STATE OF COLORADO)
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County of Garfield)

At a regular meeting of the Board of County Commissioners for Garfield County, Colorado, held in the Commissioners' Meeting Room, Garfield County Administration Building in Glenwood Springs on Monday, the 17th day of November A.D. 2014, there were present:

John Martin, Commissioner Chairman
Mike Samson, Commissioner
Tom Jankovsky, Commissioner
Andrew Gorgey, County Manager
Frank Hutfless, County Attorney
Jean Alberico, Clerk of the Board

when the following proceedings, among others were had and done, to-wit:

RESOLUTION NO. 2014 - 67

A RESOLUTION APPROVING THE FIRST AMENDMENT TO THE "GARFIELD COUNTY GREATER SAGE-GROUSE CONSERVATION PLAN"

Recitals

A. On Monday, March 18, 2013, the Garfield County Board of County Commissioners (the Board) adopted the ***Garfield County Greater Sage Grouse Conservation Plan*** (the Plan) via Resolution 2013-23 and has been implementing the principles, policies and best management practices of the Plan through land use decisions under its jurisdiction since that time.

B. Since the original adoption of the Plan in 2013, the Board recognized the need to update the habitat mapping methodology and commissioned a robust effort through the use of two model approaches to map and quantify at a finer and more accurate scale the extent of suitable Greater Sage Grouse habitat in Garfield County. Chapter 3 (Plan Area) and Chapter 4 (Habitat Mapping) have been updated based on the results of this new information. Specifically, the original Plan reflected initial habitat mapping efforts based on less sophisticated modeling techniques using characteristics more typical of national range habitats; the March 2013 Plan indicated 15,525 acres of suitable habitat within the PPR Study Area. Subsequently, more contemporary data were obtained and reviewed specific to the

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Parachute – Piceance – Roan (PPR) Study Area allowing further development of more sophisticated and statistically robust modeling methods ultimately resulting in approximately 72,896 acres of Suitable Habitat within the PPR Study Area. This effort resulted in an independent and objective peer reviewed manuscript entitled ***The Use of Modeling in a Geographic Information System to Predict Greater Sage Grouse Habitat***, now contained in full in Appendix B of the Plan.

C. The principles and policies contained within the Plan shall be used to address functional surface disturbance within Suitable Habitats in the Plan Area as depicted on a new map known as **Figure 5: Greater Sage-Grouse Management Plan Areas (MPAs).** These MPAs were developed by combining the Suitable Habitat areas resulting from both habitat models described in manuscript entitled ***The Use of Modeling in a Geographic Information System to Predict Greater Sage Grouse Habitat***. In total, the MPAs encompass 93,895 acres (or 43%) of the Plan Area. More specifically, 74,819 acres (80%) are managed under the Private Lands Management Area Plan while the remaining 19,076 acres (20%) are managed under the Public Lands Management Area Plan.

D. Additionally, Chapter 7, Section 5 (Predation) has been updated to reflect information with literature citations that better highlights the serious nature of the threat of predation on the Greater Sage Grouse which has also resulted in a new policy (Policy B) in that section stated here:

> *Encourage public agencies such as Colorado Parks and Wildlife, the Bureau of Land Management, and the US Fish and Wildlife Service to work with private land owners in areas of known Suitable Habitat to better understand the actual predation threat and then collaborate on the implementation of predator mitigation programs that discourage predators, reduce productivity and recruitment of predators, and reduce predator density.*

E. The Board of County Commissioners held a public hearing on the 17th day of November, 2014 for consideration of whether this first amendment to the Plan should be approved, during which hearing the public and interested persons were given the opportunity to express their opinions regarding the request.

F. The Board of County Commissioners closed the public hearing on the 17th day of November, 2014 to make a final decision.

G. Based on substantial competent evidence produced at the aforementioned hearing, the Board of County Commissioners has made the following determinations:

1. That proper public notice was provided as required for the hearing before the Board of County Commissioners.

2. The hearing before the Board of County Commissioners was extensive and complete, all pertinent facts, matters and issues were submitted and all interested parties were heard at that meeting.

3. For the above stated and other reasons the first amendment to the Plan is in the best interest of the health, safety, and welfare of the citizens of Garfield County.

4. That the first amendment to the Plan is in general conformance with the 2030 Comprehensive Plan, as amended.

RESOLUTION

NOW THEREFORE, BE IT RESOLVED by the Board of County Commissioners of Garfield County, Colorado, that:

A. The forgoing Recitals are incorporated by this reference as part of this resolution.

B. Garfield County adopts the First Amendment to the Plan (attached as **Exhibit A**).

Dated this 17th day of November, A.D. 20 14.

ATTEST:

GARFIELD COUNTY SEAL COLORADO

Jean M Alberico
Clerk of the Board

GARFIELD COUNTY BOARD OF COMMISSIONERS, GARFIELD COUNTY, COLORADO

Chairman

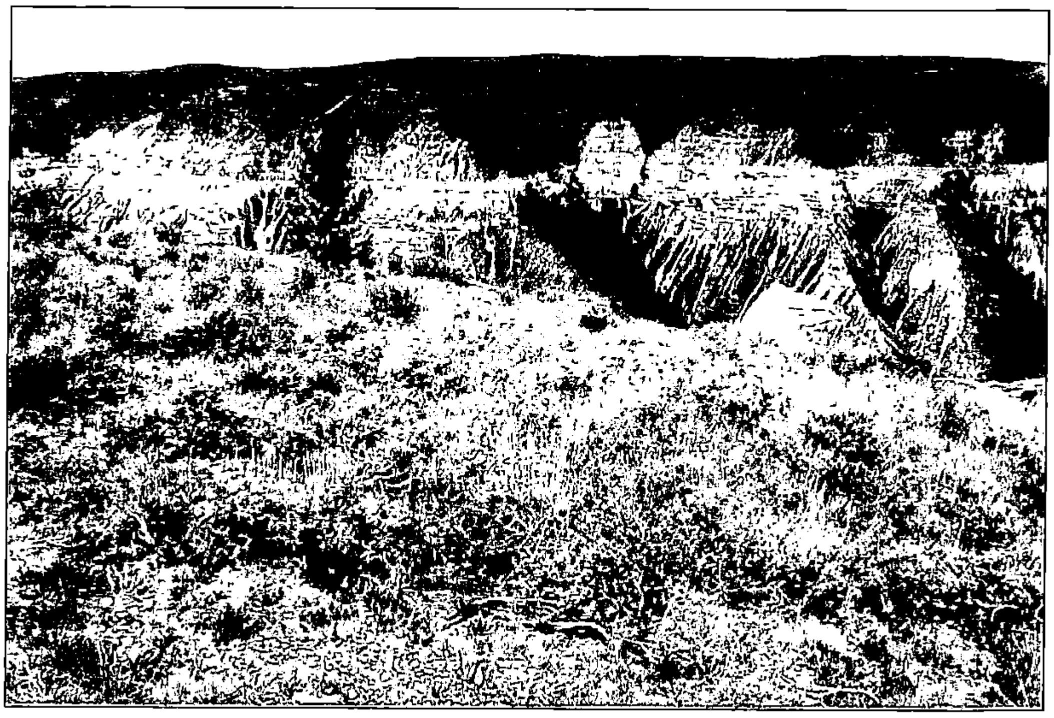
Upon motion duly made and seconded the foregoing Resolution was adopted by the following vote:

COMMISSIONER CHAIR JOHN F. MARTIN Aye / Nay
COMMISSIONER MIKE SAMSON Aye / Nay
COMMISSIONER TOM JANKOVSKY Aye / Nay

GARFIELD COUNTY

GREATER SAGE-GROUSE CONSERVATION PLAN

Adopted: March 18, 2013 (via Resolution 2013-23)
First Amendment to Plan: November 17, 2014
(via Resolution 2014-__)



Garfield County

Garfield County Board of County Commissioners
John Martin, Chairman
Mike Samson
Tom Jankovsky

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CHAPTER 1 Purpose of the Plan

The purpose of the Garfield County Greater Sage-Grouse Conservation Plan (the Plan) is to provide private and public land owners with land management principles, policies, incentives, and best management practices based on the best available science that are tailored to fit Garfield County's unique landscape and habitat characteristics for the betterment of the species.

Because of the County's unique landform, elevation, topography and vegetative cover that differ drastically from the rest of the national range, the Board of County Commissioners (the Board) commissioned an in-depth analysis, based on best available science, to determine what suitable habitat exists in the County at a refined level never before completed to obtain a very realistic and accurate picture of suitable habitat.

The land located within the Plan Area is primarily held in private ownership with the Bureau of Land Management (BLM) managing the only public lands within the Plan Area. Most of the public lands and private property in this area contain significant oil and gas resources that are actively being developed or are intended for future development. By design, this Plan will continuously adapt as science expands for the species and its habitats, as well as acknowledging advances in energy exploration technology that continue to reduce the disturbance footprint. Ultimately, this will result in adaptive land management policies intended for the continued survival and persistence of the species within the Plan Area.

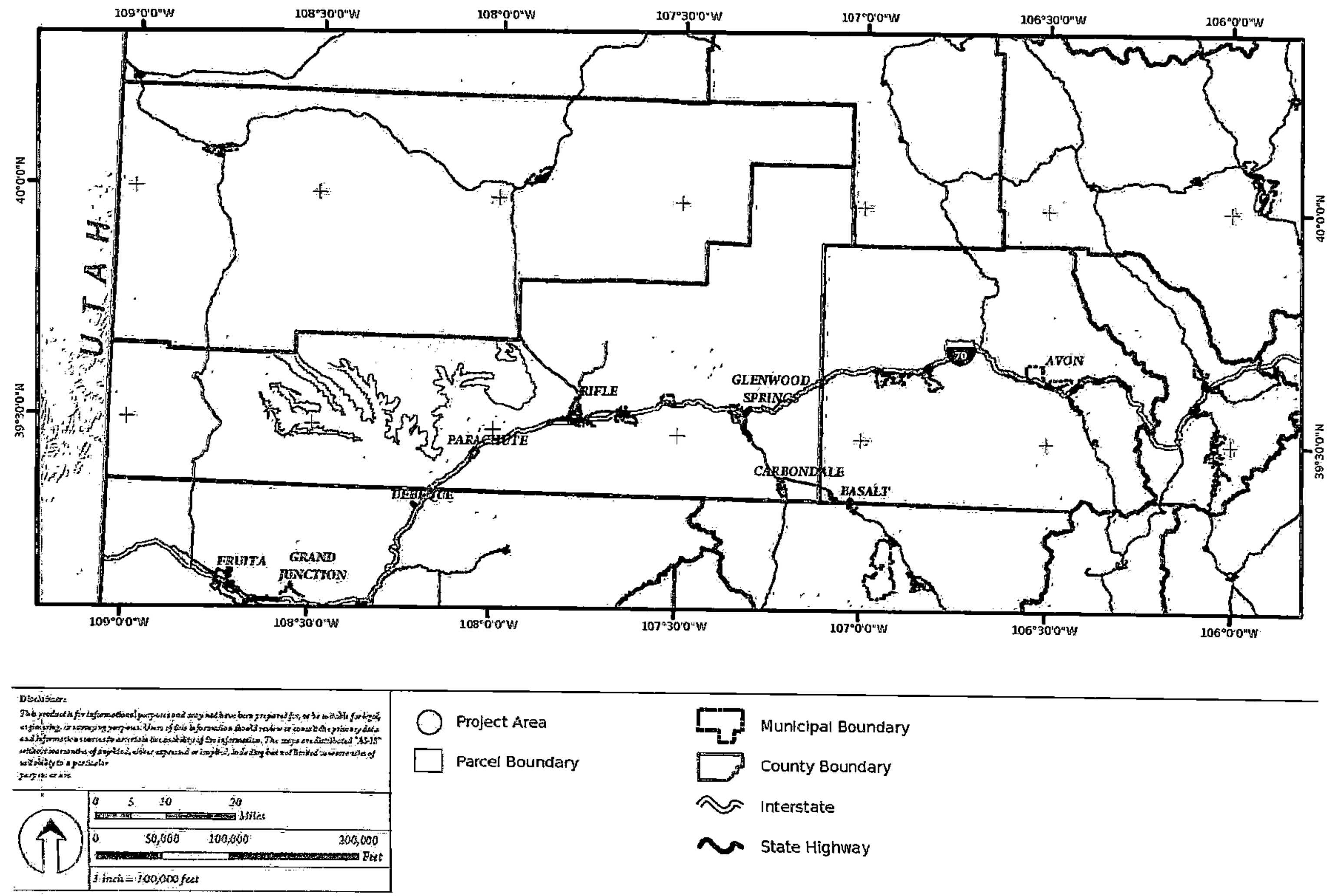
As implemented, this Plan shall require these policies and principles be applied on public lands as 'regulatory assurances' through Coordination and they will be applied on private lands as 'incentive-based assurances.' In this way, this Plan serves as a planning tool for private land owners by informing and improving their conservation efforts on a voluntary basis with the added opportunity to amend this Plan as a result of their stewardship successes.

Finally, because of the scientifically sound habitat modeling conducted to identify the suitable habitat in Garfield County which is the basis of this Plan, the County intends that this Plan may serve as a model for other counties located within the national range. Furthermore, this Plan explicitly relies on the Coordination process that requires federal and state agencies with sage-grouse management responsibilities in Garfield County to ensure that their plans are consistent with this Plan. Ultimately, the Coordination process will be the vehicle that brings disparate parties together with the same intent on making sound land management decisions that benefit the sage-grouse and its habitat recognizing that there are multiple uses being managed at the same time.

CHAPTER 2 Plan Area

The Plan Area includes the greater area where the suitable habitats are located within Garfield County and are primarily limited to the western region of the county in occupied habitats on the Roan Plateau (see **Figure 1**, below). Nearly 70% of the land within the Plan Area does not support habitat characteristics necessary to support the sage-grouse, but within this area there are small but important patches of suitable habitat. In order to ensure that habitat supporting, or has the potential to support sage-grouse is properly managed; this Plan and the associated maps identify the suitable habitats within the Plan Area, utilizing the best available science at the time of this plan's development.

Figure 1: Plan Area



Habitat Categories

Sage-grouse require somewhat different seasonal habitats distributed across sagebrush-dominated communities to complete their life cycle. All of these habitats consist of, are associated with, or are immediately adjacent to, sagebrush. The Plan utilizes the following habitat categories to define habitats in the Plan area, utilizing recent and pertinent research from the Plan area.

1. Suitable Habitat

Suitable Habitat includes all seasonal habitats (including lekking, nesting, brood rearing/summer and winter habitats) within the Plan area. Generalized characteristics of Suitable Habitat include:

- Sagebrush cover is from 10 to 50%, sometimes greater
- Cover of Mixed Mountain Shrubs is not more than 25%
- Distance to nearest forest is over 100 meters
- Distance to shrubby woodlands is over 50 meters
- Slope is flat to shallow
- Location is on or near the top of a ridgeline

Sagebrush- includes all species and sub-species of the genus *Artemisia* except the mat-forming sub-shrub species *frigida.*

Mixed Mountain Shrubs- are shrublands dominated by Utah serviceberry (*Amelanchier utahensis*), Saskatoon serviceberry (*A. alnifolia*), mountain mahogany (*Cercocarpus montanus*), oakbrush (*Quercus gambelii*), bitterbrush (*Purshia tridentata*), and may have a sagebrush component. Mapped Mixed Mountain Shrublands have greater than 10% cover of these non-sagebrush shrub species, as this is the threshold at which sage-grouse begin to show an avoidance of this community type.

Shrubby Woodlands- are vegetation communities dominated by oakbrush or pinyon (*Pinus edulis*) and Rocky Mountain juniper (*Sabina scopulorum*) or Utah juniper (*S. osteosperma*) woodlands. Mapped Shrubby Woodlands have greater than 10% cover of pinyon-juniper, as this is the threshold at which sage-grouse begin to show an avoidance of this community type.

Forests- in the Plan Area include contiguous stands larger than ½ acre of aspen (*Populus tremuloides*), Douglas-fir (*Pseudotsuga menziesii*), mixed conifers (including, but not limited to Douglas-fir, Engelmann spruce [*Picea engelmannii*], subalpine fir [*Abies bifolia*] and ponderosa pine [*Pinus ponderosa*]), pinyon-juniper woodlands, and oakbrush.

2. Seasonal Habitats

While sage-grouse generally change their use of micro-scale habitats throughout the year, sage-grouse may be found within Suitable Habitat at any time of the year. The following definitions describe general characteristics of seasonal habitats.

Nesting- Nesting habitat is generally moderately sized patches of denser and taller sagebrush, further away from roads and other activity areas. General characteristics include:

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- Sagebrush cover is generally from 20 to 50%
- Cover of Mixed Mountain Shrubs is generally not more than 10%
- Distance to nearest Forest is generally over 100 meters
- Distance to Shrubby Woodlands is generally over 50 meters

Brood Rearing- Brood rearing habitats are utilized after chicks have hatched, and are generally more mesic (moist) areas with a higher percentage of forbs and grasses which help provide higher densities of insects, plant material, and seeds for chicks, hens, as well as males during the summer and early fall months. General characteristics include:

- Sagebrush cover is generally from 10 to 30%
- Cover of Mixed Mountain Shrubs is generally not more than 10%
- Distance to nearest Forest is generally over 100 meters
- Distance to Shrubby Woodlands is generally over 50 meters

Winter Habitat- Winter habitat is generally utilized by sage-grouse from November through early April. It is primarily determined by the depth and persistence of snow cover. During more severe winters, snow can limit winter habitat to wind-swept ridges and patches of the tallest sage-brush. During the winter sage-grouse food is strictly limited to sage-brush. However, sage-grouse can do quite well on winter diets. General characteristics include:

- Sagebrush cover is generally >25%
- Cover of Mixed Mountain Shrubs is generally not more than 10%
- Distance to nearest Forest is generally over 100 meters
- Distance to Shrubby Woodlands is generally over 50 meters
- Specific areas where sage-grouse congregate should be mapped as information becomes available

3. Temporarily Disturbed

Temporarily disturbed areas have seen recent vegetation disturbance activities (such as pipeline corridors and wildfire events) and may not support sagebrush cover at a density or height suitable for sage-grouse use. If these areas occur within a block of Suitable Habitat, they will be considered Temporarily Disturbed, and still would be considered as long-term as Suitable Habitat. Temporarily Disturbed habitat will need to be tracked spatially within the Plan Area.

4. Unoccupied Suitable Habitat

Colorado Parks and Wildlife (CPW), the BLM, and energy companies within the Plan Area have conducted multiple research and investigation efforts to determine areas where sage-grouse currently occupy habitats and these areas are relatively well-known. There are also areas that support Suitable Habitat, but for which sage-grouse currently do not occupy these areas or the status of occupancy are unknown. These areas, for whatever reason, are deemed less-than-optimal by sage-grouse (e.g., due to predation pressures, non-lethal disturbances, an ineffectively small area of suitable habitat, etc.) and thus sage-grouse prefer to utilize other areas. These areas may also be degraded with regards to habitat, and do not meet life-history requirements for sage-grouse, or (as an example) may have low levels of invasion by pinyon-juniper trees, and is therefore ineffective habitat.

5. Lek No Surface Occupancy Habitat

Lek No Surface Occupancy (NSO) Habitats are areas where an Active Lek has been cited (and determined by the County to exist), which is not located in Temporarily Disturbed or Unoccupied Suitable Habitat.

CHAPTER 3 Habitat Mapping, Modeling & Methodology

This Chapter details the process by which Suitable Habitats for Greater Sage-Grouse were developed within the Plan Area.

Section 1 Goals and Objectives of Mapping Process

The habitat mapping provided by state and federal agencies in 2012 for Greater Sage-Grouse in the Plan Area previously occurred at a landscape level that did not accurately address the unique topography of the Roan Plateau, or provide planning information at resolution accurate enough for County to use in the Plan, and for relevant land-use planning activities potentially occurring within the Plan Area (Perdue and Petterson 2014). Because of the significant implications on land use and ongoing land management, the most accurate delineation of habitat was deemed necessary by the County. This habitat mapping process followed the latest and most relevant peer-reviewed habitat mapping process available for mapping large and diverse areas.

The project objective was to locate and quantify the availability of suitable sage-grouse habitat on the Roan Plateau within Garfield County, independent of analyses already performed by state and federal agencies, as well as independent of other habitat mapping efforts produced by energy companies, but still incorporating peer-reviewed and accepted habitat parameters for sage-grouse produced by the scientific community.

The process incorporated the following:

- Phase 1: Conducted a literature search and determined relevant criteria for identifying suitable habitat for the Greater Sage-Grouse within northern Colorado. Build generalized multi-criteria suitability spatial models to model areas for general habitat suitability.
- Phase 2: Re-map vegetation within the PPR Study Area to increase habitat accuracy.
- Phase 3: Perform field verifications to validate accuracy of vegetation mapping to on-the-ground habitat conditions.
- Phase 4: Build statistically robust multi-criteria suitability spatial models to delineate suitable Greater Sage-Grouse habitats.

The 220,969-acre Plan Area occurs on the Roan Plateau within Garfield County as shown in **Figure 1**. The spatial extent of the Plan Area represents all areas within the County currently indicated as Preliminary General Habitat (PGH) or Preliminary Priority Habitat (PPH) as mapped by CPW and adopted by the BLM. Of the 220,969-acre PPH analysis area, 61,338 acres (28%) are BLM Lands, while the remaining 159,631 acres (72%) are private lands.

Table 1: Literature References and Habitat Parameters Employed

Author	General Habitat	Lek/ Breeding	Nesting	Brood Rearing Summer	Summer-Fall	Winter
Apa 2010[1]						
Sagebrush	-	-	37%	30%	-	-
Total Shrub	-	-	68%	34%	-	-
Walker 2010						
Sage *dominance*	-	57-96% (100m)	-	50-92% (100m)	-	-
Sage+grass+MMS	-	90-98% (350m)	-	88-91% (350m)	-	-
Forest	-	0.5-6.5% (350m)	-	4.5-11.5% (740m)	-	-
MMS[2]	-	0-1.2% (740m)	-	0-1.3% (740m)	-	-
CO Sage-Grouse Consv. Plan 2008						
Sagebrush cover	-	20-30% around leks	15-38% avg. 27%	10-15% 20-25% for escape	>15%	>25%
NTT Report[3]						
Sagebrush cover	-	-	-	10-25%	-	-
Connelly et al. 2000						
Sagebrush cover	-	15-25%	-	10-25%	-	10-30%
Grass/forb cover	-	>25%	-	>15%	-	NA
Area with suitable habitat	-	>80%	-	>40%	-	>80%
Connelly et al. 2011						
Sagebrush cover	12-48%	Follow Connelly et al. 2000				
Grass/forb cover	-	Follow Connelly et al. 2000				
"–" indicates that no parameters were given in the publication						

Section 2 Model Methodology

To model general Greater Sage-Grouse habitats in the PPH area in Garfield County, multi-criteria suitability models were developed in a Geographic Information System (GIS) using relevant resource criteria (see **Appendix B- Sage-Grouse Habitat Model** for a detailed description of the methodology). The multi-criteria suitability models utilized two distinctly different methods of modeling; **(1) weighted overlay modeling** using a Resource Selection Function (RSF) and **(2) fuzzy modeling**. Furthermore, multi-criteria suitability models can employ two methods in developing the variables as inputs to the model framework; inductive (i.e., empirical, inferred from existing data) or deductive (i.e., non-empirical, developed from expert opinion). Due to the availability of field-collected sage-grouse signage data (e.g., feathers, droppings, located birds, lek locations, etc.), an inductive method was employed for modeling Greater Sage-Grouse habitat suitability.

Weighted overlay models function by applying logical mathematical arithmetic to multiple criteria, allowing for diverse and dissimilar criteria to be inputs to an integrated analysis (Mathworks 2014). When applied to habitat modeling, weighted overlay models are commonly referred to as a Habitat Suitability Index (HSI). In the instance of habitat modeling, the model scales, weights and integrates diverse spatial data to measure the habitat suitability of a given location on a common, relative scale. The weighted overlay approach using an RSF was selected for three reasons. First, HSI's are widely accepted and employed by state and federal wildlife agencies to model species distribution for resource management, planning and population viability analyses. In fact, HSI's are the basis for the U.S. Fish and Wildlife Service's (USFWS) Habitat Evaluation Program (HEP). Secondly, weighted overlay models have previously been employed, and are currently being employed in other ongoing research projects to study Greater Sage-Grouse habitat availability, providing results as a means for direct comparison to other HSI models. Third, using an RSF allows species distribution to be modeled using known selection preferences from statistical inference of field-collected data, thereby predicting suitable habitat patches based on known behavior of the local population.

While HSI's are widely employed as a means for modeling species' habitats, by contrast, the application of fuzzy modeling to predict species distribution has been limited to date. Fuzzy models are based on the mathematical concept of fuzzy logic, which recognizes that most objects do not have clearly defined boundaries and therefore cannot be described as only belonging to one specific category (Kainz 2008). Rather, fuzzy systems recognize the complex nature of behaviors and environments and provide a method for handling the vagueness and uncertainty inherent to both phenomena. Fuzzy models are developed using natural language to compose a set of rules that describe a certain phenomenon. For example, a rule may be stated as: "If a site is flat and the site is near water, then the site is optimal."

