APPENDIX E

FINE-FILTER CONSERVATION ELEMENT DESCRIPTIONS AND ANALYSES

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APPENDIX E-1

MULE DEER CONSERVATION ELEMENT ANALYSIS FOR THE NORTHWESTERN PLAINS ECOREGION

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1.0 INTRODUCTION

Over the past century, mule deer (*Odocoileus hemionus*) populations throughout their range have fluctuated widely; however, recent trends indicate that populations are declining throughout western North America. Much of this decline can be attributed to direct habitat loss (mainly winter range), a loss of browse species and deteriorating forage base, and weather extremes including large-scale droughts and severe winters (Heffelfinger and Messmer 2003). Mule deer were included as a fine-filter conservation element (CE) to ensure that crucial winter range and parturition areas were evaluated as part of the Rapid Ecoregional Assessment (REA) process.

Management questions (MQs) pertaining to the big game assemblage in the ecoregion were identified in Task 1 and can be summarized as: 1) where are important habitat areas for the species? and 2) how will their condition and suitability for the species change in the future? The central focus of these two MQs is to document the current status of selected CEs at the ecoregional scale and to evaluate how this status may change over a future time period. The first step is to identify suitable habitat for the CE within the ecoregion. Then, these areas are assessed relative to current and potential future change agent (CA) threats.

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2.0 CONSERVATION ELEMENT DESCRIPTION

The mule deer is restricted to western North America, with a range that extends from southern Alaska through Canada, into the entire western half of the United States, and to the highlands of central Mexico. Mule deer are very adaptable and are capable of living in a variety of different environments. This species is numerous and widespread, and can be found in habitats that range from alpine meadow, mixed forest, arid plains and open prairie. The mule deer is primarily a deer of open forests and broken brush lands.

Mule deer will migrate as far as 80 miles between summer and winter ranges. In winter, mule deer prefer lowland riparian ecosystems that provide thermal and protective cover and will concentrate in those areas. However, in summer, mule deer tend to roam widely and may concentrate around water sources where green vegetation is abundant. The mean home range for adult females can extend from 0.3 to 1.2 square miles while adult males have a mean home range of 1.2 to 4 square miles, but may be as large as 30 square miles (NRCS 2006).

Survival of mule deer is directly linked to the quality of food plants and the ability of the deer to reach it, particularly in areas of heavy snow cover concentrations. Mule deer can tolerate snow depths of 18 to 24 inches, but lower levels are sought in order to conserve energy (NRCS 2006). Poor winter range conditions and severe winter weather in the form of deep snow and cold temperatures can result in high mortality, especially among the old and young (Northwest Power and Conservation Council 2004). Nutritional status also affects a deer’s vulnerability to predation, as well as its ability to compete for food and survive when severe weather persists for extended periods. The primary cause for winter starvation is habitat in poor condition often exacerbated by too many deer and other herbivores competing for the same forage (Wyoming Fish and Game 2011).

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3.0 CONSERVATION ELEMENT DISTRIBUTION MODELING

To answer the MQs regarding the location and status of this species across the ecoregion, a variety of existing data layers representing important crucial and severe winter range, parturition areas, and travel and migration corridors for mule deer species are needed. Distribution of this species covers all five states in this ecoregion (Montana, Nebraska, North Dakota, South Dakota, and Wyoming).

3.1 DATA IDENTIFICATION

A preliminary review of potential data was conducted as part of Task 2 of Phase 1 to define available data for use in this REA (Table E-1-1). Since this species is considered to be common, occurrences are not recorded by natural heritage programs. Suitable mule deer habitat models were acquired from Gap Analysis Program (GAP) and NatureServe. Habitat data for this species was also acquired from Utah State University. There is also a Western Governors' Association (WGA) Wildlife Council Crucial Habitat Assessment Tool (CHAT) underway that could generate models and datasets for the ecoregion; however, no data are currently available.

Table E-1-1. Data Sources for Conservation Element Distribution Mapping

Data Needs	Dataset Name	Source Agency	Type/Scale	Status	Use in REA
Modeled Suitable Habitat	GAP Habitat Models	U.S. Geological Survey (USGS)	Raster (30-m)	Acquired	No[2]
	NatureServe Habitat Model	NatureServe	Polygon	Acquired	No[2]
	Mule Deer Ranges	Western Association of Fish and Wildlife Agencies (WAFWA)	Polygon	Acquired	Yes
	WGA Decision Support System (DSS) Models	WGA Pilot Crucial Habitat	Raster	Future Dataset	No[1]
	Mule Deer Habitat	Utah State University	Polygon (1:250 k)	Acquired	No[2]
Crucial and Severe Winter Ranges	Crucial and Winter Range	MT, WY, ND, SD, NE Fish and Game		Using WAFWA	No[2]

