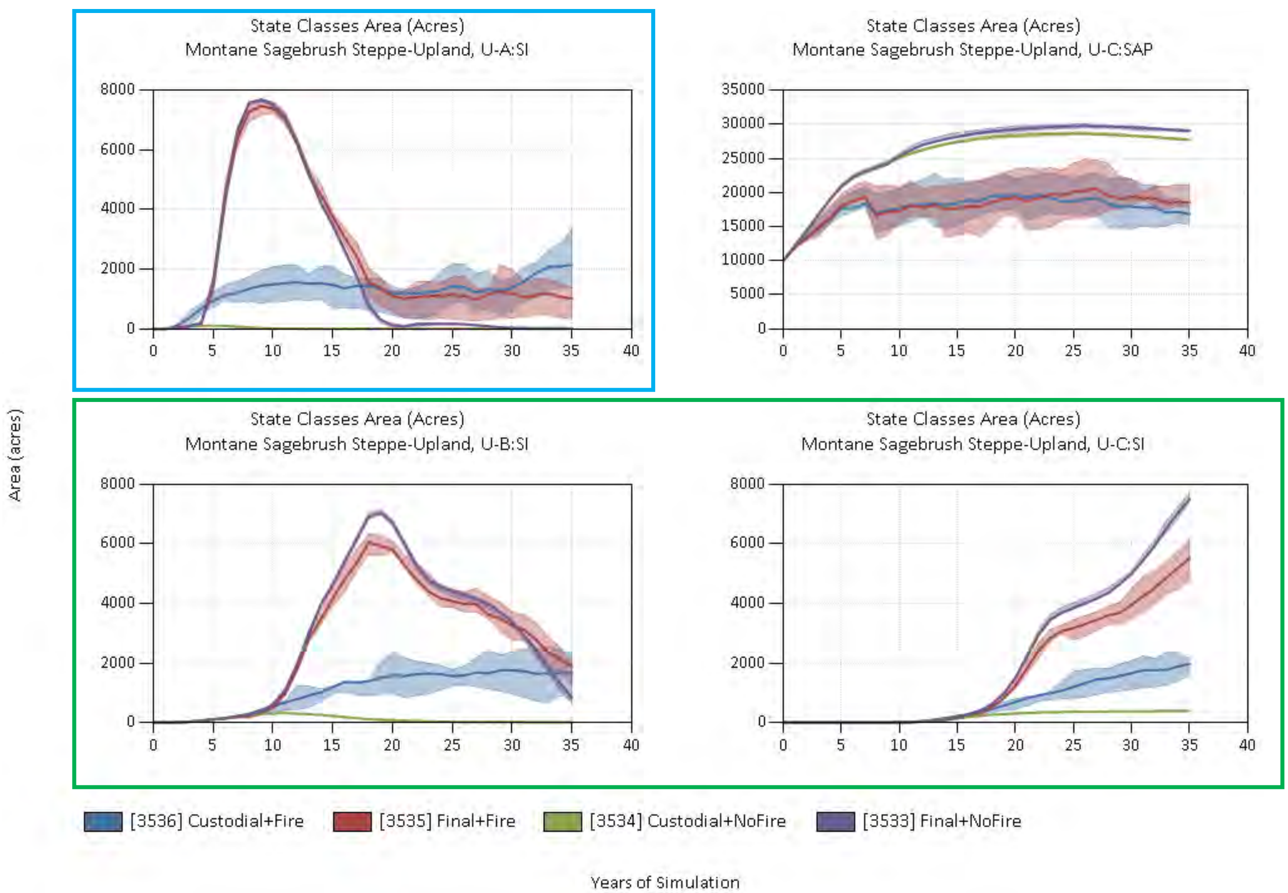


Figure 32. Montane sagebrush steppe vegetation classes recipient of restoration actions on Barrick's Bank Study Area using ST-Sim simulations. Recipient classes were combined by land ownership as the treated areas were very small on Barrick's private lands compare to those on BLM-managed lands. Color bands are the 25% to 75% percentiles. N = 10 replicates.

Montane Wet Meadow
Montane wet meadow was the last system specifically treated for GSG. Many actions were simultaneously implemented and several classes were targeted. Because many classes were affected, figures are presented by land ownership. In general, management focused on reducing hummocking, controlling exotic forbs, and restoring function to meadows encroached by shrubs and forbs. Treatments were controlled spatially, as discussed in the previous section, and their effectiveness for greater sage-grouse is dependent on distance relationships in the landscape.

On lands managed by BLM, control of exotic forbs (U-A:Exotic Forbs) was nearly complete after 5 years of simulation, whereas this class increased in the both untreated CUSTODIAL scenarios (Figure 33). Reduction of hummocked wet meadows (U-A:Hummocked) following fencing to exclude livestock and horses was barely observable due to the very low planned implementation rates (Figure 33). Each of the mid- and late-succession shrub and forb encroached classes (respectively, U-B:Shrb-Frb Encr and U-C:Shrb-Frb Encr) were reduced by 20+ acres due to vegetation mowing and herbicide application compared to the respective CUSTODIAL scenarios.

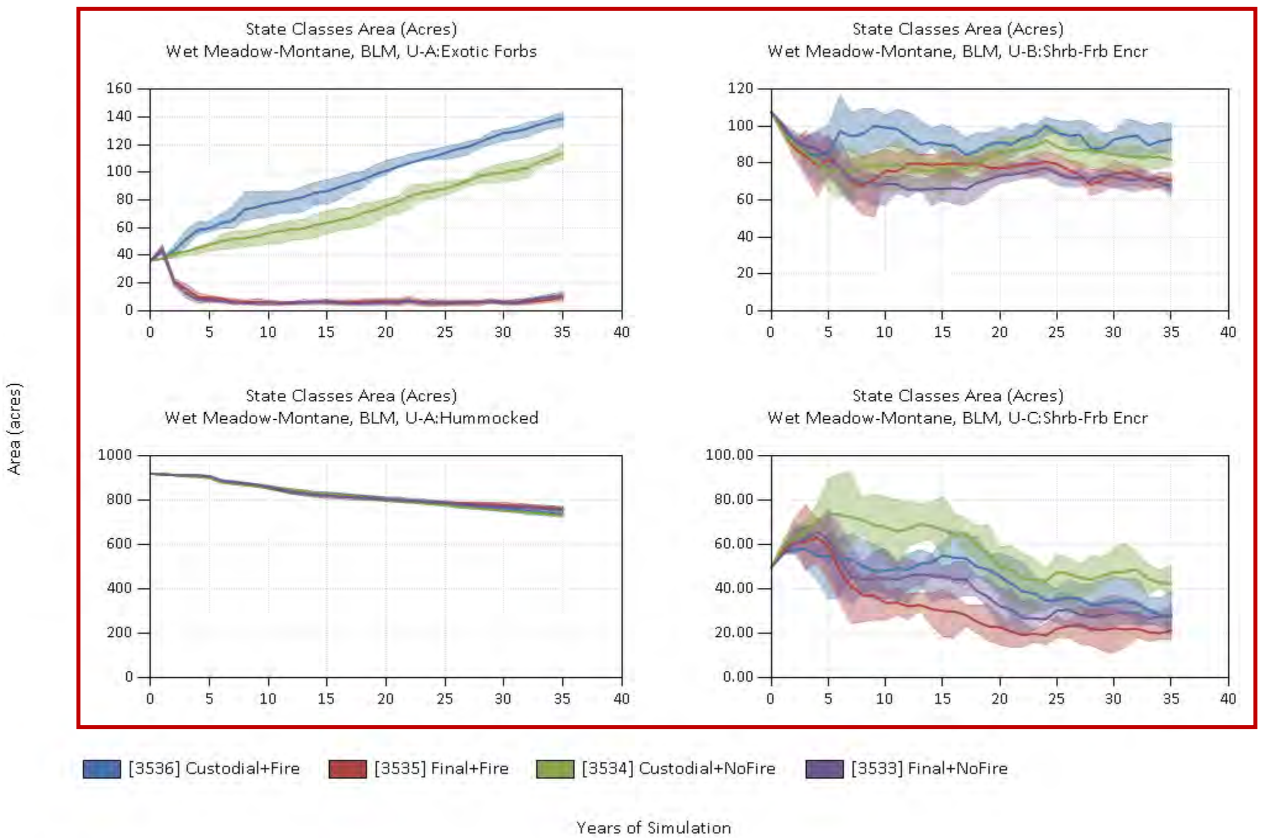


Figure 33. Montane wet meadow vegetation classes targeted for restoration in BLM-managed lands on Barrick's Bank Study Area using ST-Sim simulations. Color bands are the 25% to 75% percentiles. N = 10 replicates.

On lands owned by Barrick, the control of exotic forbs (U-A:Exotic Forbs) was nearly complete after 5 years of simulation, whereas this class increased in the both untreated CUSTODIAL scenarios (Figure 34), as observed for BLM-managed lands. Fencing to exclude livestock and horses caused an about 200 acres of hummocked wet meadows (U-A:Hummocked) to transition to reference classes (Figure 34). As observed on BLM-managed lands, each of the mid- and late-succession shrub and forb encroached classes (respectively, U-B:Shrb-Frb Encr and U-C:Shrb-Frb Encr) were reduced by 20+ acres due to vegetation mowing and herbicide application compared to the respective CUSTODIAL scenarios (Figure 34).

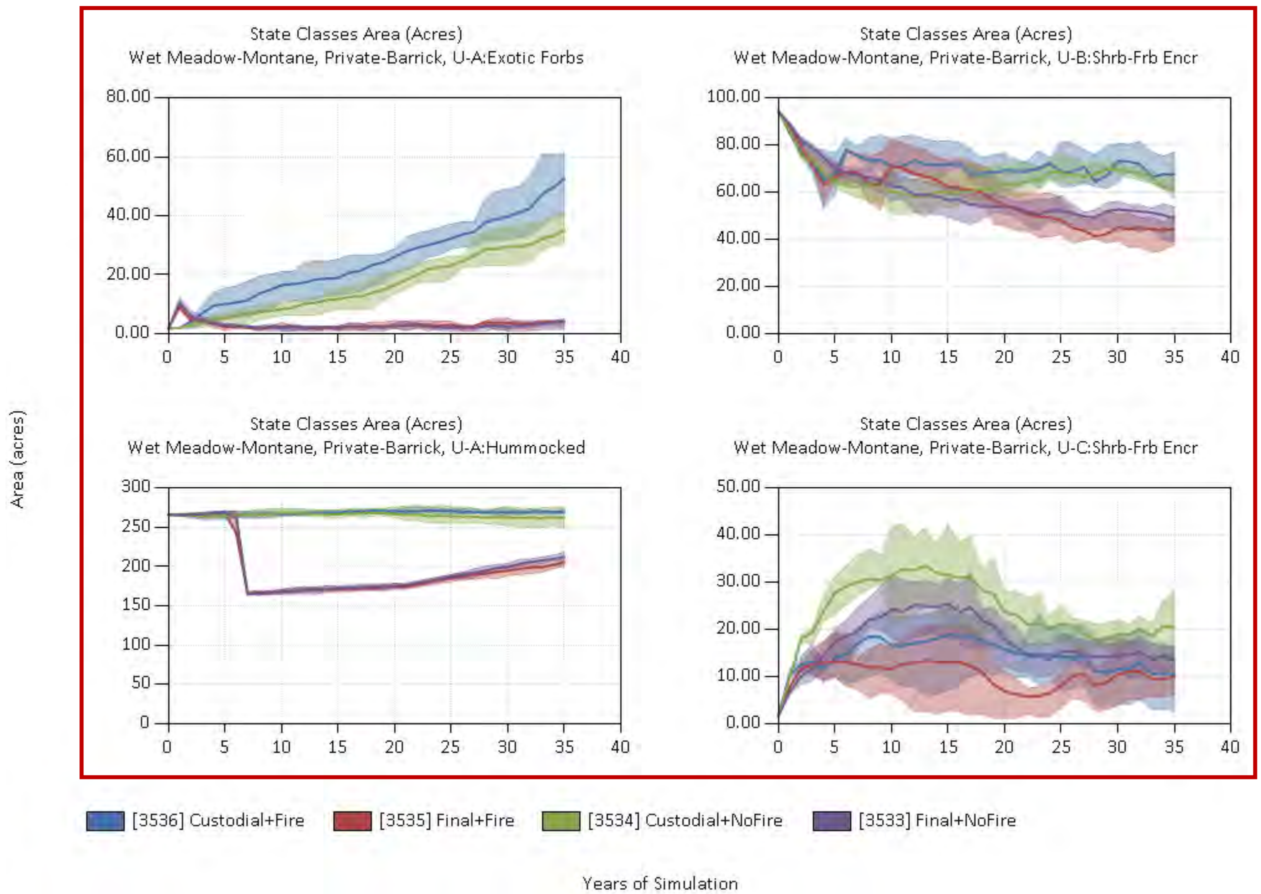


Figure 34. Montane wet meadow vegetation classes targeted for restoration in Barrick's private lands on Barrick's Bank Study Area using ST-Sim simulations. Color bands are the 25% to 75% percentiles. N = 10

The goal of restoration of wet meadows was to increase the acres of wet meadow early- and mid-succession reference classes (respectively, A:All and B:Closed). The successional duration of the early-succession class is very short, therefore the mid-succession class is the primary recipient class and the most desirable to GSG. About 200 acres more acres were observed in the mid-succession class and 25 acres in the early-succession class by year 35 in each ownership (Figure 35). This result is interesting because the source of these increases are different. On BLM-managed lands, control of exotic forbs appeared to have been the main cause of successful restoration. On Barrick private lands, fencing of hummocked wet meadows is the main contributor to restoration, though exotic control likely contributed as well (note the sharp increase of acres of at year 9 due to delayed fencing effect).

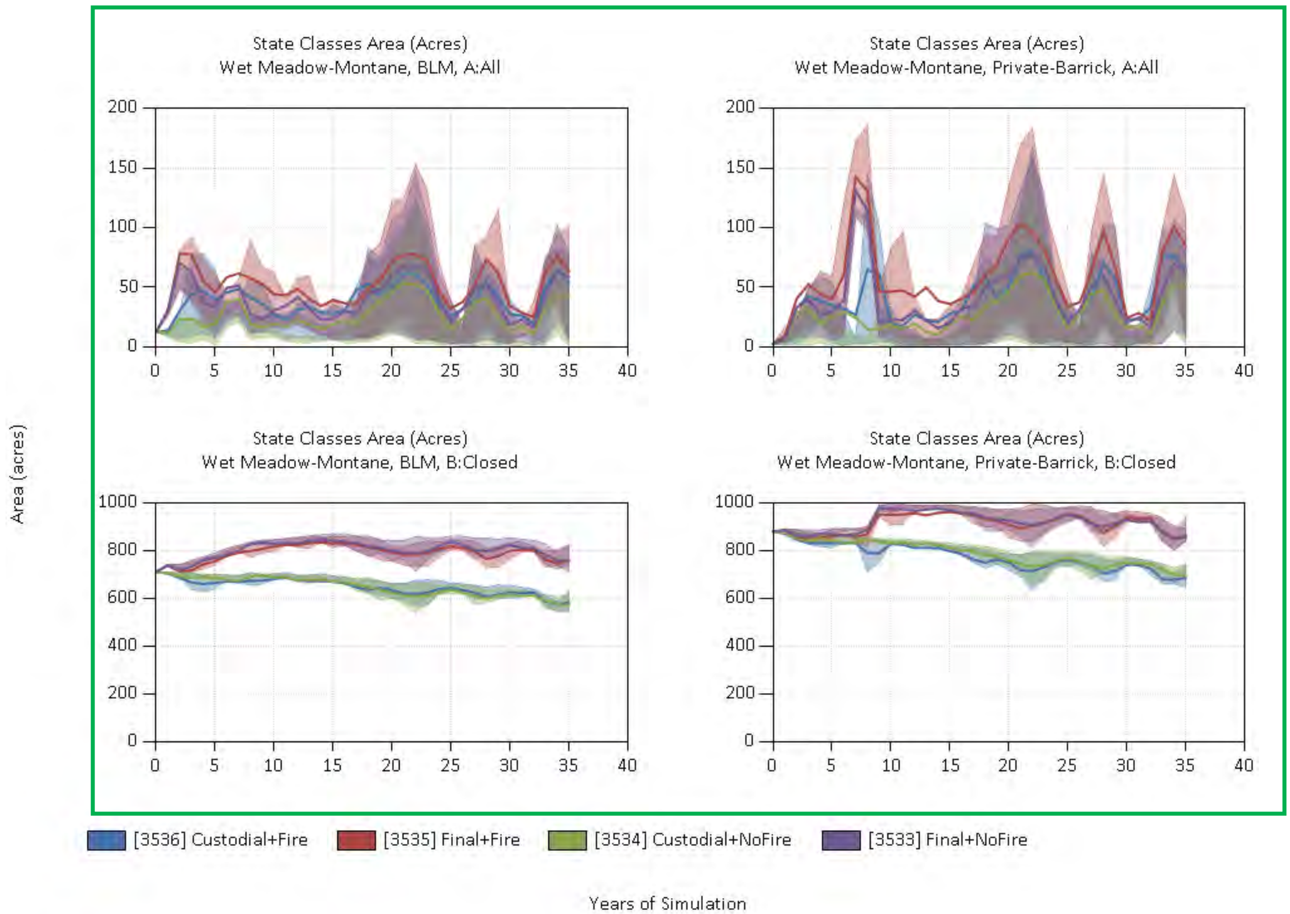


Figure 35. Montane wet meadow vegetation classes recipient of restoration actions on Barrick's Bank Study Area using ST-Sim simulations. Color bands are the 25% to 75% percentiles. N = 10 replicates.

Montane Riparian

The last managed system done for proper range management was the eradication of exotic forb and trees in montane riparian. We combined all classes with any amount of exotic forbs and trees and present results by ownership. Exotic species control was highly successful at reducing exotic species classes compared to both CUSTODIAL scenarios (Figure 36). After 5 years, areas of exotic forbs and trees were between 0 and 5 acres, inclusively (Figure 36).

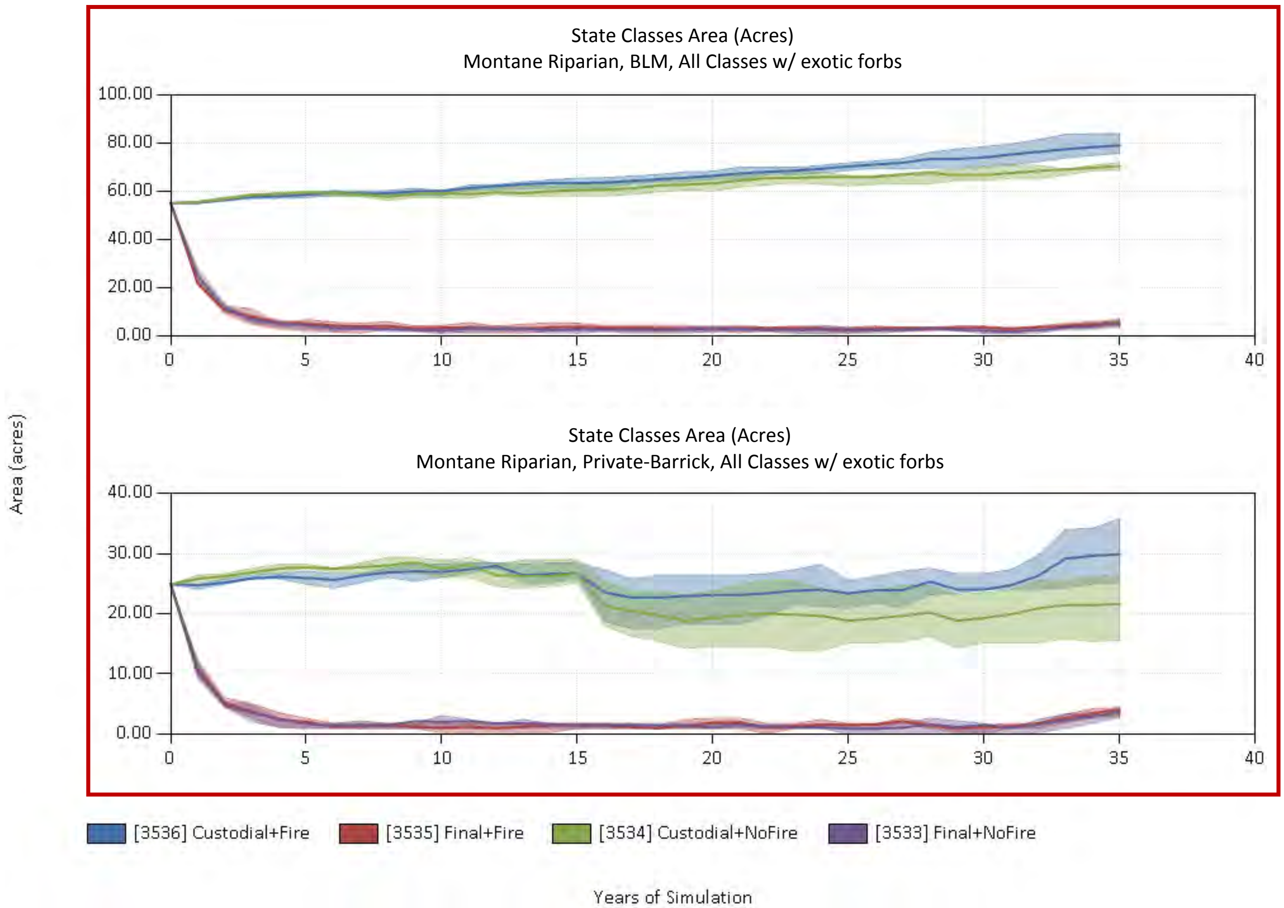


Figure 36. Montane riparian vegetation classes with exotic forbs targeted for restoration in on Barrick's Bank Study Area using ST-Sim simulations. Color bands are the 25% to 75% percentiles. N = 10 replicates.