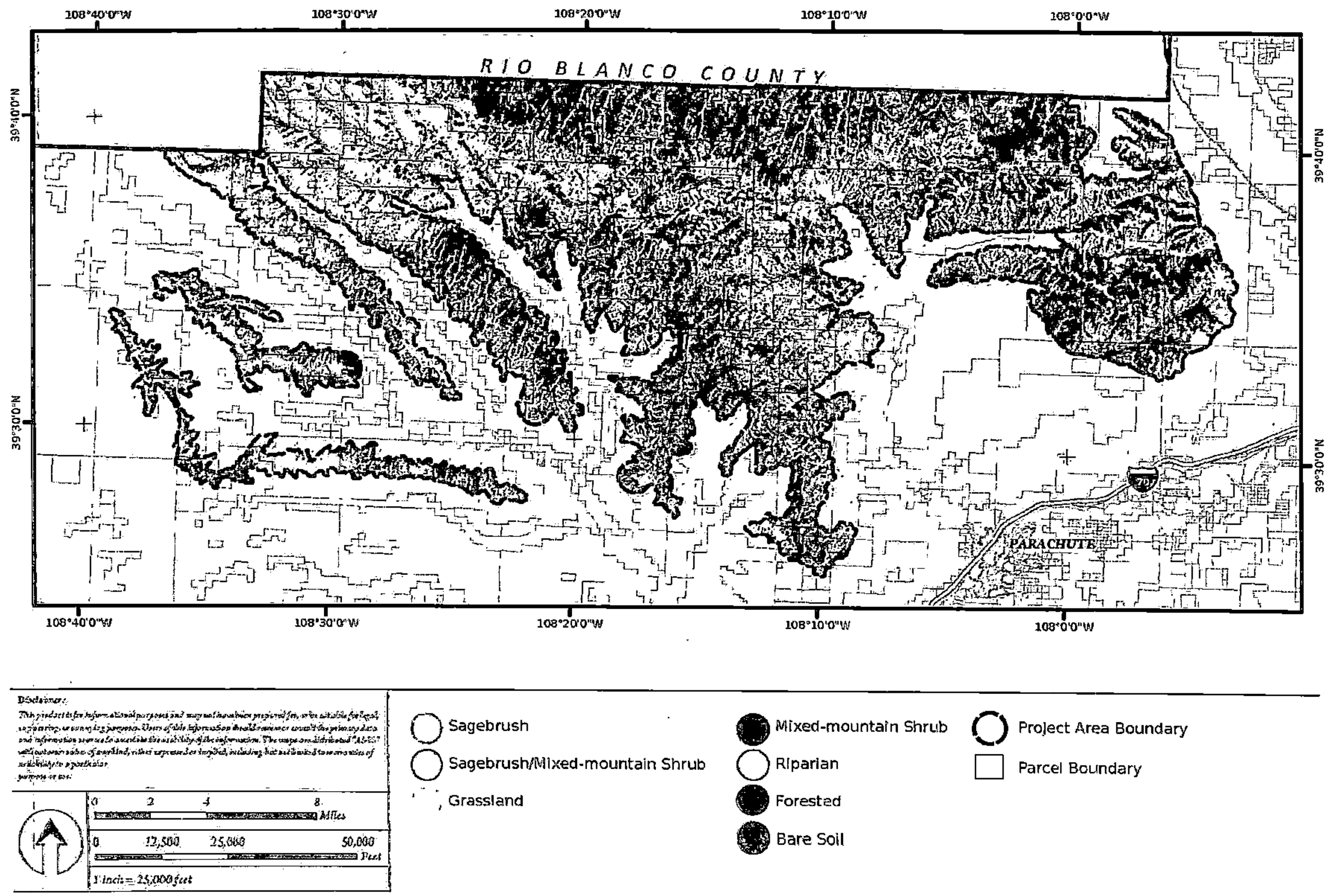
Once all fuzzy rules are established for a fuzzy model, fuzzy sets are then developed based on the pre-defined rules. Fuzzy sets are classes that allow for varying degrees of membership, rather than forcing the set to belong entirely to one class or another. For example, when considering proximity to an existing object, the distance of a given location may be described as near or far. In a weighted overlay model, the response is binary in nature; the distance of the location to the object is either near or far. However, in a fuzzy set, the same distance can be described as both near and far.

The development of a fuzzy model to study Greater Sage-Grouse habitat suitability was pursued for two primary reasons. First, the method has a distinct advantage over other model frameworks in that it considers vagueness and imprecisions that are inherent to spatial data. Secondly, because it is an intuitive system and constructed using natural language, fuzzy models can be easily understood by a wide variety of audiences.

Methods

In both modeling methods, numerous variables were considered in the analysis that may influence sage-grouse habitat selection. The variables were broadly classified as either habitat characteristics or topographical factors. All variables describing habitat characteristics were derived from a digital vegetation map developed at a 2 meter cell resolution through supervised image classification of 1 meter color-infrared aerial photography collected in 2012 as part of the National Agricultural Imagery Program (NAIP) administered by the U.S. Department of Agriculture (USDA 2012). A detailed description of the image classification process is provided in **Appendix B**. Vegetation cover types derived from the image classification process are displayed in **Figure 2**. All variables were analyzed and considered at three spatial scales, because while sage-grouse are known as a landscape level species, most of the contemporary research documenting sage-grouse use has been performed at the local scale. The scales of available habitats that influence sage-grouse selection and non-use are currently unknown; therefore, the contributing variables that may influence habitat selection are tested at multiple scales to determine which scales guide habitat selection. The selected scales employed in this analysis represent a local scale (e.g., 100 meters), an intermediate scale (e.g., 350 meters) and a landscape-level scale (e.g., 1 kilometer).

Figure 2: Vegetation Types



Spatial Data Collection

Field-collected data of point locations of sage-grouse signage were collected and compiled from three individual private landowners within the PPR Study Area (WWE 2008). In total, the compiled dataset contained 1,174 unique signage points collected from 2005 to 2012 across a contiguous area totaling 375 km^2 completely contained within the broader PPR Study Area (WWE 2008). The private lands where the field surveys were conducted occur in the central portion of the broader PPR Study Area and are considered to be representative of the diverse habitat types that naturally occur in the region. The signage point data consisted of locations indicating presence of sage-grouse, including feather and pellet presence, lek locations and physical bird sightings collected during the summer season when the PPR Study Area is snow-free and easily accessible. No telemetry data (i.e., sage-grouse outfitted with a GPS or radio-collar) were available for use in this analysis. Prior to, and after the acquisition of the sage-grouse point data, there has been a number of natural gas exploration and development activities in the analysis area, including road construction, natural gas pad development, compressor station construction, and other natural gas related support facilities. Because of these activities and the changing landscape, there was no attempt to capture these habitat impacts in the analysis, as it would have been very difficult to draw a point-in-time by which to incorporate these anthropogenic impacts.

While this data can show presence and seasonality of use, interpretation of how sage-grouse are using the area (e.g., summer foraging, winter foraging and nesting) is somewhat subjective and difficult to accurately predict. Some sage-grouse sign (such as roost piles) can reliably be used to predict winter time use, but single pellets, feathers, or tracks were assumed to not provide enough data to accurately describe use, therefore our models do not attempt to discern how seasonal habitats are being utilized by sage-grouse.

Weighted Overlay Modeling and the Resource Selection Function

The suitability of sage-grouse habitat using a weighted overlay approach was conducted using a RSF. The RSF was constructed on a presence vs. available habitat design because data contained presence-only records. This approach estimates habitat selection using a logistic function that transforms available resources into habitat suitability (Johnson et al. 2006).

The regression coefficients obtained from the analysis were applied to the respective spatial data layers for each explanatory variable as a weighted linear combination in a GIS to produce an index indicating habitat suitability for Greater Sage-Grouse. The results rank habitat suitability for sage-grouse on a continuous index of 0 to 1; 0 represents 0% probability of suitable sage-grouse habitat while a value of 1 represents 100% probability of suitable habitat for the species.

Fuzzy Modeling

Following development and analysis of the RSF model, a fuzzy model was developed to model suitable sage-grouse habitat within the PPR Study Area. All explanatory variable combinations were used to form the fuzzy model, excluding mixed sagebrush vegetation communities (e.g. sagebrush-grassland mix and sagebrush-mixed mountain shrub mix). Unlike RSF models that determine the most significant contributing explanatory variables and assign weighted coefficients, fuzzy models utilize all sets of explanatory variables without weighting assigned.

The fuzzy model was developed to distinguish between suitable and unsuitable habitats for sage-grouse in the PPR Study Area. As such, the fuzzy model equation was constructed using linguistic descriptions involving all explanatory variables. The fuzzy rules for the model were developed using 25 explanatory variables and presented in **Table 3** below.

Table 4: Fuzzy Model Rules

A site is considered suitable for Greater Sage-Grouse habitat if it meets the following criteria:		
Criteria	**Scale**	**Definition**
Slope is not steep	100 m	'not steep' defined as < 24%
	350 m	'not steep' defined as < 31%
	1 km	'not steep' defined as < 33%
Location is on or near a ridge	100 m	Defined as TPI value > 435
	350 m	Defined as TPI value > 435
	1 km	Defined as TPI value > 424
Surface curvature is more flat	100 m	'more flat' defined as < 10.71
	350 m	'more flat' defined as <13.62
	1 km	'more flat' defined as <14.46
Surrounding vegetation is dominated by sagebrush	100 m	'dominated' defined as > 48% presence
	350 m	'dominated' defined as > 41% presence
	1 km	'dominated' defined as > 35% presence
Proportion of mixed mountain shrubs are moderately low	100 m	'low' defined as < 22% presence
	350 m	'low' defined as <34% presence
	1 km	'low' defined as < 36% presence
Proportion of grasslands are low	100 m	'low' defined as < 5%
	350 m	'low' defined as < 5%
	1 km	'low' defined as < 5%
Presence of bare surfaces are moderately low	100 m	'low' defined as < 37%
	350 m	'low' defined as < 25%
	1 km	'low' defined as < 25%
Proportion forest is low	100 m	'low' defined as < 6%
	350 m	'low' defined as < 10%
	1 km	'low' defined as < 13%
Distance to forest is far		'far' defined as > 226 ft.

Results

The model results were validated using a cross-validation method used to correlate bins with area-adjusted frequencies of probability of use (see **Appendix B**). The validation technique involves five steps:

1. Divide the resulting prediction surface into a specified number of equal-area bins.
2. Determine the midpoint value for each bin area.
3. Calculate the utilization rate for each bin using the midpoint value of the bin and the area of the bin.
4. Calculate the expected number of validation records in each bin using the utilization rate from Step 3.
5. Compare the expected number of validation records to the observed number of validation records captured in each bin.

RSF Model Results

The RSF model results were split into 6 equal-area bins. The 235 field-collected presence locations withheld for model validation were cross-referenced with the bins to count the number of known observations that fell within each bin. All midpoint values were then determined to calculate the expected utilization rate for each bin. The observed and predicted location numbers were converted to percentages to assess model performance.

The RSF model validated well, supporting a good fit between observed and predicted frequencies. The top two bins predicted 97% occupancy while observed occupancy totaled 99%, representing 73,280 acres of suitable habitat within the PPR Study Area as shown in **Figure 3.** Bins 1-4 did not meet significance criteria, whereby occupancy would not likely occur ≥3% of the time (results for bins 1-4 were therefore not displayed on Figure 3).

Fuzzy Model Results

Similar to the RSF model, an attempt was made to split the fuzzy model results into six (6) equal-area ordinal bins. However, due to the similarity of the lower values returned in the predicted surface, only four distinct bins could be produced; the lowest ranked bin (bin 1) captured approximately one-half of the study area, but due to the homogeneity of the results it could not be further subdivided. Excluding the reduced number of bins, the fuzzy model results were validated using the exact same method applied to the RSF model validation explained above.

The fuzzy model validated very well, supporting a strong fit between observed and predicted frequencies. The top two bins predicted 98% occupancy while observed occupancy also totaled 98%, representing 72,852 acres of suitable habitats within the PPR Study Area as shown on **Figure 4.** Bins 1 and 2 did not meet significance criteria, whereby occupancy would not likely occur ≥2% of the time (results for bins 1 and 2 were therefore not displayed on Figure 4).

Greater Sage-Grouse Management Area

Based on the results of the Fuzzy and RSF modelling, areas deemed as suitable habitats from both models was combined in order to provide a more conservative habitat map for sage-grouse within the PPR Area. Within the modelled suitable habitat area, the principles and policies contained within this Plan shall be required for the management of sage-grouse and its habitat as depicted in **Figure 5- Garfield County Greater Sage-Grouse Management Areas**, and as detailed in **Chapter 4 Plan Implementation.** Within the Greater Sage-Grouse Management Areas, Garfield County will require consultation with applicants for activities within this area. A field verification and accompanying assessment of sage-grouse habitat conditions would be required to either dismiss the value of the habitat or that there is a need to avoid or mitigate potential impacts.

Figure 3: RSF Model Results

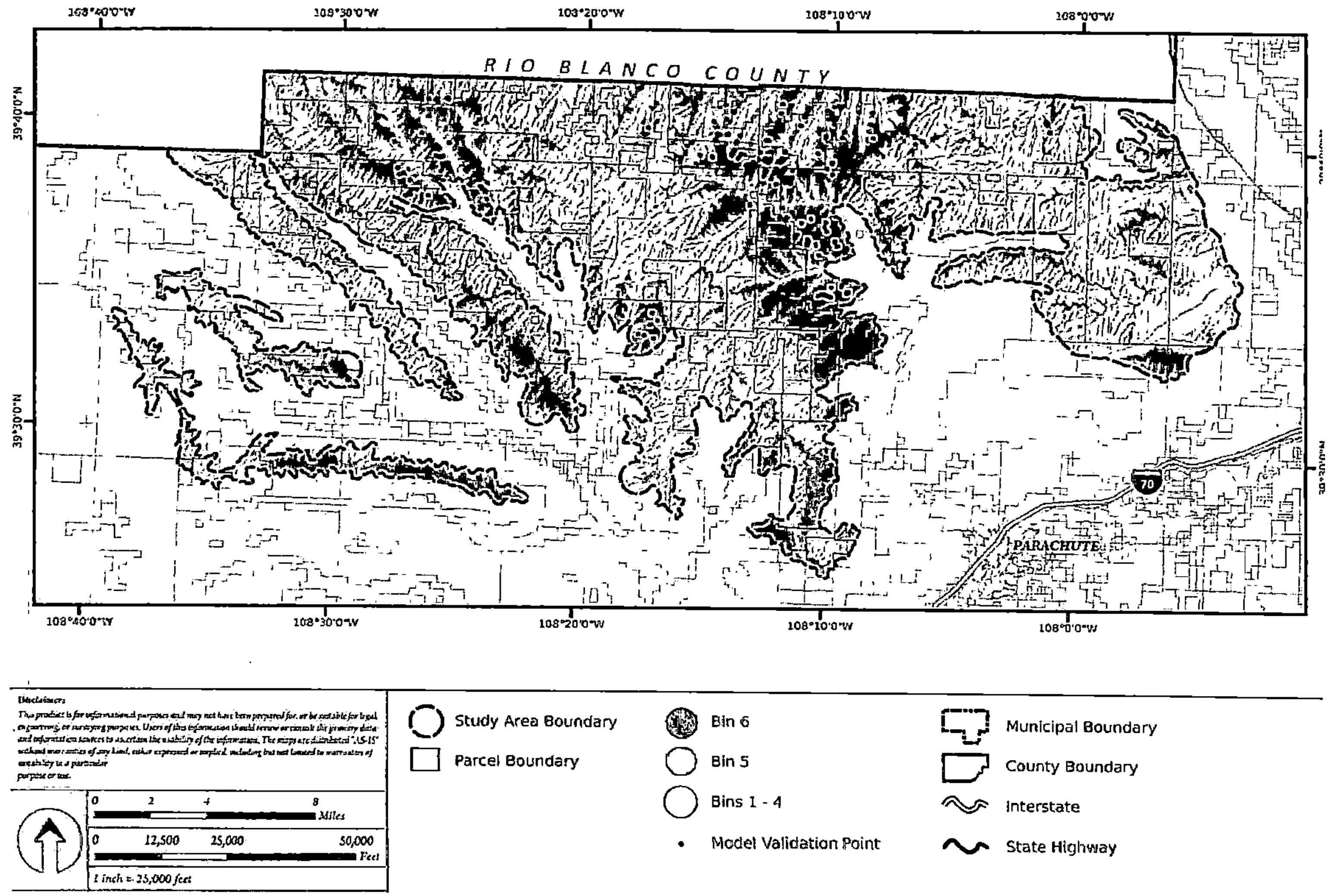
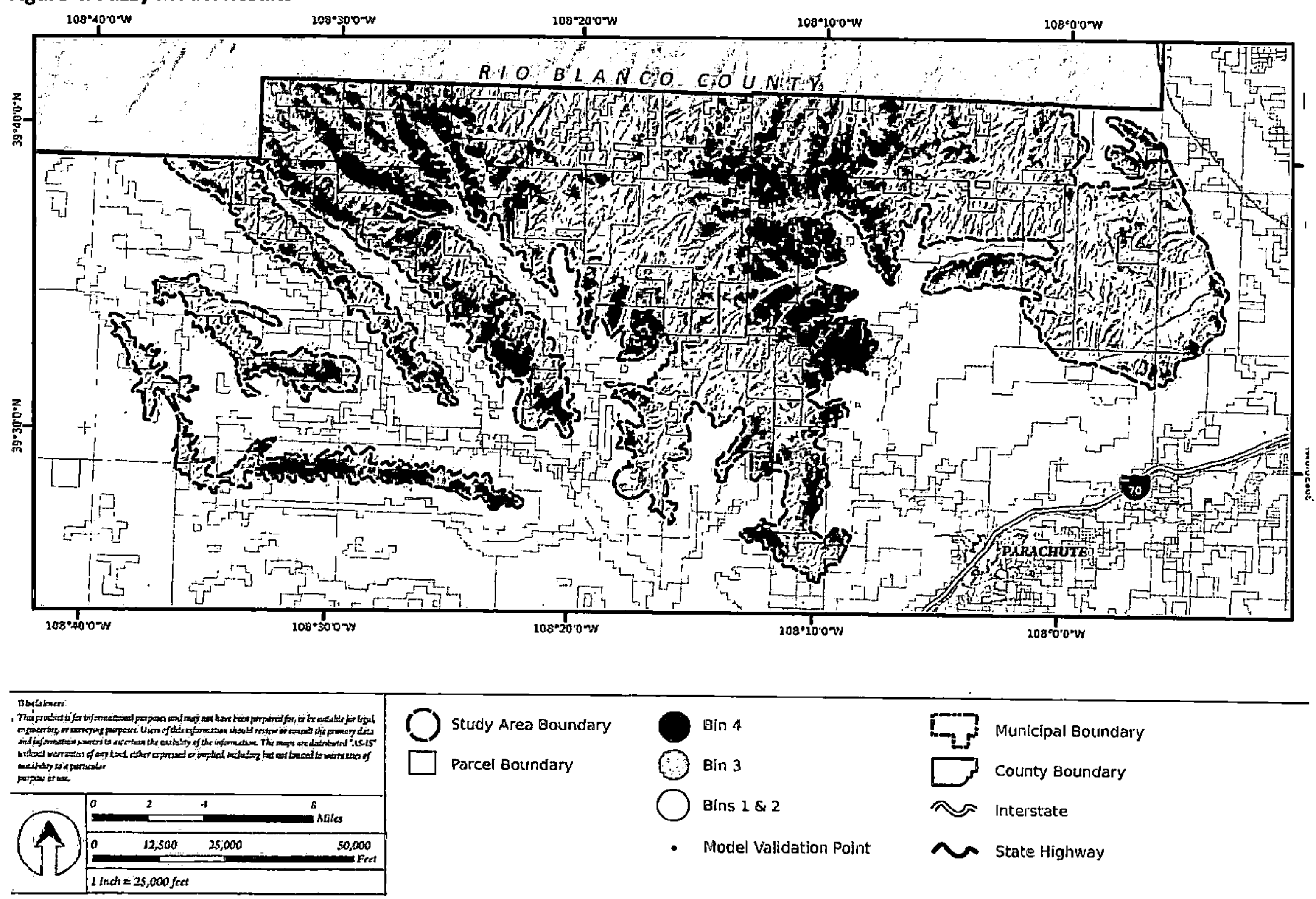


Figure 4: Fuzzy Model Results



CHAPTER 4 Plan Implementation

The Garfield County Board of County Commissioners (the BOCC) shall be responsible for managing and implementing the Plan. The principles and policies contained within the Plan shall be used to address functional surface disturbance within Suitable Habitats in the Plan Area within the political boundaries of the County as depicted on **Figure 5: Greater Sage-Grouse Management Plan Areas.** The Garfield County Greater Sage-Grouse Management Plan Areas (MPAs) were developed by combining the suitable habitat areas resulting from both habitat models described in Chapter 3. In total, the MPA's encompass 93,895 acres within Garfield County, approximately 43% of the PPR Study Area. 74,819 acres (80%) are managed under the Private Lands Management Area Plan while the remaining 19,076 acres (20%) are managed under the Public Lands Management Area Plan.

A. Implementation on Public Lands

The principles, policies, and best management practices contained within this Plan shall be required for the management of sage-grouse and its habitat on public lands that contain suitable habitat as depicted as Public Lands Management Areas shown in **Figure 5: Greater Sage-Grouse Management Plan Areas.**

B. Implementation on Private Lands

For private lands in the Plan Area, the principles, policies, and best management practices contained within this Plan are considered voluntary but are strongly encouraged for the management of sage-grouse and its habitat. In this way, private land identified as Private Lands Management Area in **Figure 5: Greater Sage-Grouse Management Plan Areas** shall serve as a consultation map whereby land use projects requiring Garfield County review and approval under the Garfield County Land Use and development Code of 2013, as amended, are encouraged to consult with a professional biologist who can provide an opinion as to the precise nature of the habitat as well as potential measures / mitigation that could be implemented if needed.

C. Implementation Process

This policy shall serve as the primary conservation policy for the sage-grouse in Garfield County. The BOCC has the unique authority to require federal and state agencies to coordinate their plans and policies with the County, therefore ensuring that all entities with responsibilities for the species and habitat are working together efficiently and effectively and not pursuing counterproductive measures. This Plan is designed to serve as the comprehensive planning document for the Greater Sage-Grouse in Garfield County.

While recognizing that each agency has its own planning processes, federal agencies are required to not only consider the County's policies, but work to resolve conflicts and make federal plans consistent with the County's policies (43 USC 1712). Federal statues require that the County's policies are integrated into the federal conservation strategy for the sage-grouse on federal lands within the County's borders. The State of Colorado has given Garfield County planning authority over lands within the County's borders, ensuring the coordination of the County's sage-grouse policy with state agencies as well.

Implementation of this Plan will be conducted through a formal coordination process with all agencies that have jurisdiction and/or responsibility for the sage-grouse and/or its habitat. The Plan will serve as the unifying and primary planning document within Garfield County.

Specifically, the BOCC shall utilize this Plan as a tool to evaluate and provide comment regarding land management decisions on both public and private lands for which it has land management jurisdiction. More specifically, the BOCC shall utilize this Plan in evaluating land use / development applications submitted under the Garfield County Land Use and Development Code of 2013, as amended as well as ensuring that any federal or state land management action remains consistent with this Plan.

D. Plan Update / Amendment Process

This Plan is managed under adaptive management principles where it is understood that the scientific understanding of the species and its habitat in will be continually expanding. This requires that the policies, principles, and best management practices of this Plan be frequently evaluated and modified as warranted by the best available science appropriate for the unique Plan Area in Garfield County.

1. Annual Review

The BOCC will conduct an annual Coordination review, commencing one year from the date of enactment of this Plan with the federal and state agencies that have habitat or species responsibilities within the Plan Area. This review process will evaluate the availability and condition of habitats, direct and indirect impacts, conservation measures, policies and best management practices being implemented by each agency for their effectiveness and applicability to the Plan Area.

Also incorporated in this review is any new science and, if warranted, modifications to the best management practices, policies, and conservation incentives within the Plan.

The Coordination review shall take place in government-to-government meetings between the different agencies and the BOCC.

The BOCC will also initiate meetings with entities that have private property interests in the Plan Area for the purpose of analyzing their conservation efforts and effectiveness, as well as any new science they may be able to contribute to the process to ensure Plan updates are also based on the best available science.

The consideration of changes to the Plan shall be discussed in these coordination meetings, followed up with a draft Plan update to be shared with all agencies through the Coordination process and private entities with private property interests for input. The input shall be considered and incorporated where appropriate into a formal written Plan update to be reviewed approved by the BOCC within 120 days of the submittal date of the requested change.

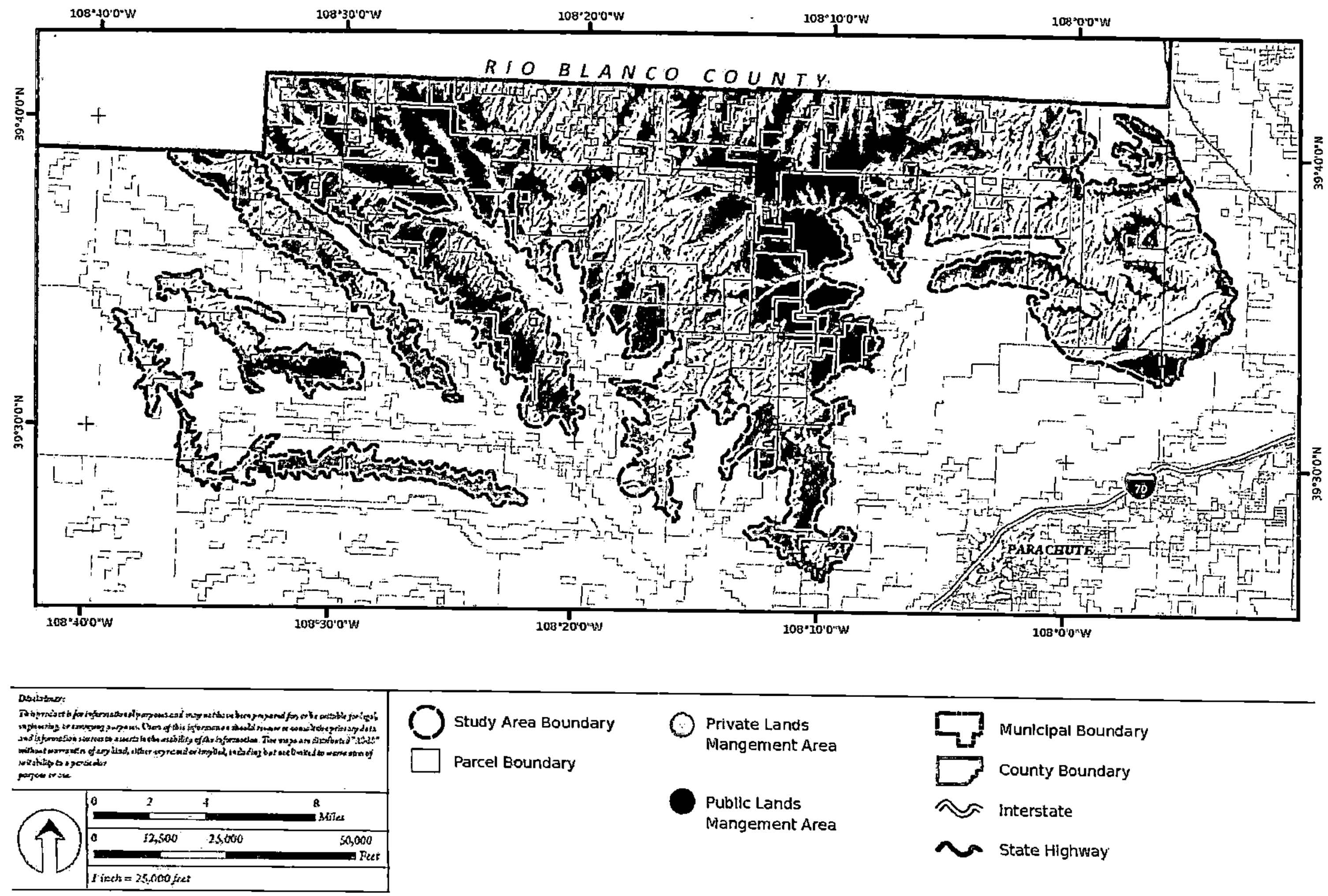
2. New Scientific Information

If at any time between the annual review period where federal or state agencies, or private entities with property interests in the Plan Area become aware of or acquire new science regarding the species or its habitat in the Plan Area within Garfield County that may warrant changes to the best management practices, conservation measures, or policies within this Plan, then they shall submit a written report to the County, including the scientific review and supporting data, for the County's consideration. If the BOCC finds changes to the Plan are warranted then it can initiate a formal review of the Plan in coordination with all entities.