[1] Data gap
[2] More representative data were selected for use

The most important datasets for mule deer are the locations of crucial and severe winter range, parturition areas, and travel and migration corridors. Mule deer migration routes are described by agency publications, internal knowledge of land managers, and conservation organizations (Western Association of Fish and Wildlife Agencies [WAFWA], Mule Deer Foundation). The Mule Deer Working Group (2005) has mapped the entire range of mule deer in North America and has identified two types of winter range: 1) winter range (defined as the part of the overall range where 90 percent of the individuals are located during the average 5 winters out of 10 from the first heavy snowfall to spring green-up, or during a site-specific period of winter) and 2) severe winter range (areas within the winter range where 90 percent of the individuals are located when annual snow pack is at its maximum and/or temperatures are at a minimum in the 2 worst winters out of 10). In addition to identifying and mapping distribution, habitat classification factors that limited habitat quality for mule deer were also identified.

The Assessment Management Team (AMT) decided that only the winter range would be used to assess CA impacts as part of the REA. The AMT has recommended using the WAFWA mule deer ranges to develop distribution layers.

3.2 DISTRIBUTION MAPPING METHODS

The WAFWA mule deer winter range data were used to create a range map for this species. The mapped data appeared to be combinations of detailed mapping and coarse-management boundaries (Figure E-1-1). After review by the Rolling Review Team (RRT), some regions were mapped at fine-scale, providing very detailed delineations of range habitat, while other areas reflected management boundaries mapped at a coarse level.

The methods for generating core habitat patches developed by the Washington Wildlife Habitat Connectivity Working Group (WHCWG) were reviewed and determined to be applicable for determining habitat patches for the mule deer within the Northwestern Plains ecoregion (WHCWG 2010). Applying the methods documented by WHCWG and adjusting parameters reflective of the study area conditions, the habitat patch layer for the mule deer was developed using the Habitat Concentration Area (HCA) tool developed by the WHCWG. The methods for developing estimates of core habitat for individual species (in the absence of quality range data) developed and applied by the Washington Connected Landscapes Project were reviewed with respect to mule deer. Some regions were mapped at fine scale, providing very detailed delineations of range habitat, while other areas reflected management boundaries mapped at a coarse level.

The HCA model uses attributes representative of the focal species and on the distribution of natural conditions. Using the HCA toolset developed by WHCWG, large, contiguous areas that have retained high levels of naturalness (i.e., core areas characterized by a relatively light human footprint) were identified. The HCAs are aggregations of habitat grid cells that are connected to one another by species-specific home range movement radius. These aggregations must typically meet a minimum size requirement needed to support multiple individuals. To implement the HCA tool, two datasets were required: (1) a habitat raster and (2) a resistance raster. The habitat raster can be derived from range data, if available, and mapped consistently at an appropriate scale. In the absence of range data, a habitat identification model can be derived from the resistance raster. For mule deer, the HCAs were developed by using a combination of *a priori* knowledge and a habitat identification model.

A binary habitat raster was developed in which a grid cell was either classed as habitat (assigned a value of 1) or non-habitat (assigned a value of 0). The WHCWG developed a habitat grid by using a resistance grid developed for mule deer and assigning all resistance values 3 or less as habitat. All values greater than 3 were assigned a non-habitat value (i.e., 0). For this application, a threshold resistance value of 5 was used to delineate between habitat and non-habitat.

The habitat resistance raster for mule deer was developed by using five variables to assess resistance: landcover, elevation, slope, housing density, and presence of transportation corridors. Each dataset was reclassified into meaningful metric categories and assigned resistance values based on those applied and reported by the WHCWG statewide project report (Table E-1-2). The landcover dataset was reclassified to general vegetation classes (see Attachment A). Various scenarios were applied and compared to WAFWA winter range data. Bureau of Land Management (BLM) wildlife ecologists further examined the patch distributions to assess the whether the outputs were reasonable, and adjusted them accordingly. This analysis adjusted resistance parameters set within the WHCWG analysis. The resistance raster output from scenario 2 (as presented in Table E-1-2) was used to develop the habitat binary raster. The proportion of habitat within a circular moving window of a size representative of the mule deer's home range radius is calculated. For this analysis, a home radius of 2,000 meters (m) was used. The outcome of this step generates a surface that identifies the areas where habitat is most concentrated.