Two types of vegetation classes were recipient of exotic species control: Reference classes either dominated by willow (A-Willow:Closed, B-Willow:Closed, C-Willow:Closed) or dominated by cottonwood (A-Cottomwood:Closed, B-Cottonwood:Closed, C-Cottonwood:Closed); or uncharacteristic inset early- and mid-succession classes with native vegetation (U-A:Inset-A and U-B:inset-B). For simplicity, we only show willow-dominated reference classes because cottonwood dominance was uncommon. In both ownerships, fire played a larger role than treatment because results from both the FINAL and CUSTODIAL scenarios with fire where closer together than those without fire (Figure 37). Willow-dominated reference classes responded to exotic control commensurate with reduction of treated classes, which was small, on both BLM-managed and Barrick's private lands compared to CUSTODIAL scenarios, with stronger increases in the early-succession class. (Figure 37).

Inset floodplain classes showed stronger exotic species control patterns of reduction compared to CUSTODIAL scenarios than willow-dominated classes (Figure 38). Although area differences between scenarios were small (about 20+ acres for BLM-managed lands and 4 acres for Barrick's private lands), these represent a large fraction of the total amount of the area dominated by exotic species.

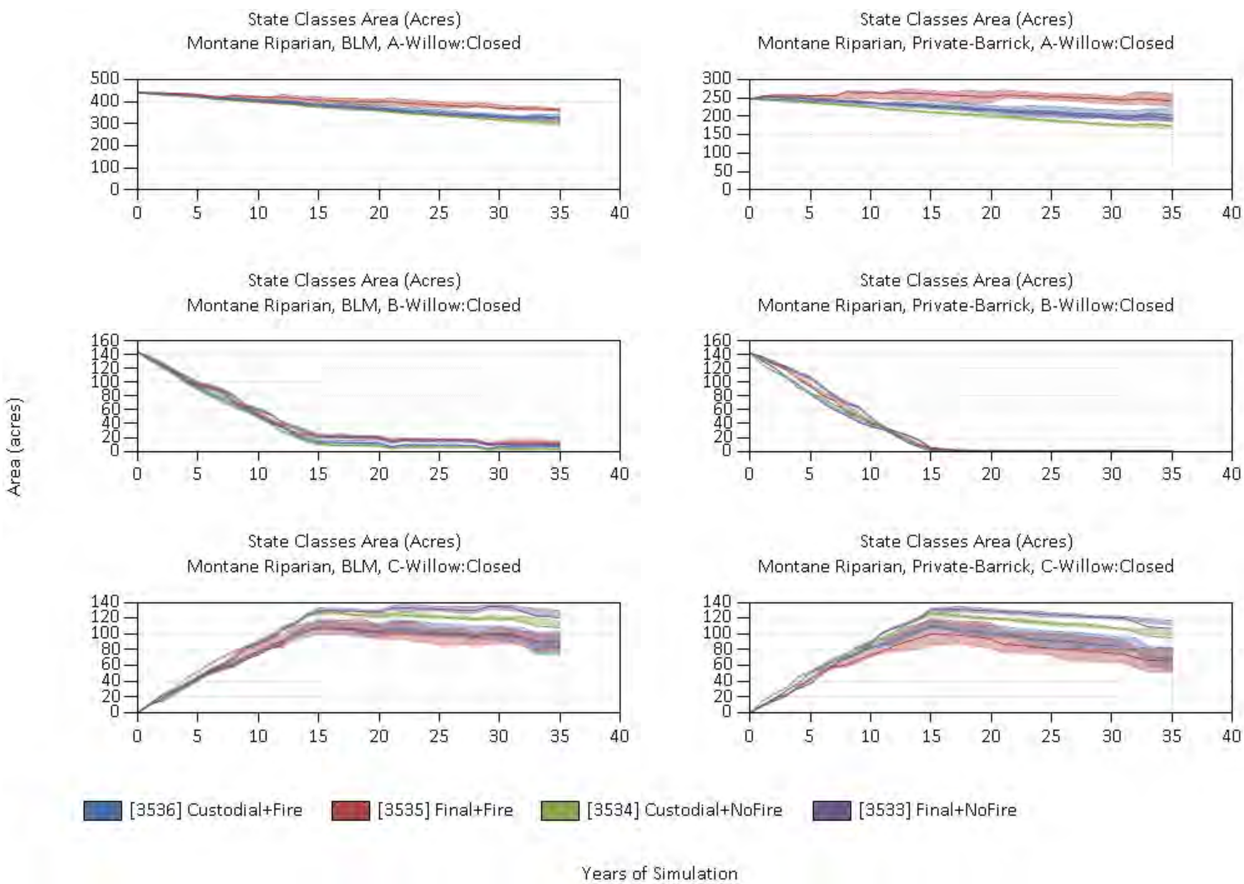


Figure 37. Montane riparian willow-dominated vegetation classes recipient of restoration actions on Barrick's Bank Study Area using ST-Sim simulations. Color bands are the 25% to 75% percentiles. N = 10 replicates.

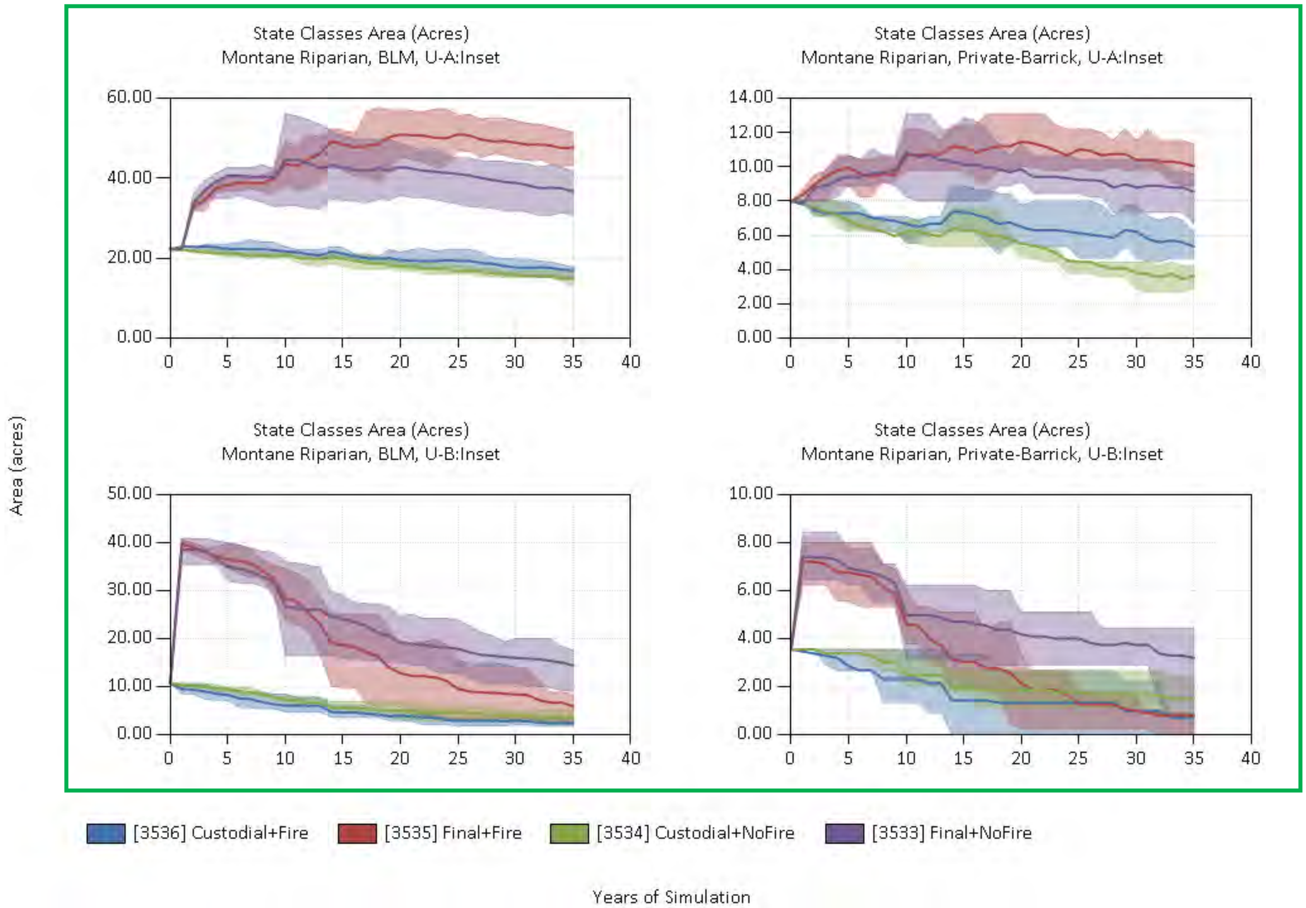


Figure 38. Montane riparian inset-floodplain vegetation classes recipient of restoration actions on Barrick's Bank Study Area using ST-Sim simulations. Color bands are the 25% to 75% percentiles. N = 10 replicates.

<u>Sage-Grouse Habitat Suitability: Bank Study Area</u>

Changes in vegetation due to natural disturbances and management actions over 35 years resulted in differences between the CUSTODIAL and FINAL scenarios with with and without fire. A few specific areas proved particularly responsive to management actions in terms of λ. (Figure 39A and B):

- The largest increase was observed in the north-central part of the old Boohoo fire scar where restoration of wet meadows and conversion of non-native annual species classes to seedings increased both nesting and brood rearing habitat. Restoration resulted in the reduction of the orange area (fire scar) from the edge to the center.
- Moving south in the landscape, a noticeable increase in λ was in the Rocky Hills section of the northern Simpson Park Range where both wet meadow restoration and chainsaw tree cutting occurred.
- Two other areas of improvement occurred in the general saddle area from the Simpson Park Range and the Roberts Mountains, mostly due to tree mastication and chainsaw cutting, and, to a lesser extent, west of the northern JD Meadows, due primarily to irrigation of pastures.

The spatial patterns of change in λ differed between the fire and no-fire scenarios (Figure 40A and B):

- While the Boohoo fire scar was restored in similar patterns in the FINAL+FIRE scenario and the FINAL+NOFIRE scenario, noticeable differences exist along the northern study area boundary and on the east side of the fire scar (Figure 40B and Figure 38B). In both scenarios, uncontrolled horse grazing likely caused the failure of restoration in the center section of the Boohoo fire scar where horses are likely to gather around an existing meadow complex.
- Although the Rocky Hills area in the northern tip of the Simpson Park Range exhibited increased λ, the area immediately north of it experienced slightly lower λ with fire (Figure 39B) compared to no fire (Figure 38B).
- The Simpson Park Range to Roberts Mountains saddle (including the Red Hills area) achieved higher λ values with restoration and fire (Figure 40B) than without fire (Figure 39B). Fire probably contributed to tree removal and burned areas with slopes <15% would have been subsequently seeded if fire happened in the first 15 years of simulations. Burned areas with slopes ≥15% would become late-brood rearing habitat at higher elevation if native grass species persisted after the fire.
- Fire with management lowered average λ for the area west of the JD Meadows (Figure 40B) compared to the CUSTODIAL+FIRE scenario (Figure 40A), a result that is different in the absence of fire (Figure 39B).

In addition to areas that received management, fire altered average λ in two more visible places where no management occurred:

- With fire and BLM's Fire Rehabilitation (an action that occurred in both CUSTODIAL and active management scenarios), the Garden Pass area south on Highway 278 (just north of Mt. Hope) showed lower λ values in the CUSTODIAL (Figure 40A) than FINAL scenarios (Figure 40B). This area supports sagebrush shrublands encroached by pinyon and juniper in addition to unwooded shrublands. Although BLM Fire Rehabilitation did occur in this area in both CUSTODIAL and FINAL scenarios, more of the restoration activity occurred in the CUSTODIAL than FINAL scenario.
- A crescent-shaped area of change for λ is found at the junction of Henderson Creek and Alpha Road, where λ values were somewhat lower in the FINAL than CUSTODIAL scenario with fire in the South Roberts Allotment (i.e., the eastern part of the crescent; Figure 40).

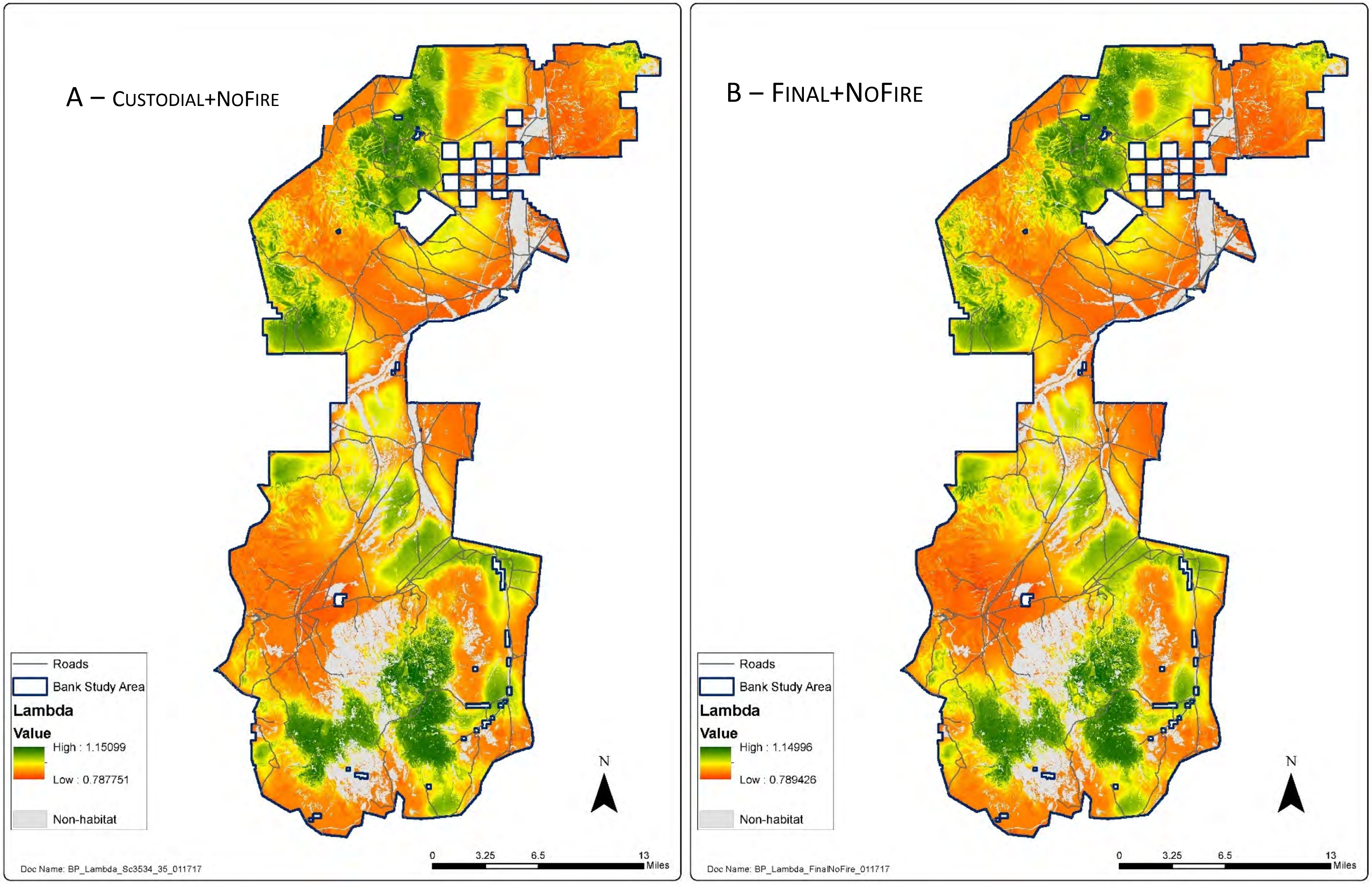


Figure 39. Spatial distribution of average λ for sage-grouse from the CUSTODIAL+NOFIRE (A) and FINAL+NOFIRE (B) after 35 years of simulation in the Bank Study Area based on 2014 1.5-m Spot 6/7 satellite imagery. N = 10.

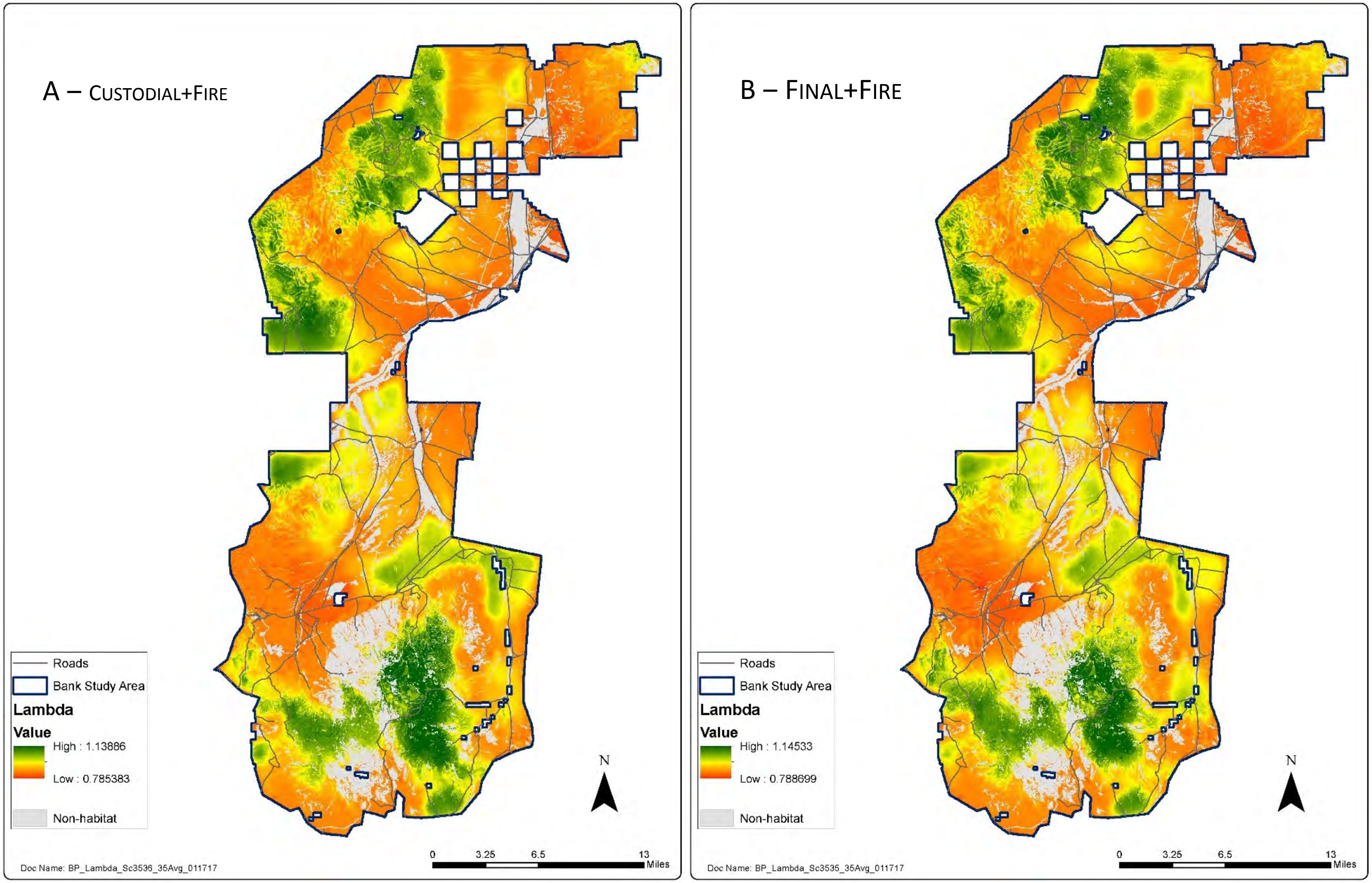


Figure 40. Spatial distribution of average λ for sage-grouse from the CUSTODIAL+FIRE (A) and FINAL+FIRE (B) after 35 years of simulation in the Bank Study Area based on 2014 1.5-m Spot 6/7 satellite imagery. N = 10.

With or without fire, average Functional Area for GSG, measured in GSG Functional Acres, was greater in the active management scenarios than their respective CUSTODIAL Scenario in all years (Table 14) when totaled across the landscape. The differences were significant in years 10, 15, 20, 25, and 30 and marginally significant (P<0.1) in years 5 and 35 with fire; all years were significant without fire (Table 13). The smallest differences between scenarios was in years 5 (315 acres) and 10 (677 acres) with fire, and in years 5 (435 acres) and 10 (588 acres) without fire. The largest observed difference was 1,034 acres in year 20 with fire (Table 14).

Table 14. GSG Functional Area (acres) estimated for the Bank Study Area for the four simulated scenarios (with fire and without fire) and the difference between the mean of FINAL and of CUSTODIAL scenarios for each year. Note, the proposed RIBs in Frenchie Flat are not included in these calculations. N = 10.