3. Additional Coordination Meetings

Additional Coordination meetings are encouraged beyond the required annual review and new scientific information review for the purpose of keeping apprised of and working to resolve all issues impacting the sage-grouse.

Figure 5: Garfield County Greater Sage-Grouse Management Areas



CHAPTER 5 Principles

Management Plan Areas. The Garfield County greater sage-grouse Management Plan Areas (MPA) were developed by combining the suitable habitat areas resulting from both habitat models described in **Chapter 4.** In total, the MPA's encompass 93,895 acres within Garfield County, approximately 43% of the PPR Study Area. 74,819 acres (80%) are managed under the Private Lands Management Area Plan while the remaining 19,076 acres (20%) are managed under the Public Lands Management Area Plan.

The Plan Principles are designed to inform and guide all decision making, regardless of specific issue or impact, as they relate to the well-being of the sage-grouse in Garfield County.

1. The sage-grouse habitat in Garfield County is naturally fragmented, as a result of topography and the patchy nature of sagebrush, non-sagebrush shrubs, meadows, aspen, and conifers in the Plan Area. Expanses of contiguous sagebrush, necessary to support a large stable population (as described by the USFWS in their March 2010 candidate determination notice), do not exist in Garfield County. Additionally, the sage-grouse population inhabiting Garfield County is a peripheral population located on the far southeastern edge of the species range. As a result, the stewardship of the population requires detailed knowledge of local conditions, including the mapping of Suitable Habitat (as determined by the process in **Appendix B**).
2. Human disturbances to Suitable Habitat are minimal, generally temporary in nature, and can be avoided or successfully mitigated in most cases.
3. Sage-grouse management decisions shall be made based on the best available scientific information that is applicable to sage-grouse habitat in Garfield County. The scientific information used will be consistent with standards of the Information Quality Act (see definitions of Quality, Objectivity, Utility and Integrity), as determined by the County.
4. Land management plans of all government agencies that have ownership or management responsibilities for the lands or species within Garfield County shall be consistent with the policies set forth in this plan subject to valid existing rights.
5. For private lands, the polices set forth in this Plan are incentive-based to be encouraged through conservation incentives and best management practices that do not encumber private property rights of the landowners but do address long-term habitat needs of sage-grouse.

6. No policies shall infringe on the private property rights of any landowner within Garfield County. All species and land coverage information gathered on private property shall be treated as the property of the landowner and shall not be used by any private or government entity for any purpose unless express, written permission has been obtained by the landowner.

7. All sage-grouse habitat and species management programs that impact the County, administered by federal and state government agencies, shall be coordinated with Garfield County, and the data collected by state and federal agencies will be shared with the County in a timely manner or be provided to the County regardless of completeness at the formal request of the County.

8. All Federal lands within the Plan Area containing suitable habitat for sage-grouse shall be managed to continue the multiple-uses of the lands as required by 43 U.S.C 1701(a)(7). No policies shall be implemented that prescribe the management of the land for a single purpose, but all functions of the land, including providing habitat for wildlife and supporting the productive uses of its resources, shall be considered with the objective of balancing and continuing all uses of the land. Unlike government-owned land where there are many property interest holders and the multiple uses must be maintained, private land owners have more discretion to manage their property for the primary purpose of conserving sage-grouse, if so desired.

9. The ability of wildlife, including sage-grouse, to habituate to inanimate manmade structures and changes to the landscape shall be acknowledged.

10. All sage-grouse conservation measures enacted on federal land or through a federal nexus shall be for the purpose of directly benefiting the species and its verified habitats. These measures shall be scientifically defensible. All data and information used to produce conservation measures shall be made available to the public and the County and shall be coordinated with the County. Additionally, the balance of impacts to other species and to human welfare must be weighed prior to approval and implementation. All planning efforts shall be governed through adaptive management principles to ensure use of the latest scientific research on sage-grouse and their habitat, best management practices, technological advances, and incorporation of impact avoidance, minimization, and mitigation opportunities are vetted and utilized.

CHAPTER 6 Policies

The policies set forth in this chapter are for the purpose of providing specific conservation measures that are to be implemented in the Plan Area in order to avoid, minimize and if necessary, mitigate impacts that may affect the suitable (and assumed occupied), temporarily disturbed and unoccupied habitat of the sage-grouse, within suitable habitats as depicted on **Figure 5: Garfield County Greater Sage-Grouse Management Areas.**

Section 1 Travel and Transportation

Because the majority of roads in the Plan Area are private roads with controlled access that are used on a limited /seasonal basis, they do not measurably contribute to bird collisions. These roads do not produce barriers to movement for sage-grouse. These same roads provide necessary access to the area to ensure proper management of resources, infrastructure and assets, and accessibility in the event of emergencies. Very few roads support through traffic. Because of the nature of the terrain, company policies, road surfaces, and driving conditions, vehicles maintain low speeds and the risk of collision with the sage-grouse is minimal.

Policy

A. Limit motorized travel to existing roads, primitive roads, and trails, as verified by Garfield County, at a minimum in Suitable Habitats and in Lek NSO areas.

B. County Roads, as determined by Garfield County and identified on County Maps, within Suitable Habitats, shall only be closed or restricted by Garfield County.

C. Allow no upgrading of existing routes, as verified by Garfield County, in Suitable Habitat or Lek NSO areas that would change route category (road, primitive road, or trail) or capacity unless the upgrading would have minimal impact on sage-grouse habitat, is necessary for motorist safety, or eliminates the need to construct a new road.

D. When reclaiming roads and trails, use locally native seed mixes as prescribed by a professional biologist and use transplanted or seeded sagebrush unless unfeasible.

Section 2 Recreation

Recreational use within the Plan Area is extremely limited because the majority of the land is privately held and access is strictly controlled. This significantly reduces potential direct or indirect impacts to sage-grouse or their habitats by the general public. Any plan for creating new or additional recreational opportunities on federal lands in Suitable Habitats must provide Garfield County a sage-grouse impact analysis for review.

Policy

A. Limit motorized recreational use to existing roads, primitive roads, and trails (as verified by Garfield County), in Suitable Habitat and Lek NSO areas.

B. Avoid all Suitable Habitat and Lek NSO areas as identified on Garfield County Habitat Maps.

Section 3 Lands and Realty Management

Habitats within the Plan Area are naturally fragmented and patchy; therefore, there are opportunities for new roads and energy development infrastructure to be placed outside Suitable Habitats. Further, any land acquisition shall be by mutual agreement between public and private entities.

Policy

A. Placement of new above-ground power lines in Suitable Habitat and Lek NSO areas is prohibited.

B. Bury new powerlines within Suitable Habitats and follow existing corridors unless there is a technical infeasibility, subject to valid existing rights. Anti-perch devices may be used where powerline burial is technically infeasible.

C. Private land ownership in sage-grouse Suitable Habitat areas should be continued and encouraged as private land conservation efforts have been the most effective methods to preserve diverse and healthy habitats for many species, including sage-grouse.

Section 4 Range Management

Garfield County continues to enjoy a long history of livestock grazing on both private and public lands. When properly managed, livestock can coexist with sage-grouse as well as help improve suitable habitat and decrease fire hazards.

Policy

A. Maintain sustainable grazing consistent with historic land use and ranching practices that are sustainable for both agricultural operations as well as sage-grouse habitats, as recommended by the U.S. Department of Agriculture and Natural Resources Conservation Service throughout the Plan Area, utilizing the best available science.

B. Livestock grazing can be utilized as a tool to properly manage sage-grouse habitat, and should not be removed from the Plan Area.

C. Any grazing restrictions or conservation measures that are put in place through a grazing permit shall be based solely on the conditions and activities specific to that permitted grazing allotment.

Section 5 Predation

Predation of sage-grouse eggs, juveniles, and adults occurs naturally, but can increase in association with human development, unless precautions are undertaken. Scientific research has shown that the predators on sage grouse are generalists, meaning that they prey on other species as well, and in some cases their populations are subsidized by human sources of food. Sage-grouse eggs are preyed upon by red foxes, coyotes, badgers, ravens, and (sometimes) black-billed magpies. Common predators of juvenile and adult sage-grouse include golden eagles, prairie falcons (as well as other raptors), coyotes, badgers, red fox and bobcats. Younger birds (especially broods), may be preyed upon by raven, red fox, northern harrier, ground squirrel, snakes, and weasels. However, of these predators, research has shown that ravens are the most abundant and have the greatest impact on the populations studied.

While predation on sage grouse occurs at all stages of the life cycle, it is predation on nests and broods that is generally recognized as having the largest deleterious effect on annual survivorship and recruitment in populations. Adding to this problem is the fact that predators, such as ravens, are subsidized by humans to the point where they exceed historic levels in some areas by as much as 1,500%. In such cases, management actions, especially where predators like ravens are abundant and sage-grouse mortality is high (such as in the Plan Area), may be needed to ensure that sage-grouse populations are not depressed by a known and potentially mitigated source of mortality.

Ravens are clever and highly adaptable in their behavior. They use communication and group foraging which allows them to opportunistically exploit food resources associated with humans (e.g., landfills, trash, road kill, unattended food, and carrion from livestock operations). In contrast, sage-grouse are very stereotypic in their behavior and rely on cryptic coloration, which makes them vulnerable to predation by ravens. As a result of these and other unintended food subsidies, raven populations have greatly expanded in the West. This, in turn, has impacted many species, including desert tortoises, marbled murrelets, least terns, California condors, and sage-grouse.

While reducing human-supplied food subsidies to predators is an essential part of any management strategy, it may not be effective unless coupled with active deterrents or management actions to reduce raven density (i.e., Coates and Delehanty 2010; Dinkins 2013). The last reported research on nest and brood survival in the PPR population (Apa 2010), estimated annual nest success between zero and 40%, and substantially lower chick survival. By the end of that study, *"Only 2 chicks remained radio-marked after 30 days of age. Apparent brood survival was 86% (n = 12/14) at 7 days, 62% (n = 9/14) at 14 days, and 14% (n = 2/14) at 30 days."* Those data indicate predation could be holding back the PPR population.

Policy

A. Encourage and review applicant's use of anti-perch devices, burying of powerlines, closed rubbish bins, removal of road kill and dead livestock, and other methods to discourage predators on sage-grouse and limit excess predation. If predation on sage-grouse is documented to have a deleterious effect on the PPR Area sage-grouse population, then allow for appropriate mitigation of predation under USDA guidance.

B. Encourage public agencies such as CPW, the BLM, and the USFWS to work with private land owners in areas of known Suitable Habitat to better understand the actual predation threat, then collaborate on the implementation of predator mitigation programs that discourage predators, reduce productivity and recruitment of predators, and reduce predator density.

Section 6 Wild Horse and Burro Management

Wild Horses and Burro's are not known to occur within the Plan Area and therefore do not presently impact sage grouse habitat.

Policy

A. Collaborate with appropriate agencies to discourage establishment of (feral) wild horse populations that could be detrimental to sage-grouse habitat.

Section 7 Mineral Development

The extraction of fluid minerals in Garfield County is accomplished using increasingly advanced technologies, more efficient operations, avoidance of critical habitats, impact minimization, mitigation, and more habitat restoration than in the past. As a result, surface disturbances can be minimal and temporary. The fast pace of these technological developments has meant that the primary literature on the impacts of mineral extraction on sage-grouse in Wyoming, that is cited in the majority of the federal government publications, is inconsistent with current practices and habitat types in Garfield County. It is anticipated that the advanced technologies currently in use, as well as future ones under development, will continue to allow the efficient extraction of resources while avoiding or minimizing impacts to sage-grouse and other species.

Policy

A. Close suitable habitat (**Figure 5**) as determined by the County's GIS mapping to future mineral leasing surface disturbance unless the fluid resource cannot be extracted without minimal surface disturbance. In this case, the Best Management Practices (see **Chapter 7**) will be followed and if necessary mitigation utilized to ensure a no net loss to sage grouse habitat and no deleterious demographic effect on the population.

B. All active Leks identified outside of Suitable Habitat shall have a 0.6 mile NSO for all non-functional surface disturbance as defined in the Colorado State Plan. Exceptions for allowing functional disturbance within the 0.6 mile NSO may be allowed for exceptional or unique topography or other non-contributing habitat aspects or circumstances that will not adversely impact sage-grouse. If the resources cannot be accessed without disturbing the active Lek NSO habitat, then Best Management Practices will be followed and necessary mitigation utilized to ensure a no net loss to sage grouse potential habitat and no deleterious demographic effect on the population.

C. No federal land mineral withdrawals shall be made in Suitable Habitat areas if the resources can be accessed and extracted without surface disturbance.

Section 8 Wildfire Suppression, Fuels Management and Fire Rehabilitation

A. Fuels Management Policy

1) Provide technical (GIS) support that can be used by landowners for voluntary fuels management that is consistent with sage-grouse habitat protection and enhancement.

2) Work with landowners to design fuels management projects in Suitable Habitat to strategically and effectively reduce wildfire threats.

3) During fuels management project design, consider the utility of using livestock to strategically reduce fine fuels (Diamond at al. 2009), and implement grazing

management that will accomplish this objective (Davies et al. 2011 and Launchbaugh et al 2007). Consult with ecologists to minimize impacts to native perennial grasses consistent with the objectives and conservation measures of the range management policy.

B. **Emergency Stabilization and Rehabilitation Policy**
   1) Follow the County's habitat restoration policy in developing an emergency rehabilitation plan for temporarily disturbed areas within suitable habitat.
   2) Coordinate with appropriate agencies in developing and implementing rehabilitation plans.
   3) Collaborate with private landowners and leaseholders to integrate their expertise and knowledge of local conditions into rehabilitation plans.

Section 9 Habitat Restoration

The naturally patchy habitat in the Plan Area requires that habitat restoration projects be planned accordingly and that creating large contiguous landscapes of sagebrush is not consistent with the plant communities in the Plan Area.

Policy

A. Encourage habitat restoration projects on private land. Request that private landowners report annually on the progress of restoration efforts (providing spatial data associated with an API number, date, and status of restoration), so the County may track disturbed vs. restored acreages in and near Suitable Habitat.

B. Recognizing that local conditions in the Plan Area differ from those range-wide for sage-grouse, the County's mapped Suitable Habitat will be used for quantifying habitat conservation objectives of no net loss of Suitable Habitat (excluding that resulting from wildfire and temporary disturbances, as permitted).

C. Require the use of native plant species for restoration based on availability, and probability of successful establishment.

D. Encourage local private landowners to share information among themselves and the County on restoration design and strategies to obtain favorable outcomes.

E. In former sagebrush habitat or in habitat to be converted to sagebrush: make re-establishment of sagebrush and desirable understory plant cover (relative to ecological site potential) the highest priority for restoration efforts.

Section 10 Monitoring and Habitat Category Changes

The primary objective of this plan is to ensure the long-term health and continued existence of sage-grouse in Garfield County. Regular monitoring of the species and its habitat in Garfield County is essential to ensuring the policies and best management practices are updated and implemented within the Plan Area.

Policy

A. All federal and state agencies with management responsibilities in the Plan Area for the species and/or its habitat shall provide the County with an annual update of the monitoring programs they have in place, data collected and specifics about their collection protocols. These agencies will inform the County of proposed research projects and allow for the County's input and collaboration prior to implementation.

B. All data shall be collected and studies prepared using protocols that will ensure the quality, utility, objectivity and integrity of the information as required under the Information Quality Act.

C. All data that is gathered in the Plan Area shall be shared with the County in a timely manner, and supplied to the County regardless of its state of completion at the formal request of the County.

D. Private landowners are also encouraged to monitor and share data collected on private property with the County.

E. All data that is shared with the County that is not public information will be treated as confidential and used by the County only to help inform its policies and best management practices.

CHAPTER 7 BEST MANAGEMENT PRACTICES

1) West Nile Virus

Recommend pond designs based upon current recommendations of the CPW. *"Require treatment of waste water pits and any associated pit containing water that provides a medium for breeding mosquitoes with Bti (Bacillus thuringiensis v. israelensis) or take other effective action to control mosquito larvae."* These actions will reduce the distribution and abundance of mosquitoes that vector West Nile virus and reduce the risk of West Nile virus transmission to sage-grouse and other wildlife (Walker, B. 2008, before the Oil and Gas Commission of the State of Colorado on Draft Rule 1204, DOCKET NO. 0803-RM-02.

http://cogcc.state.co.us/rulemaking/StaffPreHearState/Exhibits/FINAL DOW TESTIMONY/B.Walker Testimony-041808 FINAL.pdf)

2) Fluid Mineral Development within Suitable Habitat

A. Establish speed limits on county roads near suitable sage-grouse habitat that are appropriate to safety and reducing vehicle/wildlife collisions.

B. Encourage clustering / centralization of disturbances, operations (fracture stimulation, liquids gathering, etc.), and facilities.

C. Encourage use of directional and horizontal drilling to reduce surface disturbance, and adoption of new technologies.

D. Encourage placement of infrastructure in already disturbed locations where the habitat has not been restored.

E. Encourage use of wood (or other material) mats for drilling activities to reduce vegetation disturbance and for roads between closely spaced wells to reduce soil compaction and maintain soil structure to increase likelihood of vegetation reestablishment following drilling.

F. Encourage a phased development approach with concurrent reclamation.

G. Encourage placement liquid gathering facilities outside of priority areas. Have no surface tanks at well locations within priority areas (minimizes perching and nesting opportunities for ravens and raptors and truck traffic). Pipelines must be under or immediately adjacent to the road (Bui et al. 2010).

H. Restrict the construction of tall facilities and fences to the minimum number and amount needed. To discourage avian predators, require installation of anti-perch devices on new fences and facilities within 4 miles of Suitable Habitat where avian predation has been identified as a cause of mortality. Additionally, encourage retrofitting of existing fences and structures with anti-perch devices that are also located within 4 miles of Suitable Habitat where avian predation has been identified as a cause of mortality.

l. Site and/or minimize linear ROWs to reduce disturbance to sagebrush habitats.

CHAPTER 8 GLOSSARY OF TERMS

Active Lek. Active leks are defined as locations where two or males have been observed and documented as actively courting females in the last two years the lek was surveyed (Doherty et al. 2011).

Adaptive Management. A scientific approach to adaptive management of wildlife populations requires that threats and management actions be treated as potentially falsifiable hypotheses, rather than certain knowledge. If the presumed threats to a population are ranked in order of importance (based on plausible cause and effect mechanisms), then even hypothetical threats can be prioritized and subsequently investigated in a scientific manner.

Best Management Practices (BMPs). A suite of techniques that guide or may be applied to management actions to aide in achieving desired outcomes. BMPs are often developed in conjunction with land use plans, but they are not considered a planning decision unless the plans specify that they are mandatory.

Brood Rearing Habitat. Brood rearing habitats are utilized after chicks have hatched, and are generally more mesic (moist) areas with a higher percentage of forbs and grasses which help provide higher densities of insects, plant material, and seeds for chicks, hens, as well as males during the summer and early fall months. Specifically:

- Sagebrush cover is generally from 10 to 30%
- Cover of Mixed Mountain Shrubs is generally not more than 10%
- Distance to nearest Forest is generally over 100 meters
- Distance to Shrubby Woodlands is generally over 50 meters

Consistent: possessing firmness or coherence; marked by harmony, regularity, or steady continuity: free from variation or contradiction. (Webster Revised Dictionary)

Coordinate. Equal in rank or order; not subordinate. (Webster's Revised Unabridged Dictionary)

Coordination. The act of coordinating; the act of putting in the same order, class, rank, dignity, etc.; as, the coordination of the executive, the legislative, and the judicial authority in forming a government; the act of regulating and combining so as to produce harmonious results; harmonious adjustment as, a coordination of functions. (Webster's Revised Unabridged Dictionary)

Coordination Process. A process mandated by federal law that requires federal agencies to coordinate their plans, programs and management activities with local governments. The minimum parameters of this process were defined by Congress at 43 USC 1712(c)(9) and prescribe that the agencies (1) keep apprised of State, local, and tribal land use plans; (2) assure that consideration is given to those State, local, and tribal plans that are germane in the development of land use plans for public lands; (3) assist in resolving, to the extent practical, inconsistencies between Federal and non-Federal Government plans; (4) provide for meaningful public involvement of State and local government officials, both elected and appointed, in the development of land use programs, land use regulations, and land use decisions for public lands, including early public notice of proposed decisions which may have a significant impact on non-Federal lands; and (5) make land use plans consistent with State and local plans to the maximum extent the Secretary finds consistent with Federal law. (Federal Land Policy and Management Act, 43 USC 1701)

Coordination Meeting. A government-to-government meeting between a government agency or agencies and the BOCC. These meetings are public meetings, publicly noticed with agenda provided in advance. While public comment is not received during the meeting, the public is encouraged to attend and provide comments during later regular BOCC meetings as the intent is for the coordination process to be open and transparent to the public. The discussion is between the agency and the BOCC and is for the purpose of fulfilling the coordination duty, informing the agencies and BOCC of relevant projects, plans, studies and management activities. It is also the forum for discussion towards the resolution of unresolved conflicts between the counties policies and plans and the agencies programs.

Cooperation. The act of cooperating, or operating together to one end; joint operation; concurrent effort or labor. (Webster's Revised Unabridged Dictionary)

Collaborate. To work together with another toward a common goal, especially in an intellectual endeavor; as, four chemists collaborated on the synthesis of the compound; three authors collaborated in writing the book. (Webster's Revised Unabridged Dictionary)

Conserve. To cause no degradation or loss of sage-grouse habitat. Conserve can also refer to maintaining intact sagebrush steppe by fine tuning livestock use, watching for and treating new invasive species and maintaining existing range improvements that benefit sage-grouse etc.

Development. Active drilling and production of natural gas and oil wells.

Development Area. Areas primarily leased with active drilling and wells capable of production in payable quantities.

Enhance. The improvement of habitat by increasing missing or modifying unsatisfactory components and/or attributes of the plant community to meet sage-grouse objectives. Examples include modifying livestock grazing systems to improve the quantity and vigor of desirable forbs, improving water flow in riparian areas by modifying existing spring developments to return more water to the riparian area below the development, or marking fences to minimize sage-grouse hits and mortality.

Exploration. Active drilling and geophysical operations to 1) determine the presence of the mineral resource; or 2) determine the extent of the reservoir.

Forests. Forests in the Plan area include contiguous stands larger than 1/2 acre of aspen (*Populus tremuloides*), Douglas-fir (*Pseudotsuga menziesii*), mixed conifers (including, but not limited to Douglas-fir, Engelmann spruce [*Picea engelmannii*], subalpine fir [*Abies bifolia*] and ponderosa pine [*Pinus ponderosa*]), pinyon-juniper woodlands, and oakbrush.

Inactive Lek. Any lek where sufficient data suggests that there was no strutting activity throughout a strutting season. Absence of strutting grouse during a single visit is insufficient documentation to establish that a lek is inactive. This designation requires documentation of either: 1) an absence of sage-grouses on the lek during at least 2 ground surveys separated by at least seven days. These surveys must be conducted under ideal conditions (April 1-May 7 (or other appropriate date based on local conditions), no precipitation, light or no wind, half-hour before sunrise to one hour after sunrise) or 2) a ground check of the exact known lek site late in the strutting season (after April 15) that fails to find any sign (tracks, droppings, feathers) of strutting activity. Data collected by aerial surveys should not be used to designate inactive status as the aerial survey may actually disrupt activities.

Late Brood Rearing Area. Habitat includes mesic sagebrush and mixed shrub communities, wet meadows, and riparian habitats as well as some agricultural lands (e.g. alfalfa fields, etc).

Lek Complex. A lek or group of leks within 2.5 km (1.5 mi) of each other between which male sage-grouse may interchange from one day to the next. Fidelity to leks has been well documented. Visits to multiple leks are most common among yearlings and less frequent for adult males, suggesting an age-related period of establishment (Connelly et al. 2004).

Lek. A traditional courtship display area attended by male sage-grouse in or adjacent to sagebrush dominated habitat. A lek is designated based on observations of two or more male sage-grouse engaged in courtship displays. Sub-dominant males may display on itinerant strutting areas during population peaks. Such areas usually fail to become established leks. Therefore, a site where less than five males are observed strutting should be confirmed active for two years before meeting the definition of a lek (Connelly et al 2000, Connelly et al. 2003, 2004).