The HCA tool then deletes the grid cells in areas where habitat is sparse. Habitat grid cells are removed from the habitat binary raster if the proportion of the habitat within the home range radius was less than 0.89. This prevents habitat concentrations from forming in areas where habitat is not concentrated to the level which would be considered core habitat. Only grid cells meeting the minimum average habitat value of home range were evaluated. The threshold habitat value was set to 0.75. Grid cells meeting the minimum average habitat value of home range were than compared to the 0.75 threshold, and, if greater, were then classified as core habitat.

Table E-1-2. Variables Used for Habitat Resistance Model for the Mule Deer

Spatial Data Layers	Data Source	Factors Used	Initial (WHCWG)	Scenario 2
Landcover/ Land Use	GAP	Agriculture	5	2
		Urban/developed	100	100
		Water	20	20
		Sparsely vegetated	5	5
		Alpine	0	0
		Riparian	0	0
		Wetland	1	1
		Grass-dominated	2	2
		Shrub-dominated	2	2
		Dry forest	0	0
		Wet forest	0	0
Elevation	USGS National Elevation Dataset (NED)	0-250 m	0	0
		>250-500 m	0	0
		>500-750 m	0	0
		>750-1,000 m	0	0
		>1,000 – 1,500 m	0	0
		>1,500 – 2,000 m	1	0
		>2,000 – 2,500 m	2	1
		>2,500 – 3,300 m	25	2
		>3,300 m	25	25
Slope	USGS NED	0 - 20 degrees	0	0
		>20 - 40 degrees	0	0
		>40 degrees	30	30
Acres/ Dwelling Unit (ac/du)	Housing Density 2000, Natural Resource Ecology Lab, Colorado State University 2008	>80 ac/du	0	0
		>40 to <80 ac/du	0	0
		>20 to <40 ac/du	1	1
		>10 to <20 ac/du	2	2
		<10 ac/du	10	10
Transportation Freeway	Topologically Integrated Geographic Encoding and Referencing (TIGER) Line Roads Census 2000	>500-1,000 m	0	0
		>0-500 m	0	0
		centerline	200	200
Transportation Secondary Highway	TIGER Line Roads Census 2000	>500-1,000 m	0	0
		>0-500 m	0	0
		centerline	20	20
Transportation Local Road	TIGER Line Roads Census 2000	>500-1,000 m	0	0
		>0-500 m	0	0
		centerline	2	2

Remaining habitat grid cells are joined together if they are within a home range distance. Habitat areas were expanded outward (from the remaining habitat grid cells after step 4) up to a total cost-weighted distance equal to the species' home range movement radius (2,000 m). This effectively joins nearby habitat grid cells together if the intervening landscape supports movements within the home-range connectivity.

The WHCWG statewide application of the HCA tool removed HCAs smaller than a threshold that was meaningful to the mule deer range. This analysis of patch size sought to examine a range of habitat patches, thus a low threshold was established (100 hectare [ha]). This process was reapplied to develop a secondary patch size layer used within the connectivity analysis to develop connectivity corridors between large, significant habitat patches. This secondary patch size layer used a threshold of 100 square kilometers (km^2) to limit habitat patches to large core areas. Figure E-1-2 shows the core patch habitats used to define the winter range distribution of mule deer in the ecoregion for this REA.

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4.0 CONCEPTUAL MODELS

The current and potential future threat analyses were based on CE-specific ecological conceptual models, selected environmental variables (Key Ecological Attributes [KEAs]) likely to be impacted by CAs, and the availability of data.

4.1 ECOLOGICAL PROCESS MODEL

The ecological process model (Figure E-1-2) was developed to identify and link the key life cycle processes to specific ecological factors, or KEAs, that have the greatest potential to affect mule deer habitat throughout the ecoregion. As noted in the species description, winter ranges within the ecoregion are critical habitat for the mule deer. Forage quality and accessibility is a key factor in winter survival and parturition.

The key processes are identified in the model as green boxes. Following Unnasch et al. (2009), three broad headings or categories of KEAs (size, condition, and context) are identified in the model as blue diamonds. Size refers to attributes related to habitat or patch size, condition refers to the condition of the habitat, and context refers to the spatial structure of the habitat. At the landscape level, the KEAs under the condition category will be the most challenging to spatially represent and will primarily depend on the data available.

4.2 SYSTEM-LEVEL CONCEPTUAL MODEL

The system-level conceptual model (Figure E-1-3) illustrates the interactions between the CAs and the primary habitat functions of this species. The primary CAs for this CE are development, climate change, invasive species, and wildfire, which are identified across the top of the figure in red. The important factors (or “drivers”) affecting the abundance and distribution of mule deer populations include those that impact survival, reproduction, distribution, density, and metapopulation structure.