Scenario	Yr. 0	Yr. 5	Yr. 10	Yr. 15	Yr. 20	Yr. 25	Yr. 30	Yr. 35
CUSTODIAL+FIRE FUNCTIONAL ACRES	164,039	163,850	163,321	163,102	163,196	163,191	163,085	162,854
FINAL+FIRE FUNCTIONAL ACRES	164,039	164,165	163,997	164,090	164,230	164,022	163,889	163,616
2-WAY ANOVA		$F_{1,9}$ = 3; P<0.0978	$F_{1,9}$ = 12; P<0.0078	$F_{1,9}$ = 30; P<0.0004	$F_{1,9}$ = 22; P<0.0011	$F_{1,9}$ = 7; P<0.0301	$F_{1,9}$ = 12; P<0.0067	$F_{1,9}$ = 4.5; P<0.0609
FINAL+FIRE FUNCTIONAL ACRES *difference*	*0*	*315*	*677*	*988*	*1,034*	*831*	*804*	*763*
CUSTODIAL+NO FIRE FUNCTIONAL ACRES	164,039	164,538	164,757	164,819	164,801	164,781	164,715	164,620
FINAL+NO FIRE FUNCTIONAL ACRES	164,039	164,973	165,344	165,670	165,671	165,656	165,598	165,546
2-WAY ANOVA		$F_{1,9}$ = 3,681; P<0.0000	$F_{1,9}$ = 1,410; P<0.0000	$F_{1,9}$ = 1,974; P<0.0000	$F_{1,9}$ = 3,067; P<0.0000	$F_{1,9}$ = 1,299; P<0.0000	$F_{1,9}$ = 1,491; P<0.0000	$F_{1,9}$ = 1,906; P<0.0000
FINAL+NO FIRE FUNCTIONAL ACRES *difference*	*0*	*435*	*588*	*851*	*870*	*875*	*883*	*927*

The two primary differences between the two fire and two no-fire scenarios were the level of variability and the magnitude of change in Functional Area. In the absence of fire, standard errors were very small (Figure 41B), such that even minute differences were highly significant. Fire activity explained nearly all the width of the standard errors in the scenarios as fire likely burned nesting habitat (Figure 41A). In the absence of fire, Functional Area steadily climbed as formerly burned vegetation with some native species composition experienced succession towards nesting habitat, and because management improved sage-grouse habitat (Figure 41B). In the presence of new fires, these processes also occurred while at the same time fire events may have temporarily removed nesting habitat and created early-succession vegetation classes that directly reduce nest success (Figure 41A).

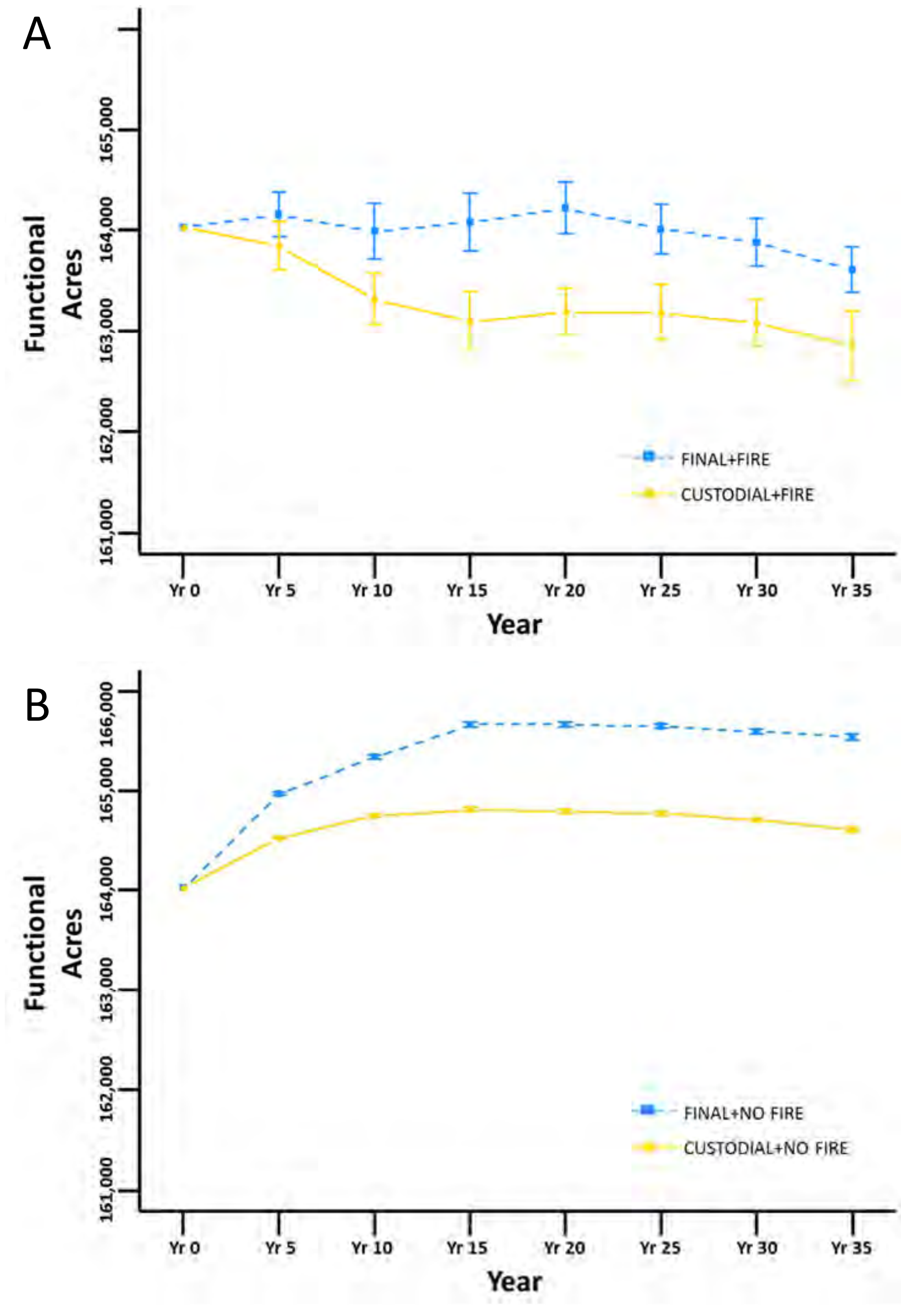


Figure 41. Time series of functional Area (acres) for the Bank Study Area comparing the A) CUSTODIAL+FIRE and FINAL+FIRE scenarios and B) CUSTODIAL+NO FIRE and FINAL+NO FIRE scenarios. Plotted are the means and standard errors across the 10 replicates for each scenario. Note, these results do not include the proposed RIBs in the Frenchie Flat area which are accounted for in Table 15.

An additional analysis was conducted to assess the impact of the proposed RIBs in the Frenchie Flat region of the Bank Study Area. All pixels within the stamp were converted to the "Mine-Active" ecological system, and thus, represent a conversion from a GSG useable system (here, Big Sagebrush+trees) to an unusable ecological system. In year 0 compared to the CUSTODIAL scenario, the stamping in of the RIBs accounted for a loss of 102 functional acres for both fire and no fire scenarios (Table 15). With fire, the peak in functional acre loss was in year 25, and at year 35 a total 107 were estimated as lost. Without fire, the peak loss was at year 15 (a difference of 108 functional acres lost) and maintained at that level throughout the simulation (Table 15).

Table 15. GSG Functional Area (acres) estimated for the Bank Study Area (with fire and without fire) and the difference between the mean of RIBS and of CUSTODIAL scenarios for each year. N = 10.

Scenario	Yr. 0	Yr. 5	Yr. 10	Yr. 15	Yr. 20	Yr. 25	Yr. 30	Yr. 35
CUSTODIAL+FIRE FUNCTIONAL ACRES	164,039	163,850	163,321	163,102	163,196	163,191	163,085	162,854
RIBS+FIRE FUNCTIONAL ACRES	163,937	163,746	163,213	162,994	163,088	163,082	162,977	162,746
RIBS+FIRE FUNCTIONAL ACRES *difference*	*-102*	*-104*	*-107*	*-108*	*-108*	*-109*	*-109*	*-107*
CUSTODIAL+NO FIRE FUNCTIONAL ACRES	164,039	164,538	164,757	164,819	164,801	164,781	164,715	164,620
RIBS+NO FIRE FUNCTIONAL ACRES	163,937	164,433	164,649	164,711	164,693	164,673	164,607	164,511
RIBS+NO FIRE FUNCTIONAL ACRES *difference*	*-102*	*-105*	*-107*	*-108*	*-108*	*-108*	*-108*	*-108*

TNC performed an assessment of three privately held wet meadows (Tonkin, Big Springs, and Shipley Meadows, HUMMOCK scenarios). In this scenario, the management of the private lands was assumed to degrade the private meadows into the Hummocked class. TNC assessed the functional acre impact due to degradation of these wet meadows in four different scenarios: HUMMOCK-CUSTODIAL+FIRE, HUMMOCKED-CUSTODIAL+NOFIRE, HUMMOCK-FINAL+FIRE, HUMMOCK-FINAL+NOFIRE.

When the wet meadows were converted to "U-A:Hummocked", there was little visible change around Tonkins Meadow, but noticeable reduction in λ in observed in the Big Springs and Shipley Meadows area (Figure 42). Conversion of all three meadows to class "U-A:Hummocked" accounted for a functional acre loss of 367 compared to CUSTODIAL at year 0. With fire, the loss of functional acres was reduced to 266 by year 35 compared to the CUSTODIAL (Table 16). Without fire, the hummocking caused a loss of 298 functional acres at year 35 compared to the CUSTODIAL (Table 16).

When the hummock stamp was applied to the FINAL+FIRE results, an average of 249 functional acres were lost compared to the FINAL+FIRE scenario (Table 17). Without fire, an estimated 292 functional acres were lost compared to FINAL+NOFIRE scenario (Table 17). The difference between fire and no fire scenarios is likely caused by the burning of nesting habitat near Big Springs and Shipley Meadows. As fire removes the available nesting near the wet meadows, the importance of meadows to chick survival is decreased (Figure 42 and Figure 43).

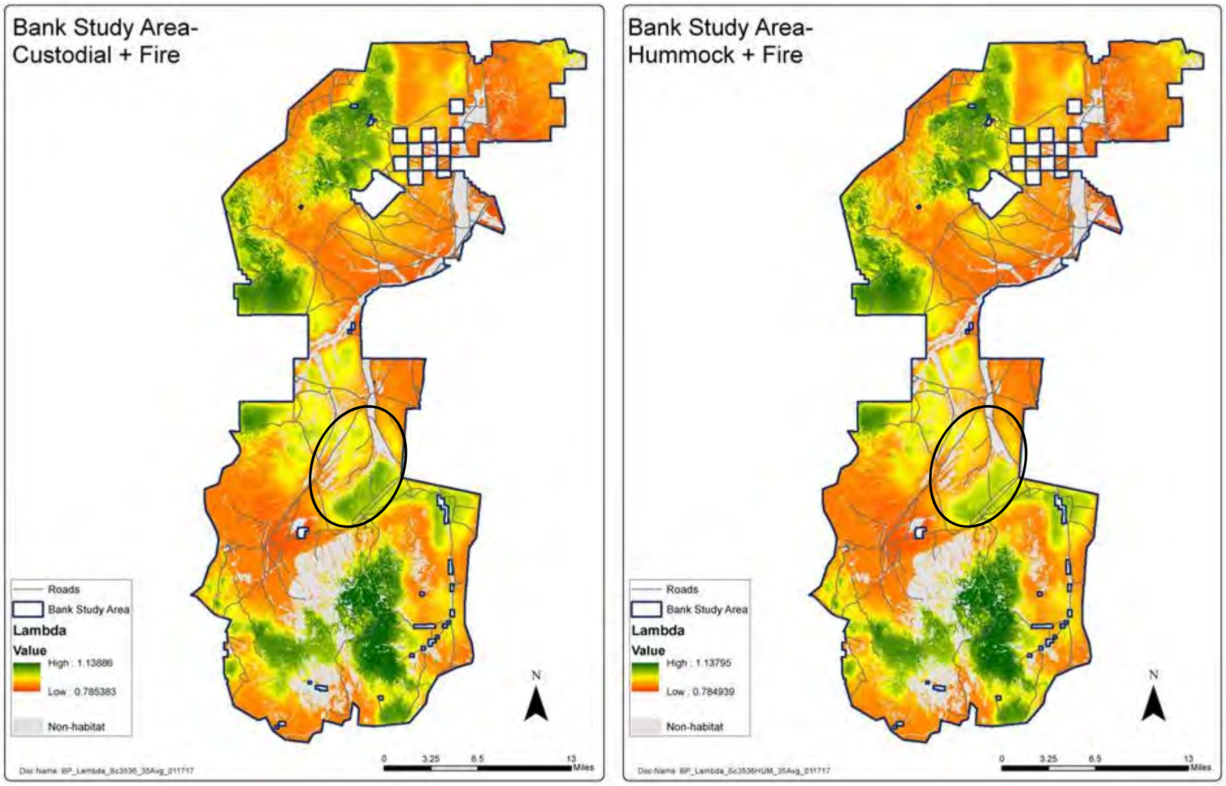


Figure 42. Spatial distribution of average λ for sage-grouse from the CUSTODIAL (left) and HUMMOCK (right) with fire after 35 years of simulation in the Bank Study Area based on 2014 1.5-m Spot 6/7 satellite imagery. Note the black oval which highlights where most change in habitat suitability was observed. N = 10.

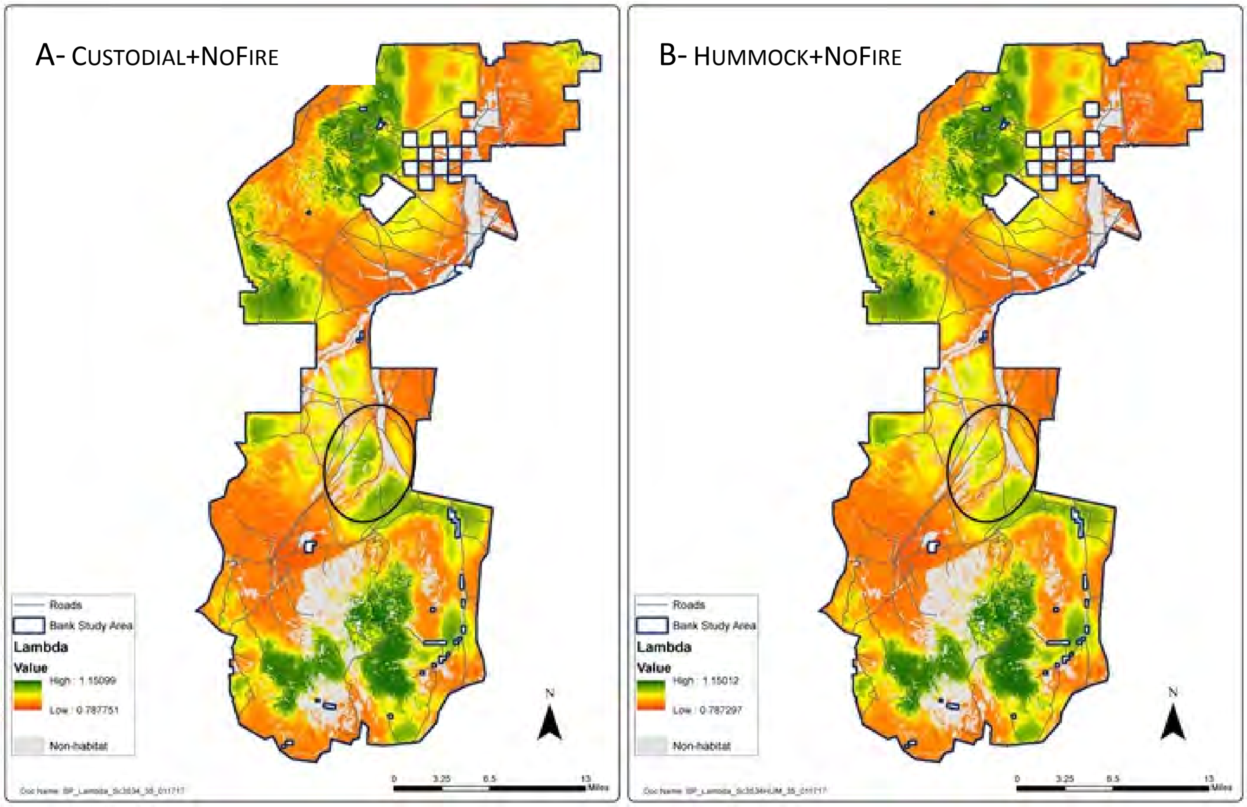


Figure 43. Spatial distribution of average λ for sage-grouse from the Custodial+NoFire (A) and Hummock+NoFire (B) after 35 years of simulation in the Bank Study Area based on 2014 1.5-m Spot 6/7 satellite imagery. Note the black oval which highlights where most change in habitat suitability was observed. N = 10.

Table 16. GSG Functional Area (acres) estimated for the Bank Study Area (with fire and without fire) and the difference between the mean of Hummock-Custodial and of Custodial scenarios for each year. N = 10.

Scenario	Yr 0	Yr 5	Yr 10	Yr 15	Yr 20	Yr 25	Yr 30	Yr 35
Custodial+Fire Functional Acres	164,039	163,850	163,321	163,102	163,196	163,191	163,085	162,854
Hummock-Custodial+Fire Functional Acres	163,671	163,503	163,010	162,813	162,923	162,910	162,809	162,588
Hummock-Custodial+FIRE Functional Acre *difference*	*-367*	*-347*	*-310*	*-289*	*-272*	*-281*	*-276*	*-266*
Custodial+No Fire Functional Acres	164,039	164,538	164,757	164,819	164,801	164,781	164,715	164,620
Hummock Custodial +No Fire Functional Acres	163,671	164,186	164,424	164,495	164,485	164,469	164,409	164,321
Hummock Custodial +No Fire Functional Acre *difference*	*-367*	*-352*	*-333*	*-324*	*-316*	*-312*	*-306*	*-298*

Table 17. GSG Functional Area (acres) estimated for the Bank Study Area (with fire and without fire) and the difference between the mean of HUMMOCK-FINAL and of FINAL scenarios for each year. N = 10.

Scenario	Yr 0	Yr 5	Yr 10	Yr 15	Yr 20	Yr 25	Yr 30	Yr 35
FINAL+FIRE FUNCTIONAL ACRES	164,039	164,165	163,997	164,090	164,230	164,022	163,889	163,616
HUMMOCK-FINAL+FIRE FUNCTIONAL ACRES	163,671	163,860	163,704	163,815	163,960	163,766	163,645	163,367
HUMMOCK-FINAL+FIRE FUNCTIONAL ACRE *difference*	*-367*	*-305*	*-293*	*-275*	*-269*	*-256*	*-244*	*-249*
FINAL+NO FIRE FUNCTIONAL ACRES	164,039	164,973	165,344	165,670	165,671	165,656	165,598	165,546
HUMMOCK-FINAL+NO FIRE FUNCTIONAL ACRES	163,671	164,646	165,029	165,367	165,376	165,354	165,298	165,255
HUMMOCK-FINAL+NO FIRE FUNCTIONAL ACRE *difference*	*-367*	*-326*	*-315*	*-304*	*-295*	*-302*	*-300*	*-292*

Using a similar analysis, TNC estimated the loss of functional acres if the three privately held meadows were converted to exotic forbs. This analysis was only conducted using the CUSTODIAL+FIRE and the CUSTODIAL+NO FIRE scenarios. Conversion to exotic forbs showed similar temporal patterns as the HUMMOCK assessment; however, the magnitude of change was greater when the meadows were reclassified as exotic forb classes (Table 18). The difference between the scenarios is because while hummocked classes represent a useable, but poor quality, habitat exotic forb dominated classes provide no benefit to GSG. At year 0, conversion to exotic forbs resulted in a decrease of 668 functional acres compared to CUSTODIAL, both with and without fire on the landscape. When fire was present the loss of functional acres was 462 at year 35. Without fire, year 35 represented a loss of 568 functional acres. As with the HUMMOCK scenario, removal of nesting habitat near the meadows decreased the relative importance of the meadows, and thus reduced functional acre loss.

Table 18. GSG Functional Area (acres) estimated for the Bank Study Area (with fire and without fire) and the difference between the mean of EXOTIC FORBS and of CUSTODIAL scenarios for each year. N = 10.

Scenario	Yr 0	Yr 5	Yr 10	Yr 15	Yr 20	Yr 25	Yr 30	Yr 35
CUSTODIAL+FIRE FUNCTIONAL ACRES	164,039	163,850	163,321	163,102	163,196	163,191	163,085	162,854
EXOTIC FORBS+FIRE FUNCTIONAL ACRES	163,371	163,215	162,754	162,588	162,728	162,709	162,610	162,392
EXOTIC FORBS +FIRE FUNCTIONAL ACRE *difference*	*-668*	*-635*	*-567*	*-513*	*-468*	*-482*	*-475*	*-462*
CUSTODIAL+NO FIRE FUNCTIONAL ACRES	164,039	164,538	164,757	164,819	164,801	164,781	164,715	164,620
EXOTIC FORBS +NO FIRE FUNCTIONAL ACRES	163,371	163,898	164,144	164,217	164,209	164,193	164,134	164,051
EXOTIC FORBS +NO FIRE FUNCTIONAL ACRE *difference*	*-668*	*-640*	*-613*	*-602*	*-592*	*-588*	*-581*	*-568*

Cost Overview

The total 35-year cumulative costs totaled for all ecological systems were always higher for BLM-managed lands ($12+ million) than Barrick's private lands ($3.3+ million; Table 14). Differences between the FINAL+NOFIRE and FINAL+FIRE scenarios were relatively minor. When fire was present on BLM-managed lands, cost increase by $1 million in big sagebrush shrubland – upland but decreased by about $500,000 in montane sagebrush steppe and a few other systems as fire consumed trees at higher elevations and created more vegetation classed dominated by non-native annual species at lower elevations (Table 19). The same tradeoff between big sagebrush systems was not observed on Barrick's private lands. The greatest costs were observed in big sagebrush shrubland - upland and in montane sagebrush steppe on BLM lands and in big sagebrush shrubland - upland and wet meadow-montane on Barrick's private lands.

Table 19. Overview of average 35-year cumulative cost by ownership, management scenario, and ecological system. Many expensive actions were front-loaded during the first 10 years of simulation (Table 12). Sample size was 10 replicates.