Mitigation. Compensating for resource impacts by replacing or providing substitute resources or habitat.

Mixed Mountain Shrubs. Shrublands dominated by Utah serviceberry (*Amelanchier utahensis*), Saskatoon serviceberry (*A. alnifolia*), mountain mahogany (*Cercocarpus montanus*), oakbrush (*Quercus gambelii*), bitterbrush (*Purshia tridentata*), and may have a sagebrush component. Mapped Mixed Mountain Shrublands have greater than 10% cover of these non-sagebrush shrub species, as this is the threshold at which sage-grouse show a strong avoidance of this community type.

Multiple Use: The management of the public lands and their various resource values so that they are utilized in the combination that will best meet the present and future needs of the American people; making the most judicious use of the land for some or all of these resources or related services over areas large enough to provide sufficient latitude for periodic adjustments in use to conform to changing needs and conditions; the use of some land for less than all of the resources; a combination of balanced and diverse resource uses that takes into account the long-term needs of future generations for renewable and nonrenewable resources, including, but not limited to, recreation, range, timber, minerals, watershed, wildlife and fish, and natural scenic, scientific and historical values; and harmonious and coordinated management of the various resources without permanent impairment of the productivity of the land and the quality of the environment with consideration being given to the relative values of the resources and not necessarily to the combination of uses that will give the greatest economic return or the greatest unit output. (Federal Land Policy and Management Act, 43 USC 1702(c)).

Nesting Habitat. Nesting habitat is generally moderately sized patches of denser and taller sagebrush, further away from roads and other activity areas. Specifically:

- Sagebrush cover is generally from 20 to 50%
- Cover of Mixed Mountain Shrubs is generally not more than 10%
- Distance to nearest Forest is generally over 100 meters
- Distance to Shrubby Woodlands is generally over 50 meters

Occupied Lek: A lek that has been active during at least one strutting season within the prior 10 years.

Offsite Mitigation. Compensating for resource impacts by replacing or providing substitute resources or habitat at a different location than the project area.

Range Improvement. Any activity, structure or program on or relating to rangelands which is designed to improve production of forage; change vegetative composition; control patterns of use; provide water; stabilize soil and water conditions; and provide habitat for livestock and wildlife. The term includes, but is not limited to, structures, treatment projects, and use of mechanical means to accomplish the desired results.

Reclamation. Rehabilitation of a disturbed area to make it acceptable for designated uses. This normally involves re-contouring, replacement of topsoil, re-vegetation, and other work necessary to ensure eventual restoration of the site.

Restoration. Implementation of a set of actions that promotes plant community diversity and structure that allows plant communities to be more resilient to disturbance and invasive species over the long term. The long-term goal is to create functional, high quality habitat that is occupied by sage-grouse. Short-term goal may be to restore the landform, soils and hydrology and increase the percentage of preferred vegetation, seeding of desired species, or treatment of undesired species.

Sagebrush. Includes all species and sub-species of the genus *Artemisia* except the mat-forming sub-shrub species *A. frigida.*

Shrubby Woodlands. Vegetation communities dominated by oakbrush or pinyon (*Pinus edulis*) and Rocky Mountain juniper (*Sabina scopulorum*) or Utah juniper (*S. osteosperma*) types. Mapped Shrubby Woodlands have greater than 10% cover of pinyon-juniper, as this is the threshold at which sage-grouse show a strong avoidance of this community type.

Suitable Habitat. Suitable Habitat includes all seasonal habitats (including lekking, nesting, brood rearing/summer and winter habitats) within the Plan Area. Suitable Habitat has been mapped by Garfield County, and is considered a Consultation Area for activities requiring Garfield County permitting. Specifically, Suitable Habitat includes:

- Sagebrush cover is generally from 10 to 50%
- Cover of Mixed Mountain Shrubs is generally not more than 20%
- Distance to nearest Forest is generally over 100 meters
- Distance to Shrubby Woodlands is generally over 50 meters
- Grass/forb dominated habitats (with >10% sagebrush cover) within 20 meters of sagebrush habitat
- Contiguous habitats >3 acres in size, or part of a block of Suitable Habitats in close proximity

Temporarily Disturbed Areas. Areas that have seen recent vegetation disturbance activities (such as pipeline corridors and wildfire events) may not support sagebrush cover at a density or height suitable for sage-grouse use. If these areas occur within a block of Suitable Habitat, they will be considered Temporarily Disturbed, and still would be considered as long-term as Suitable Habitat. Temporarily Disturbed habitat will need to be tracked spatially within the Plan area.

Unoccupied Lek. A lek that has either been "destroyed" or "abandoned."

Unoccupied Suitable Habitat. Areas that support Suitable Habitat, but for which sage-grouse currently do not occupy these areas or the status of occupancy are unknown. These areas, for whatever reason, are deemed less-than-optimal by sage-grouse (e.g., due to predation pressures, non-lethal disturbances, too small an area of suitable habitat, etc.) and thus sage-grouse prefer to utilize other areas.

Winter Habitat. Winter habitat is generally utilized by sage-grouse from November through early April. It is primarily determined by the depth and persistence of snow cover. During more severe winters, snow can limit winter habitat to wind-swept ridges and patches of the tallest sage-brush. During the winter sage-grouse food is strictly limited to sage-brush. However, sage-grouse can do quite well on winter diets. Specifically:

- Sagebrush cover is generally >25%
- Cover of Mixed Mountain Shrubs is generally not more than 10%
- Distance to nearest Forest is generally over 100 meters
- Distance to Shrubby Woodlands is generally over 50 meters

Appendix A- Literature Cited and General References

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Appendix B- Sage-Grouse Habitat Modelling Process

The following paper described in detail the methodologies employed to map vegetation community types and model greater sage-grouse habitats within Garfield County.

USE OF MODELLING IN A GEOGRAPHIC INFORMATION SYSTEM TO PREDICT GREATER SAGE-GROUSE HABITAT

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ABSTRACT In Colorado (and across many western States) the Bureau of Land Management (BLM) is in the process of producing a greater sage-grouse (*Centrocercus urophasianus* [sage-grouse]) Resource Management Plan Amendment/ Environmental Impact Statement (RMPA/EIS) for the BLM's Northwest Colorado District, to assess impacts of potentially implementing sage-grouse habitat management conservation strategies (BLM 2013). If approved, the RMPA/EIS would amend current BLM Resource Management Plans and U.S. Forest Service Land and Resource Management Plans that would guide the management of greater sage-grouse habitat on public lands administered by the BLM and the U.S. Forest Service and on private lands with a federal nexus to the BLM planning process (e.g., projects extracting federal minerals or accessing federal lands across private lands). A key component of implementing sage-grouse conservation strategies is accurately predicting where sage-grouse habitat occurs; however, the current sage-grouse Preliminary Priority Habitat and Preliminary General Habitat used in the RMPA/EIS was in large part based on habitat modeling conducted at large scales (Doherty et al. 2010, Rice et al. 2013), which makes land use planning, accurate impact assessments and project implementation at the project level difficult due to the inherent inaccuracies of large scale habitat maps. We employed two different methods to map and quantify at a finer and more accurate scale the extent of suitable sage-grouse habitat found in Garfield County, Colorado. We started by mapping vegetation at a 2 m cell resolution in order to capture nuances in sage-grouse habitats given sage-grouse preference of habitat at smaller scales (Connelly et al. 2000, Hagen et al. 2007), and then employed: (1) a weighted overlay as a habitat suitability index (HSI) using a resource selection function (RSF) and (2) fuzzy modeling at 10 m cell resolution. We validated this technique against tracked (i.e., radio-collar and Global Positioning System [GPS]) sage-grouse as well as data from previous pedestrian surveys documenting where evidence of sage-grouse occupancy had occurred.

KEY WORDS *Centrocercus urophasianus*, greater sage-grouse, Colorado, fuzzy model, resource selection model, habitat suitability index, Geographic Information System (GIS).

Within the Piceance, Parachute, Roan (PPR) area (Figure 1), there have been a number of studies investigating greater sage-grouse (*Centrocercus urophasianus* [sage-grouse]) and the uniqueness of the habitats in this area (Braun 1995, Hagen 1999, Apa 2006, Apa et al. 2007, Colorado Parks & Wildlife [CPW] 2008, Sauls et al. 2006-2008, WestWater Engineering [WWE] 2008, Walker et al. 2010[3], and Apa et al. 2010[4]). The PPR area habitats are known for the steepness of habitats, the

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[3] The information in Walker et al. 2010 is considered preliminary and subject to further evaluation, therefore our research does not utilize or rely on this information, and our citation of this work is for general information regarding CPW's in-process investigations.

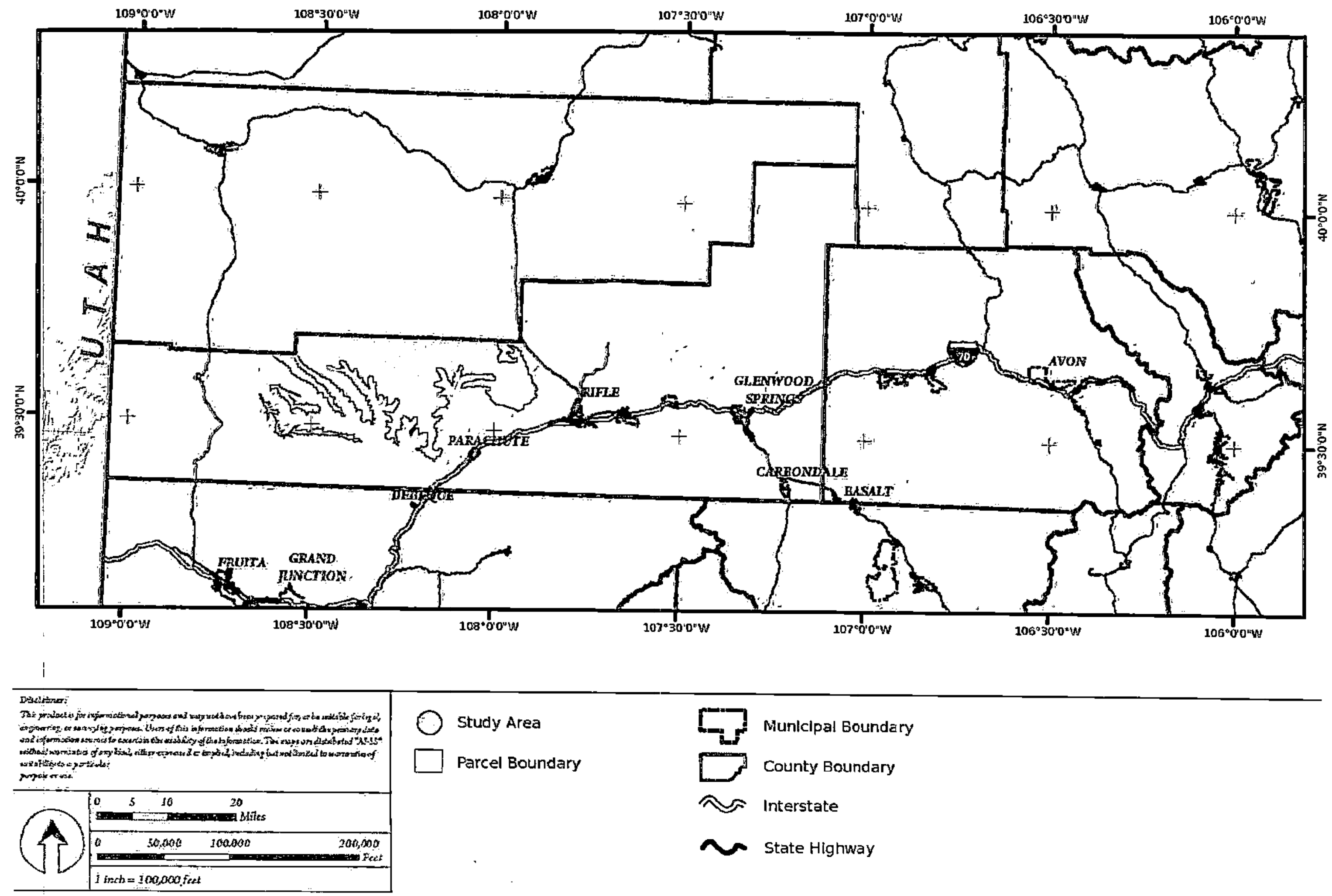
variety in vegetation conditions, and the limited spatial extent of "typical" sage-grouse habitats. Additionally, the number of studies in the PPR is also due to a combination of the significant mineral resources in this area; primarily natural gas and oil shale, but also the presence of sage-grouse and the atypical habitat found in this area. Instead of the large expanses of rolling sagebrush (*Artemisia tridentata*) steppe typically occupied by sage-grouse (Knick and Connelly 2011, Sage-grouse National Technical Team 2011), the PPR area has narrow ridgelines supporting sagebrush, which quickly grade into mixed mountain shrub habitats and other unsuitable habitat types on side slopes (Apa 2006). Of note, is that the rough topography and patches of non-habitat do not appear to pose a movement barrier to sage-grouse (Apa 2006, Apa et al. 2007, WWE 2008). Because of the mineral resources, energy company exploration and energy development is very common; much of the private lands within the PPR area are owned by energy companies. Energy companies have funded a number of CPW, consultant, and university studies in this area, and of these studies a number have been focused on mapping the unique habitats and discerning how sage-grouse utilize these atypical habitats (Hagen 1999, Sauls et al. 2006, 2008, WWE 2008, Apa et al. 2007, 2010 and Walker et al. 2010).

Of all the studies reviewed, they have all been relatively consistent with reporting how sage-grouse utilize habitats in the PPR area; sage-grouse are still strongly associated with sagebrush-dominated habitats, generally at the higher elevations, and favor sagebrush-dominated habitats at multiple spatial scales. In other words, sage-grouse favor larger areas of sagebrush dominated habitats, but can also be found in smaller patches of sagebrush. As these patches get smaller, or occur in landscapes more dominated by unsuitable habitats (e.g., mixed mountain shrublands), their use of sagebrush habitats can decline (Apa 2006, Apa et al. 2007, WWE 2008). Sage-grouse in the PPR area are unique in that their occupied habitats are much smaller in spatial extent and patch size when compared to other more "typical" sage-grouse habitats occupied by other populations (Connelly et al. 2000, et al. 2004). Sage-grouse also are found to utilize sagebrush habitats with a notable presence of other shrub species (e.g., snowberry [*Symphoricarpos oreophilus*], Utah serviceberry [*Amelanchier utahensis*]), but generally when these other shrub species occupy >25% of the shrub component, sage-grouse use of these areas appears to decline based on preliminary research (Sauls et al. 2006-2008, Apa et al. 2007, WWE 2008).

We have found that there have been multiple efforts to map suitable sage-grouse habitats in the area, and all are fairly accurate and relevant (given the acknowledged limitations of the data and methods employed). Some of the more accurate habitat maps have likely been "hand draw" or delineated from aerial imagery and topography (e.g., Sauls et al. 2006-2008, WWE 2008), but this technique is difficult or impossible to repeat, and is highly dependent upon the knowledge and biases of the authors conducting the habitat delineations. Nevertheless, these products appear to be very accurate when compared to on-the-ground conditions.

[4] The information in Apa et al. 2010 is considered preliminary and subject to further evaluation, therefore our research does not utilize or rely on this information, and our citation of this work is for general information regarding CPW's in-process investigations.

Figure 1: The PPR Study Area in Colorado.



Rice et al. (2013) published their sage-grouse habitat mapping technique which was used to develop Preliminary Priority Habitat/Preliminary General Habitat (PPH/PGH) habitat maps in Colorado, including the PPR area. When compared to previous habitat mapping efforts produced by the BLM, private consultants, and interim work by CPW (Sauls et al. 2006-2008, WWE 2008, Walker et al. 2010), the PPH/PGH mapping appeared to over-predict habitat. Despite available vegetation datasets, their model was not able to discern between the sagebrush and sagebrush/mixed mountain shrubland habitats known to be used by sage-grouse, and the non-habitat areas of steeper draws, canyons, aspen (*Populus tremuloides*) stands, contiguous mixed mountain shrubland or Douglas-fir (*Pseudotsuga menziesii*) stands in the PPR area.

Because of the large change in previous characterizations of sage-grouse habitat in Garfield County to what is now shown in PPH and PGH maps, we attempted a new, repeatable habitat modelling technique in a Geographic Information System (GIS) to accurately locate and quantify the availability of suitable greater sage-grouse habitat in the PPR area within Garfield County (PPR Study Area), independent of maps already produced by the BLM, CPW, or other interested parties (including energy companies, which have performed a number of sage-grouse habitat mapping efforts). Yet we still incorporated the data that documented existing sage-grouse research, information, data and peer-reviewed and accepted habitat parameters for sage-grouse in development of our suitable habitat model. Predictive models that locate and quantify the availability of suitable habitats for a given species are predominately based on quantifying the relationships between species selection and surrounding environmental factors. This paper discusses the two different methods used to map and quantify the extent of suitable sage-grouse habitat found in the PPR area: (1) weighted overlay as a habitat suitability index (HSI) using a resource selection function (RSF) and (2) fuzzy modeling.

In recent years, the approaches to modelling species habitat availability have advanced significantly, providing a number of statistically rigorous methods for predicting and evaluating species distribution (Rushton et al. 2004, Guisan and Thuiller 2005). Our approach to mapping and quantifying the extent of suitable sage-grouse habitat within the PPR Study Area utilized two distinctly different methods of modeling within a geospatial environment; (1) weighted overlay modeling using an RSF and (2) fuzzy modeling. The weighted overlay approach using an RSF was selected for three reasons. First, weighted overlay models, commonly known as Habitat Suitability Indexes (HSI), are widely accepted and employed by State and Federal wildlife agencies to model species distribution for resource management, planning and population viability analyses, including the U.S. Fish and Wildlife Service (USFWS) Habitat Evaluation Program (HEP) (USFWS 1980, 1981). Secondly, weighted overlay models have previously been employed, and are currently being employed in other ongoing research projects to study sage-grouse habitat availability, which provides results from our efforts as a means for direct comparison to other RSF/HSI models in Colorado (Sauls et al. 2008, Walker et al. 2010, Rice et al. 2013). Third, using an RSF allows species distribution to be modeled using known selection preferences from statistical inference of field-collected data, thereby predicting suitable habitat patches based on known behavior of the local population. By contrast, the application of fuzzy modeling to predict species distribution has been much more limited to date; however, at least one study has occurred whereby fuzzy logic was employed to map suitable sage-grouse and mule deer habitats in northwest Colorado (Hibbs 2011). This method is gaining acceptance and increased utilization based on the ability of the model to consider vagueness and imprecisions inherent in the attributes of spatial data; a limitation of other model methods. Fuzzy logic is intuitive and constructed using natural language, allowing the reasoning behind a fuzzy system to be simple and easily understood by a wide variety of audiences (Mathworks 2014a). For this reason, we also selected the fuzzy model approach to predict species habitat distribution within the PPR Study Area.

Weighted Overlay and Resource Selection Function

Weighted overlay models function by applying logical mathematical arithmetic to multiple criteria, allowing for diverse and dissimilar criteria to be inputs to an integrated analysis (Mathworks 2014a). In the instance of an HSI, the model scales, weights and integrates diverse spatial data to measure the habitat suitability of a given location on a common, relative scale. Furthermore, an HSI can employ two methods in developing the criteria as inputs to the model framework; inductive (i.e., empirical, inferred from existing data) or deductive (i.e., non-empirical, developed from expert opinion). We pursued an inductive approach to our habitat modeling for two reasons: (1) we had access to spatially-explicit field-collected data of sage-grouse sign and occupancy, and (2) deductive approaches have the possibility of introducing bias from expert-opinion.

An RSF model is a form of an HSI with statistical rigor (Boyce et al. 2002); it is a mathematical function that predicts resource or habitat use proportional to probability of use (Manley et al. 2002). While other models are developed based on expert opinion, RSF models are estimated directly from empirical data (Boyce et al. 2002). Empirical models analyze a species' habitat selection by relating known occurrences of the species (presence) with data quantifying background environmental variables. An RSF model predicts species distribution based on the theory of habitat selection; where habitat use exceeds availability, habitat selection is inferred; and where habitat use is less than availability, habitat avoidance is inferred (Johnson and Gillingham 2005).

An RSF is generally developed from observations of either presence vs. absence or presence vs. available resource units. Both methods employ a logistic regression model utilizing a binary response (observation) that either implies presence (y=1) or absence or random location (y=0). For each observation, a set of measured habitat criteria exist, χ. For the probability of occurrence [$P(y=1|\chi)$], the dependent variable can be estimated with the following equation:

$$P(y=1|\chi)=\left(\frac{\exp(\beta_0+\beta_1\chi_1+...+\beta_p\chi_p)}{1+\exp(\beta_0+\beta_1\chi_1+...+\beta_p\chi_p)}\right)$$

where $(\beta_0...\beta_p)$ are maximum likelihood estimates of logistic regression coefficients and $(\chi_1...\chi_p)$ represent values for environmental criteria as a set of independent variables (Pearce and Boyce 2006). The equation returns values on a continuous scale of zero to one, with higher values indicating a higher level of habitat suitability.

Fuzzy Modeling

Behavioral and environmental phenomena are inherently complex, demonstrating vagueness and uncertainty that are difficult to express with crisp class boundaries. Most phenomena do not have clearly defined boundaries and are better expressed linguistically with degrees of membership to a set, rather than forcing a rigid classification to a single class (Kainz 2008). Fuzzy systems are a method that handles vagueness and uncertainty in spatial data. Fuzzy logic recognizes that most objects cannot be defined as belonging to one specific category or another (Zadeh 1965). When applied to habitat models, species presence does not imply absolute favorability or absolute un-favorability, but rather a degree of favorability.

Fuzzy inference is the process of mapping linguistic terms to an output using a fuzzy logic system. Generally speaking, fuzzy inference involves three steps: (1) identifying input terms and constructing linguistic if-then rules, (2) defining fuzzy sets and assigning fuzzy membership and (3) performing fuzzy overlay with a fuzzy operator.

The objective of fuzzy inference is to use the set of if-then statements to map results to an output space. The if-then statements, also known as fuzzy rules, refer to explanatory variables and adjectives that describe them. Fuzzy rules are constructed with both an antecedent and a consequent; the "If" portion of a statement is the antecedent, while the "then" portion of the statement is the consequent (Mathworks 2014b). Prior to developing the set of fuzzy rules, all variables must first be identified including their descriptive adjectives.

A typical rule in a fuzzy system may take the following form:

If A_1 *is* X_1, *And* A_2 *is* X_2,... *And* A_n *is* X_n, *Then B is Y.*

where $X, \ldots X_n$ and Y are fuzzy sets defined by $A_1 \ldots A_n$ fuzzy membership functions. In natural language, the form may be expressed as: "If site is flat and site is near water, then site is optimal."

Once all fuzzy rules are established for the fuzzy system, fuzzy sets are developed based on the pre-defined rules. Fuzzy logic is based on classical set theory, whereby an element must be either fully part of a set or fully excluded from a set; such a set is known as a "crisp" set. Extending this theory, fuzzy logic is based on fuzzy sets that allow for various degrees of membership to a class rather than forcing a response whereby the element is either asserted or denied.

For example, when considering proximity to an existing object, the distance of a given location may be described as near or far. In a classical set, the elicited response is binary in nature; the distance of the location to the object is either near or far. However, in a fuzzy set, the same distance can be described as both near and far.

Elements are related to a fuzzy set by fuzzy membership functions. Fuzzy membership assigns a fuzzy score for an element to a class based on a sliding scale between zero and one, where zero implies no membership and one implies full membership. The membership functions transform explanatory data in terms of suitability to a continuous scale of 0 to 1 using a variety of functions and arithmetic operators. The transformation method utilized depends on how the data are distributed and contribute to suitability. While numerous fuzzy membership functions exist, three fuzzy membership functions were utilized in this analysis; fuzzy linear membership, fuzzy small membership and fuzzy large membership. These membership functions are demonstrated in Figures 2 - 4.

Figure 2: Fuzzy linear membership function

Fuzzy Linear Membership

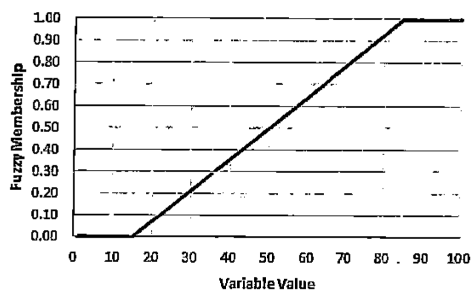
Equation: $\mu(x) = 0$ if $x < \min$,

$\mu(x) = 1$ if $x > \max$,

$$\mu(x) = \frac{(x - \min)}{(\max - \min)}$$

Description

A linear increasing or decreasing membership between user-specified minimum and maximum inputs.



Required Inputs

Min: *User-defined value to assign threshold for non-membership*

Max: *User-defined value to assign threshold for full membership*

Figure 3: Fuzzy small membership functions

Fuzzy Small Membership

Equation:

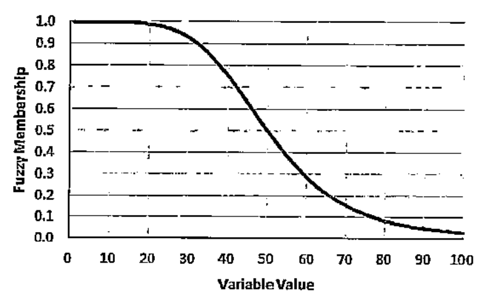
$$\mu(x) = \frac{1}{1 + \left(\frac{x}{f_2}\right)^{f_1}}$$

f_1 = spread

f_2 = midpoint

Description

Sigmoid curve function where shape is defined by a user-specified midpoint and spread. Lower variable values are assigned higher degrees of membership.