4.2.1 Development

The specific types of development that may be a risk to the important winter habitat for the mule deer include roads, oil and gas exploration and development, urban/exurban expansion, and renewable energy development. Habitat loss and fragmentation from urban and exurban development is a risk to mule deer populations in the ecoregion. Development increases the need for roadways. Roads are widely recognized by the scientific community as having a range of direct, indirect, and cumulative effects on wildlife and their habitats (Trombulak and Frissell 2000; Gucinski et al. 2001; Gaines et al. 2003; Wisdom et al. 2004a; Wisdom et al. 2004b; New Mexico Department of Game and Fish 2005). Roads, in general, are less of a constraining factor to mule deer movements than to other ungulate populations (pronghorn), unless they are bordered by game-proof fences. However, Rost and Bailey (1979) found that mule deer avoid roads, particularly within 200 m of a road, dependent on travel volume, and habitat (i.e., greater avoidance on shrub habitat as compared to forested pine and juniper habitats). Wisdom et al. (2004a) found that movement rates increase in response to off-road activities. Taylor and Knight (2003) noted that mule deer showed a 96 percent probability of flushing within 100 m of hikers or mountain bikers located off trails and suggested that the area around existing trails that may be impacted by recreationists was a 200-m “area of influence”. Physiological stresses occur when energy expenditures by an animal are increased due to alarm and/or avoidance movements. These are generally attributed to interactions with humans and/or activities associated with human presence (traffic, noise, pets, etc.). Added consequences from human presence include, but are not limited to, mortality and injury due to vehicle collisions, illegal hunting, and harassment from a variety of increasing recreational activities (WAFWA 2010).

The rapid expansion of energy infrastructure in the west has the potential to impact mule deer habitat. Oil and gas development creates a complex network of roads, well pads, pipelines, pumping stations, and other infrastructure across the landscape. Increasingly, studies are demonstrating many of the negative effects on wildlife related to oil and gas development (Colorado Department of Wildlife et al. 2008; Wyoming Game and Fish Department 2004; Confluence Consulting 2005; Holloran 2005; Sawyer et al. 2006; Berger et al. 2006). Direct impacts include the loss of habitat to well pads, access roads, and pipelines. Indirect impacts may include changes in distribution and stress, or activity caused by increased human disturbances (e.g., traffic, noise, human use). Sawyer and Nielsen (2010) found at the Pinedale Anticline Project Area that mule deer avoided areas close to well pads and did not acclimate to well pads. Lower predicted probabilities of use within 2.7 to 3.7 kilometers (km) of well pads suggested indirect habitat losses may be substantially larger than direct habitat losses (Sawyer et al. 2006). Overall, energy development at this site reduced mule deer abundance to its lowest level since energy development begun (Sawyer and Nielsen 2010).

4.2.2 Climate Change

The primary impacts of climatic conditions on mule deer and their habitat are through the effects of the moisture and temperature regime on forage resources (i.e., productivity, species composition, and nutrient content are affected by drought, late frosts, etc.), and snow depth on winter ranges and migration corridors. Mule deer are less affected by severe cold weather than by high levels of snow cover, which restrict access to forage. Gilbert et al. (1970) stated that snow depth over 18 inches precluded use of winter range by deer, but energy costs of locomotion for mule deer increase significantly at 10 inches (25 centimeters [cm]), regardless of the density of snow (Parker et al. 1984). Lower snowfall is projected to occur in much of western North America as a result of climate change, which may reduce the importance of traditional winter ranges for mule deer. However, global warming patterns are projected to lead to loss of sagebrush winter ranges and increase pinyon-juniper communities, which will reduce the habitat quality of winter ranges (Lutz et al. 2003).

Declining amounts and duration of snow on winter ranges will benefit mule deer if the vegetative community on winter ranges meets the nutritional demands of these species. However, climate-induced changes could begin to expose native plant communities to invasive weed species or exacerbate current invasive weed problems, which may alter fire regimes. Generally, ecoregional differences in the impact to mule deer populations are expected to occur as climate change progresses (deVos and McKinney 2007). Montheith et al. (2011) documented that autumn migration of mule deer in the Sierra Nevada Range was highly variable and associated with patterns of winter weather (cold and snow), whereas spring migration coincided with decreasing snow depth and advances in plant phenology. They suggested that the association between seasonal migration and environmental conditions provides convincing evidence that those migratory patterns may be altered by global climate change. Climate change is thought to negatively affect abundance and distribution of mule deer in hotter and drier ecoregions. In ecoregions where extreme winters presently limit these populations in some years, short-term effects on abundance and distribution may be positive; long-term effects are uncertain.