Ownership/System	FINAL+NOFIRE		FINAL+FIRE	
	Cumulative Cost ($)	±95% CI	Cumulative Cost ($)	±95% CI
BLM				
Big Sagebrush-upland	4,725,755	*45,205*	5,701,419	*254,318*
Black Sagebrush	1,396,602	*40,868*	1,213,527	*84,999*
Low Sagebrush	532,265	*56,904*	509,837	*51,382*
Montane Riparian	83,688	*2,210*	79,340	*2,675*
Montane Sagebrush Steppe	5,051,878	*55,958*	4,598,823	*338,372*
Wet Meadow-Montane	262,631	*9,442*	268,181	*7,155*
Total	**12,052,819**	*126,173*	**12,366,126**	*455,949*
Barrick-Private				
Big Sagebrush-upland	1,679,562	*23,394*	1,933,462	*85,036*
Black Sagebrush	14,223	*802*	25,228	*7,515*
Greasewood	552,873	*390*	553,229	*548*
Low Sagebrush	39,718	*5,327*	48,783	*6,802*
Montane Riparian	29,793	*1,855*	28,233	*2,642*
Montane Sagebrush Steppe	40,657	*898*	38,988	*5,467*
Wet Meadow-Montane	962,602	*3,893*	967,906	*7,012*
Total	**3,319,427**	***22,463***	**3,595,824**	***95,272***

Areas of Events and Implementation

The discussions in the preceding section on CUSTODIAL and FINAL management scenarios made reference to non-management transitions (natural and anthropogenic) and implemented management actions that would affect vegetation classes. This section summarizes those processes and treatment selections via a set of maps displaying the annual frequency (number of years a pixel received the disturbance out of 350 possible year-events) of a transition for any pixel. The higher the frequency, the more a pixel was selected for either fire or management actions within a given scenario.

Overall, fire was the only non-management disturbance that was widespread enough to affect landscape sage-grouse habitat suitability and, therefore, merit summary attention. Table 20 shows the management actions that had substantial use in any active management scenario:

Table 20. Management actions implemented by ownership in the Bank Study Area.

Management Action/Treatment	BLM	Private-Barrick
AerialSeed+Masticate+Plateau	X	X
Chainsaw-Thinning	X	X
Exotic-Control	X	X
Fence&Water-Delivery	X	X
Fence-Inspect&Maintain	X	X
Herbicide-Plateau+Seed+Shrub-Planting	X	X
Herbicide-Shrubs+Mow	X	X
Irrigation		X
Small-Tree-Lopping	X	X
Weed-Survey+Spot-Treat	X	X

The maps on the following pages display results of the spatial output of disturbances (Table 21). Note that fire maps could only be shown for the two scenarios with fire, and management actions could only be shown for the FINAL scenarios without and with fire. These maps show where the transitions were most likely to occur in the model (for example, areas of greatest fire risk) and reveal to managers the potential locations to place management actions given the constraints imposed on simulations. For example, a manager could design a current restoration project for the Bank Study Area to convert an annual grassland to a seeding of mixed introduced and native species by overlapping Figure 54 with our maps of ecological systems and vegetation classes, specifically the non-native annual species class.

Table 21. Index to Figures that show management treatments within ecological systems of the two Project Areas.

Management Action/Treatment	Scenario Implemented	Figure Number
Fire	CUSTODIAL +Fire; FINAL+Fire	Figure 45
Tree Removal		
AerialSeed+Masticate+Plateau	FINAL+NoFire; FINAL +Fire	Figure 46
Chainsaw-Thinning	FINAL +NoFire; FINAL +Fire	Figure 47
Small-Tree-Lopping	FINAL +NoFire; FINAL +Fire	Figure 48
Exotic Forb and Tree Control		
Exotic-Control	FINAL +NoFire; FINAL +Fire	Figure 49
Weed-Survey+Spot-Treat	FINAL +NoFire; FINAL +Fire	Figure 50
Wet Meadow Restoration		
Fence&Water-Delivery	FINAL +NoFire; FINAL +Fire	Figure 51
Fence-Inspect&Maintain	FINAL +NoFire; FINAL +Fire	Figure 52
Herbicide-Shrubs+Mow	FINAL +NoFire; FINAL +Fire	Figure 53
Non-Native Annual Species Class Reduction		
Herbicide-Plateau+Seed+Shrub-Planting	FINAL +NoFire; FINAL +Fire	Figure 54
GSG Late-brood Habitat Creation		
Irrigation	FINAL +NoFire; FINAL +Fire	Figure 55

In the custodial CUSTODIAL+FIRE scenario, the BLM Fire Rehab treatment occurred on an average of approximately 1,500 acres per year. This is largely replaced by other, more effective management treatments in the FINAL+FIRE scenario. The additional fuel breaks and the aggressive treatment of annual species to achieve more fire-resistant vegetation in the FINAL+FIRE scenario on the Bank Study Area helped decrease average area burned per year compared to the CUSTODIAL+FIRE scenario (Figure 44). The average area burned per year was lower in the Final=Fire scenario than in the Custodial+Fire scenario is all but a few years with the maximum difference amounting to about 5,000 acres in one year. Differences in maximum area burned were substantially larger, sometimes reaching 20,000 acres (Figure 44).

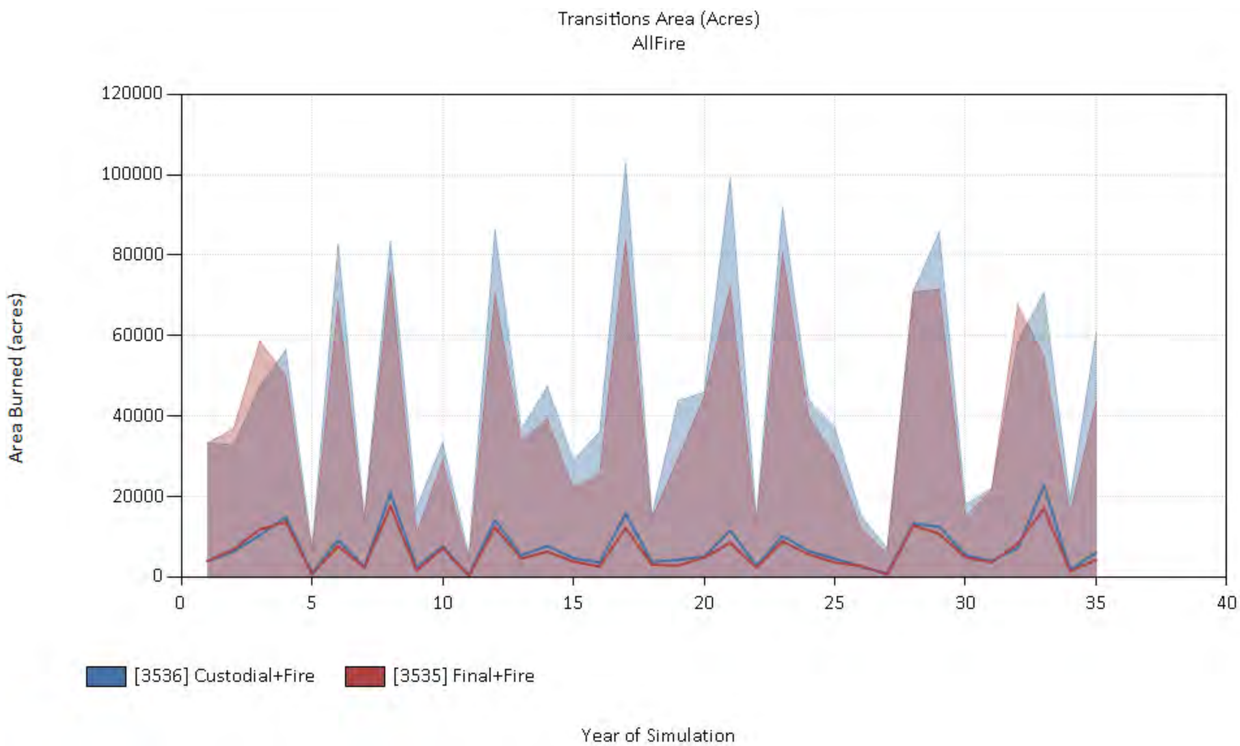


Figure 44. Time series of area burned (acres) for the Bank Study Area comparing the CUSTODIAL+FIRE and FINAL+FIRE scenarios. Plotted are the means (solid lines) and min/max of area burned across the 10 replicates for each scenario. In nearly all years, the maximum area burned and the average area burned was lower in the FINAL+Fire than in the CUSTODIAL+Fire.

The largest change in the annual frequency of fire events was observed in the area of the BooHoo fire scar (red area; Figure 45). This was also the area of most aggressive restoration designed to restore non-native annual species vegetation classes to seedings with a long fire return interval. Fire activity in the Simpson Park Range, the saddle from the Simpson Park Range to Roberts Mountains, the Piñon Range east of the Hay Ranch headquarters, Frenchie Flats, east of the Potato Patch allotment, and the Garden Pass area south of Highway 278 also showed moderate decreases of fire probability in the active management scenario. The unintended consequence of creating fuel breaks and adding seedings with long fire return intervals was to move the placement of larger fires to areas without fuel breaks and seedings, which are often better GSG habitat at higher elevations. Three areas in the FINAL+FIRE scenario experienced slightly more fire than the CUSTODIAL+FIRE scenario: north of the Buckhorn Mine in the Cortez Range, east of the northern pasture of the JD Meadows, and the area of the old Fraser Fire towards the northern toe of the Roberts Mountains (Figure 45).

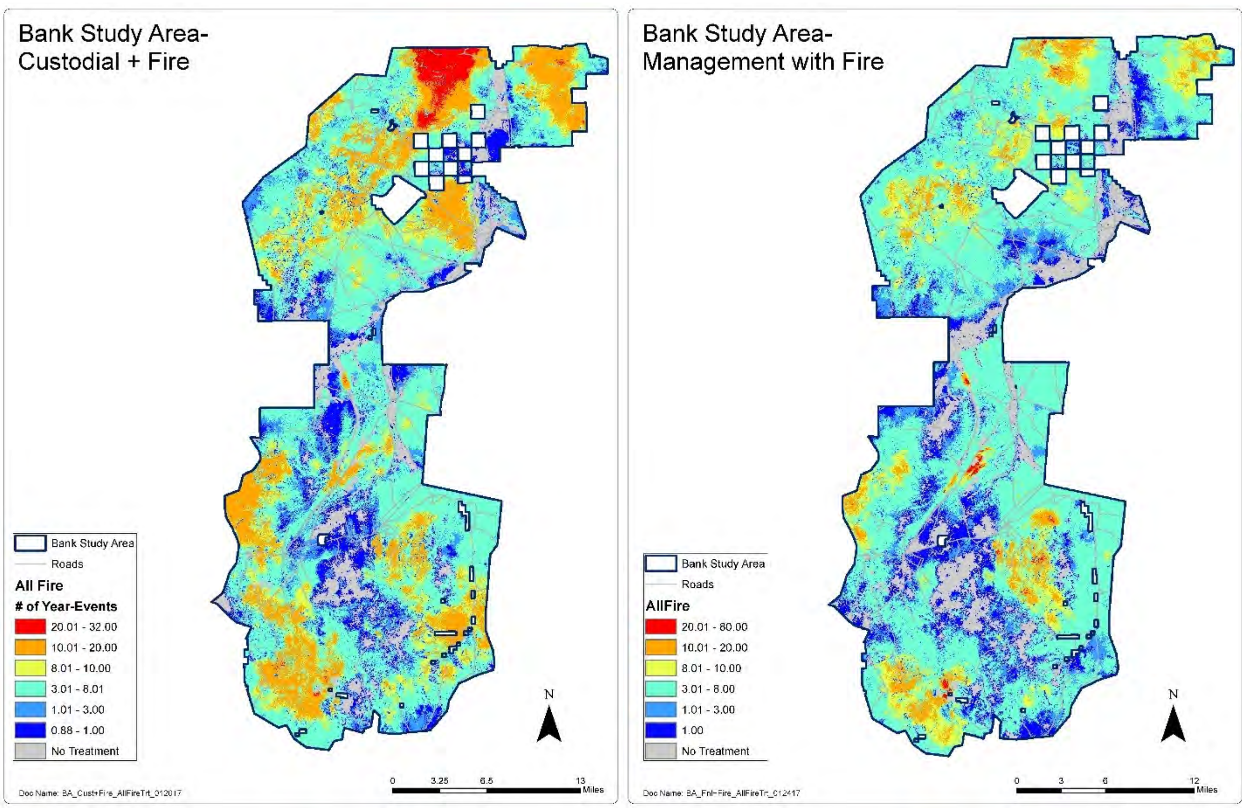


Figure 45. Annual frequency of all observed fire year-events created by ST-Sim in each scenario calculated for 10 replicates and 35 years on the Bank Study Area. The frequency of occurrence of any disturbance can be expressed as the number of years a pixel received a disturbance (year-events) based on a maximum of 350 year-events (350 = 10 replicates × 35 years). Other than no fire (i.e. "No Treatment"), the lowest annual frequency category represents 1 fire year-event out of 350 possible ones. Scenarios: CUSTODIAL+FIRE on left and Final+FIRE on right.

Removal of mature pinyon and juniper encroaching either big sagebrush shrublands and montane sagebrush steppe following by seeding covered the same areas in both FINAL scenarios; however, the highest annual frequencies of implementation were more concentrated in the presence of fire (Figure 46). Essentially, the east slope of the Simpson Park Range, the Red Hills area of the northwest corner of the Roberts Mountains, and the northern toe of the Roberts Mountains attracted nearly all the implementation activity for the action AerialSeed+Masticate+Plateau. As fire removed trees before restoration was scheduled in some replicates, the annual frequency of implementation dropped. The wooded shrublands west of the Tonkin meadows were consistently chosen for action and would create nesting habitat adjacent to the wet meadow, albeit relatively far from the closest lek.

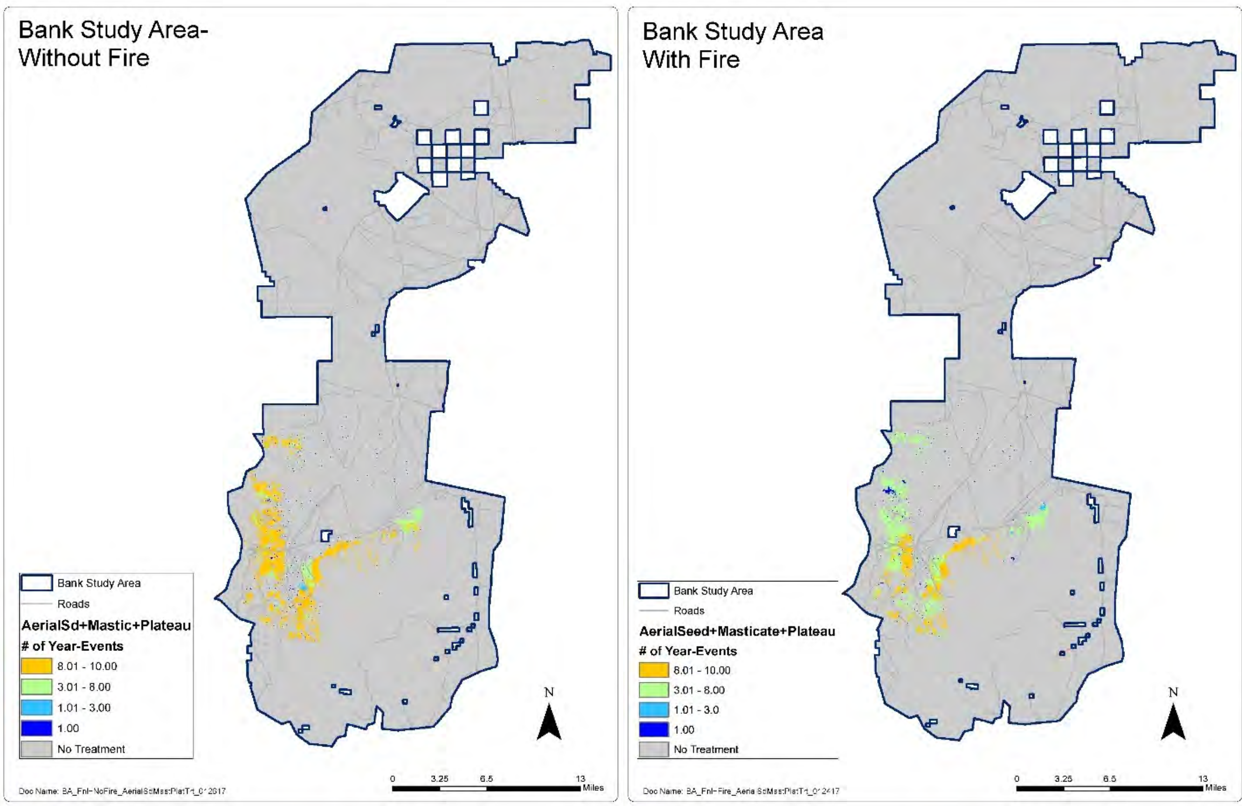


Figure 46. Annual frequency of all observed AerialSeed+Masticate+Plateau year-events created by ST-Sim in each scenario calculated for 10 replicates and 35 years on the Bank Study Area. Other than no implementation, the lowest annual frequency category represents 1 year-event out of 350 possible year-events (350 = 10 replicates × 35 years). Scenarios: FINAL+NOFIRE on left and B = FINAL+FIRE on right.

The annual frequency of Chainsaw-Thinning occupied areas similar as the AerialSeed+Masticate+Plateau action because those are the wooded areas; however, Chainsaw-Thinning targeted mature trees in black and low sagebrush only (Figure 47). Scattered chainsaw operations were also implemented in the Cortez Range. The area of highest likelihood for this action (in all replicates) was just southwest of the Tonkin Meadow, whereas a few locations had intermediate annual frequency in the Simpson Park Range.

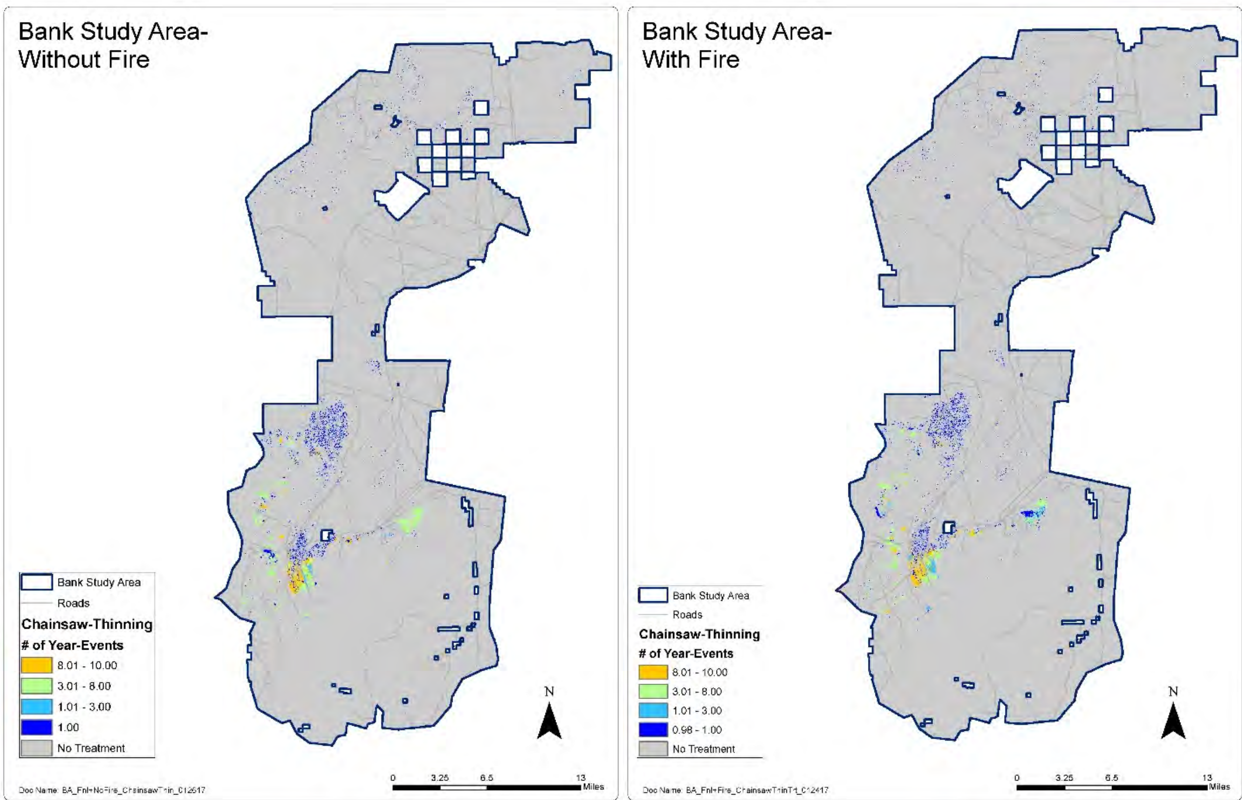


Figure 47. Annual frequency of all observed Chainsaw-Thinning year-events created by ST-Sim in each scenario calculated for 10 replicates and 35 years on the Bank Study Area. Other than no implementation, the lowest annual frequency category represents 1 year-event out of 350 possible year-events (350 = 10 replicates × 35 years). Legend of scenarios: Scenarios: Final+NoFire on left and B = Final+Fire on right.

Small-tree lopping was the third action designed to remove trees from shrublands. This action targets younger trees in systems and classes useable by sage-grouse but in danger of converting into a true tree-encroached class as the young trees mature. The Simpson Park Range and the Red Hills area in the northwest corner of the Roberts mountains were the primary zones of implementation, with greater concentration of activity in three pockets (Figure 48). Scattered small-tree lopping was also observed in the Cortez Range.