Required Inputs

Midpoint: *User-defined value to specify crossover point; assigned 0.5 membership value. Values lower than the midpoint have a higher degree of membership; values higher than the midpoint have a lower degree of membership.*

Spread: *User-defined value to prescribe the shape and character of the sigmoid curve.*

Figure 4: Fuzzy large membership function

Fuzzy Large Membership

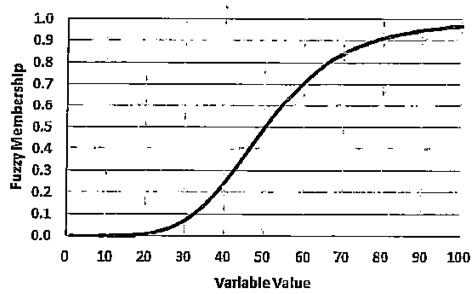
Equation: $$\mu(x) = \frac{1}{1 + \left(\frac{x}{f_2}\right)^{-f_1}}$$

f_1 = spread

f_2 = midpoint

Description

Sigmoid curve function where shape is defined by a user-specified midpoint and spread. Higher variable values are assigned higher degrees of membership.



Required Inputs

Midpoint: *User-defined value to specify crossover point; assigned 0.5 membership value. Values higher than the midpoint have a higher degree of membership; values lower than the midpoint have a lower degree of membership.*

Spread: *User-defined value to prescribe the shape and character of the sigmoid curve.*

When all explanatory data have been transformed to membership data, fuzzy overlay functions are used to combine the data to produce a single truth value that ranges in degree from 0 to 1. Once all inputs are fuzzified, the degree to which each part of the antecedent is satisfied for each rule is known (Mathworks 2014b). The overlay functions investigate the relationship between membership data and attempt to quantify the interaction between them, ultimately returning the degree of membership to the final set for all areas included in the analysis. The fuzzy overlay functions are listed and described in Figure 5. The fuzzy model returns a raster dataset with cell values ranging on a continuous scale from zero to one, with higher values indicating a higher degree of truth.

Figure 5: Fuzzy overlay functions

Overlay Function	Equation	Description
Fuzzy AND	$= Min(\chi_1, \chi_2, ... \chi_n)$	*Decreasing function. Fuzzy AND returns the minimum value of all sets at each cell location.*
Fuzzy OR	$= Max(\chi_1, \chi_2, ... \chi_n)$	*Increasing function. Fuzzy OR returns the maximum value of all sets at each cell location.*
Fuzzy PRODUCT	$= \chi_1 * \chi_2 ... \chi_n$	*Decreasing function. For each cell location, Fuzzy PRODUCT multiplies the fuzzy values of each set.*
Fuzzy SUM	$= 1 - ((1 - \chi_1) * (1 - \chi_2)...(1 - \chi_n))$	*Increasing function. For each cell location, Fuzzy SUM adds the fuzzy values of each set.*
Fuzzy GAMMA	$= (1 - ((1 - \chi_1) * (1 - \chi_2)...(1 - \chi_n)))^\gamma * (\chi_1 * \chi_2 ... \chi_n)^{1-\gamma}$	*Increasing/Decreasing function. Fuzzy GAMMA is the product of Fuzzy PRODUCT and Fuzzy SUM, both raised to the power of gamma.*

Study Area

The 894-km² project Study Area occurs on the Roan Plateau within Garfield County, at the southern end of the Piceance Basin in an area known as the PPR area (PPR Study Area, Figure 1). The spatial extent of the analysis area represents all areas within Garfield County currently indicated as PPH and PGH as mapped by CPW (Rice et al. 2013) and adopted by the BLM in their Resource Management Plan Amendment/ Environmental Impact Statement (RMPA/EIS) for the BLM's Northwest Colorado District. Our study area is limited to just Garfield County within the greater PPR area. Of the Study Area, 248 km² (28%) of surface lands are managed by the BLM, while the remaining 646 km² (72%) are private and State lands. Land use in the Study Area continues to be managed for summertime cattle ranching and energy development of primarily natural gas, with some limited oil shale resource exploration.

Vegetation is relatively heterogeneous, and was dependent upon slope, aspect, and elevation. Three subspecies of big sagebrush occupy the Study Area, and the location of these subspecies is dependent upon soil type. Basin big sagebrush (*A. t. tridentata*) is the prevalent vegetation throughout the lower drainages at elevations of 1,800 m – 1,980 m (Cottrell and Bonham 1992). *A. t. wyomingensis* is restricted to upland ridges at elevations of 1,900 m – 1,980 m (Cottrell and Bonham 1992). *A. t. vaseyana* is confined to high mountain areas at elevations > 2,070 m. Pinyon pine (*Pinus edulis*) and juniper (*Sabina [Juniperus] osteosperma* and *S. scopulorum*) woodlands dominate the landscape until approximately 1,980 m. Big sagebrush, Utah serviceberry, oakbrush (*Quercus gambelii*), and antelope bitterbrush (*Purshia tridentata*) comprise most of the transitional ecotone vegetation type. Pinyon/juniper habitat types are relatively uncommon within the PPR Study Area in Garfield County, and were much more common to the north in Rio Blanco County where elevations are lower. Elevations of 2,380 m to 2,590 m are dominated by big sagebrush interspersed with grass and forb-dominated meadows. North aspects often host substantial groves of aspen, serviceberry, and mountain snowberry. Big sagebrush and Douglas-fir dominate south and northwest aspects at elevations > 2,500 m respectively. Free water can be scarce in dry years or late in the summer as most springs are in the bottom of steep canyons. There are scattered stock tanks and dugouts for watering cattle, which are usually associated with roadways.

METHODS

Biophysical Habitat Factors

Numerous variables were considered in our analysis that may influence sage-grouse habitat selection. The variables were broadly classified as either habitat characteristics or topographical factors. All variables describing habitat characteristics were derived from a digital vegetation map developed at a 2 m cell resolution through supervised image classification of 1 m color-infrared aerial photography collected in 2012 as part of the National Agricultural Imagery Program (NAIP) administered by the U.S. Department of Agriculture (USDA 2012). A detailed description of the image classification process is provided in Appendix A. Vegetation cover types derived from the image classification process are displayed in Figure 6. Topographic variables were derived from a 10-meter digital elevation model (DEM) acquired from the U.S. Geologic Survey (USGS), National Elevation Dataset. Topographic variables considered in this analysis include percent slope, topographic position index (TPI) and surface roughness, or curvature.

Percent slope were derived directly from the 10-meter USGS DEM. TPI is a relative measure of a locations elevation, or slope position, as compared to surrounding elevations or positions. TPI was calculated using Jenness Enterprises DEM Surface Tools v. 2.1.375. Curvature, or surface roughness, was developed by computing the standard deviation of slope within a defined neighborhood.

Vegetation variables were developed as percent proportion of specified vegetation communities within a defined scale; likewise, all topographic variables were derived as mean values within a defined scale. All variables were analyzed and considered at three spatial scales, because while sage-grouse are known as a landscape level species, most of the contemporary research documenting sage-grouse use has been performed at the local scale. The scales of available habitats that influence sage-grouse selection and non-use are currently unknown; therefore, the contributing variables that may influence habitat selection are tested at multiple scales to determine which scales guide habitat selection. The selected scales employed in this analysis represent a local scale (e.g., 100 meters), an intermediate scale (e.g., 350 meters) and a landscape-level scale (e.g., 1 kilometer). While the distances are somewhat arbitrary (i.e., a distance of 300 or 400 meters would equally be considered an intermediate scale), they reflect distances used in other contemporary studies of sage-grouse habitat selection conducted both within the PPR Study Area and the defined national range. At each scale, statistics were generated using a moving circular window across the project Study Area, at distances of 100 m, 350 m and 1 km, respectively. A detailed summary of all variables considered in the scope of this analysis are presented in Table 1. Table 2 shows the summary of explanatory variables at 939 sites indicating sage-grouse presence in the defined analysis area.

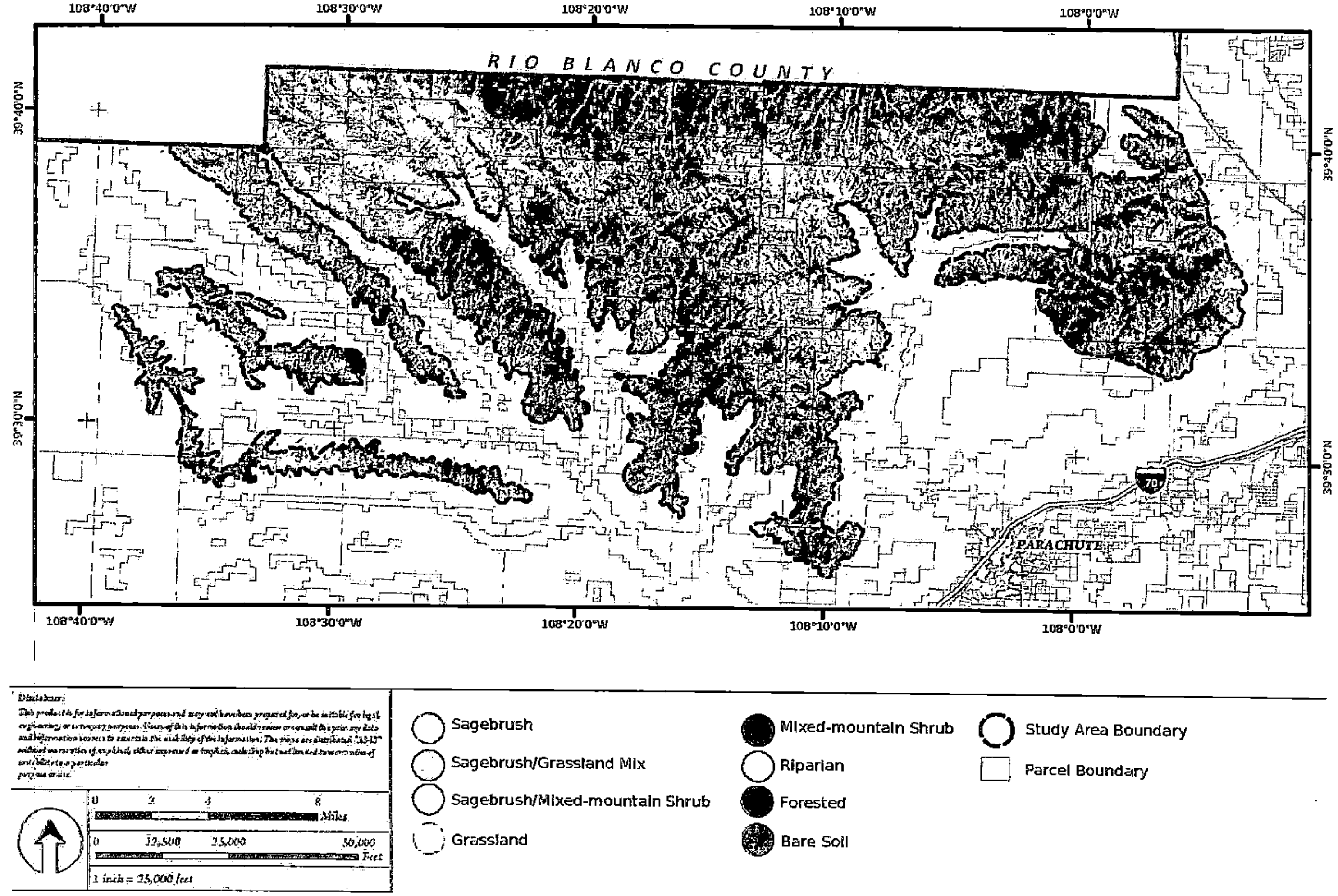
Table 1: Summary and Description of all Explanatory Variables. Summary and description of all explanatory variables used in assessing sage-grouse habitat suitability in the defined analysis area.

Variable	Name	Description
Vegetation		
sg100	Sage-dominated, 100-meters	*Percent proportion of all sage-dominated vegetation communities within a 100-meter radius.*
sg350	Sage-dominated, 350-meters	*Percent proportion of all sage-dominated vegetation communities within a 350-meter radius.*
sg1k	Sage-dominated, 1-kilometer	*Percent proportion of all sage-dominated vegetation communities within a 1-kilometer radius.*
sgmms100	Sage-dominated + mixed mountain shrubs, 100-meters	*Percent proportion of all sage-dominated and mixed mountain shrub vegetation communities within a 100-meter radius.*
sgmms350	Sage-dominated + mixed mountain shrubs, 350-meters	*Percent proportion of all sage-dominated and mixed mountain shrub vegetation communities within a 350-meter radius.*
sgmms1k	Sage-dominated + mixed mountain shrubs, 1-kilometer	*Percent proportion of all sage-dominated and mixed mountain shrub vegetation communities within a 1-kilometer radius.*
mms100	Mixed mountain shrubs, 100-meters	*Percent proportion of all mixed mountain shrub vegetation communities within a 100-meter radius.*
mms350	Mixed mountain shrubs, 350-meters	*Percent proportion of all mixed mountain shrub vegetation communities within a 350-meter radius.*
mms1k	Mixed mountain shrubs, 1-kilometer	*Percent proportion of all mixed mountain shrub vegetation communities within a 1-kilometer radius.*
sggr100	Sage-dominated + grasslands, 100-meters	*Percent proportion of all sage-dominated and grassland vegetation communities within a 100-meter radius.*
sggr350	Sage-dominated + grasslands, 350-meters	*Percent proportion of all sage-dominated and grassland vegetation communities within a 350-meter radius.*
sggr1k	Sage-dominated + grasslands, 1-kilometer	*Percent proportion of all sage-dominated and grassland vegetation communities within a 1-kilometer radius.*
gr100	Grasslands, 100-meters	*Percent proportion of all grassland vegetation communities within a 100-meter radius.*
gr350	Grasslands, 350-meters	*Percent proportion of all grassland vegetation communities within a 350-meter radius.*
gr1k	Grasslands, 1-kilometer	*Percent proportion of all grassland vegetation communities within a 1-kilometer radius.*
bare100	Barren surface, 100-meters	*Percent proportion of all bare surface within a 100-meter radius.*
bare350	Barren surface, 350-meters	*Percent proportion of all bare surface within a 350-meter radius.*
bare1k	Barren surface, 1-kilometer	*Percent proportion of all bare surface within a 1-kilometer radius.*
for100	Forested areas, 100-meters	*Percent proportion of all forested vegetation communities within a 100-meter radius.*
for350	Forested areas, 350-meters	*Percent proportion of all forested vegetation communities within a 350-meter radius.*
for1k	Forested areas, 1-kilometer	*Percent proportion of all forested vegetation communities within a 1-kilometer radius.*
for_dist	Distance to forest	*Distance to forested areas.*
Topographic		
slope100	Percent slope, 100-meters	*Mean percent slope within a 100-meter radius.*
slope350	Percent slope, 350-meters	*Mean percent slope within a 350-meter radius.*
slope1k	Percent slope, 1-kilometer	*Mean percent slope within a 1-kilometer radius.*
tpi100	Topographic position index, 100-meters	*Mean topographic position index within a 100-meter radius.*
tpi350	Topographic position index, 350-meters	*Mean topographic position index within a 350-meter radius.*
tpi1k	Topographic position index, 1-kilometer	*Mean topographic position index within a 1-kilometer radius.*
curve100	Curvature, 100-meters	*Mean curvature within a 100-meter radius.*
curve350	Curvature, 350-meters	*Mean curvature within a 350-meter radius.*
curve1k	Curvature, 1-kilometer	*Mean curvature within a 1-kilometer radius.*

Table 2: Summary of Explanatory Variable. Summary of explanatory variables at 939 sites indicating Greater Sage-grouse presence in the defined analysis area.

Variable	Mean ± Std. Dev.	Median	25% - 75% Quartiles	Min.	Max.
Vegetation					
sg100	0.7348 ± 0.2549	0.7981	0.5757 – 0.9606	0.0	1.0
sg350	0.6339 + 0.2278	0.6819	0.4792 – 0.8229	0.0183	0.9725
sg1k	0.5441 + 0.1935	0.5662	0.3852 – 0.712	0.0794	0.8579
sgmms100	0.8117 + 0.2206	0.8886	0.6963 – 0.9973	0.0	1.0
sgmms350	0.8046 + 0.1219	0.8229	0.7355 – 0.9098	0.2744	0.9725
sgmms1k	0.7472 + 0.0896	0.7674	0.6804 – 0.8166	0.406	0.9367
mms100	0.0792 + 0.1363	0.0	0.0 – 0.112	0.0	1.0
mms350	0.1707 + 0.1647	0.1226	0.0177 – 0.2908	0.0	0.7918
mms1k	0.203 + 0.1546	0.1936	0.0571 – 0.3236	0.0046	0.7236
sggr100	0.6589 + 0.2944	0.7056	0.4456 – 0.9324	0.0	1.0
sggr350	0.5556 + 0.2523	0.5729	0.3455 – 0.7901	0.0032	0.9777
sggr1k	0.4736 + 0.1993	0.4687	0.3265 – 0.6536	0.0719	0.8721
gr100	0.0127 + 0.0407	0.0	0.0 – 0.0	0.0	0.5066
gr350	0.0236 + 0.0305	0.0119	0.0018 – 0.0329	0.0	0.2354
gr1k	0.0267 + 0.0203	0.0227	0.0123 – 0.0364	0.0	0.1782
bare100	0.1642 + 0.2082	0.0883	0.0 – 0.2429	0.0	1.0
bare350	0.134 + 0.1119	0.0897	0.0496 – 0.1968	0.0	0.7104
bare1k	0.1596 + 0.0891	0.1472	0.087 – 0.2032	0.0205	0.4628
for100	0.0088 + 0.0463	0.0	0.0 – 0.0	0.0	0.511
for350	0.0378 + 0.0646	0.0048	0.0 – 0.0514	0.0	0.439
for1k	0.0663 + 0.0621	0.049	0.018 – 0.1042	0.0	0.3586
for_dist	452.19 + 396.17	320.16	190.26 – 551.73	0.0	2,568.6
Topographic					
slope100	17.08 + 6.93	15.98	11.6 – 21.65	4.6167	45.1652
slope350	25.43 + 5.39	25.3	21.26 – 28.84	13.8007	44.647
slope1k	29.28 + 3.72	28.78	26.5 – 31.55	23.0494	40.4389
tpi100	483.93 + 22.0	482.42	468.24 – 501.61	384.584	551.082
tpi350	463.76 + 18.29	464.6	452.22 – 478.16	405.514	520.361
tpi1k	442.38 + 11.77	444.83	435.05 – 451.61	405.554	465.649
curve100	7.9699 + 2.7441	7.604	5.838 – 9.8535	2.7412	19.3061
curve350	11.1652 + 2.4527	11.134	9.2925 – 12.6971	6.0214	20.107
curve1k	12.738 + 1.725	12.4362	11.4627 – 13.9053	10.0158	17.5551

Figure 6: Vegetation Types. Vegetation types within the PPR Study Area derived from image classification of color-infrared National Agricultural Imagery Program (NAIP) aerial photography collected in 2012.



Spatial Data Collection

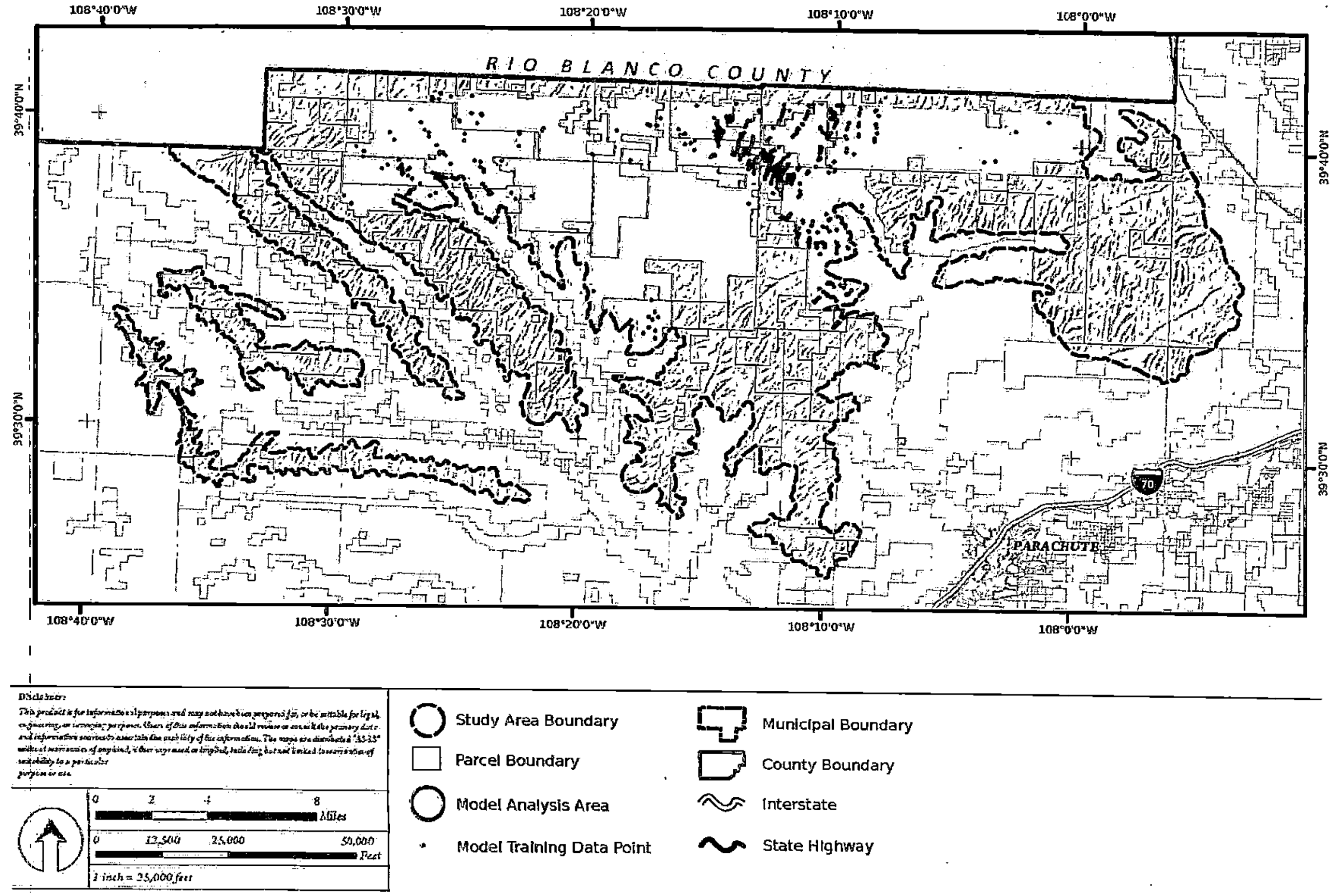
Field-collected data of point locations of sage-grouse signage were collected and compiled from three individual private landowners within the PPR Study Area (WWE 2008). In total, the compiled dataset contained 1,174 unique signage points collected from 2005 to 2012 across a contiguous area totaling 375 km^2 completely contained within the broader PPR Study Area (WWE 2008). The private lands where the field surveys were conducted occur in the central portion of the broader PPR Study Area and are considered to be representative of the diverse habitat types that naturally occur in the region; the surveyed area is displayed on Figure 7. The signage point data consisted of locations indicating presence of sage-grouse, including feather and pellet presence, lek locations and physical bird sightings collected during the summer season when the PPR Study Area is snow-free and easily accessible. All signage data were collected using resource-grade Global Positioning Systems (GPS) with an assumed 2 m horizontal precision. No telemetry data (i.e., sage-grouse outfitted with a GPS or radio-collar) were available for use in this analysis. Prior to, and after the acquisition of the sage-grouse point data, there has been a number of natural gas exploration and development activities in the analysis area, including road construction, natural gas pad development, compressor station construction, and other natural gas related support facilities. Because of these activities and the changing landscape, we did not attempt to capture these habitat impacts in our analysis, as it would have been very difficult to draw a point-in-time by which to incorporate these anthropogenic impacts. An incorporation of these habitat impacts could be incorporated into subsequent modelling analysis investigating direct and indirect impacts to sage-grouse habitats, but such an analysis was beyond the scope of our efforts.

While this data can show presence and seasonality of use, interpretation of how sage-grouse were using the area (e.g., summer foraging, winter foraging and nesting) is somewhat subjective and difficult to accurately predict. Some sage-grouse sign (such as roost piles) can reliably be used to predict winter time use, but single pellets, feathers, or tracks were assumed to not provide enough data to accurately describe use, therefore our models do not attempt to discern how habitats are being utilized by sage-grouse.

Analysis Area

While the model analysis area covered the entire extent of the 894 km^2 PPR Study Area, the model was trained on available point locations collected within the 375 km^2 acres of private lands. The training area, displayed in Figure 7, occurs in the central portion of the broader PPR Study Area, containing a variety of habitat types and topographical features that are assumed to represent the diverse topography and vegetation communities of the broader PPR Study Area.

Figure 7: *Model training area. Defined area used for habitat model training and locations of signage points collected from 2005-2012 within the broader PPR Study Area.*



Resource Selection Function

We first assessed suitability of sage-grouse habitat using a weighted overlay approach utilizing a RSF. The RSF was constructed on a presence vs. available habitat design because our data contained presence-only records, with no attempt to track absence locations. The presence vs. available habitat design characterizes a sample of sites where species' presence is recorded from a sample of resources available in the surrounding environment (Boyce et al. 2002). By contrast, a presence vs. absence design characterizes a sample of sites where species' presence is recorded by contrasting a sample of resources in sites the species are known to be absent. A concern with the presence vs. absence approach is the potential for a false negative error for presence thereby introducing potential bias to the model. While we can ensure that presence records indicate species use, we cannot say with certainty that unused sites (or absence records) are not actually utilized (Boyce et al. 2002). By contrast, a presence vs. available habitat design allows for contamination, defined as having a mixture of both used and unused resources present in the random sample of available resource units. This approach estimates habitat selection using a logistic function that transforms available resource distribution into the used distribution (Johnson et. al. 2006)

The field-collected sage-grouse data contained 1,174 unique point features (WWE 2008). For model analysis, we implemented a 5-1 training-to-validation ratio which is commonly recommended in k–fold partitioning designs to reduce cross-validation variance and bias (Breiman and Spector 1992). As such, 939 point features (80%) were randomly selected to represent presence locations; the remaining 235 point features (20%) were withheld for model validation. An additional 939 point features were randomly generated within the analysis area to quantify resource availability. In total, the compiled training dataset contained a total of 1,878 point features, with half of the features identifying known presence locations and the remaining half used for sampling available resources within the defined analysis area.