4.2.3 Invasive Species

Habitat fragmentation creates landscapes made of altered habitats or developed areas fundamentally different from those shaped by natural disturbances that species have adapted to over evolutionary time (Noss and Cooperrider 1994). These changes very likely manifest themselves as changes in vegetative composition, often to weedy and invasive species. This, in turn, changes the type and quality of the food base as well as the structure of the habitat. Increased ‘edge effect’ between developed and undeveloped areas often results in reduced forage quality and security cover, potentially increasing deer susceptibility to predation (WAFWA 2010).

In addition, some invasive species (especially *Bromus* spp.) can alter fire regimes and thus affect entire landscapes and their communities. The increase of severe droughts associated with global warming will exacerbate cheatgrass growth and the spread of other harmful invasive species, thereby converting sagebrush steppe into exotic annual grassland with less forage value. Furthermore, cheatgrass and other invasive plants increase the frequency and intensity of wildfires, thereby leaving sagebrush habitat with little chance of recovering (National Wildlife Foundation 2012).

4.2.4 Wildfire

Fire generally has a beneficial impact on mule deer habitat by stimulating earlier greenup, increased nutritional quality of forage, and more herbaceous plants. However, fire can also facilitate invasion by cheatgrass, which has low value as mule deer forage. The absence of fire for 50 years or more, with subsequent conifer encroachment, canopy closure, and deterioration of herbaceous and shrub understories, has resulted in deterioration of big game habitat. Loovas (1976) reported that fire suppression in the Black Hills of South Dakota resulted in thickening of pine stands and decreases in secondary stages of plant succession important to mule deer. Mule deer generally seem to prefer recently burned areas, as long as herbaceous vegetation and re-sprouting browse species remain viable and nutritious (Hobbs and Spowart 1984). The effects of fire on mule deer habitat are widely varied and well documented in the literature. In general, fires that create mosaics of forage and cover are beneficial. Deer seem to prefer foraging in burned compared to unburned areas, although preference may vary seasonally. This preference may indicate an increase in plant nutrients, which usually occurs following fire. Hobbs and Spowart (1984) warned about making conclusions regarding the benefits of fire based on forage studies alone. Their study of fire on nutrition in Colorado revealed increases in the quality of deer diets due to changes in forage selection, not increases in nutrients of previously selected forage. Burning sagebrush communities can result in significant increases of herbaceous plants favored by mule deer. However, when sagebrush is the only cover, its complete removal can be detrimental to mule deer, especially on winter range. Shrubs and forbs in pinyon (*Pinus spp.*) juniper (*Juniperus spp.*) communities tend to increase the first few years following fire, providing valuable browse to mule deer, which may increase use of these areas up to 15 years (McCullogh 1969). Stager and Klebenow (1987) reported that the beneficial effects of fire for mule deer in pinyon-juniper stands can last as long as 115 years.

4.3 CHANGE AGENTS PROPOSED FOR ANALYSIS

Although numerous attributes and indicators affecting this species were initially identified in early phases of this REA, not all are included in this analysis. The specific indicators that could not be modeled are identified with an asterisk on Figure E-1-2. Analysis for the invasive species CA is not included for this CE because the direct effect indicators were determined to be data gaps or because it was impractical to model at the ecoregional scale because appropriate geospatial data were not available. Further information on the data gaps for indicators are discussed in the respective CA contained in Appendix C.

Analysis for the development, wildfire, and climate change CAs are included for this CE.

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5.0 CHANGE AGENT ANALYSIS

A current status and future threat assessment for the mule deer was conducted for this ecoregion using the 12-digit Hydrologic Unit Codes (HUCs) as the analysis unit. Based on the ecological process and system-level models, KEAs were identified for the current status and future threat analyses with a specific emphasis on the ability to measure impacts using existing geospatial data. The CAs evaluated for current status include development and wildfire. The CAs evaluated for future threats include development and climate change.

Since the scale of the analysis is at the HUC 12, a layer of 6th level watersheds was extracted for the ecoregion. A geographic information system (GIS) process was iterated through the KEA indicators and determined the metric values associated with some watersheds. In other instances, sufficient published data indicated cut-off points for these values. These values were added as an attribute to the HUC 12 layer. Since the primary reporting units for final mapping outputs is at a minimum of the 6th level watershed (HUC 12) for the CEs, the values from the final output maps need to be added as an attribute to the HUC 12 watersheds. In some cases, zonal statistics will be calculated to determine a value associated with each watershed. The final layers will be created by combining the HUC 12 watersheds (with ranked KEAs) with the final suitable habitat layer and the habitat layer from the current status CA layer.