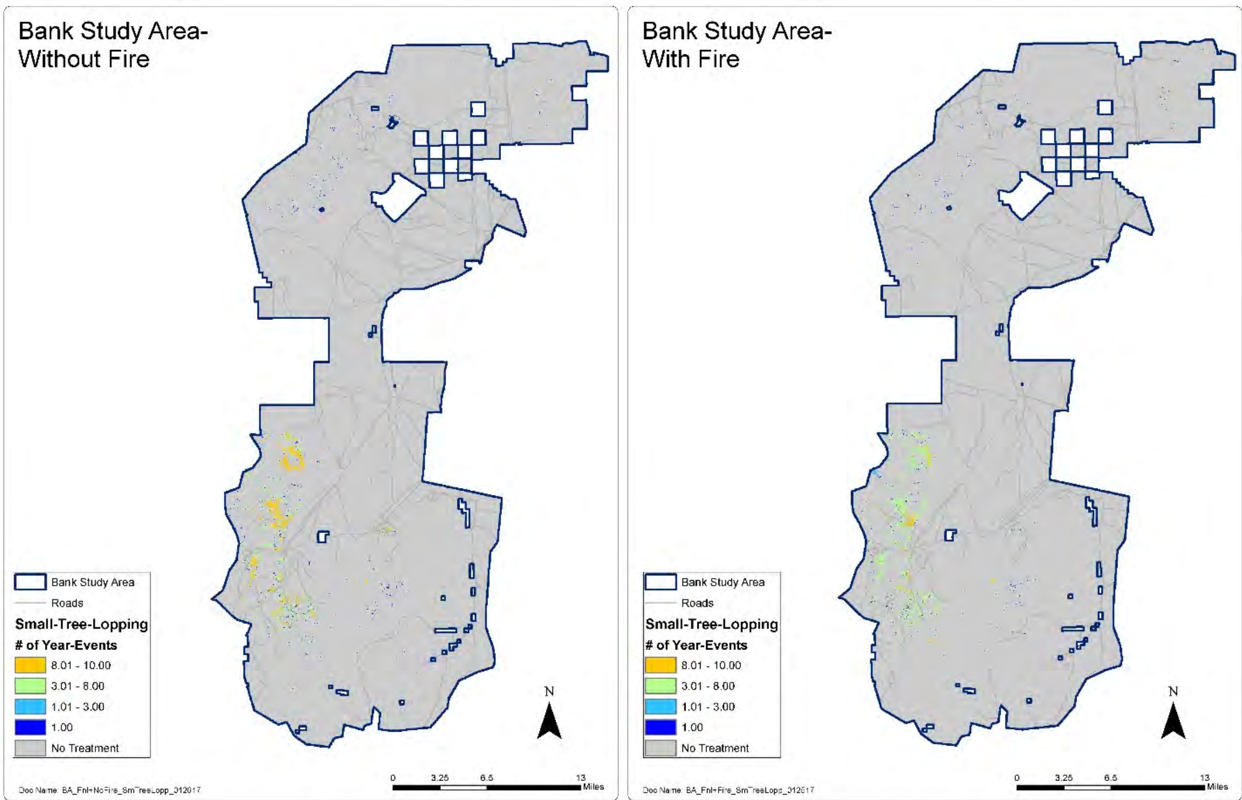


Figure 48. Annual frequency of all observed Small-Tree-Lopping year-events created by ST-Sim in each scenario calculated for 10 replicates and 35 years on the Bank Study Area. Other than no implementation, the lowest annual frequency category represents 1 year-event out of 350 possible year-events (350 = 10 replicates × 35 years). Scenarios: FINAL+NOFIRE on left and FINAL+FIRE on right.

Of the two actions to control exotic forb and tree species, Weed-Control only targeted vegetation classes in montane riparian or wet meadows. Exotic species control occurred throughout the Bank Study Area; however, the annual frequency of implementation was generally low except in a few localized places in the Cortez Range and in the Tonkin Meadows where the annual probability was highest (Figure 49). Currently these areas have tall whitetop, salt cedar, and knapweed.

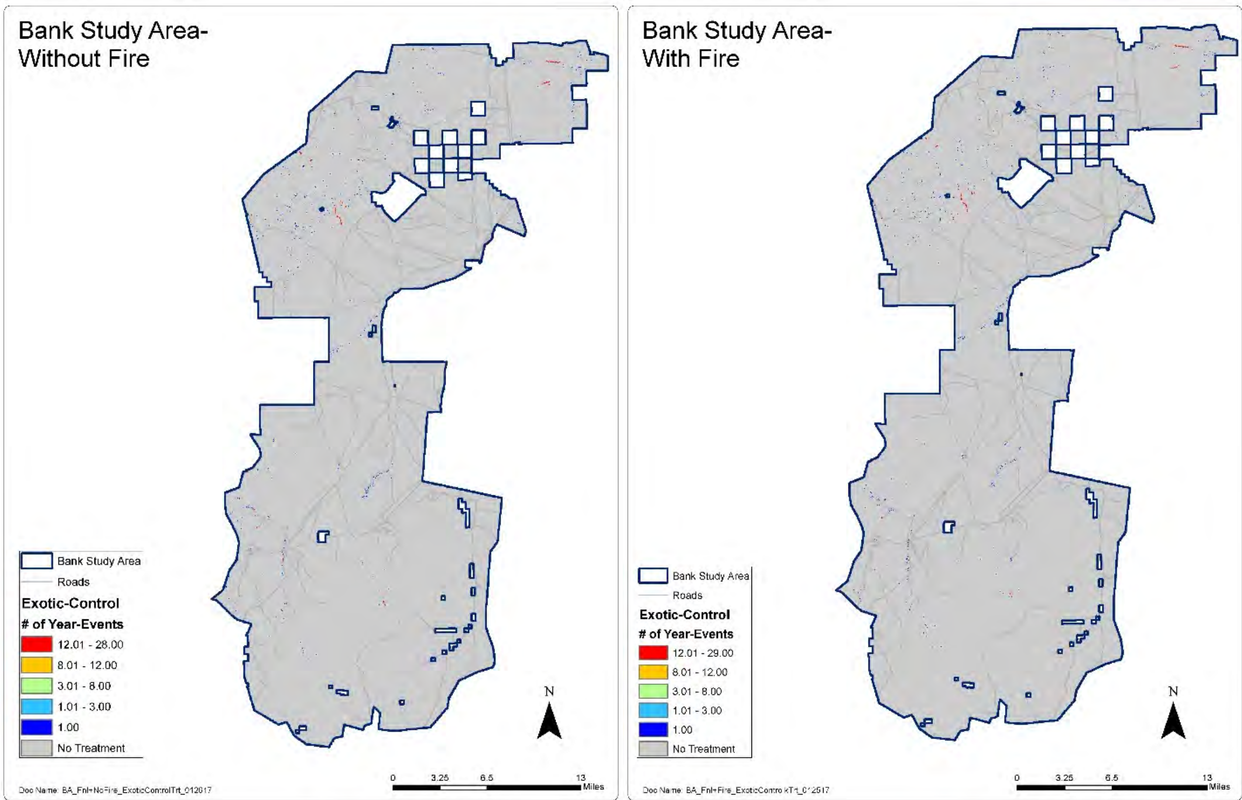


Figure 49. Annual frequency of all observed Exotic-Control year-events created by ST-Sim in each scenario calculated for 10 replicates and 35 years on the Bank Study Area. Other than no implementation, the lowest annual frequency category represents 1 year-event out of 350 possible year-events (350 = 10 replicates × 35 years). Scenarios: FINAL +NOFIRE on left and FINAL +FIRE on right.

The second exotic species prevention and control action was Weed-Inventory+Spot-Treat action (Figure 50). Although any one pixel was visited every three years at most, the area covered for weed inventory was more extensive (Figure 50) than for Exotic-Control (Figure 49) because all montane riparian and wet meadows were targeted, except for already invaded classes. Only a few areas were visited in all replicates. The presence of fire had no apparent effects on this action. Alone this method of exotic species prevention and spot control was very effective and inexpensive.

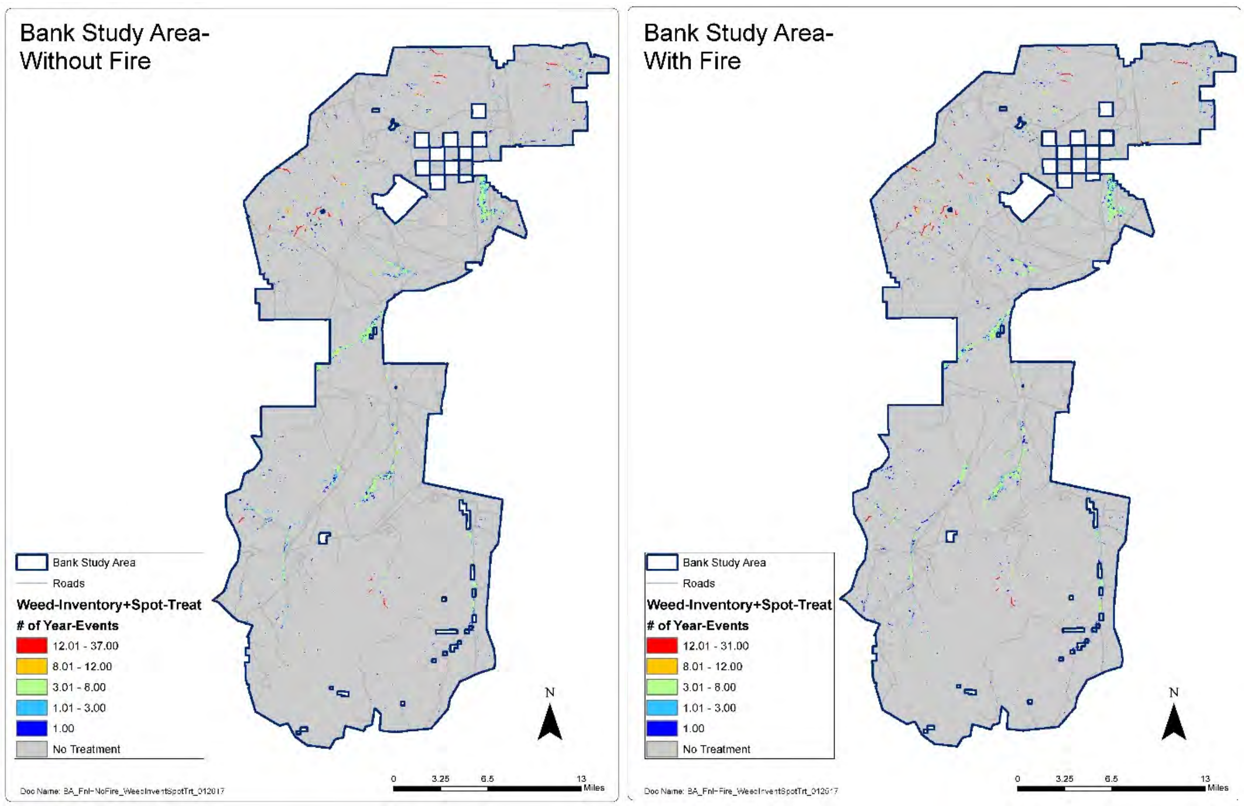


Figure 50. Annual frequency of all observed Weed-Inventory+Spot-Treat year-events created by ST-Sim in each scenario calculated for 10 replicates and 35 years on the Bank Study Area. Other than no implementation, the lowest annual frequency category represents 1 year-event out of 350 possible year-events (350 = 10 replicates × 35 years). Scenarios: FINAL +NOFIRE on left and FINAL +FIRE on right.

The Exotic Forb treatment and Weed-Inventory+Spot-Treat action were conducted on some BLM lands outside of Barrick's management control. Due to the spatial extent and context of these treatments, they are not considered to contribute to uplift in GSG habitat suitability as implemented. However, these treatments are considered highly important for overall range health. Because of the critical nature of these treatments, it is assumed that the BLM is likely to implement them as needed.

Degraded montane wet meadows were treated with fencing to control livestock and horse access and providing an alternative water delivery system for excluded ungulates (Fence&Water-Delivery) (Figure 51). Many wet meadows were excluded from management; however, most available wet meadows on Barrick's private lands and a few on BLM-managed lands were treated (Figure 51). There was no difference between the two scenarios without and with fire. Wet meadows that received this action in every replicate were the Lone Tree and Cherry Springs complexes, Indian Springs, Big Spring, and Indian Creek complex.

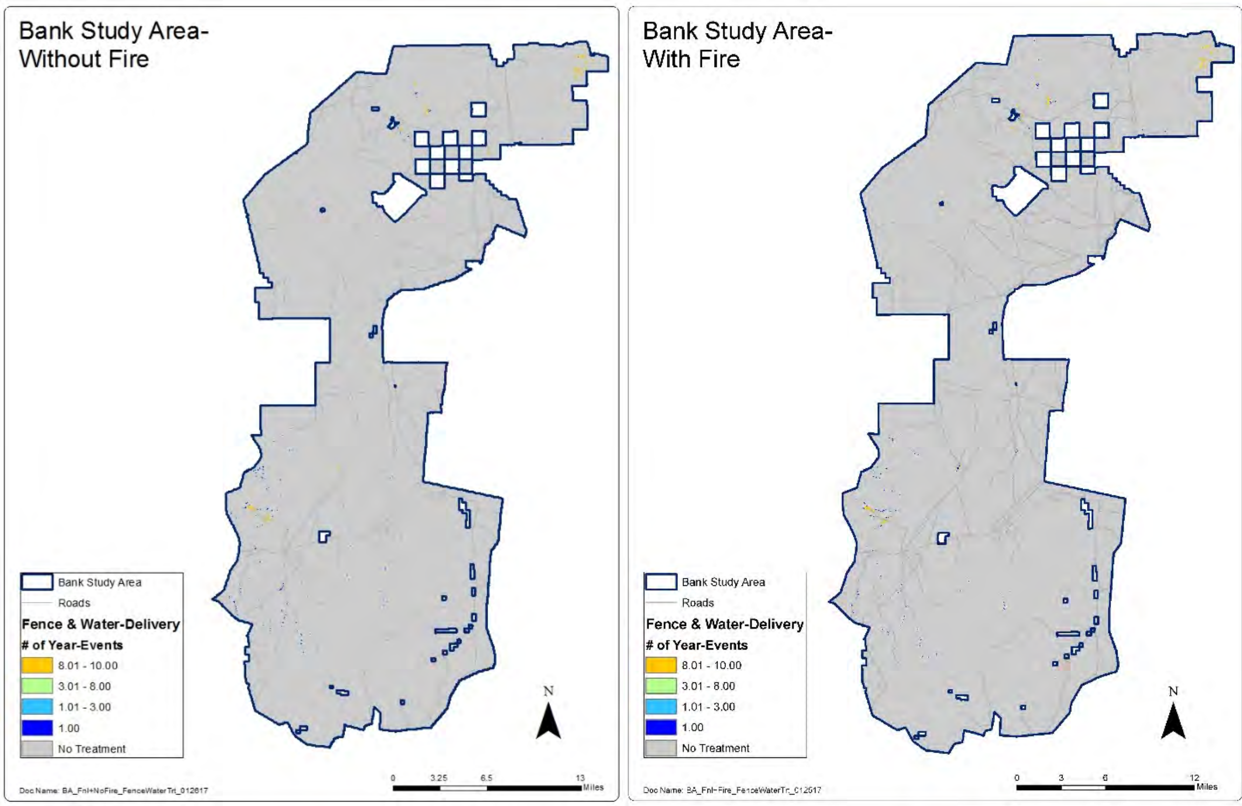


Figure 51. Annual frequency of all observed Fence&Water-Delivery year-events created by ST-Sim in each scenario calculated for 10 replicates and 35 years on the Bank Study Area. Other than no implementation, the lowest annual frequency category represents 1 year-event out of 350 possible year-events (350 = 10 replicates × 35 years). Scenarios: FINAL +NOFIRE on left and FINAL +FIRE on right.

Once wet meadows were fenced, the Fence-Inspect&Maintain action was initiated about four years after the last fencing. Fence inspection and maintenance occurred at most every four years. Therefore, the location of annual frequencies of Figure 51 and Figure 52 were nearly identical. There was nearly no difference between the scenarios without and fire (Figure 52).

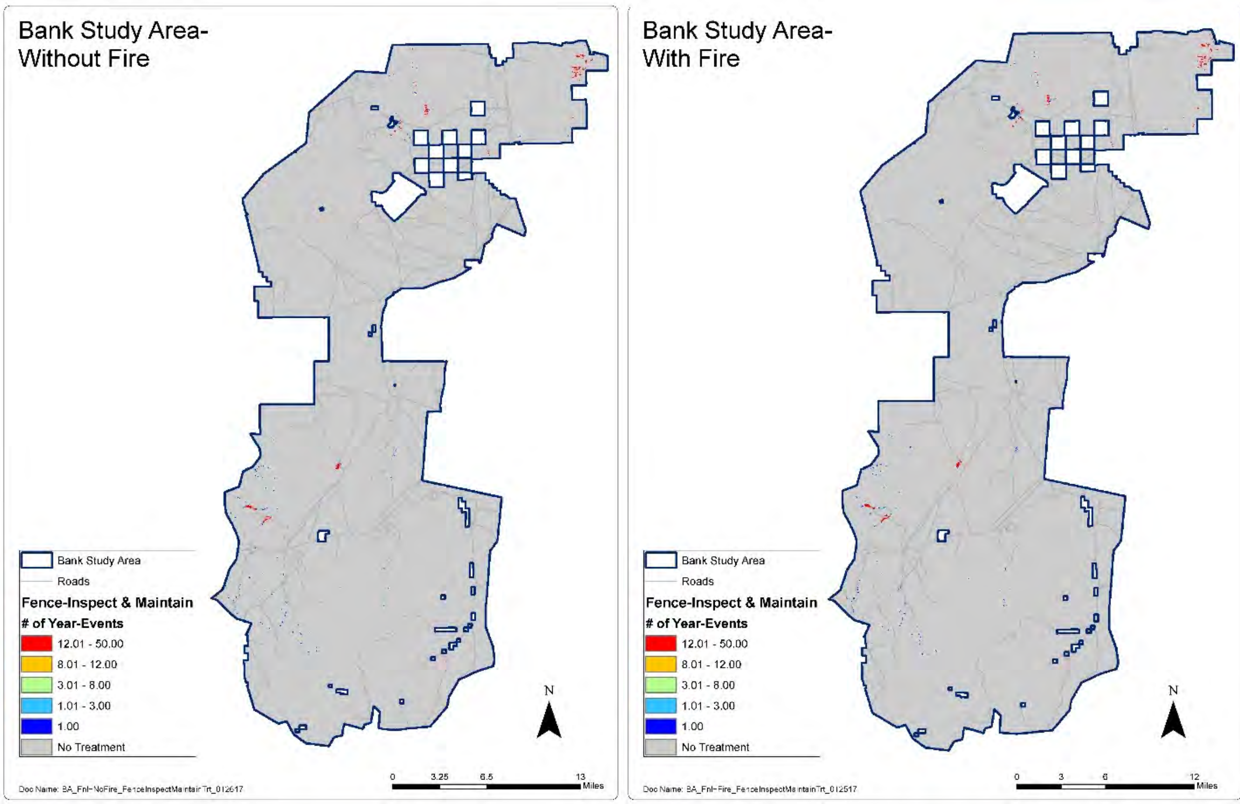


Figure 52. Annual frequency of all observed Fence-Inspect&Maintain year-events created by ST-Sim in each scenario calculated for 10 replicates and 35 years on the Bank Study Area. Other than no implementation, the lowest annual frequency category represents 1 year-event out of 350 possible year-events (350 = 10 replicates × 35 years). Scenarios: Final +NoFire on left and Final +Fire on right.

The third wet meadow restoration action consisted of spraying herbicide on native perennial shrubs, generally rabbitbrush, or forbs (e.g. Iris) and mowing them (Herbicide-Shrubs+Mow). Very few meadows contained the shrub-forb-encroached class and, as a result, implementation is difficult to see at this scale (See red circles; Figure 53).

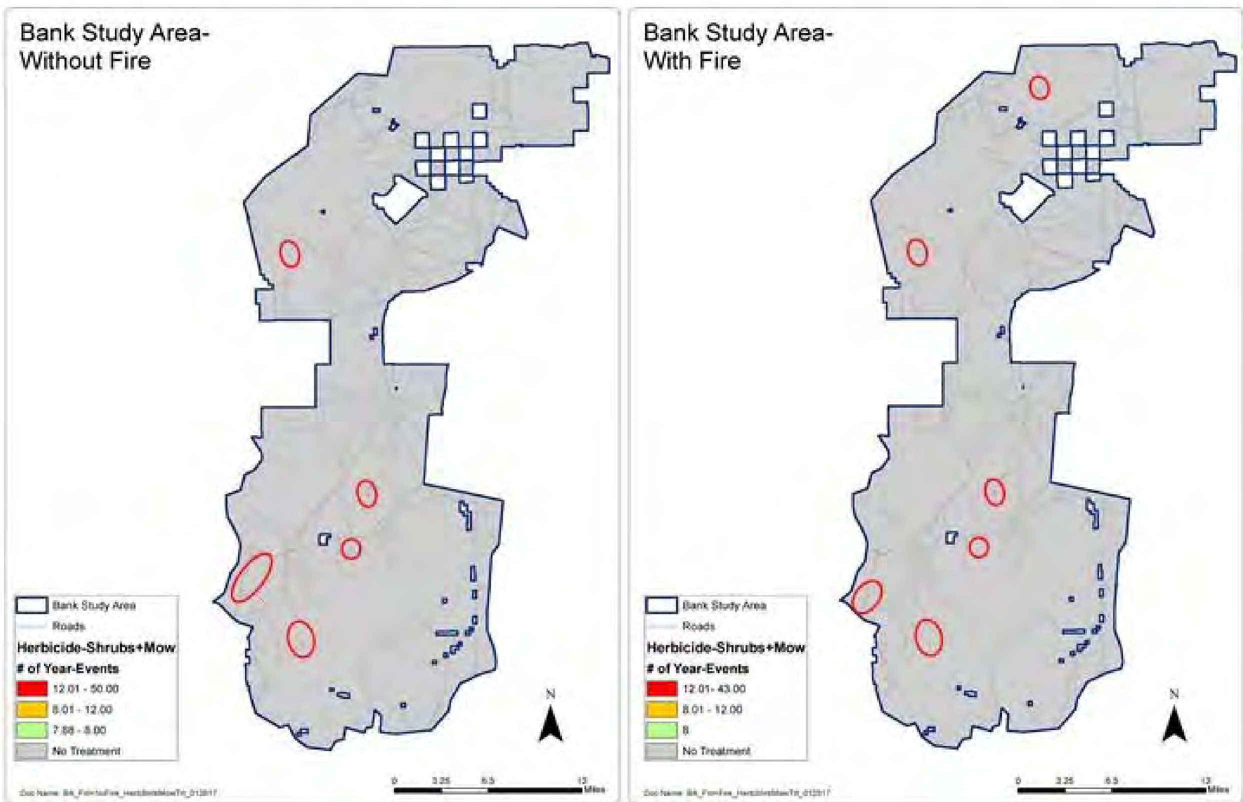


Figure 53. Annual frequency of all observed Herbicide-Shrubs+Mow year-events created by ST-Sim in each scenario calculated for 10 replicates and 35 years on the Bank Study Area. Red ellipses surround small and nearly invisible areas of implementation. Other than no implementation, the lowest annual frequency category represents 1 year-event out of 350 possible year-events (350 = 10 replicates × 35 years). Scenarios: FINAL +NOFIRE on left and FINAL +FIRE on right.