We first assessed linear correlation among the potential set predictor variables using Pearson correlation coefficients. When two parameters were correlated ($r > 0.65$), the variables were allowed to compete to determine which independent parameter better explained variance in the dependent variable. The remaining variables were tested for significance ($\rho < 0.1$) using both forward and backward stepwise selection to test all possible explanatory variable combinations and construct a model that best fit the training data; models were evaluated on the basis of samples size corrected Akaike Information Criterion (AIC) scores. AIC scores attempt to minimize model bias while maximizing model precision (Gunn et al. 2004). Models with the lowest AIC scores are considered the most parsimonious and have maximum support for the model (Goodenough et al. 2012). The selected model was further evaluated using bootstrap methods; the data was randomly re-sampled 10,000 times to generate 95% confidence intervals for regression coefficients and estimate standard errors of regression parameters. The full set of explanatory variables retained for model analyses with estimated coefficients, standard errors, upper and lower confidence intervals and significance values are summarized in Table 3. All statistical analyses were performed in the R Project for Statistical Computing using the stats (R Core Team 2013), aod (Lesnoff and Lancelot 2012), Hmisc (Harrell and Dupont 2014) and boot packages (Cantey and Ripley 2013).

After determining the best fit model, the regression coefficients obtained from the analysis were applied to the respective spatial data layers for each explanatory variable as a weighted linear combination in a GIS to produce a predictive surface.

The regression equation for the final model is expressed in the following form:

Y=-16.037746

- 1.841643 * for350

- 18.10309 * gr1k

- 1.829971 * mms100

- 2.321588 * mms1k

+ 14.394478 * sg1k

- 14.473146 * sggr1k

- 0.10506 * slope_100

- 0.122239 * slope_1k

+ 0.044144 * tpi_100

where Y is the probability of occurrence of sage-grouse.

The probability of occurrence was logit transformed using the equation:

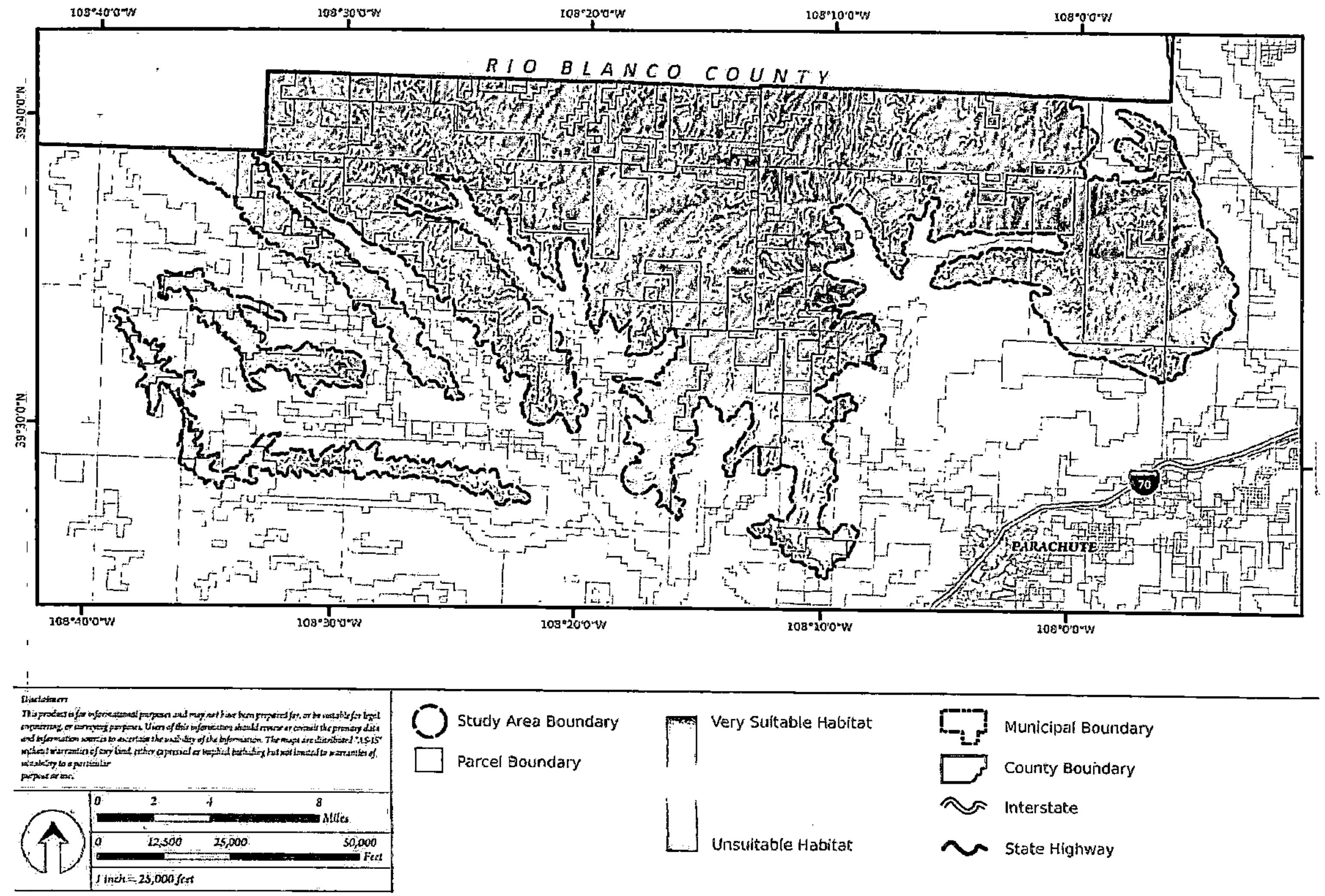
$$P = e^Y /(1+e^Y)$$

The resulting output (Figure 8) predicts probability of occurrence for sage-grouse on a continuous index of 0 to 1; 0 represents 0% probability of suitable sage-grouse habitat while a value of 1 represents 100% probability of suitable habitat for the species.

Table 3: RSF model variable coefficients. Summary of Coefficients of Explanatory Variables used to Predict Suitable Sage-Grouse Habitat

			95% Confidence Interval		
Variable	**Coefficient**	**Std. Error**	***Lower***	***Upper***	***ρ* Value**
Intercept	-16.037746	3.0156	-22.811554	-10.918313	< 0.0001
sg1k	14.394478	2.229340	10.536357	19.309086	< 0.0001
mms100	-1.829971	0.698993	-3.279840	-0.542836	0.0037
mms1k	-2.321588	1.559011	-5.482815	0.583278	0.0841
sggr1k	-14.473146	2.161593	-19.251208	-10.785774	< 0.0001
gr1k	-18.103090	4.942620	-29.617783	-10.155660	< 0.0001
for350	-1.841643	1.155621	-4.152190	0.376809	0.0964
slope100	-0.105060	0.015353	-0.139571	-0.079109	< 0.0001
slope1k	-0.122239	0.047573	-0.216595	-0.031149	0.003
tpi100	0.050775	0.004596	0.044144	0.062215	< 0.0001

Figure 8: RSF model results. Raw RSF model results for PPR sage-grouse habitat.



Fuzzy Model

Following development and analysis of the RSF model, a fuzzy model was developed to model suitable sage-grouse habitat within the PPR Study Area. We utilized all explanatory variable combinations to form our fuzzy model, excluding mixed sagebrush vegetation communities (e.g. sagebrush-grassland mix and sagebrush-mixed mountain shrub mix). Unlike RSF models that determine the most significant contributing explanatory variables and assign weighted coefficients, fuzzy models utilize all sets of explanatory variables without weighting assigned. Because fuzzy logic examines the degree to which a specific location belongs to multiple sets, assigning weights to explanatory variables is illogical as increasing the weight of one factor over another does not increase the potential of belonging to one or more sets; the location is either a member of the set or not (ESRI 2014).

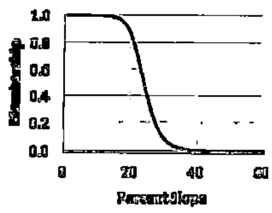
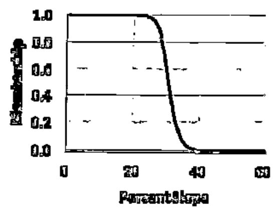
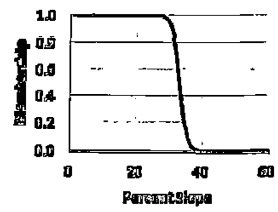
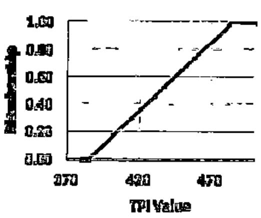
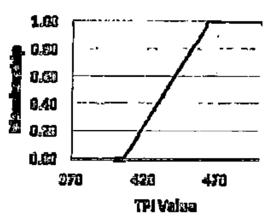
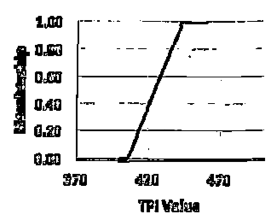
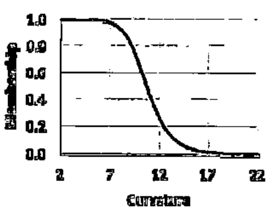
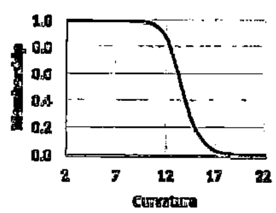
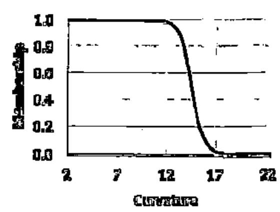
The fuzzy model was constructed to distinguish between suitable and unsuitable habitats for sage-grouse in the PPR Study Area. No attempt was made to model seasonal habitats or model effectiveness and quality of habitats. As such, the fuzzy model equation was constructed using linguistic descriptions involving all explanatory variables; the linguistic descriptions were qualified using the statistics derived for all explanatory variables listed in Table 4. The fuzzy rule for the model was developed using 25 explanatory variables.

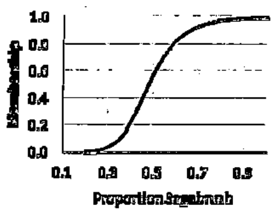
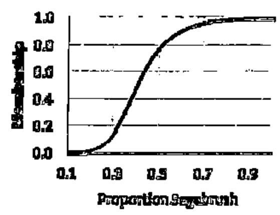
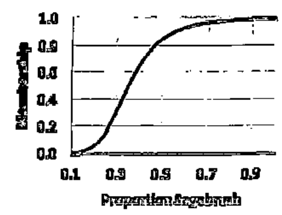
The fuzzy memberships were fitted from the statistics gathered for each variable in Table 4. Sinusoidal memberships were formed using the variable's mean plus or minus one standard deviation for the midpoint value with a spread value that assigned near full membership at the variable's mean. Linear memberships were formed using the minimum value of the variable as the minimum point and the mean specified as the maximum point allowing full membership. The fuzzy membership equations and graphs defining probability of membership for each explanatory variable are listed in Table 5.

Table 4: Fuzzy Model Rule

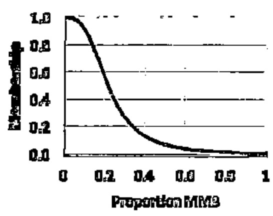
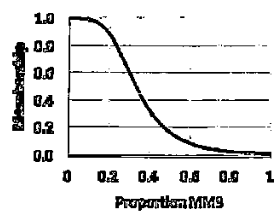
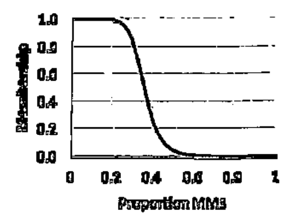
A site is considered suitable for Greater Sage-grouse habitat if it meets the following criteria:		
Criteria	**Scale**	**Definition**
Slope is not steep	100 m	'not steep' defined as < 24%
	350 m	'not steep' defined as < 31%
	1 km	'not steep' defined as < 33%
Location is on or near a ridge	100 m	Defined as TPI value > 435
	350 m	Defined as TPI value > 435
	1 km	Defined as TPI value > 424
Surface curvature is more flat	100 m	'more flat' defined as < 10.71
	350 m	'more flat' defined as <13.62
	1 km	'more flat' defined as <14.46
Surrounding vegetation is dominated by sagebrush	100 m	'dominated' defined as > 48% presence
	350 m	'dominated' defined as > 41% presence
	1 km	'dominated' defined as > 35% presence
Proportion of mixed mountain shrubs are moderately low	100 m	'low' defined as < 22% presence
	350 m	'low' defined as <34% presence
	1 km	'low' defined as < 36% presence
Proportion of grasslands are low	100 m	'low' defined as < 5%
	350 m	'low' defined as < 5%
	1 km	'low' defined as < 5%
Presence of bare surfaces are moderately low	100 m	'low' defined as < 37%
	350 m	'low' defined as < 25%
	1 km	'low' defined as < 25%
Proportion forest is low	100 m	'low' defined as < 6%
	350 m	'low' defined as < 10%
	1 km	'low' defined as < 13%
Distance to forest is far		'far' defined as > 226 ft.

Table 5: Fuzzy Set Membership Functions

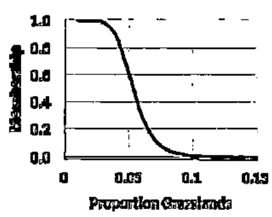
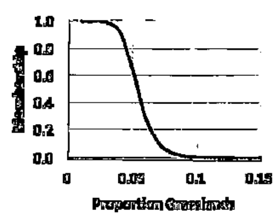
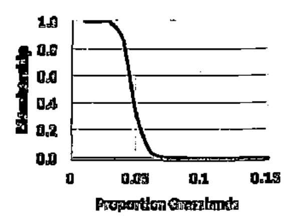
Percent Slope		
100 m (Local Scale)	***350 m (Intermediate Scale)***	***1 km (Landscape Scale)***
$\mu(x)=\frac{1}{1+\left(\frac{x}{24.01}\right)^{10}}$	$\mu(x)=\frac{1}{1+\left(\frac{x}{30.82}\right)^{20}}$	$\mu(x)=\frac{1}{1+\left(\frac{x}{33.0}\right)^{30}}$
		
Topographical Position Index (TPI)		
100 m (Local Scale)	***350 m (Intermediate Scale)***	***1 km (Landscape Scale)***
$\mu(x)=0$ if $x<385$, $\mu(x)=1$ if $x>484$, $\mu(x)=\frac{(x-385)}{(484-385)}$	$\mu(x)=0$ if $x<406$, $\mu(x)=1$ if $x>464$, $\mu(x)=\frac{(x-406)}{(464-406)}$	$\mu(x)=0$ if $x<406$, $\mu(x)=1$ if $x>442$, $\mu(x)=\frac{(x-406)}{(442-406)}$
		
Surface Curvature		
100 m (Local Scale)	***350 m (Intermediate Scale)***	***1 km (Landscape Scale)***
$\mu(x)=\frac{1}{1+\left(\frac{x}{10.71}\right)^{9}}$	$\mu(x)=\frac{1}{1+\left(\frac{x}{13.62}\right)^{15}}$	$\mu(x)=\frac{1}{1+\left(\frac{x}{14.46}\right)^{23}}$
		
Proportion Sagebrush		
100 m (Local Scale)	***350 m (Intermediate Scale)***	***1 km (Landscape Scale)***
$\mu(x)=\frac{1}{1+\left(\frac{x}{0.48}\right)^{-7}}$	$\mu(x)=\frac{1}{1+\left(\frac{x}{0.41}\right)^{-6}}$	$\mu(x)=\frac{1}{1+\left(\frac{x}{0.35}\right)^{-5}}$

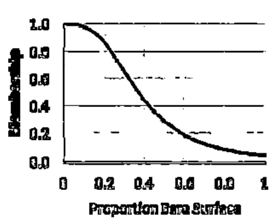
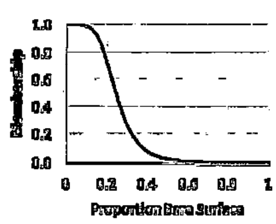
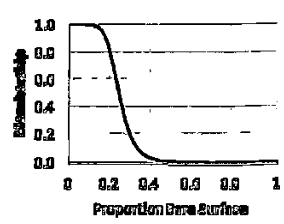
Proportion Mixed Mountain Shrubs

100 m (Local Scale)	350 m (Intermediate Scale)	1 km (Landscape Scale)
$\mu(x)=\frac{1}{1+\left(\frac{x}{0.22}\right)^{3}}$	$\mu(x)=\frac{1}{1+\left(\frac{x}{0.34}\right)^{4}}$	$\mu(x)=\frac{1}{1+\left(\frac{x}{0.36}\right)^{9}}$
		

Proportion Grasslands

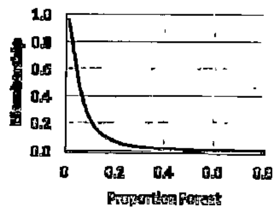
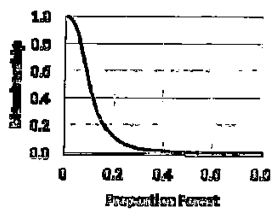
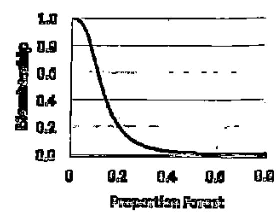
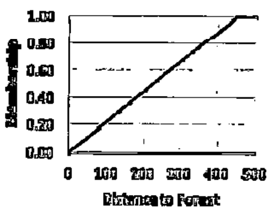
100 m (Local Scale)	350 m (Intermediate Scale)	1 km (Landscape Scale)
$\mu(x)=\frac{1}{1+\left(\frac{x}{0.05}\right)^{7}}$	$\mu(x)=\frac{1}{1+\left(\frac{x}{0.05}\right)^{8}}$	$\mu(x)=\frac{1}{1+\left(\frac{x}{0.05}\right)^{11}}$
		

Proportion Bare Surface

100 m (Local Scale)	350 m (Intermediate Scale)	1 km (Landscape Scale)
$\mu(x)=\frac{1}{1+\left(\frac{x}{0.37}\right)^{3}}$	$\mu(x)=\frac{1}{1+\left(\frac{x}{0.25}\right)^{5}}$	$\mu(x)=\frac{1}{1+\left(\frac{x}{0.25}\right)^{7}}$
		

Proportion Forest

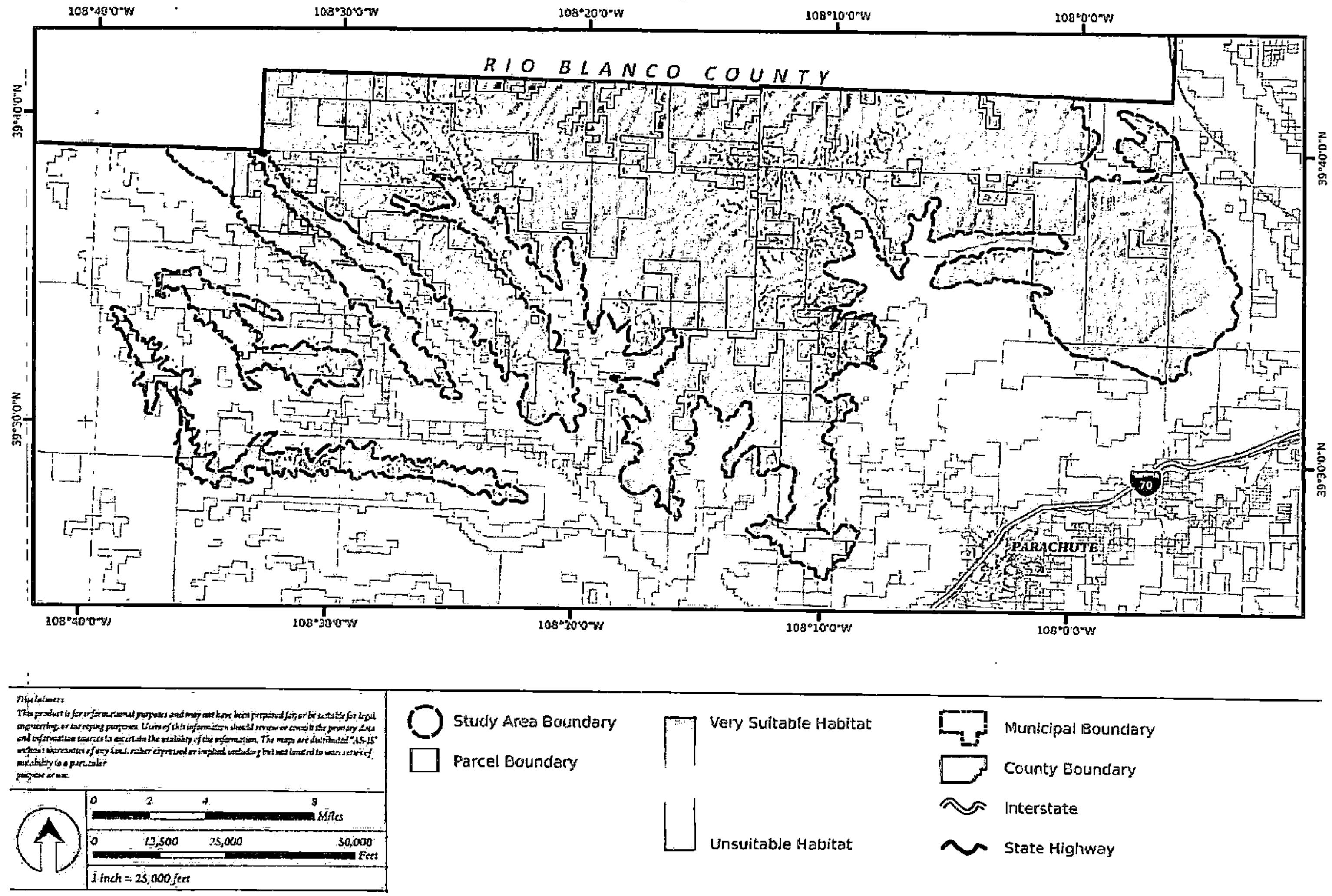
100 m (Local Scale)	350 m (Intermediate Scale)	1 km (Landscape Scale)

$\mu(x)=\dfrac{1}{1+\left(\dfrac{x}{0.06}\right)^2}$	$\mu(x)=\dfrac{1}{1+\left(\dfrac{x}{0.10}\right)^3}$	$\mu(x)=\dfrac{1}{1+\left(\dfrac{x}{0.13}\right)^3}$
		
Distance to Forest		
$\mu(x)=0$ if $x<0$, $\mu(x)=1$ if $x>452$, $\mu(x)=\dfrac{(x-0)}{(452-0)}$		
		

After fitting memberships to all model sets, the sets were combined and analyzed using the Gamma overlay operator using a gamma power of 0.9. The Gamma overlay technique is a combination of the Fuzzy Sum and Fuzzy Product overlay techniques. Fuzzy sum, an increasive function, is employed when the combination of evidence from all sets is more important than any single piece of evidence; by contrast, the Fuzzy Product technique, a decreasive function, is employed when the combination of evidence from all sets is less important than any single piece of evidence. When the Gamma value is applied as 1.0, the results are precisely the same as the Fuzzy Sum technique; when the Gamma value is 0, the results are precisely the same as the Fuzzy Product technique. Initially the Fuzzy Sum technique was employed as no single piece of evidence influenced sage-grouse habitat selection, but rather selection was determined by variety of combined factors. However, the results of the Fuzzy Sum technique ranged from 0.999504 – 1.0, far too similar to accurately distinguish between habitat types and probable selection. As such, the Gamma overlay technique was employed to decrease the results, increasing the range of values returned and provide greater contrast in suitable habitats across the Study Area landscape. Initially, we knew the gamma operator would be higher to maintain the increasing function of the combined evidence. As such, we explored various results using a gamma value of 0.8, 0.85, 0.9 and 0.95. Results using a gamma operator of 0.8 and 0.85 did not adequately delineate utilized habitats, a conclusion based on observing known signage points that were not captured by the model results. By contrast, using the gamma operator of 0.95 greatly over-predicted habitat utilization, a conclusion gained by observing broad forested areas on gentler slopes delineated as suitable habitats. As such, the selected model employed a gamma value of 0.9 which maintains the increasive function of the combined evidence, yet provides adequate distinction between areas of non-utilization.

The resulting output (Figure 9) predicts probability of occurrence for sage-grouse on a continuous index of 0 to 1 using fuzzy logic; 0 represents 0% probability of suitable sage-grouse habitat while a value of 1 represents 100% probability of suitable habitat for the species.

Figure 9: Fuzzy model results. Raw fuzzy model results for PPR sage-grouse habitat.



RESULTS

RSF Model Validation

The RSF model results were validated using a k-fold cross-validation method used to correlate ranked bins with area-adjusted frequencies of predicted values (Johnson et al. 2006). The validation technique involves five steps:

1. Divide the resulting prediction surface into a specified number of progressively ranked equal-area bins.
2. Determine the midpoint value of the RSF score for each bin area.
3. Calculate the utilization rate for each bin using the following formula:

   $$U(x_i) = w(x_i)A(x_i) / \sum_j w(x_j)A(x_j)$$

   where $w(x_i)$ is the midpoint RSF value of bin i and $A(x_i)$ is the area of bin i (Boyce and McDonald 1999).
4. Estimate the expected number of validation records within each bin using the following formula:

   $$N_i = N * U(x_i)$$

   where N is the total number of validation observations used and $U(x_i)$ is the utilization function from step 3.
5. Calculate the observed number of validation records within each bin and regress against the predicted number of locations for each bin.

A well-fit model, one proportional to probability of use, would have a slope equal to 1, an intercept of 0, with a high R^2 value and an insignificant X^2 goodness-of-fit value (Johnson et al. 2006).