5.1 CURRENT STATUS FOR MULE DEER

5.1.1 Key Ecological Attribute Selection

Table E-1-3 identifies the original KEAs proposed in Task 3 and which of these were used in the final current status analysis. Not all of the KEAs proposed were used, based on the rationale provided. Other KEAs were used but are not directly related to CAs. For example, the KEA related to corridor width is an important aspect of the quality and utility of habitat available to species such as mule deer. However, this indicator was excluded from the analysis because of the focus upon winter range habitat. Experts concluded that mule deer typically navigate corridors during their migration between winter and summer ranges and since summer range habitat had been excluded, there would be little movement of mule deer between the winter range habitats during the winter season.

Table E-1-3. Key Ecological Attributes Retained or Excluded for the Mule Deer

Category	Attribute	Explanation
1. Size	Patch Size (Availability of contiguous, large, native habitat patches)	HCA tool was used; however, this output was retained and further refined by removing transportation corridors, which had the effect of breaking patches up to reflect ground conditions.
	Corridor Width	Excluded from the analysis because of the focus upon winter range habitat.
2. Condition	Fire regime Vegetation Condition Class (VCC)	Excluded because it was observed that the dataset classified grassland communities as having a high departure from original conditions that was not agreed upon by regional experts.
3. Context	Habitat Heterogeneity (Patch Density - no./100 ha)	Retained to evaluate spatial heterogeneity within landscape context.
	Distance to roads	Retained to evaluate anthropogenic risks.
	Development (minimum distance from well pads)	Retained to evaluate anthropogenic risks.
	Permeability (mean annual snow depth)	Excluded because dataset was not suitable for assessing the barriers to movement (melting, compaction, sublimation) presented to mule deer herds by snow depth. No other dataset was available.

The KEAs proposed to evaluate wildfire were excluded because the RRT disagreed with information from the Fire Regime Vegetation Condition Class (VCC) data regarding the condition of the grassland communities within the ecoregion. Therefore, the potential risks related to wildfire on this CE were not assessed for this REA.

Climate change conditions were also not evaluated because the KEA selected (mean annual snow depth) was not suitable for assessing the barriers to mule deer movement (melting, compaction, sublimation). A qualitative discussion regarding the potential impacts of climate change on this CE is presented in Section 5.

Table E-1-4 identifies the KEAs, indicators, and metrics that were used to evaluate the CAs and pathways affecting this CE across the ecoregion (as illustrated on Figure E-1-3). Several indicators were used to assess the current status for this CE. Size and landscape context indicators (e.g., heterogeneity, distance to roads, fragmentation) of the applicable output will be incorporated into a GIS overlay analysis.

Table E-1-4. Mule Deer Key Ecological Attributes, Indicators, and Metrics for Current Status Assessment for the Northwestern Plains Ecoregion

Category	Ecological Attribute	Indicator / Unit of Measure	Metric			Data Source	Citation
			Poor = 3	Fair = 2	Good = 1		
Size	Connectivity & Context Cover Landscape Structure Escape	Patch Size (Availability of contiguous, large native habitat patches)	<300 ha	300-500 ha	>500 ha	GAP National Land Cover Data (NLCD)	Best Judgment
Landscape Context	Connectivity & Context	Habitat Heterogeneity (Patch Density - no./100 ha)	<0.3 or >0.55	0.3-0.4	0.40-0.55	GAP NLCD	Kie et al. 2002
	Landscape Structure	Distance to roads	<300 m	300-1,000 m	>1,000 m	TIGER Linear features	Poor 2010
		Development (minimum distance from well pads)	<300 m	300-1,000 m	>1,000 m	O&G wells	Sawyer et al. 2006

In most cases, the metrics used to identify attribute quality were based on available publications, coupled with expert analysis and professional judgment in association with data-driven metrics. This process was carried out through the establishment of a CE RRT comprised of BLM wildlife biologists and state-level experts. The RRT met periodically to contribute information and to analyze input attributes and outputs that were derived from various forms of spatial analyses in GIS. This process enabled the RRT to determine the efficacy of attributes, indicators, and metrics, as well as to ascertain the accuracy of each step of the modeling process. Metrics used were equally weighted when evaluating the overall current status of the CE.

5.1.1.1 Patch Size

Patch size was selected as an indicator of spatial distribution (home-range), which has been related to a variety of factors including body size, trophic level, sex and age reproductive status, seasonal availability of forage and water, and intra- and inter-specific competition. Home-range size in mule deer correlates with a variety of landscape metrics and may therefore play a role in determining population densities (Kie et.al. 2002).

Using the HCA toolset developed by WHCWG (2010), large, contiguous areas were identified that have retained high levels of naturalness (i.e., core areas characterized by a relatively light human footprint).