Seeding and shrub planting with spraying of imazapic herbicide (Plateau™) of non-native annual species classes (Herbicide-Plateau+Seed+Shrub-Planting) was the most widespread restoration action that accounted for the greatest expense. This action was primarily used from the Boohoo fire scar east to the Piñon Range, in Frenchie Flats, in the western and burned side of Simpson Park Range, along the Tonkin Road's fire, and northwest toe of the Roberts Mountains, in parts of the Fraser fire scar, east and west of the JD Meadows and lower Henderson Creek, and, to a lesser extent, north of the Buckhorn Mine (Figure 54). The old fire scars were the areas of consistent implementation in most replicates. The presence of fire increased the use of this action in all these areas, especially around the JD Meadows and the eastern slope of Simpson Park Range, as new classes of non-native annual species were created and selected for restoration before implementation was greatly reduced by year 9 and stopped by year 21. Also, this action was used after failures were experienced during tree mastication and seeding (AerialSeed+Masticate+Plateau; most management actions have an associated failure rate).

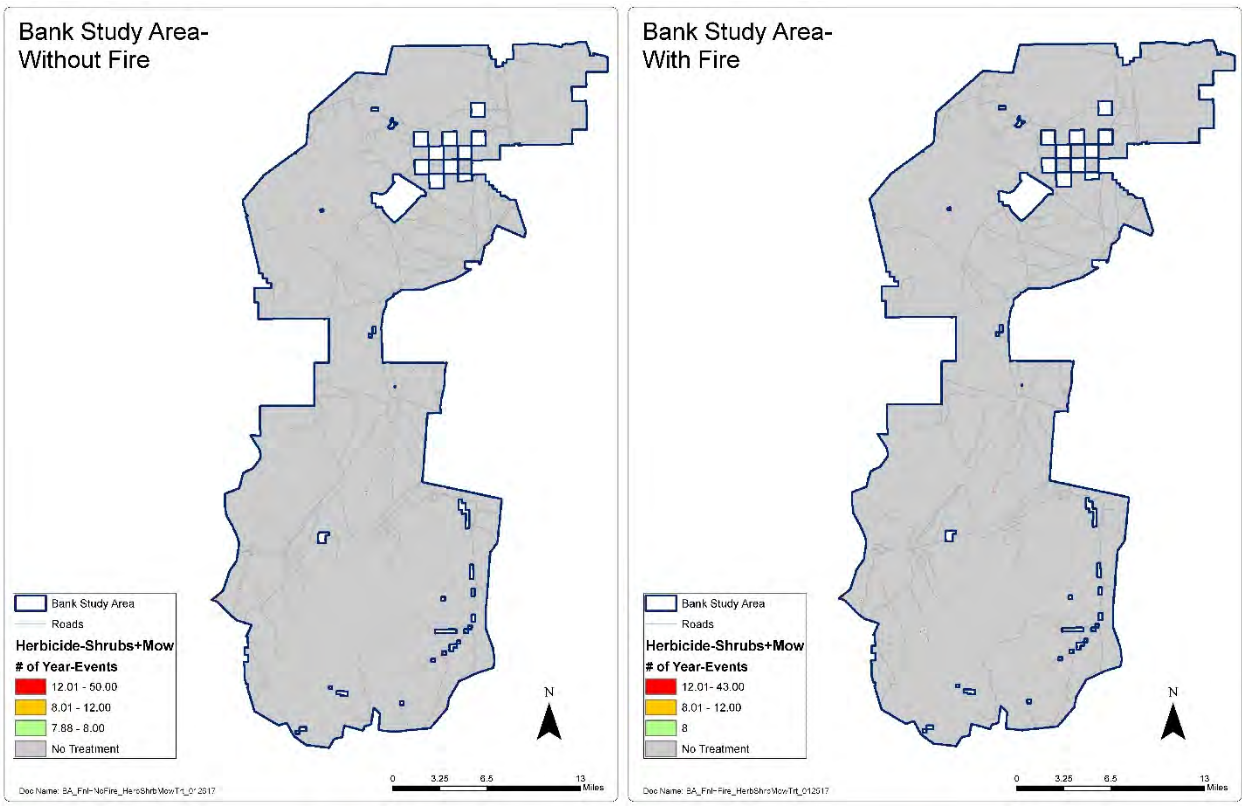


Figure 54. Annual frequency of all observed Herbicide-Plateau+Seed+Shrub-Planting year-events created by ST-Sim in each scenario calculated for 10 replicates and 35 years on the Bank Study Area. Other than no implementation, the lowest annual frequency category represents 1 year-event out of 350 possible year-events (350 = 10 replicates × 35 years). Scenarios: FINAL+NoFire on left and FINAL+Fire on right.

The last management action of the FINAL scenarios was irrigation of greasewood in the JD Meadows only (Figure 55). No difference was observed between without and with fire.

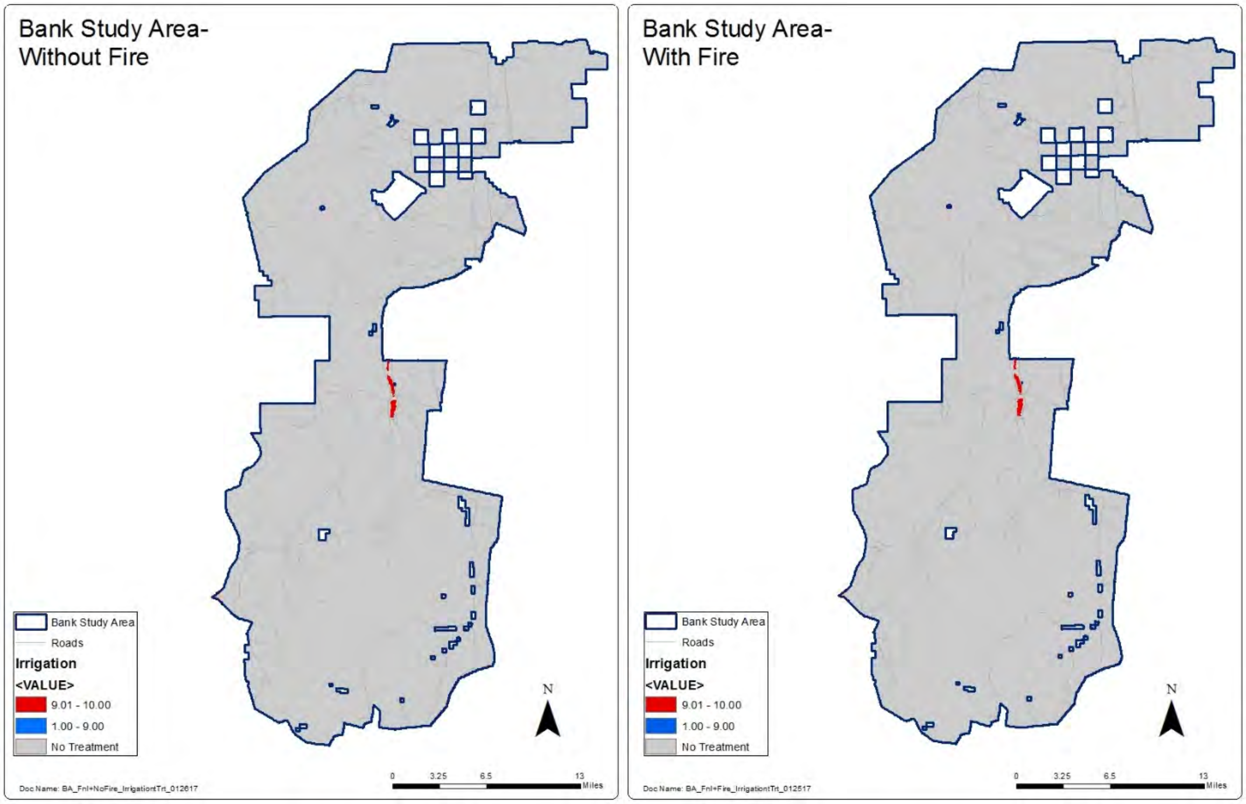


Figure 55. Annual frequency of all observed Irrigation year-events created by ST-Sim in each scenario calculated for 10 replicates and 35 years on the Bank Study Area. Other than no implementation, the lowest annual frequency category represents 1 year-events out of 350 possible year-events (350 = 10 replicates × 35 years). Scenarios: FINAL+NOFIRE on left and B = FINAL+FIRE on right.

Plan of Operations Study Area

Change in Vegetation Classes

While no vegetation management was implemented in simulations for the Plan of Operations Study Area, vegetation classes experienced change, especially with fire. Only vegetation classes that impact sage-grouse habitat suitability and that are indicative of general range management problems will be shown. These results show the change in vegetation across the landscape without the influence of the proposed Deep South Expansion Project.

Big Sagebrush Semi-Desert
The lowest elevation sagebrush system in the Plan of Operations Study Area possibly used by sage-grouse was big sagebrush semi-desert. This system was not present in the Bank Study Area. The Big Sagebrush Semi-Desert system has no trees, but is dominated by nonnative annual species class and mid- and late-succession classes with only understories of non-native annual species (U-B:SA and U-C:SA, respectively; Figure 56). Fire resulted in an increase of the non-native annual species primarily by burning the late-succession class and replacing it with non-native annual species class (U-C:SA; Figure 56). The widespread presence of the non-native annual species class and lack of native herbaceous vegetation for insects and chicks create generally poor nesting and early brood-rearing habitat for sage-grouse.

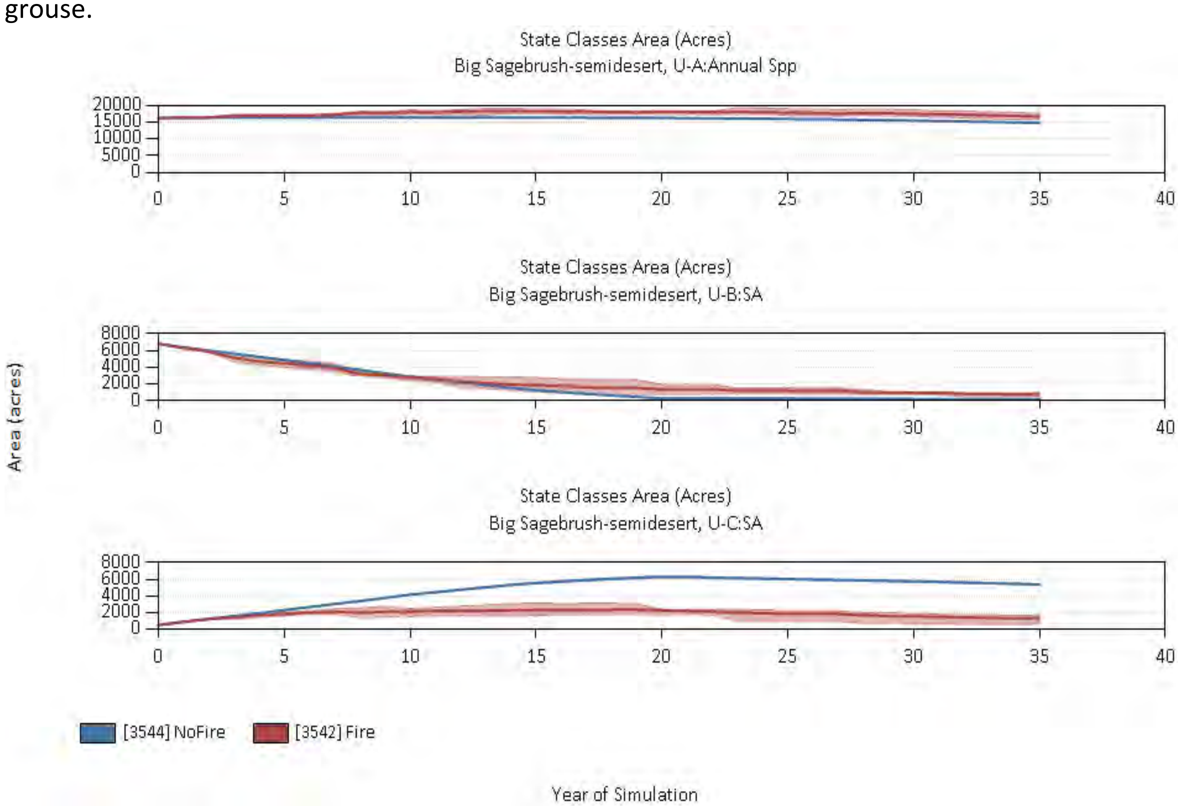


Figure 56. Big sagebrush semi-desert vegetation classes on Barrick's Plan of Operations Study Area using ST-Sim simulations. Color bands are the 25% to 75% percentiles. N = 10 replicates.

Big Sagebrush Shrubland on Upland Soils (Big Sagebrush-upland+trees)
In the Plan of Operations Study Area, Big Sagebrush shrubland on upland soils is in the elevation zone just above big sagebrush semi-desert. Uncharacteristic classes also dominated this system. By far, the non-native annual species class was the most abundant (up to about 35,000 acres with fire on average at year 35), which will affect sage-grouse nesting choices and success (Figure 57). With fire, the area of this class increased by 10,000 acres over 35 years, although most of the increase was achieved by year 20. The primary classes that convert to non-native annual species class due to fire were late-succession depleted sagebrush (U-C:Depleted), the late-succession with non-native annual species class (U-C:SA), early-succession and late-succession shrubland of mixed native and non-native annual species classes (U-A:SAP and U-C:SAP, respectively), and tree-encroached or trees with non-native annual species class (U-E:TEA; Figure 47). Note that when the U-C:SAP class burns, about 50% transitions to U-A:SAP with the rest transitioning to U-A:Annual Species. These classes (U-A:Annual Species, U-A:SAP, U-C:SAP) were often dominant, except when trees were present. Within this system the early-succession classes (U-A:Annual Spp and U-A:SAP) and the wooded class (U-E:TEA) do not increase sage-grouse habitat suitability for GSG.

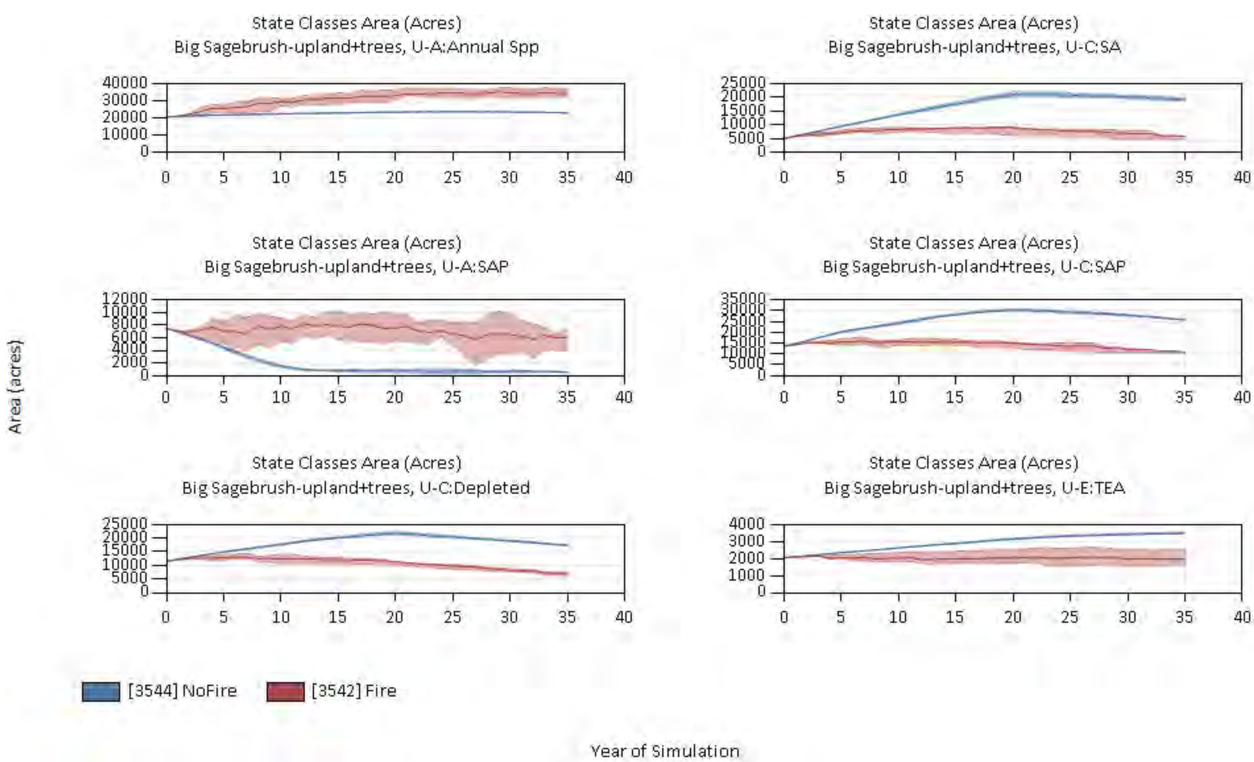


Figure 57. Big sagebrush shrubland with trees vegetation classes on Barrick's Plan of Operations Study Area using ST-Sim simulations. Color bands are the 25% to 75% percentiles. N = 10 replicates.

Dwarf Sagebrush Systems (Black and Low Sagebrush)

Dwarf sagebrush systems tended to be dominated by classes beneficial to GSG (i.e. mid- and late-succession reference classes and uncharacteristic classes with sagebrush cover and without trees). Other classes which did not benefit GSG, such as early-succession reference (A:All) or uncharacteristic (U:Annual Spp and U-A:SAP) classes or late-succession wooded classes (D:Open and U-D:TEA), were also abundant (Figure 58). Fire greatly increased early-succession classes at the expense of non-wooded late-succession reference classes (C:Closed, not shown) and uncharacteristic classes (U-C:Depleted, not shown). Fire was beneficial in removing the uncharacteristic wooded class U-D:TEA; however, wooded shrublands are neutral for GSG habitat suitability, whereas the resulting early-succession classes are negatively contributing to nesting success, unless early-succession classes were sufficiently high in elevation where they positively contributed to late-brood survival.

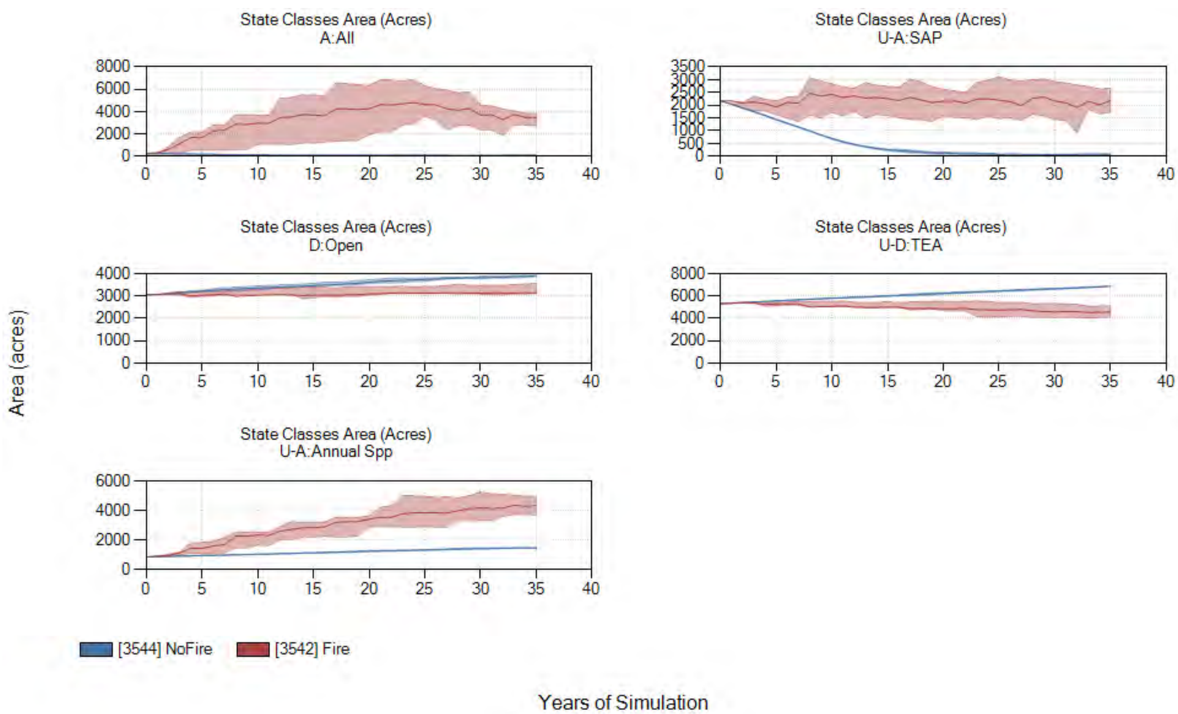


Figure 58. Combined black and low sagebrush vegetation classes on Barrick's Plan of Operations Study Area using ST-Sim simulations. Color bands are the 25% to 75% percentiles. N = 10 replicates.