RSF Model Results

The RSF model results were split into 6 equal-area ordinal bins. The 235 field-collected presence locations withheld for model validation were cross-referenced with the ordinal bins to count the number of known observations that fell within each bin. We then determined all midpoint values to calculate the expected utilization rate $U(x_i)$ for each bin. The observed and predicted location numbers were converted to percentages to assess model performance and fit using linear regression. In addition, chi-square tests were used to assess model fit, while Spearman correlation coefficients were calculated to assess significance between predicted and observed frequencies.

The RSF model validated well, having a slope of 0.779 (95% CI: 0.626 – 0.932), an intercept of 0.037 (95% CI: -0.024 – 0.097) and an R^2 value of 0.9615. The chi-square goodness-of-fit test supported a good fit between observed and predicted frequencies (χ^2 = 18, ρ = 0.2627). The top two bins predicted 97% occupancy while observed occupancy totaled 99% in bins 5 and 6, totaling 297 km^2 within the PPR Study Area (Figure 10). Bins 1-4 did not meet significance criteria, whereby occupancy would not likely occur $\geq$3% of the time (results for bins 1-4 were therefore not displayed on Figure 10).

In addition, the RSF model was validated against an independent dataset of known lek locations collected by CPW within the PPR Study Area from 1997 – 2012, containing a total of 85 unique point locations (CPW 2013). The model produced a slope of 0.926 (95% CI: 0.814 – 1.034), an intercept of 0.012 (95% CI: -0.027 – 0.051) and an R^2 value of 0.985. The chi-square goodness-of-fit test supported a good fit between observed and predicted frequencies ($\chi^2 = 24$, $\rho = 0.2424$).

The validation results indicate the RSF model is a good predictor for sage-grouse habitat suitability within the PPR Study Area. Model validation results are summarized in Figure 11, which shows expected versus observed proportion of presence observations for withheld validation sample (n = 235) and independent CPW lek samples (n = 85). The dashed line represents perfect fit, having a slope of 1 with intercept of 0. Solid line depicts the fitted regression with point markers displayed as black diamonds.

Figure 10: RSF model bins. RSF model habitat map for PPR sage-grouse habitat.

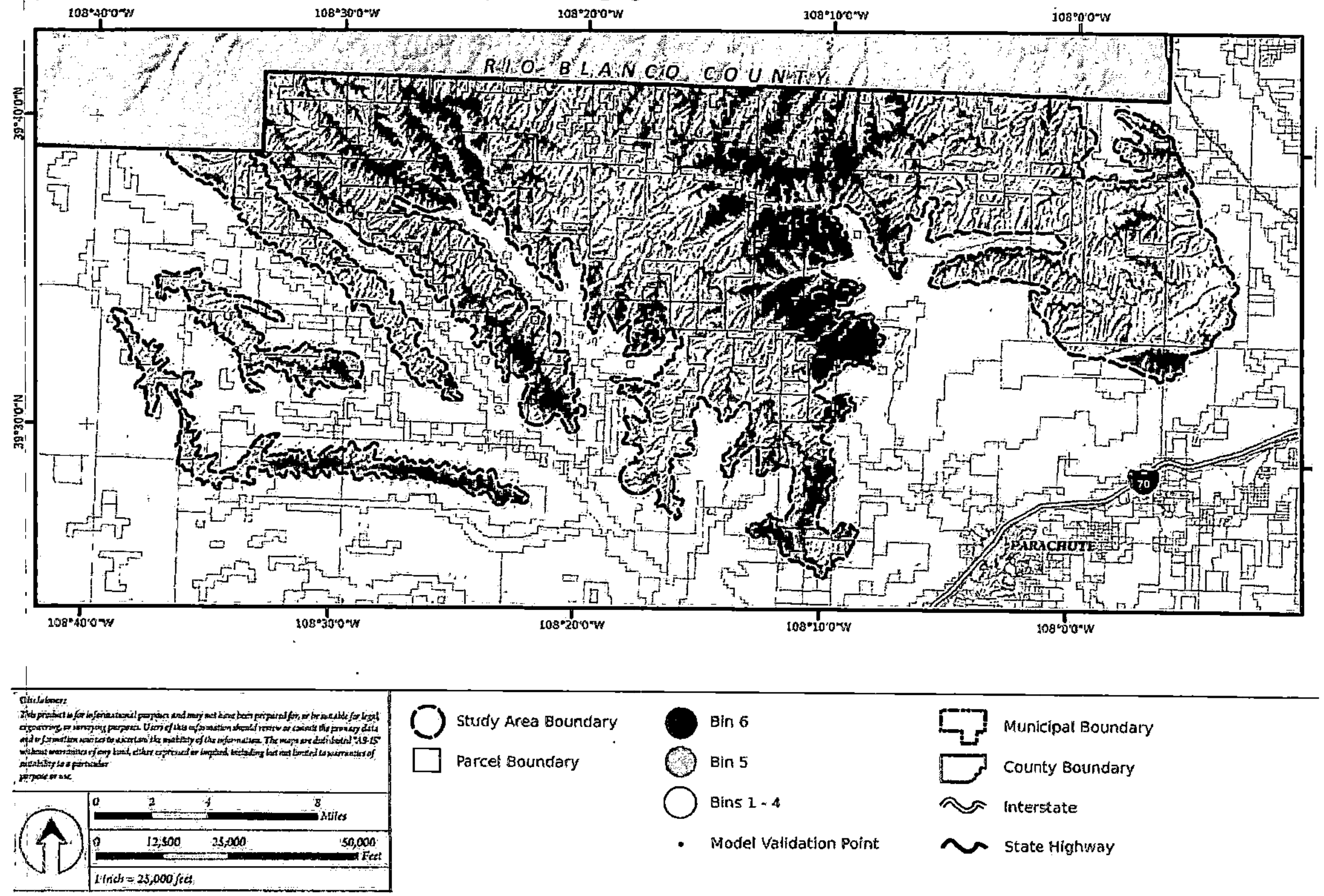
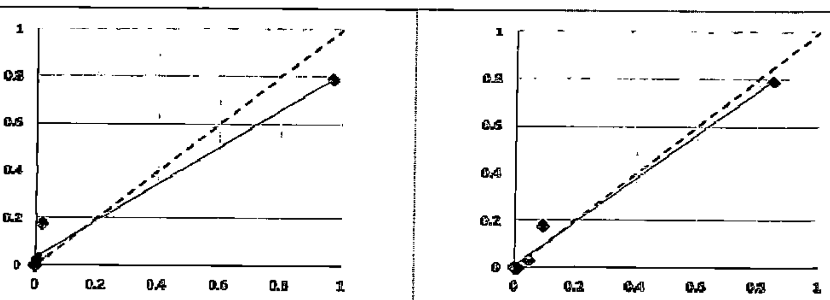


Figure 11: RSF Validation Results: Expected vs. Observed Proportion of Presence Observations.



	Withheld Validation Set			CPW Lek Validation Set		
Regression	$y = 0.779x + 0.037$, Adj.. r^2 = 0.9519			y=0.926x+0.012, Adj. r^2 = 0.9814		
Chi-square	χ^2	Deg. Of Freedom	p	χ^2	Deg. Of Freedom	p
	18	15	0.2627	24	20	0.2424
Spearman correlation	r^2	p		r^2	p	p
	0.9411	0.005		0.8986	0.015	0.015

Fuzzy Model Validation

Validation of the fuzzy model habitat results followed the same k-fold cross-validation procedure applied to the RSF habitat model as outlined above.

Fuzzy Model Results

Similar to the RSF model, we attempted to split the fuzzy model results into six (6) equal-area ordinal bins. However, due to the homogeneous nature of the lower values returned in the predicted surface, only four distinct bins could be produced; the lowest ranked bin (bin 1) captured approximately one-half of the study area, but due to the homogeneity of the results it could not be further subdivided. Therefore a total of four bins for the fuzzy model results are shown in Figure 12, with bin 1 being non-suitable habitat.

The 235 field-collected presence locations withheld for model validation were cross-referenced with the ordinal bins to count the number of known observations that fell within each bin. We then determined all midpoint values to calculate the expected utilization rate $U(x_i)$ for each bin. The observed and predicted location numbers were converted to percentages to assess model performance and fit using linear regression. In addition, chi-square tests were used to assess model fit, while Spearman correlation coefficients were calculated to assess significance between predicted and observed frequencies.

The fuzzy model validated very well, having a slope of 1.031 (95% CI: 0.998 – 1.064), an intercept of 0.005 (95% CI: -0.017 – 0.007) and an R^2 value of 0.9989. The chi-square goodness-of-fit test supported a good fit between observed and predicted frequencies (χ^2 = 18, p = 0.1157). The top two bins (bins 3 and 4) predicted 98% occupancy and observed occupancy totaled 98% totaling 294.8 km^2 within the PPR Study Area. Bins 1-2 did not meet significance criteria, whereby occupancy would not likely occur ≥2% of the time (results for bins 1-2 were therefore not displayed on Figure 12).

In addition, the fuzzy model was validated against the independent dataset of known lek locations collected by CPW within the PPR Study Area from 1997 – 2012, containing a total of 85 unique point locations (CPW 2013). The model produced a slope of 1.22 (95% CI: 1.069 – 1.37), an intercept of -0.037 (95% CI: -0.083 – 0.01) and an R^2 value of 0.984. The chi-square goodness-of-fit test supported a good fit between observed and predicted frequencies (χ^2 = 24, ρ = 0.0895).

The validation results indicate the fuzzy model is a good predictor for sage-grouse habitat suitability within the PPR Study Area. Model validation results are summarized in Figure 13.

Figure 12: Fuzzy model bins. Fuzzy model habitat map for PPR sage-grouse habitat.

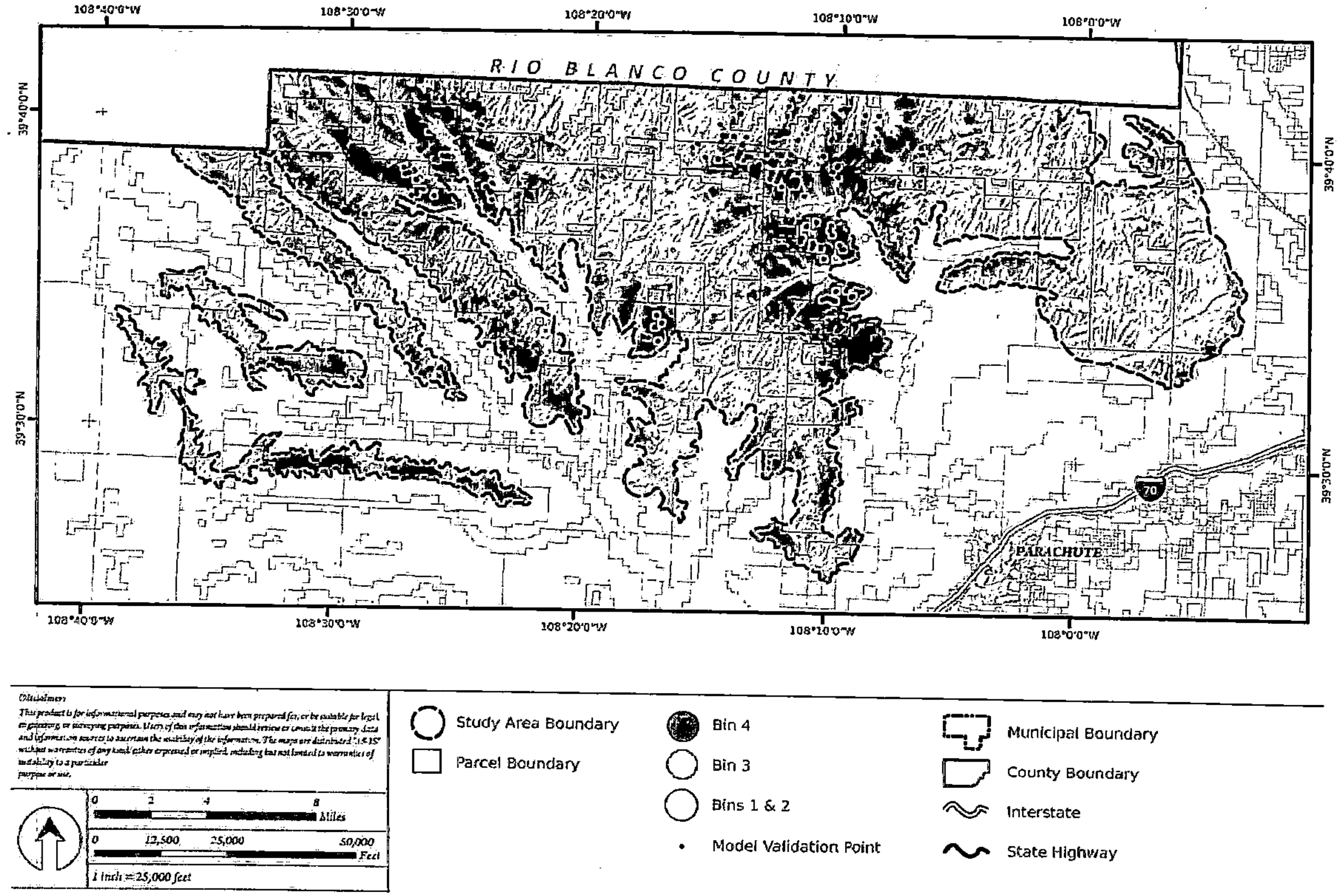
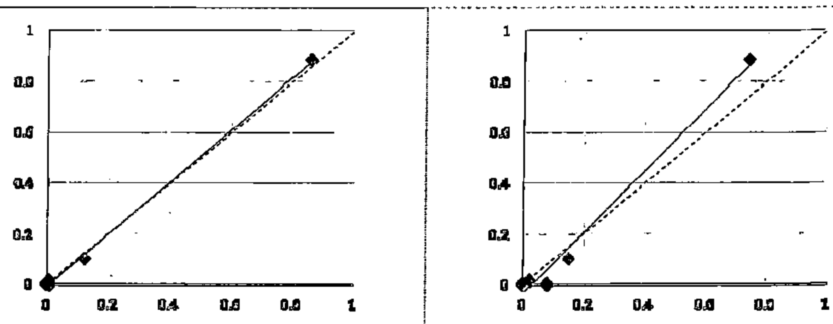


Figure 13: Fuzzy Validation Results: Expected vs. Observed Proportion of Presence Observations.



	Withheld Validation Set			CPW Lek Validation Set		
Regression	$y = 1.031x + 0.017$, Adj. r^2 = **0.9987**			$y = 1.22x - 0.037$, Adj. r^2 = **0.9805**		
Chi-square	χ^2	**Deg. Of Freedom**	p	χ^2	**Deg. Of Freedom**	p
	18	12	0.1157	24	16	0.0895
Spearman correlation	r^2	ρ		r^2	ρ	
	0.9852	0.0003		0.9412	0.005	

Model Assumptions and Limitations

Two primary subjects limit the predictive accuracy of the habitat models developed in this exercise; explanatory variables and uncertainties inherent to the sage-grouse signage points. Concerning explanatory variables, issues that may influence habitat selection beyond the scope of this analysis include 1) accuracy of the classified vegetation dataset, 2) omission of other potentially influential explanatory variables and 3) temporal discrepancies that exist between the signage points and explanatory variables. Regarding signage points, uncertainty exists in terms of understanding the full context of sage-grouse use and behavior at each signage location, as well as the limitation of not being able to discern seasonal use and occupation of an area.

As sage-grouse are a sagebrush obligate species, utilization of a vegetation dataset that accurately depicts vegetation communities and distribution of sagebrush is paramount to understanding habitat selection. Our decision to develop and utilize a vegetation dataset derived from classification of 1 m 4-band aerial photography was motivated by the both the attribute and spatial inaccuracies inherent to both the CVCP (Colorado Vegetation Classification Project [CPW 2003), and LANDFIRE (2010) vegetation datasets. Furthermore, the cell resolutions of each dataset, 25 m and 3 m respectively, are more applicable to development of a regional scale model, as opposed to the local scale model produced for this analysis.

While the results of the vegetation validation indicate an acceptable level of accuracy, only 45 of the 98 field validation locations were able to be field validated due to timing restrictions that prevented access to some private lands. For that reason, additional ocular assessments were performed by visually comparing the classified vegetation communities to underlying high-resolution photography (i.e. 30-cm cell resolution), as well as comparing the classified vegetation dataset results to other areas were data was verified in the field, including field-collected photographs and vegetation plot data. Following these secondary assessments, we were satisfied with the vegetation dataset produced from the image classification process and firmly believe it is the best available data to employ for habitat modeling for this location and scale of analysis. Nevertheless, a limited level of inaccuracy still exists in the data thereby influencing the predictive ability of the habitat models.

A second model limitation is the omission of other potentially influential explanatory variables, including anthropogenic factors and other resource-related criteria including canopy heights and densities, understory vegetation composition, soil types, wildfire risks and others. Anthropogenic variables (e.g., roads, well pads, compressors, pipeline corridors, water facilities, etc.) were excluded due to the lack of available data depicting these features and the inability to accurately produce data that adequately represented anthropogenic factors in a timely manner. Furthermore, recent literature reveals conflicting results on what types of anthropogenic factors and to what degree these features may impact habitat selection for the greater sage-grouse (Ramey, Brown and Blackgoat 2011). For example, a number of currently active and historical natural gas well pad sites exist across the PPR Study Area; based on photo interpretation, it is not evident in every case to determine which sites are active versus inactive. While an inactive pad site is still considered an anthropogenic impact, we know that some of historical pad sites in the PPR Study Area are used as lek locations (based on CPW lek count data). Due to the uncertainty in identifying anthropogenic factors in a timely manner, as well as the uncertainty in how they influence habitat selection, anthropogenic factors were excluded as an explanatory variable in this analysis.

Several other resource-related explanatory variables were omitted from this analysis as well, primarily due to the fact that literature and expert opinion do not indicate them to be primary indicators of habitat selection for sage-grouse, but also due to inadequate or inaccurate data sources. Data depicting canopy heights and densities are available for the project area from the LANDFIRE (2011) suite of data products, but review of the data revealed broad areas where the data did not accurately reflect on-the-ground conditions. Other omitted resource explanatory variables (e.g., soil types, wildfire risks, livestock grazing pressure, climatic change) were excluded due to either their marginal influence in determining habitat selection or lack of data at the project level scale. While these variables are not considered to be key predictors of sage-grouse use and occupation, inclusion of these variables in the models would marginally strengthen the predictive ability of the habitat models.

The temporal discrepancies between the sage-grouse signage points and explanatory variables are an additional limitation of the habitat models. While we know the precise locations of when the signage points were collected, we do not know with certainty what the ground conditions were during the period that the bird was present at the location. The vegetation dataset we developed was produced from NAIP photography collected in 2012, therefore reflecting recent ground conditions. However, the collection of the signage points occurred from across a seven year period from 2005 – 2012. For that reason, uncertainty exists in accurately defining the conditions that existed at the precise point in time that the sage-grouse was present at the signage location.

Lastly, due to the inability to discern the duration of sage-grouse presence in a defined area, as well as the type of habitat use and behavior at each signage locations, the models are unable to classify seasonal habitats. In fact, the sage-grouse signage points are a collection of a data that most likely include indications of use across all seasons. Without knowing the precise time that the grouse were at the signage locations, it is not possible to predict seasonal use with these models.

Recognizing the limitations and uncertainties in the habitat models, we are satisfied with the predictive ability of the models as confirmed through significance in our model validation results, as well as concurrence with other similar models performed at similar scales within the PPR Study Area (Sauls et al. 2006, Walker et al. 2010). Future modeling efforts could be strengthened through inclusion of some of the omitted variables, as well as utilization of telemetry datasets that depicts marked bird locations at precise dates and times to generate a larger dataset of points for model training, including the ability to model and predict seasonal habitats.

DISCUSSION

RSF and fuzzy models utilizing field-collected sage-grouse data both accurately predicted use of habitats at local (100 m), intermediate (350 m) and landscape scales (1 km). These models were validated using randomly selected unique point features, which resulted in ranked bins accurately predicting frequencies of use. The RSF model validated with an R^2 value of 0.9615. The top two bins predicted 97% occupancy while observed occupancy totaled 99% in bins 5 and 6, totaling 297 km^2 within the PPR Study Area. The RSF model was also validated against known lek locations, which also produced an R^2 value >0.98.

The fuzzy model utilized all sets of explanatory variables, without weighting, allowing a variable to exist in multiple bins at various degrees of membership. The results clearly showed that the fuzzy habitat model accurately validated against randomly selected sage-grouse location data and lek sites. The fuzzy model validated with an R^2 value of 0.9989. The top two bins predicted 98% occupancy and observed occupancy totaled 98% in bins 3 and 4, totaling 295 km^2 within the PPR Study Area. In addition, the fuzzy model was validated against the independent dataset of known lek locations, with the model producing an R^2 value of 0.984 against lek locations.

MANAGEMENT IMPLICATIONS

We constructed two predictive models using distinctly different methods to assess sage-grouse habitat suitability within the PPR Study Area. The models demonstrate that of the 894 km^2 Study Area mapped as PPH and PGH by CPW, only 295 km^2 (34%) of the Study Area actually supported suitable sage-grouse habitats. Results suggest that a combination of both vegetation and topographic variables at multiple scales best explain habitat selection by sage-grouse in the PPR Study Area. The RSF model indicates a strong preference for sagebrush-dominated vegetation communities, while demonstrating negative associations with grassland, mixed mountain shrub and forested vegetation communities.

This is further supported by the vegetation selection index (Table 6), a generalized method of quantifying resource selection whereby the amount of a resource utilized is compared to resource availability; ratios producing a value greater than one indicate selection while ratios less than one indicate avoidance (Manly et al. 1992). The vegetation selection index indicates a selection rate of 54% for sagebrush-only and dominated landscapes, and 19% for sagebrush communities containing a marginal mixed mountain shrub component. Topographic variables indicate a negative association with slope and a positive association with a higher topographical position index (TPI), implying that local sage-grouse population prefer flatter areas on the top of ridgelines. These results are consistent with other previous and ongoing fine-scale modeling efforts conducted in the Study Area (Sauls et al. 2008; Walker et al. 2010) which indicate the PPR sage-grouse population select for sage-dominated vegetation communities that occur along ridge tops with shallow slopes. Sage-grouse preference of flatter terrain is also observed in other populations (Hupp and Braun 1989, Doherty et al. 2008) and can be an important habitat factor (Knick and Connelly 2011).

Table 6: Vegetation Selection Index

	Available		Utilized			
Vegetation Type	**Acres**	**%**	**Points**	**%**	**Selection Rate**	**Calibrated Selection Rate**
Bare	28,302.8	13%	287	24%	1.91	26%
Forest	33,992.1	15%	2	< 1%	0.01	< 1%
Grassland	19,611.1	9%	7	1%	0.07	1%
Mixed mountain shrub	69,614.7	31%	22	2%	0.06	1%
Riparian	70.9	< 1%	0	< 1%	0.00	< 1%
Sage dominant	59,995.1	27%	786	67%	4.01	54%
Sage/Mixed Mountain Shrub	9,496.0	4%	70	6%	1.39	19%

By contrast, the results of our two fine-scale predictive models differed dramatically from the CPW sage-grouse mapping that delineates PPH and PGH habitats for the species within the PPR Study Area. The disparate results are likely explained by differences in 1) spatial resolution of the data employed in the model analyses and 2) explanatory variables employed in the models. Regarding spatial resolution, our models used raster data with 10 m cell resolution, similar to the Sauls (et al. 2008) and Walker (et al. 2010) models, as compared to the Rice (et al. 2013) model that utilized raster data with a 1-kilometer cell resolution. The difference in cell resolution equates to a loss of information in the model results that are invaluable for local management policies and practices; for every possible single response in the Rice (et al. 2013) model analyses, there were 10,000 possible responses in our model results.

Secondly, the Rice (et al. 2013) model, once an area was known to be occupied sage-grouse, only considered vegetative explanatory variables, omitting significant topographical variables including slope, surface roughness and topographic or slope position. Particularly to the PPR Study Area, topographical variables are significant predictors of sage-grouse utilization; omission of these critical explanatory variables in assessing habitat suitability fails to recognize the diverse environment of the PPR Study Area, the limited areas of gentler terrain, and how the naturally fragmented landscape is selectively utilized by the local sage-grouse population.

While Rice (et al. 2013) omitted the use of topographic variables in their models due to model scale, they recognized that localized studies indicate these factors strongly contribute to actual sage-grouse habitat utilization. Furthermore, Rice (et al. 2013) did emphasize that "finer-scale and site-specific information" should be used to identify priority areas for sage-grouse conservation. Our results support and quantify the conclusions of Rice (et al. 2013) that finer-scale analysis is needed to adequately assess sage-grouse habitat suitability.

While the Rice (et al. 2013) model analysis is not technically flawed, the dramatically broader spatial resolution of the data employed, combined with the omission of critical explanatory topographic variables, has the unintended consequence of over-predicting habitat by a three-fold factor in the PPR Study Area; the Rice (et al. 2013) model results indicate the entirety of the Study Area is suitable sage-grouse habitat to some degree.

Gross over-prediction of habitats may not help support habitat management or species conservation, but rather may unnecessarily dilute conservation activities and priorities resulting in ineffective allocation of habitat improvement strategies. Preliminary Priority Habitat is defined by the Sage-Grouse National Technical Team (NTT 2011) as "Areas that have been identified as having the highest conservation value to maintaining sustainable sage-grouse populations. These areas would include breeding, late brood-rearing, and winter concentration areas. These areas have been identified by state fish and wildlife agencies in coordination with respective BLM offices". Designated PPH/PGH habitats within the BLM's Draft RMPA/EIS have certain goals, objectives and management guidance associated for PPH/PGH areas. For example, the RMPA/EIS has: habitat restoration objectives to improve sagebrush habitats, wildfire management priorities, seasonal restrictions for fuels management activities, access restrictions, grazing restrictions, and other actions which may not actually benefit sage-grouse if PPH/PGH designations were erroneously applied to non-habitat. Goals and objectives tied to erroneously designated PPH/PGH areas could burden land management agencies with unnecessary management targets and "habitat improvement" targets in areas that were never, and will never actually be occupied by sage-grouse.