Using the patch layer outputs for the mule deer, the layer output (low threshold) was reclassified based on the patch acreage ranges established for this indicator and assigned associated values between 1 and 3 (Table E-1-3). This layer was converted to raster with assigned values. Zonal statistics were applied against the layer using the HUC 12 watershed GIS layer to determine an overall summary score for the patches contained within each watershed. The habitat patch size by HUC is presented on Figure E-1-4.

5.1.1.2 Habitat Heterogeneity (Patch Density)

Spatial heterogeneity is a structural feature of landscapes that can be defined as the complexity and variability in the habitat of the species. Large mammalian herbivores require temporally and spatially diverse habitat elements such as food and cover; these mammals can have significant effects on vegetation composition and basic ecosystem processes such as nutrient cycling, thereby acting as keystone species (Kie et. al. 2002).

Habitat heterogeneity was assessed by using the core habitat developed for the patch size analysis. This dataset was evaluated by applying the following patch density equation to assess the level of habitat heterogeneity:

$$PD = \frac{N}{A}$$

where PD = Patch Density, N = number of unique patches, and A = unit area (100 ha).

The patch layer had the roads layer removed from it to develop a more realistic representation of the landscape. Each patch contained within the 'core habitat' GIS layer was then attributed with a unique identifier. The core habitat was then intersected with the HUC 12 watershed boundary layer. This process allowed each patch to be assigned with a unique HUC 12 identifier. The associated GIS attribute table was imported to excel, and pivot tables were developed based upon the HUC 12 identifier. The data were summarized by performing a count of unique patch identifiers and the total area of patches per watershed. The patch density was then calculated. Each patch density value was then graded. The resulting summary table was then rejoined to the HUC 12 watershed GIS dataset. The patch density values were scored based on the metric values presented in Table E-1-2. The habitat heterogeneity by HUC is presented on Figure E-1-5.

5.1.1.3 Distance to Roads

Roads limit connectivity through the creation of physical barriers such as right-of-way fences, increased mortality due to collisions, and behavioral alienation (avoidance of roads or high-traffic volumes) (WHCWG 2010). This KEA was used as an indicator to assess potential impacts from development.

Road features were identified using Topologically Integrated Geographic Encoding and Referencing (TIGER) line data; features mapped as freeways, secondary roads, and local roads were extracted. Distance from roads was assessed for three distance zones, as noted in Table E-1-2. Outputs from proximity analysis were converted to raster datasets and then combined based on distance zone. Summary zonal statistics were applied to the graded data to generate a rating for each watershed included within the HUC 12 watershed boundary dataset. A proximity analysis was performed and then assigned scores based on the metric values presented in Table E-1-2. The distance to roads layer output is presented on Figure E-1-6.

5.1.1.4 Distance to Development (Oil and Gas)

Development was characterized as the minimum distance from well pads at which mule deer are most likely to occur over 3 years of progressive oil and gas development. This KEA was used as an indicator to assess potential risk related to oil and gas development.

Well point data were compiled into one dataset from all applicable states. Distance from the well pad was assessed for 3 distance zones, as noted in Table E-1-2. Outputs from proximity analysis were converted to raster datasets and then combined based on distance zone. Summary zonal statistics were applied to the graded data to generate a rating (majority) for each watershed included within the HUC 12 watershed boundary dataset. The distance to development layer output is presented on Figure E-1-7.

5.1.2 Current Status of Mule Deer Habitat

The individual KEA analyses provide the basis for the compilation of an overarching data layer that defines the current status of mule deer habitat for each HUC across the ecoregion. In order to create a current status layer, an overall score for each HUC was calculated. To generate overall scores for each watershed, all scored criteria were additively combined. Each watershed has the potential to receive a maximum score of 12 points (i.e., 4 indicators assessed, each having a grading system of 1 to 3). The summed scores were then divided by a factor of 12 to yield a value between 0 and 1. This final overall score was then ranked as poor, fair or good based on the natural breaks method, which seeks to reduce the variance within classes while maximizing the variance between classes. The overall current status layer for the mule deer is presented on Figure E-1-8

The core habitat patch model (Figure E-1-4) indicates that the poorest density of mule deer habitat is in the northeastern boundary of the ecoregion, as well as some smaller clusters in the southeast and southwest. The overall current status indicates that some threat to mule deer habitat exists, resulting primarily from roads (Figure E-1-6) in the northeast and southeast and existing oil and gas wells in the southwest (Figure E-1-7).

A summary of the current status ratings based on the CE distribution is provided in Table E-1-5. The CE distribution layer was used to calculate the total number of square miles of CE habitat and a percentage of the total number of square miles per HUC that were rated as good, fair, or poor. The results of the current status assessment indicate that approximately 64.3 percent of the 6th level HUC watersheds that intersect the mule deer distribution received an overall rating of fair or poor.