Montane Sagebrush Steppe
Montane sagebrush steppe was different than the previous sagebrush systems because at higher elevation there is a tradeoff between loss of nesting habitat to fire and gain of brood-rearing habitat due to fire. While early-succession classes only provide late-brood-rearing habitat and late-successional classes only provide the highest quality nesting, mid-successional classes contribute to both life history stages. Fire had a moderate to small effect on the reduction of late-succession classes and growth of early-succession class, except for the late-succession class with mixed native grass and non-native annual species class that decreased by 6,000 acres (U-C:SAP; Figure 49). The wooded uncharacteristic class (U-E:TEA) experienced a 1,000-acre decrease due to fire, which likely benefited GSG. The bulk of the burned area was evenly distributed to non-native annual species (U-A:Annual Spp; Figure 59), early succession mixed native grass and non-native annual species (U-A:SAP; Figure 59), and seedings created by the BLM fire rehabilitation action that eventually transitioned to brood-rearing and nesting habitat (U-A:SI not shown).

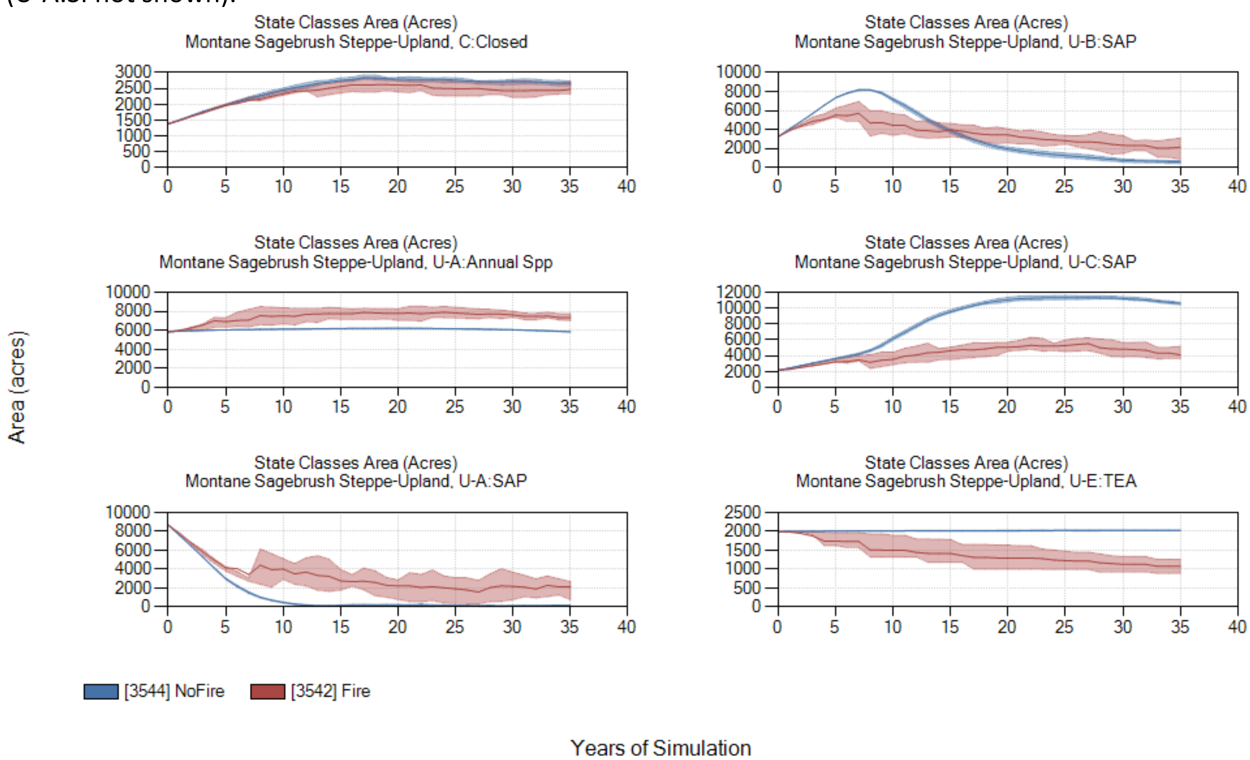


Figure 59. Montane sagebrush steppe vegetation classes on Barrick's Plan of Operations Study Area using ST-Sim simulations. Color bands are the 25% to 75% percentiles. N = 10 replicates.

Montane Wet Meadow

The wet meadow vegetation classes most beneficial to GSG habitat suitability (A:All and B:Closed) increased by 50 acres with fire because the less beneficial late-succession reference class (U-C:Open) burned (Figure 60). Hummocked meadows (U-A:Hummocked) did not change with fire, whereas late-succession exotic species (U-A:Exotic Forb) and shrub and forb-encroached (U-C:Shrb-Frb-Encr) classes that burned caused recruitment into their respective early-succession classes (Figure 60). Changing the succession phase of these uncharacteristic classes had no effect on GSG habitat suitability.

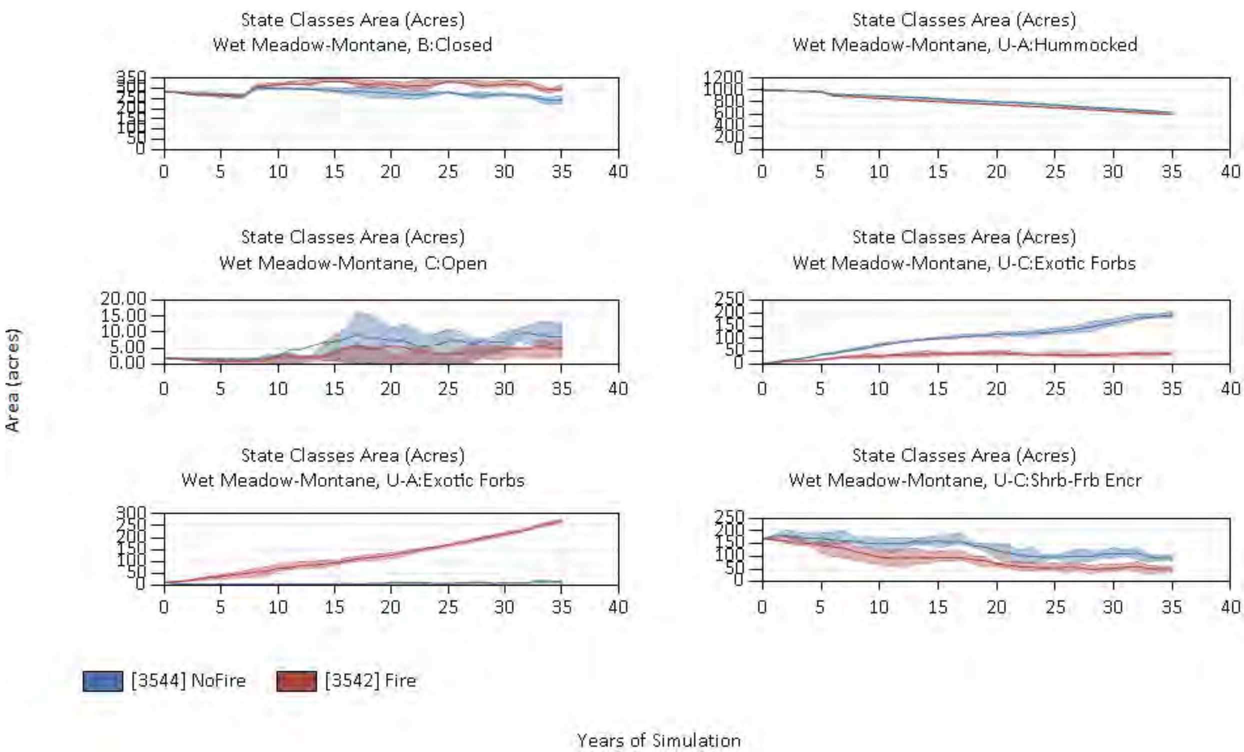
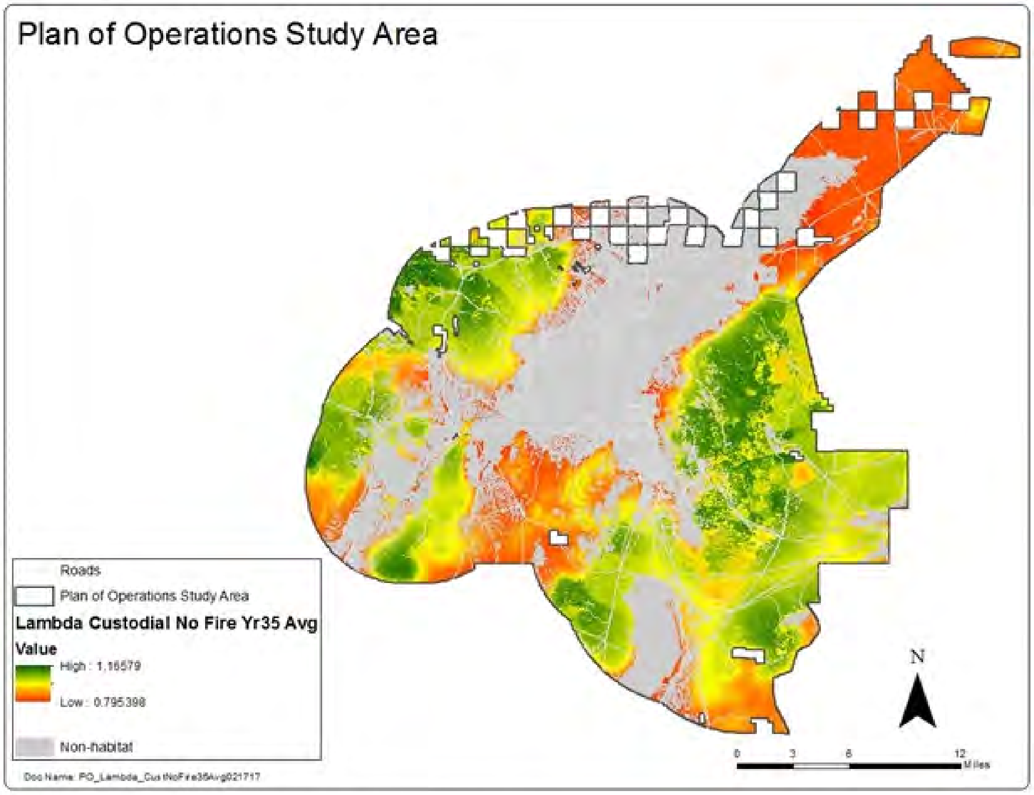


Figure 60. Wet meadow vegetation classes on Barrick's Plan of Operations Study Area using ST-Sim simulations. Color bands are the 25% to 75% percentiles. N = 10 replicates.

Sage-Grouse Habitat Suitability: Plan of Operations Study Area

After 35 years, visual differences in λ between the CUSTODIAL and PROPOSED MINE DEVELOPMENT were slight with or without fire. Also in all λ surfaces that contribute to the averages presented in Figure 61 and Figure 62, the greatest habitat suitability was at higher elevations in sagebrush systems as very few montane wet meadows were found at lower elevations. In general, the Plan of Operations Study Area has fewer water sources at lower and middle elevations compared to the Bank Study Area.

Without fire, the greatest decrease for λ was south of Rocky Pass and the proposed reservoir on the ridge to Red Mountain (part of the northern extent of the Toiyabe Range; Figure 61). The loss of an irrigated pasture in basin wildrye bottomland to the reservoir was the main cause to reduced λ through deceased chick survival. Other changes were visually imperceptible, but picked up during functional acre accounting. Fire generally lowered λ everywhere (Figure 62) compared to the no-fire λ surface (Figure 61). Although the effect of the proposed reservoir on λ south of Rocky Pass was more difficult to see with fire, the decrease in λ was still visible.



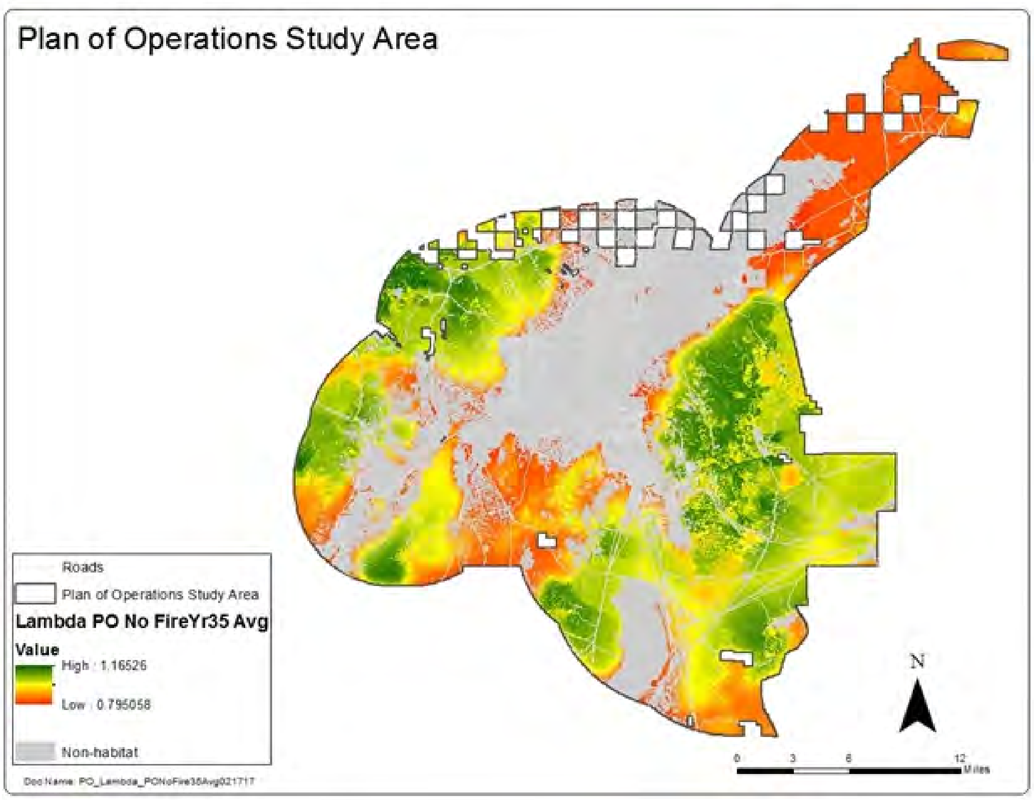
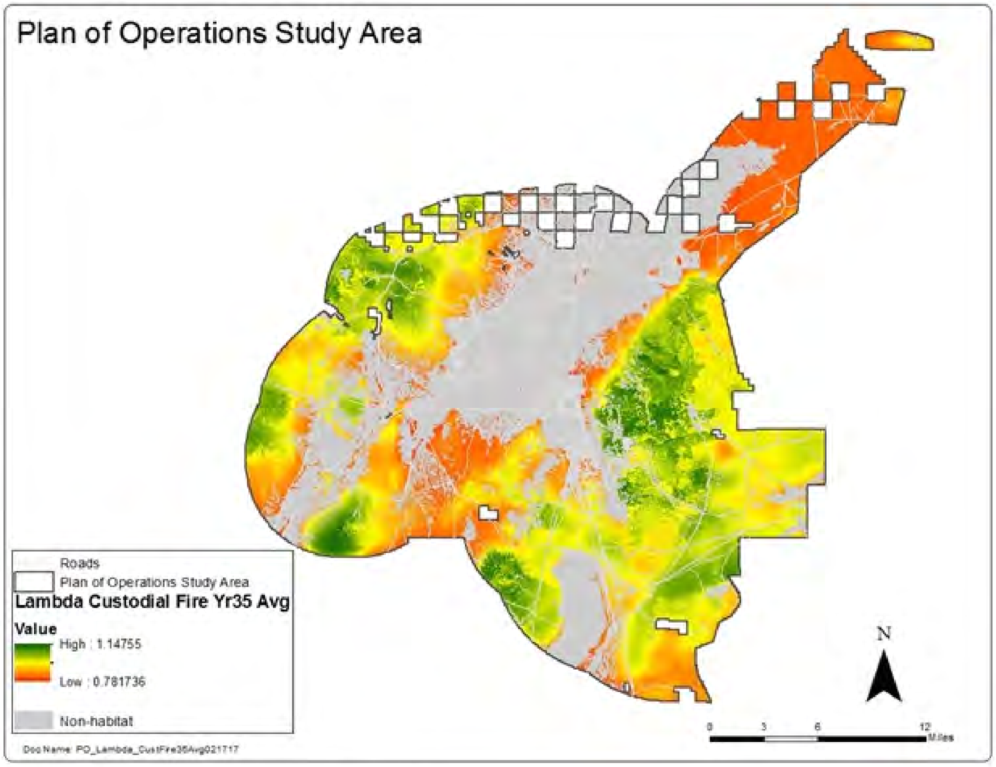


Figure 61. Average lambda after 35 years comparing the CUSTODIAL+NOFIRE and a PROPOSED MINE DEVELOPMENT+NOFIRE scenarios. These results are without fire occurring on the landscape. N = 10.



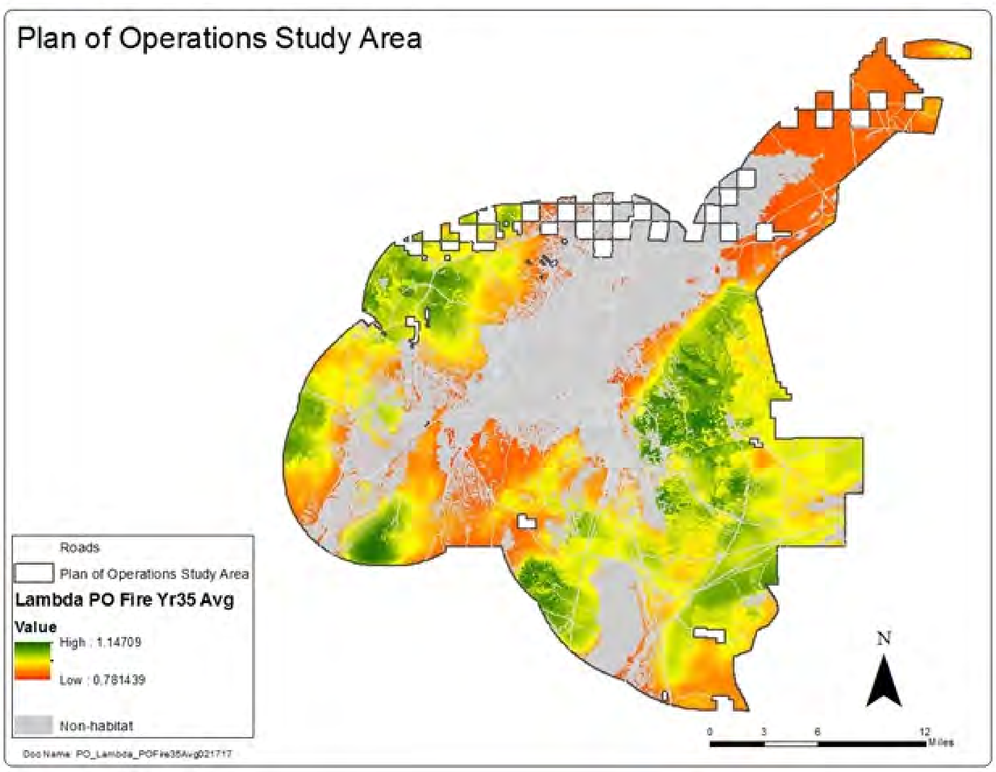


Figure 62. Average lambda after 35 years comparing the CUSTODIAL +FIRE and a PROPOSED MINE DEVELOPMENT+ FIRE scenarios. These results are with fire occurring on the landscape. N = 10.

Over the 35 years of simulations without fire, Functional Area (acres) increased until year 15 due to recovery from past fires in the Plan of Operations Study Area (Figure 63). A slight downward slope was registered after year 20, due probably to tree encroachment and weed invasion. When fire was present, Functional Area consistently decreased after year 5 (Figure 64). The PROPOSED MINE DEVELOPMENT reduced Functional Acres by a fixed amount compared to the CUSTODIAL scenario regardless of fire due to the methodology of stamping in the mine infrastructure.

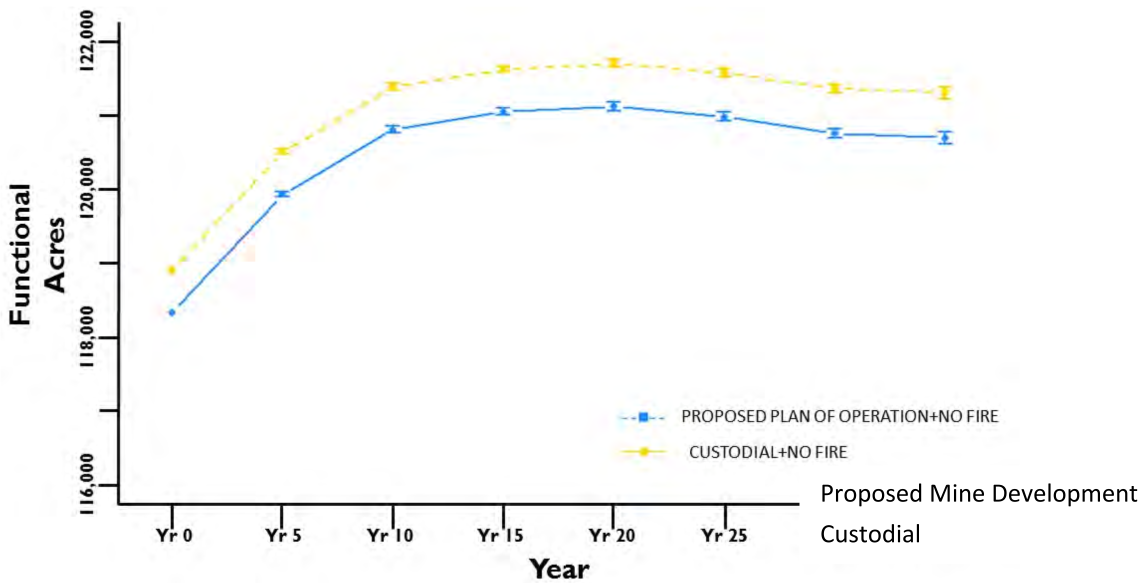


Figure 63. Time series of functional acres for the Impact Area comparing the CUSTODIAL +FIRE and a PROPOSED MINE DEVELOPMENT+FIRE scenarios. These results are without fire occurring on the landscape. N = 10.