Additionally, applying erroneously mapped PPH/PGH designations on areas which do not support sage-grouse habitat may burden or restrict other land use activities; for example, the RMPA/EIS would impose a 3% surface disturbance cap on PPH/PGH areas, and even if the area is field-validated as being non-habitat, the validation process could be time consuming and burdensome for both land owners, land managers and regulatory agencies. When PPH/PGH areas may be over predicting habitat by around 60% in the PPR Study Area alone, this could impose significant burdens on landowners and land managers across very large areas.

With potential listing of the species under the Endangered Species Act, truly understanding and spatially depicting sage-grouse habitat could further inform policy and management of the species. Omission of critical explanatory data, or utilizing over-predicting habitat models could also lead managers to the conclusion that there is more available habitat than there truly is. The use of coarse models to map PPH/PGH attempts to predict important ("priority") habitats for sage-grouse conservation, yet as Rice (et al. 2013) indicates "At the broad scale of these models, detecting specifics for individual birds or individual locations is not possible." We believe that even our models are still not accurate enough to detect specifics for "individual birds or individual locations", but the results presented by utilizing higher resolution vegetation data and more accurate modelling techniques still paints a much different picture of sage-grouse habitat suitability. While our model is not intended to drive regional policy, it presents additional information to help land use managers make more informed and hopefully more accurate and relevant decisions regarding management of sage-grouse habitats, and to help conservation efforts become more effective and meaningful at a scale and in locations that are more relevant to sage-grouse.

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SAGE-GROUSE HABITAT MODEL
APPENDIX A: USING IMAGE CLASSIFICATION TO DEVELOP VEGETATION COVER TYPES

Introduction

Publicly available datasets depicting vegetation cover types across the project area were initially employed in the spatial models; the datasets include LANDFIRE vegetation cover (LANDFIRE 2011) and the Colorado Vegetation Classification Project (CVCP) (CPW 2003). However, review of the data revealed widespread inaccuracies in correctly identifying and classifying the vegetative cover types when compared to high-resolution aerial photography. In addition, the cell resolution of both the LANDFIRE and CVCP datasets, measured at 30-meters and 25-meters respectively, were too coarse to accurately delineate vegetation communities at the local scale. As a result, the spatial inaccuracies combined with the mistyped vegetative in both datasets led to our conclusion that the datasets were inadequate in appropriately identifying suitable vegetative cover types at the local scale.

In an effort to increase the accuracy of the spatial data depicting existing vegetative cover types within the Study Area, an image classification process involving color-infrared aerial photography was performed to better represent vegetation communities. Image classification is achieved by combining multiple bands from the same image to detect relative color, color intensity and texture to form clusters based on similar return values. Two major categories of image classification include supervised and unsupervised classification. Supervised classification is a method whereby the user defines training sites of known vegetation types within the analysis area; the training sites are subsequently used to as reference for classifying all other remaining pixels in the image into respective vegetation groups (Busch n.d.). By contrast, an unsupervised classification process relies on software analysis to identify and define similar pixel groups without user-defined training sites; the software uses a variety of statistical algorithms and techniques to identify related pixels and group them into similar classes (Busch, n.d.). Subsequently, the user assigns vegetation communities to the resulting classes using a combination of photo-interpretation and field-collected data.

Color-infrared photography provides four bands that detect specific wavelength ranges of reflected solar radiation; three bands within the visible light spectrum (e.g., red, green and blue), and a fourth near infrared band that measures reflected radiation beyond the visible light spectrum. The band combinations can yield a variety of properties and characteristics of the objects and vegetation interpreted in the aerial photography, including vegetation health, vegetation moisture and species identification (USDA 2008). For example, using the near infrared, red and green spectral bands to produce a 'false color' image (e.g., mapping the near infrared, red and green bands to RGB) provides high contrast between heavily vegetated areas (i.e., aspen, mixed conifer, and mixed mountain shrubs), less vegetated areas (grasslands, shrublands, etc.) and barren areas. Furthermore, within forested areas, image combinations utilizing the near infrared band help to distinguish between deciduous and coniferous tree species. Deciduous trees contain more chlorophyll and therefor reflect an intense bright red, while coniferous trees contain less chlorophyll and reflect lighter tones of red, magenta or pink. Within grassland and shrub communities, delineations were detected in a similar manner; the higher chlorophyll content in grasses and forbs caused these communities to reflect much brighter as compared to adjacent sagebrush communities.

Materials and Methods

The image classification for this project was performed on four-band 1-meter resolution photography acquired in 2011 from the USDA as part of the NAIP (USDA 2012) within the defined PPR Study Area. The NAIP imagery was re-sampled from 1-meter, to 2-meter cell resolution to facilitate accurate grouping of similar vegetation classes by minimizing noise that results from mixed vegetation stands. The four-bands were subsequently combined using a number of techniques to yield band derivatives that distinguished and delineated presence of vegetation, amount of chlorophyll, band reflectance values and relative textures. The band derivatives were finally employed in an unsupervised image classification exercise to identify and delineate distinct vegetation communities within the PPR Study Area.

Initially, the classification effort sought to identify the following vegetation cover types described in Table 1 below.

Table 1: Cover type classifications.

Cover Type	
Sagebrush	Gambel Oak
Sagebrush-dominated/grassland mix	Pinyon-Juniper
Sagebrush-dominated/mixed mountain shrub mix	Aspen
Grassland	Mixed conifer
Grass-dominated/mixed mountain shrub mix	Riparian
Mixed mountain shrubs	Bare surface

The primary intent of the classification exercise was to delineate both cohesive and mixed communities at a fine scale to study how they might influence habitat selection at the local scale. Secondarily, we hoped to distinguish Gamble oak and pinyon-juniper dominated stands from mixed mountain shrubs, consisting primarily of snowberry, service berry and bitterbrush, to examine if one cover type exerted greater influence in habitat selection within the PPR Study Area.

Results and Discussion

The cover type map units were broadly defined and included several vegetation communities. The forested cover type included woodland areas dominated by aspen or conifers with mixed understories. The mixed mountain shrublands consisted of Utah serviceberry, mountain snowberry, bitterbrush and Gamble oak interspersed with grassland and herbaceous understories. The grasslands included bunchgrass meadows, allowing for encroachment of mixed mountain shrubs up to 25%. Sagebrush communities were dominated by a variety of sagebrush species, interspersed with bunchgrass and herbaceous understories. Both sagebrush-dominated/mixed mountain shrub and sagebrush-dominated/grassland mixed cover types contained a variety of sagebrush species intermixed with mixed mountain shrublands and bunchgrass meadows, with sagebrush cover ranging from 50% - 75%, respectively within these two cover types.

98 random points were generated across the project area for the purposes of field validation. Excluding bare surface and riparian cover types, each community was assigned 10 randomly generated points to inspect and confirm via field verification, with mixed conifer stands being assigned 8 randomly generated points for verification. Of the 98 potential points, only 45 were able to be field verified due to timing restrictions/limitations and limited access to some private lands.

The initial image classification exercise attempted to distinguish Gamble oak and pinyon-juniper from the broader mixed mountain shrublands cover type. In addition, aspen stands were classified separately from mixed conifer stands. The initial classification effort correctly identified 31 of the 45 of the randomly sampled field plots. Results of the initial classification effort are provided in Table 2 below.

Table 2: Accuracy assessment of initial image classification.

Cover Type	# Correct	Total Plots	% Correct
Aspen	7	7	100%
Gamble Oak	2	3	67%
Grasslands	1	3	33%
Grassland/mixed mountain shrubs	0	6	0%
Mixed Conifer	7	7	100%
Mixed mountain shrubs	4	5	80%
Pinyon-juniper	0	4	0%
Sagebrush	3	3	100%
Sagebrush-dominated/grass	3	3	100%
Sagebrush-dominated/mixed mountain shrubs	4	4	100%
Total	**31**	**45**	**68%**

The validation of the initial classification effort resulted in a total of 68% of the field plots being correctly identified which falls below the acceptable interpretation accuracy of 85% (Anderson et al. 1976). While several communities validated with 100% accuracy, the low predictive accuracy for Gamble oak, pinyon-juniper, grasslands and grassland/mixed mountain shrubs cover types hampered the accuracy of the overall classified dataset.

Field validation revealed that map units typed as pinyon-juniper cover type were, in fact, mixed mountain shrubland communities. Consequently, the pinyon-juniper mapped units were converted to mixed mountain shrubland communities. Likewise, while two of the three Gamble oak sample plots were correctly verified, they nevertheless contained a high percentage of mixed mountain shrublands; the third sample plot was field verified as mixed mountain shrublands. As such, the Gamble oak map units were also converted to mixed mountain shrublands, based on limitations in the model accurately distinguishing between Gamble oak and other mixed mountain shrub species.

In addition, the poor predictive accuracy of grassland and grassland/mixed mountain shrub communities warranted a second review of the data. Of the six field plots for grass/mixed mountain shrub cover types, none were accurately verified. Rather five of the six sample plots revealed a much higher percentage of shrubs, while the sixth plot was verified as sagebrush. Furthermore, only one of the three grassland field sample plots was correctly verified; the remaining two plots were identified as sagebrush communities. Subsequently, the units originally mapped as either grasslands or grass/mixed mountain shrub cover types were re-analyzed and re-typed as either grassland, mixed mountain shrublands or sagebrush. Lastly, both aspen and mixed conifer cover types were combined to form a single forested cover type.

The revised classified dataset was re-validated using the original 45 field verified sample plots. The secondary validation effort against the revised dataset correctly identified 41 of the 45 randomly sampled field plots. Results of the revised vegetation classification accuracy assessment are presented in Table 3 below.

Table 3: Accuracy assessment of final image classification.

Cover Type	# Correct	Total Plots	% Correct
Grassland	1	3	33%
Forested	14	14	100%
Mixed mountain shrubs	16	18	89%
Sagebrush	3	3	100%
Sagebrush-dominated/grass	3	3	100%
Sagebrush-dominated/mixed mountain shrubs	4	4	100%
Total	31	45	87%

The second validation of the revised classification effort resulted in a total of 87% of the field plots being correctly identified, indicating the dataset meets acceptable interpretation accuracy. Overall, most mapped communities validated exceptionally well, excluding grassland communities which still had a low predictive accuracy of 33%, and to a lesser degree, mixed mountain shrubland cover types. An error matrix for the mapped cover types are presented in the Table 4 below.

Table 4: Error matrix for final mapped cover types.

Mapped Cover Type	Actual Cover Type					
	Grassland	Forested	Mixed mountain shrubs	Sagebrush	Sage-dominated/grass	Sage-dominated/mixed mountain shrubs
Grassland	1			2		
Forested		14				
Mixed mountain shrubs		1	16	1		
Sagebrush				3		
Sagebrush-dominated/grass					3	
Sagebrush-dominated/mixed mountain shrubs						4
Total	**1**	**15**	**16**	**6**	**3**	**4**

Overall, the final classified cover type dataset resulted in seven distinct cover types within the PPR Study Area. The results of the classification are quantified in Table 5 below.

Table 5: Final image classification cover types quantified.

Cover Type	Acres	% of Study Area
Bare	28,303	13%
Grassland	19,611	9%
Forested	33,992	15%
Mixed mountain shrubs	69,615	31%
Riparian	71	< 1%
Sagebrush	38,240	17%
Sagebrush-dominated/grass	21,756	10%
Sagebrush-dominated/mixed mountain shrubs	9,496	4%
Total	**221,084**	**100%**

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Appendix C- Original Plan Resolution

STATE OF COLORADO)
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County of Garfield)

At a regular meeting of the Board of County Commissioners for Garfield County, Colorado, held in the Commissioners' Meeting Room, Garfield County Administration Building in Glenwood Springs on Monday, the 18th day of March A.D. 2013, there were present:

John Martin, Commissioner Chairman
Mike Samson, Commissioner
Tom Jankovsky, Commissioner
Andrew Gorgey, County Manager
Frank Hutfless, County Attorney
Jean Alberico, Clerk of the Board

when the following proceedings, among others were had and done, to-wit:

RESOLUTION NO. 2013-23

A RESOLUTION APPROVING THE "GARFIELD COUNTY GREATER SAGE-GROUSE CONSERVATION PLAN"

Recitals

A. Portions of western Garfield County are currently managed for Greater Sage-Grouse (sage-grouse) and habitat protection as detailed in the ***Parachute - Piceance - Roan Sage-grouse Conservation Plan*** (PPR Plan) approved by Colorado Parks and Wildlife (CPW) in April, 2008 which was a multiple year planning effort with broad-base support from private land owners, state and federal agencies and special interest groups. The PPR Plan serves as the primary management framework for both public and private lands in Garfield County that have been identified as having suitable sage-grouse habitat by CPW.

B. To date, the PPR Plan has provided valuable guidance to private landowners and state and federal agencies in Garfield County since its completion in 2008. The Garfield County Greater Sage-Grouse Conservation Plan (the Plan) serves as a necessary refinement of the PPR Plan, which enhances the ability to effectively protect and manage key habitat components. This is achieved primarily through a high-resolution habitat identification and mapping effort, which utilizes the best available science. The Plan is designed to reflect the unique characteristics of the habitat in Garfield County and to acknowledge the latest research and technological advances in energy development.

C. The U.S. Fish and Wildlife Service (the Service) listed the sage-grouse as a Candidate species (warranted but precluded) for Endangered status in 2010, with a pending decision for a final determination anticipated in September, 2015.

D. Garfield County has entered into a Memorandum of Understanding (MOU) with the Bureau of Land Management (BLM) as well as participated as a Cooperating Agency in the review of the Northwest Colorado Sage-grouse Environmental Impact Analysis (EIS).

E. In addition to participating as a Cooperating Agency, on June 18, 2012 Garfield County adopted Resolution 2012-51, "Asserting Coordination Regarding the Sage-grouse with all Federal and State Agencies Maintaining Jurisdiction Over Lands and/or Resources Located within Garfield County, Colorado." As a result, the County has requested the BLM, through this Coordination process, to reconcile their planning efforts such as the Alternatives proposed in the BLM EIS with local planning efforts in Garfield County.

F. At the direction of the U.S. Department of Interior, a National Technical Team (NTT) was assembled which produced a set of conservation strategies, known as the NTT Report in December, 2011. While the NTT Report used the Wyoming region as the basis for the national habitat range characteristics and subsequent land use management recommendations, it does not address the unique landscape qualities, habitat characteristics or land uses found in western Garfield County.

G. As a result of an attempt to reproduce the Preliminary Priority Habitat mapping and the methodologies employed by CPW and adopted by the BLM, Garfield County was unable to reproduce that mapping due to the coarseness of the data. Because of this, much of the habitat mapping used to delineate populations and habitat had serious validity issues and inaccurately classified large areas of unsuitable habitat as potential grouse habitat. As a result, Garfield County commissioned a highly accurate mapping exercise of potential sage-grouse habitat in Garfield County using a much more sophisticated and robust model that ultimately revealed that suitable and effective habitat in the County exists in a significantly different pattern, which is considerably different to the habitat supported by and cited by the NTT Report.

H. The BLM has a statutory duty to manage lands under their direct or indirect jurisdiction for multiple uses of resources, and not for a single purpose. The implementation of the NTT recommendations across large areas of Garfield County through an amendment to the applicable Resource Management Plans would burden large areas of private lands that are not suitable sage-grouse habitats with severe land use restrictions.

I. Garfield County remains concerned that if NTT recommendations are adopted across all currently proposed Preliminary Priority Habitat, Preliminary General Habitat, and Linkage Areas as mapped by CPW without regard to local conditions and using accurate data, then large swaths of non-habitat on public and private lands in the County would be encumbered and burdened with unnecessary regulations that would 1) significantly hurt local economies and 2) would misallocate resources which would not help recover the species.

J. As stated by CPW and the BLM through the Coordination process, the habitat maps for the Sage-grouse using CPW data is very inaccurate as it was gathered at very coarse resolution for broad-scale planning efforts, and no verification studies of habitats have been conducted for these mapped areas. As a result, much of the habitat described as Preliminary Primary Habitat and Preliminary General Habitat includes conifer forests, aspen stands, oakbrush, grasslands, steep slopes, cliffs and rocky outcrops, and contiguous areas of mixed mountain shrublands, all of which are not suitable for the sage-grouse.

K. The Service's Candidate notice identifies oil and gas development as a key impact leading to the reduction of sage-grouse habitat, while this impact is estimated to directly impact less than 1% of habitats, and indirectly impact 8% of habitats. This is a significantly smaller impact than other, larger impacts to habitats, but is consistently cited as a major impact. Further, the determinations regarding oil and gas impacts has been made relying on studies prepared from data collected in high density natural gas fields established in the 1980's – 1990's in the Pinedale and Powder River Basin areas in Wyoming. Such intensive pad density is no longer utilized by the industry in Wyoming or in Garfield County due to advances in technology and a shift in the BLM's fluid minerals policies, which are significantly reducing the industry's impact on the land and further minimizing impacts to the species.

L. Garfield County's primary source of revenue that supports the operations and welfare of the County and its citizens comes directly and indirectly from the oil and gas industry. Garfield County's ability to protect the health, safety and welfare of its citizens, as well as ensure continued protection for all wildlife and their habitats, and the productive use of lands depends on the continuation of balanced development by the oil and gas industry, agriculture and recreation interests.

M. The Board of County Commissioners held a public hearing on the 18th day of March, 2013 for consideration of whether the Plan should be approved, during which hearing the public and interested persons were given the opportunity to express their opinions regarding the request.

N. The Board of County Commissioners closed the public hearing on the 25th day of March, 2013 to make a final decision.

O. Based on substantial competent evidence produced at the aforementioned hearing, the Board of County Commissioners has made the following determinations:

Reception#: 856166
11/18/2014 04:19:42 PM Jean Alberico
102 of 106 Rec Fee:$0.00 Doc Fee:0.00 GARFIELD COUNTY CO

Reception#: 832657
03/20/2013 10:21:59 AM Jean Alberico
4 of 56 Rec Fee:$0.00 Doc Fee:0.00 GARFIELD COUNTY CO

1. That proper public notice was provided as required for the hearing before the Board of County Commissioners.

2. The hearing before the Board of County Commissioners was extensive and complete, all pertinent facts, matters and issues were submitted and all interested parties were heard at that meeting.

3. For the above stated and other reasons the Plan is in the best interest of the health, safety, and welfare of the citizens of Garfield County.

4. That the Plan is in general conformance with the 2030 Comprehensive Plan, as amended.

5. Garfield County has the explicit authority to "plan for and regulate the use of land by regulating the use of land on the basis of the impact thereof on the community or surrounding areas . . . (and) planning for and regulating the use of land so as to provide planned and orderly use of land and protection of the environment in a manner consistent with constitutional rights." (C.R.S. § 29-20-104(1)(g) and (h)).

6. The Board of County Commissioners, pursuant to 43 U.S.C. § 1712, has formally enacted Coordination (via Resolution 2012-57) with all state and federal agencies acknowledging that federal law requires the BLM to (1) make its plans consistent with this Plan and related policies; (2) include this plan as an alternative pursuant to 43 U.S.C. § 4332(e); and, (3) in the event it cannot reach consistency, state why it cannot resolve the conflicts with Garfield County. Resolution 2012-57 also acknowledges that federal law requires the Service to take into account all local efforts to conserve species prior to making a listing determination and to coordinate with the County when determining critical habitat. The resolution also acknowledges the County's primary planning authority for lands and wildlife within its boundaries, which it exercises in part by coordinating with all other state agencies to ensure the policies set forth in this plan are consistently and uniformly applied.

RESOLUTION

NOW THEREFORE, BE IT RESOLVED by the Board of County Commissioners of Garfield County, Colorado, that:

A. The forgoing Recitals are incorporated by this reference as part of this resolution.

B. Garfield County adopts the Plan (attached as Exhibit A) as a refinement of the existing Parachute-Piceance-Roan Plan. The Plan serves as an update to the PPR Plan with policies specific to the County based on the most current best available science and the unique landscape found in the County as depicted in the sage-grouse Habitat Map incorporated therein.

C. Garfield County recognizes the statutory obligation of the Bureau of Land Management to make its planning, inventory and management activities consistent with the policies of Garfield County and will continue to work to resolve the conflicts with the agency.

Dated this 19th day of March, A.D. 20 13.

GARFIELD COUNTY SEAL COLORADO

ATTEST:

Jean M Alberico
Clerk of the Board

GARFIELD COUNTY BOARD OF COMMISSIONERS, GARFIELD COUNTY, COLORADO

[signature]
Chairman

Upon motion duly made and seconded the foregoing Resolution was adopted by the following vote:

COMMISSIONER CHAIR JOHN F. MARTIN ______ Aye / Nay
COMMISSIONER MIKE SAMSON ______ Aye / Nay
COMMISSIONER TOM JANKOVSKY ______ Aye / Nay

Appendix D- Updated Plan Resolution

STATE OF COLORADO)
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County of Garfield)

At a regular meeting of the Board of County Commissioners for Garfield County, Colorado, held in the Commissioners' Meeting Room, Garfield County Administration Building in Glenwood Springs on Monday, the 17th day of November A.D. 2014, there were present:

John Martin, Commissioner Chairman
Mike Samson, Commissioner
Tom Jankovsky, Commissioner
Andrew Gorgey, County Manager
Frank Hutfless, County Attorney
Jean Alberico, Clerk of the Board

when the following proceedings, among others were had and done, to-wit:

RESOLUTION NO. 2014 - __

A RESOLUTION APPROVING THE FIRST AMENDMENT TO THE "GARFIELD COUNTY GREATER SAGE-GROUSE CONSERVATION PLAN"

Recitals

A. On Monday, March 18, 2013, the Garfield County Board of County Commissioners (the Board) adopted the ***Garfield County Greater Sage Grouse Conservation Plan*** (the Plan) via Resolution 2013-23 and has been implementing the principles, policies and best management practices of the Plan through land use decisions under its jurisdiction since that time.

B. Since the original adoption of the Plan in 2013, the Board recognized the need to update the habitat mapping methodology and commissioned a robust effort through the use of two model approaches to map and quantify at a finer and more accurate scale the extent of suitable Greater Sage-Grouse habitat in Garfield County. Chapter 3 (Plan Area) and Chapter 4 (Habitat Mapping) have been updated based on the results of this new information. Specifically, the original Plan reflected initial habitat mapping efforts based on less sophisticated modeling techniques using characteristics more typical of national range habitats; the March 2013 Plan indicated 15,525 acres of suitable habitat within the PPR Study Area. Subsequently, more contemporary data were obtained and reviewed specific to the Parachute – Piceance – Roan (PPR) Study Area allowing further development of more sophisticated and statistically robust modeling methods ultimately resulting in approximately 72,896 acres of Suitable Habitat within the PPR Study Area. This effort resulted in an independent and objective peer reviewed manuscript entitled ***The Use of Modeling in a Geographic Information System to Predict Greater Sage Grouse Habitat***, now contained in full in Appendix B of the Plan.

C. The principles and policies contained within the Plan shall be used to address functional surface disturbance within Suitable Habitats in the Plan Area as depicted on a new map known as **Figure 5: Greater Sage-Grouse Management Plan Areas (MPAs)**. These MPAs were developed by combining the Suitable Habitat areas resulting from both habitat models described in manuscript entitled ***The Use of Modeling in a Geographic Information System to Predict Greater Sage Grouse Habitat***. In total, the MPAs encompass 93,895 acres (or 43%) of the Plan Area. More specifically, 74,819 acres (80%) are managed under the Private Lands Management Area Plan while the remaining 19,076 acres (20%) are managed under the Public Lands Management Area Plan.

D. Additionally, Chapter 7, Section 5 (Predation) has been updated to reflect information with literature citations that better highlights the serious nature of the threat of predation on the Greater Sage Grouse which has also resulted in a new policy (Policy B) in that section stated here:

Encourage public agencies such as Colorado Parks and Wildlife, the Bureau of Land Management, and the US Fish and Wildlife Service to work with private land owners in areas of known Suitable Habitat to better understand the actual predation threat and then collaborate on the implementation of predator mitigation programs that discourage predators, reduce productivity and recruitment of predators, and reduce predator density.

E. The Board of County Commissioners held a public hearing on the 17th day of November, 2014 for consideration of whether this first amendment to the Plan should be approved, during which hearing the public and interested persons were given the opportunity to express their opinions regarding the request.

F. The Board of County Commissioners closed the public hearing on the 17th day of November, 2014 to make a final decision.

Reception#: 856166
11/18/2014 04:19:42 PM Jean Alberico
106 of 106 Rec Fee:$0.00 Doc Fee:0.00 GARFIELD COUNTY CO

G. Based on substantial competent evidence produced at the aforementioned hearing, the Board of County Commissioners has made the following determinations:

1. That proper public notice was provided as required for the hearing before the Board of County Commissioners.

2. The hearing before the Board of County Commissioners was extensive and complete, all pertinent facts, matters and issues were submitted and all interested parties were heard at that meeting.

3. For the above stated and other reasons the first amendment to the Plan is in the best interest of the health, safety, and welfare of the citizens of Garfield County.

4. That the first amendment to the Plan is in general conformance with the 2030 Comprehensive Plan, as amended.

RESOLUTION

NOW THEREFORE, BE IT RESOLVED by the Board of County Commissioners of Garfield County, Colorado, that:

A. The forgoing Recitals are incorporated by this reference as part of this resolution.

B. Garfield County adopts the First Amendment to the Plan (attached as **Exhibit A**).

Dated this _________ day of ______________________________, A.D. 20_______.

ATTEST:

GARFIELD COUNTY BOARD OF COMMISSIONERS, GARFIELD COUNTY, COLORADO

____
Clerk of the Board

____
Chairman

Upon motion duly made and seconded the foregoing Resolution was adopted by the following vote:

COMMISSIONER CHAIR JOHN F. MARTIN ________________________, Aye / Nay
COMMISSIONER MIKE SAMSON ________________________, Aye / Nay
COMMISSIONER TOM JANKOVSKY ________________________, Aye / Nay