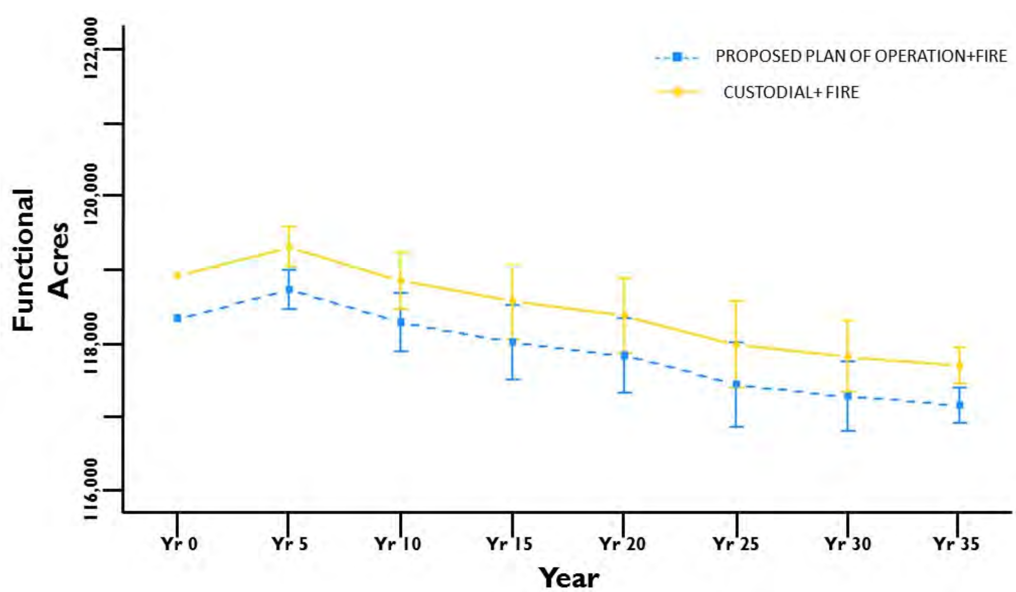


Figure 64. Time series of functional acres for the Impact Area comparing the CUSTODIAL+FIRE and PROPOSED MINE DEVELOPMENT+FIRE scenarios. These results are with fire occurring on the landscape. N = 10.

Table 22 summarizes simulated functional habitat area for GSGs, measured in Functional Acres, in the Plan of Operations Study Area for the CUSTODIAL and PROPOSED MINE DEVELOPMENT scenarios with and without fire. The table also includes the differences in functional acres between the PROPOSED MINE DEVELOPMENT and CUSTODIAL scenarios. Without fire, functional acre losses ranged from a low of 572 FAs in year 0 to a high of 606 FAs in year 30. Fire slightly reduced the losses because the adjacent nesting areas decline with fire present and increased the year variability among replicates. Functional Acre losses ranged from 572 in year 0 to 529 in year 35.

Table 22. GSG Functional Area (acres) estimated for the Plan of Operations Study Area for the four simulated scenarios (with fire and without fire) and the difference between the CUSTODIAL and PROPOSED MINE DEVELOPMENT scenarios at 5-year intervals. N = 10.

Scenario	Yr 0	Yr 5	Yr 10	Yr 15	Yr 20	Yr 25	Yr 30	Yr 35
CUSTODIAL+ NOFIRE	118,906	120,500	121,373	121,611	121,691	121,563	121,352	121,291
PROPOSED MINE DEVELOP+ NOFIRE	118,333	119,926	120,799	121,035	121,112	120,968	120,745	120,687
Difference	*-572*	*-574*	*-575*	*-576*	*-579*	*-595*	*-606*	*-604*
CUSTODIAL+ FIRE	118,906	119,284	118,838	118,561	118,372	117,985	117,825	117,701
PROPOSED MINE DEVELOP +FIRE	118,333	118,715	118,281	118,013	117,837	117,449	117,292	117,172
Difference	*-572*	*-569*	*-557*	*-548*	*-536*	*-536*	*-533*	*-529*

4. Key Conclusions

The TNC Model predicted a net conservation gain for GSG within the study area. This net gain included direct and indirect impacts to habitat from new infrastructure in the Plan of Operations Study Area and uplift provided by preservation and extensive restoration efforts for habitat in the Mitigation Area. TNC reached this conclusion by successfully coupling a complex state-and-transition simulation model supported by high-resolution vegetation maps and a private-public collaboration with a demographically-based GSG habitat suitability model. Reaching a net conservation gain required (1) transforming an academic and statistical habitat suitability model into an applied model and (2) expanding the tools of the well-established ST-Sim state-and-transition simulation software to allow for innovations in modeled fire behavior, grazing management, and spatially dynamic assignment of management priority based changing GSG vital rates. Next, we expand on important findings and assumptions.

1. Compared to the CUSTODIAL management scenario, the PROPOSED MINE DEVELOPMENT resulted in the loss of functional acres on the Plan of Operations Study Area. This loss of functional acres ranged over time from 572 to 606 without fire and from 529 to 572 with fire (Table 23).
2. The building of Rapid Infiltration Basins (RIBs) and supporting infrastructure in the Bank Study Area's Frenchie Flat added a peak loss of approximately 109 functional acres with and without fire (Table 23).

Table 23: Predicted loss of Functional Acres from scenarios conducted on the Bank and Plan of Operations Study Areas to model the effect of proposed mining operations on GSG Habitat. Functional Acre difference is the difference between a management scenario and its corresponding CUSTODIAL Scenario.

Scenario	Yr 0	Yr 5	Yr 10	Yr 15	Yr 20	Yr 25	Yr 30	Yr 35
PoO SA+NoFire Functional Acre *Difference*	*572*	*574*	*575*	*576*	*579*	*595*	*606*	*604*
PoO SA+ Fire Functional Acre *Difference*	*572*	*569*	*557*	*548*	*536*	*536*	*533*	*529*
Bank SA RIBs+ Fire Functional Acre *difference*	*102*	*104*	*107*	*108*	*108*	*109*	*109*	*107*
Bank SA RIBs+ NoFire Functional Acre *difference*	*102*	*105*	*107*	*108*	*108*	*108*	*108*	*108*

3. Compared to the CUSTODIAL management scenario, restoration actions in the FINAL management scenario increased functional acres from 435 to 927 without fire and from 315 to 1,034 with fire (Table 24).

4. The condition of three currently intact wet meadows, Shipley, Tonkin, and Big Springs, was modeled in various states of degradation to explore how functional acres are impacted when these meadows are hummocked and invaded by exotic forbs. The HUMMOCK scenario predicted that preservation of these intact wet meadows led to an uplift of 367 functional acres at year 0 compared to CUSTODIAL with and without (Table 24). For the EXOTIC FORB scenario, preservation is predicted to have 668 more functional acres at year 0, with and without fire.

Table 24: Predicted gain of Functional Acres from scenarios conducted on the Bank Study Area to model the effect of restoration and preservation of important habitat. Functional Acre difference is the difference between a management scenario and its corresponding CUSTODIAL Scenario.

Scenario	Yr. 0	Yr. 5	Yr. 10	Yr. 15	Yr. 20	Yr. 25	Yr. 30	Yr. 35
Bank SA Final+Fire Functional Acre *difference*	*0*	*315*	*677*	*988*	*1,034*	*831*	*804*	*763*
Bank SA Final+NoFire Functional Acre *difference*	*0*	*435*	*588*	*851*	*870*	*875*	*883*	*927*
Bank SA Hummock+Fire Functional Acre *difference*	*367*	*347*	*310*	*289*	*272*	*281*	*276*	*266*
Bank SA Hummock+NoFire Functional Acre *difference*	*367*	*352*	*333*	*324*	*316*	*312*	*306*	*298*
Bank SA Exotic Forbs+Fire Functional Acre *difference*	*668*	*635*	*567*	*513*	*468*	*482*	*475*	*462*
Bank SA Exotic Forbs +NoFire Functional Acre *difference*	*668*	*640*	*613*	*602*	*592*	*588*	*581*	*568*

5. With fire, a steady decline was observed in the CUSTODIAL management in the Bank Study Area (a similar pattern was observed in the Plan of Operation area); this reflects the scientific consensus that these systems are in decline primarily due to the fire-invasive weed cycle.

6. Large fires that occur in the last 10 years of a 35-year simulation explain most of the large decrease in habitat suitability and functional acres as recovery of nesting habitat after restoration is not possible and such actions were not deployed during the last 10 years of simulations. This is especially true for the active management scenario in the Bank Study Area.
7. Fire activity explained most of the variation among replicates per scenario.
8. Implementation of restoration actions in the scenario without fire primarily represented current restoration needs based on accumulation of past disturbances, whereas the scenario with fire represented current and future management needs.
9. Restoration of degraded GSG habitat was only accomplished on the Bank Study Area, though within the project boundary of Plan of Operation Study Area restoration opportunities may exist far enough from planned impacts to improve GSG.
10. Due to a lack of complete control of public grazing, two large areas of the Bank Study Area were excluded from most management actions (i.e. portions South Buckhorn Allotment and Roberts Mountain Allotment). However, these areas contain large amounts of degraded sagebrush, and thus provide additional opportunity for restoration and GSG habitat improvement, especially in the Roberts Mountain Allotment.
11. This project revealed a stark difference between single species management to increase GSG habitat suitability and good range improvement. Many actions that would be conducted to improve range condition, such as restoring depleted sagebrush into seedings, is detrimental to GSG nest-site selection and nest success in the short and intermediate terms, and, moreover, drain funding away from actions that directly increase habitat suitability. Despite the benefits for long-term habitat structure, any actions that remove sagebrush cover and create early-succession vegetation classes are detrimental to GSG nesting and were discouraged by the BLM during workshops.
12. The restoration of vegetation classes dominated by non-native annual species into seedings composed of mixed introduced and native grass species supplemented with planted native sagebrush and other shrubs in both big sagebrush, black, and low sagebrush ecological systems was perhaps the most important action to implement in proximity of leks and late-brood habitat as nesting habitat is the most limiting habitat in burned areas.
13. Restoration of degraded vegetation classes in wet meadows, or creation of irrigated pastures in otherwise degraded bottomland systems, that were isolated and distant from late-brood vegetation classes and systems, but sufficiently close to an active lek and nesting habitat, was an important contributor to increased habitat suitability.
14. Removal of trees in reference, tree-encroached, or wooded shrubland invaded by non-native annual species classes using a masticator with seeding or chainsaws was another important contributor to increased habitat suitability. Interestingly, fires naturally removed trees and, therefore, the ST-Sim software shifted treatments and budget allocation such that some burned areas were more cheaply treated as vegetation classes dominated by non-native annual species.
15. Because of the spatial dependence of GSG life history, the location of restoration actions was extremely important for success.
    - For chick survival, GSG habitat suitability increased most when management actions for late brood habitat improvement were isolated from other late-brood habitat but near a nest site or a lek. In other words, restoring a wet meadow close to other wet meadows or high-elevation sagebrush would not increase habitat suitability, whereas restoring an exactly

similar wet meadow far away from other late-brood vegetation would greatly increase habitat suitability as long as the quality nesting habitat was available.

- Restoring vegetation dominated by non-native annual species was only valuable to enhancing nesting if management actions were conducted in proximity of a lek and late-brood rearing habitat,

16. The creation of functional area, the speed of vegetation succession, and the resistance of restored area from fire depended on a variety of assumptions built into the simulation models. Two actions' successes that most critically dependent on assumptions were seeding and fuel breaks, more precisely (a) the grass species in the seed mix for seedings and (b) the shrub species mix for fuel breaks.

    - It was assumed that all seedings deployed in the simulation were a mix of introduced and native grass species with planted sagebrush and bitterbrush plugs. The introduced grass species was crested wheatgrass, *Agropyron cristatum,* at lower to middle elevations and intermediate wheatgrass, *Thinopyrum intermedium*, where appropriate (at higher elevations). It was also assumed that the ratio of introduced species to native grass species decreased as elevation increased (in other words, more natives could be used at higher elevations); however, introduced species would remain dominant in the seed mix until the transition from upland to mountain soil of montane sagebrush steppe (i.e., the 14-inch precipitation zone). Through the workshop process, it was determined that current Great Basin native seed technology is such that seeding success with native species varies from 0% in Wyoming big sagebrush semi-desert to 10% in upland Wyoming big sagebrush. Moreover, native species seedings currently do not withstand invasion by non-native annual species and do not withstand grazing during the first five years (though research is being done to increase the success of native seedings).
    - In the ST-Sim model, seedings included the practice of planting appropriate plugs of mostly sagebrush species and antelope bitterbrush (*Purshia tridentata*). This action was modeled to shorten the duration of the early-succession phase by five years, thus accelerated the increase of GSG nest success by 5 years when shrub cover matured into the mid-succession phase and also increased both chick survival and nest success in montane sagebrush steppe. Without shrub planting, gains in functional area would be delayed by five years; therefore, growing sagebrush and bitterbrush in nurseries a few years prior to seeding, which were modeled to be as much as 24,000 acres during the 10 years of simulation, is an important logistic detail that will need to be addressed now. Additionally, shrub plugs would increase the number of plants that successfully transition to established juveniles compared to seeded shrub species. This is especially important given the competition that crested wheatgrass can exert on seeded native species (Pehrson and Sowell 2011, McAdoo et al. 2016).
    - Introduced species were modeled in the simulation for six important reasons that determine functional acres:
        - Each seeding would behave as a strong fuel break (500 to 1,000-year mean fire return interval compared to 50 to 120-year mean fire return interval for native grasses) that protected other nesting habitat;
        - Introduced species surrounding shrubs would insure that planted shrubs would be protected from fire;

        - Introduced species would better prevent invasion of non-native annual species and halogeton than native species – in the model, invasion by cheatgrass shorten the fire-free interval and subsequent fire can burn nesting habitat and delay the creation of functional acres;
        - Native seedings are more susceptible to drought conditions. Severe drought during the first or second year of any seeding (introduced or native) caused 100% failure in the model, whereas drought after the second year halts succession of the seeding for one year for 90% of the seeded area, but the remaining 10% was unaffected. For native species seedings with a lower success rates regardless of drought, severe drought would need to be modeled and we would assume a high sensitivity to severe drought approaching a 100% failure rate in Wyoming big sagebrush during the first five years of the seeding;
        - In the model, new introduced species seedings were rested from cattle grazing during the first three years. Grazing resumed after three years and it was assumed that cattle would be managed to mitigate grazing-caused failure. If native species were used, seedings would need to be rested five years from cattle; otherwise, the seeding would mostly fail;
        - Regardless of seed origin, grazing by wild horses or unbranded and unclaimed domestic horses will result in 100% failure if a seeded pixel was grazed in either of the first two years. However, introduced species seedings will not fail due to grazing after two years of rest. For native species, seeding failure rate would be 100% if horse grazing did occur in those first 5 years.
    - Forage kochia (*Bassia prostrata*) could not be used in any significant amount for seedings (not the case for fuel breaks; see below) because this species prevents the establishment of sagebrush, which is necessary for GSG habitat suitability. Therefore, it was implied that "seedings" mostly excluded forage kochia in the models.
    - In designing and implementing fuel breaks in the model, several criteria were used: (a) fuel break vegetation should not burn (fire can jump a fuel break, but the species inside the break are not prone to burning because of structural properties and plant tissue moisture), except for singeing where fire contacts the fuel break; (b) to reduce future upkeep cost, the break's vegetation had to be largely self-maintaining in order to prevent vertical woody fuel build-up (i.e., establishment by sagebrush, other native shrubs, and trees); and (c) non-native annual species invasion had to be avoided or minimized. Given these specifications, most land managers would select only one commercially available and cost-efficient species for fuel breaks: forage kochia. Crested wheatgrass or intermediate wheatgrass at higher elevations could be used, but each would fail on preventing woody fuel build-up because sagebrush, pinyon, and juniper are predicted to easily establish in narrow seedings of crested wheatgrass or intermediate wheatgrass.

17. In order to generate significant functional acre uplift as early as possible, the majority of proposed actions had to be primarily front-loaded to the first 12 years of the FINAL scenario regardless of the presence of fire (> $12 million of the roughly $16 million spent). When fire was present in the simulated landscape, this created a trade-off. Large fires that occurred between years 12 and 24 could theoretically be restored and contribute to nesting habitat by the end of a simulation. However, these fires were not restored in sufficient amount due to funds being concentrated before

year 12. If additional resources were available, then we expect increases in functional acres at the end of the simulation.

18. A major component of the total cost of this project was the restoration of wet meadows because fencing meadows and building an alternative water delivery system with water delivered outside the fence was one the most expensive action per unit area. In the model, we chose this high cost because this was the approach currently deployed by Barrick on private lands, but it should be understood that alternative, often less expensive, options could be considered or tested, such as employing riparian riders (i.e., cowboying) that frequently push livestock and horses away from wet meadows and springs.

This project touched many aspects of land management and, especially, revealed new areas for innovation and research, in particular:

1. A large fraction of GSG habitat suitability depends on the quantification of chick survival (Atamian et al. 2010, Gibson et al. 2016b), which due to statistical limitations was explained by only one covariate in central Nevada demographic habitat suitability models: distance to late-brood habitat (Nonne et al. 2013). As chicks and hens die during their transition from the nest to the late-brood habitat, the sample size is reduced (due to mortality). As sample size decreases, there becomes insufficient explanatory power to detect statistical effects from other environmental variables. Basic questions remain regarding density-dependence effects on brood-habitat quality (how does competition among hens and their broods impact chick survival), how brood-rearing habitat geometry affects use, and habitat requirements during the bird's transition from nesting to brood-rearing habitats. These questions can only be answered with a greater sample size. Although these important habitat characteristics to GSG have not been quantified (though see Casazza et al. 2011), the impacts to habitat suitability will likely magnify with climate change as water availability is predicted to decrease (Collins et al. 2013). Land managers would likely benefit from having more options to restore and target wet meadows and high-elevation sagebrush communities.

A final conclusion of this report was to list how the completed work deviated from Exhibit C to the Bank Enabling Agreement. Four minor topics are relevant:

1. This project did not use Unified Ecological Departure (UED) as a metric to assess the success of the proposed management scenario. As UED is specific to each ecological system and does not consider proximity factors that are critical to GSG habitat suitability, and there was no plan to restore ecological systems not used by GSG (for example, aspen), it was determined that UED would not be a measure of success for this project. Whereas reduction of UED is likely correlated with improved GSG habitat in the long run, improvement of GSG habitat based on habitat suitability does not always cause an appreciable reduction in UED, especially if any management budget is limited.
2. Because reducing UED was not a final objective for this project, and because only one final scenario was designed, Return on Investment both at the ecological system and the landscape-scale could not be assessed, therefore it is not included as a metric in this report.
3. In the Bank Enabling Agreement, λ is relativized by dividing by the maximum λ (λ_{max}) found on the current landscape. When the Agreement was conceived, University of Nevada, Reno wildlife biologists had never worked with alternative and future vegetation surfaces, assuming that λ_{max} would be static across all simulation. The problem became that the future maximum possible value

of λ would remain unknown until each new simulation was completed. To avoid computational inconsistencies created by alternative vegetation surfaces and to ensure compatibility of relativized λ among all simulations, a single value of “2” was selected.

4. The Bank Enabling Agreement mentions three GSG vital rates: nest-site selection, nest success, and chick survival. Female survival was not explicitly stated (though was always a part of the λ calculation) because the best science at the time of the signing assumed a fixed female survival value across the landscape. However, due to improvements to the habitat suitability based on research outside of the BEA, University of Nevada, Reno researchers recommended spatially estimating female survival to represent the known trade-off between reproductive success and female survival.

Acknowledgements

This project was funded by Barrick Gold of North America. We are grateful to Bob Ingersoll, Bill Upton, Gail Ross, George Fennemore, Steve Schoen, Brian Taylor, and Jeff Dickie from Barrick for their many contributions to this project. Invaluable help was provided in the field by Barrick staff Kim Wolf and Gail Ross, and the security and safety staff at the JD Lodge and Control 1 at the Pipeline Mine. Barrick ranch managers Doug Groves (Hay Ranch), Sam Kaster (Dean Ranch), and Gary McCuin (JD Ranch) provided field support and advice for modeling management actions.

The following contractors made important contributions to the project:

Jeff Campbell, Spatial Solutions, Inc.
Colin Daniel, ApexRMS, Ltd.
Leonardo Frid, ApexRMS, Ltd.
Kristin Kane, University of Nevada, Reno
Greg Low, Applied Conservation Inc.
Jim Sedinger, University of Nevada, Reno.

The authors gratefully acknowledge the contributions of many to the success of this project, especially by the following individuals:

Steve Abele, FWS
Rich Adams, BLM
Sam Ault, BLM
Gary Back, Great Basin Ecology in Elko
Erik Blomberg, University of Maine
Kent Bloomer, BLM
Charlie D. Clements, ARS, US Department of Agriculture
Stephanye Cox, BLM
Megan Creutzburg, Portland State University
Lara Niell Enders, Sagebrush Ecosystem Technical Team, US Fish and Wildlife Service
Todd Erdody, BLM
Shawn Espinosa, NDOW
Melissa Faigeles, Sagebrush Ecosystem Technical Team
Steve Foree, NDOW
Doug Furtado, BLM
Dan Gibson, Virginia Polytechnic Institute and State University
Sandy Gregory, BLM
Tyson Gripp, BLM
Hanes Holman, Elko Land and Livestock
Matt Jeffress, NDOW
K.C. Kacey, Sagebrush Ecosystem Technical Team
Ted Koch, FWS
Lindsey Leismeister, NDOW
Andrea Litt, Montana State University
Gary McCuin, Barrick-Cortez Inc.
Raul Morales, BLM

Patti Nowak, NRCS, US Department of Agriculture
Mike Podborney, NDOW
Kelly Redmond, Desert Research Institute
Scott Roberts, NDOW
Josh Robbins, BLM
Shawn Servoss, BLM
Alan Shepherd, BLM
John Sherve, BLM
Jill Silvey, BLM
Genevieve Skora, FWS
Michael Vermeys, BLM
Peter Weisberg, University of Nevada, Reno
Ken Wilkenson, BLM
John Wilson, BLM

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