Table E-1-5. Summary of Current Status Ratings for the Mule Deer

Overall Rating by 6th Level HUC	Total Square Miles[a]	Percentage of Total Square Miles[a, b]
Good	84,030	35.6
Fair	133,030	56.4
Poor	18,718	7.9

[a] These values include only the area of HUCs that intersect with the CE distribution layer.
[b] Values rounded to one decimal place.

5.2 FUTURE THREAT ANALYSIS FOR THE MULE DEER

The system-level model (Figure E-1-3) was used to create a series of intermediate layers primarily based on the geospatial data available on the future projections for the development and climate change CAs. Future threats were evaluated for development for a short-term time horizon (5 to 10 years) and for climate change for a long-term time horizon (50-year; 2050 to 2069).

Because of the inherent inaccuracies of the temporal scale of the future data, it is only possible to infer information pertaining to a subjective future period (rather than a specific time period) for some of these attributes. However, because of the limits placed on these data outputs, it is fair to assume that this model predicts the overall future potential for these attributes within this ecoregion. It is an upper limit of potential growth and should therefore be carefully applied to future estimates of their affect on mule deer populations.

5.2.1 Development Change Agent

Future spatial data for development was limited to future potential energy development, modeled urban growth, and potential agricultural development, as discussed in the development CA analysis presented in Appendix C-1.

Because mule deer are so wide-spread throughout the northwestern plains, they are at risk from both fossil and renewable energy development. The mule deer distribution areas in western North Dakota and northeastern Wyoming are at the highest risk from potential future energy development.

The future threats to the mule deer from development are most notable in the southwestern portion of the ecoregion. Future agricultural development (Figure C-1-1) activities in the southwestern area may be a risk to mule deer through loss of habitat, especially in potential migration corridors. However, mule deer are very adaptable to agriculture. The southwestern portion of the ecoregion is also an important area for future oil and gas extraction, in addition to having the highest potential for solar energy development (Figures C-1-3 through C-1-8).

5.2.2 Climate Change

The climate CA layer was created through the results of the 2025 and 2060 U.S. Geological Survey (USGS) climate change models. These models should document areas that may be negatively and positively affected by climate change. Climate change was modeled based on a 15-km grid created for regional analysis based on a comparison of current climate patterns to future modeled climate patterns resulting in the delta (change) output figures. Further details regarding the climate change analysis are provided in Appendix C-5.

With temperature increases expected across North America, lower snowfall is projected to occur in the ecoregion. Changes in traditional summer/winter ranges may lead to a short-term positive effect on the abundance and distribution of mule deer in this ecoregion. Increases in populations or ranges of mule deer within the region will depend on forage availability and quality, with a likely increase in competition for available resources.

The NatureServe Climate Change Vulnerability Index (NSCCVI) tool was utilized to assess mule deer vulnerability to the effects of climate change. Using annual raster datasets from NatureServe to perform climate change calculations in ArcGIS (through the Predicted Temperature 2040-2069 [Fahrenheit (F)] and the Predicted Hamon ratio of actual evapotranspiration to potential evapotranspiration [AET : PET] Moisture Metric 2040-2069 datasets), the NSCCVI calculator was applied and produced an Index score of not vulnerable/increase likely. The NSCCVI tool indicated that available evidence suggests the abundance and/or range extent of this species within geographical area assessed is likely to increase by 2050. The assessment rating was largely based on a majority of neutral and somewhat decreased vulnerability scores calculated when assessing factors that influence vulnerability, such as dispersal and movements, sensitivity to temperature and moisture changes (historical thermal/hydrological niche), dependence on ice or snow-cover habitats, reliance on interspecific interactions to generate habitat, and dietary versatility.

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6.0 MANAGEMENT QUESTIONS

The relevant MQs for the mule deer include those defined as part of the Landscape Species/Species Richness category. The overall MQ was: Where are the key habitat types (seasonal, refuges, corridors/connectivity, migration routes, concentrations of regionally significant species, etc.) for landscape species, keystone species, regionally significant species, and regionally significant suites of species? This MQ was considered in implementing the GIS analyses. Emphasis was placed on the spatial relationship of attributes mentioned in the MQs and the distribution map for the CE. Specific MQ examples for the REA were developed in Task 1 and are presented in Appendix A. Several of these MQs are discussed below to demonstrate the functionality of the REA and to provide an opportunity to discuss significant data gaps that were identified during the REA.

6.1 WHERE ARE AREAS THAT HAVE POTENTIAL FOR RESTORING REGIONALLY SIGNIFICANT SPECIES HABITAT OR HABITAT CONNECTIVITY FOR REGIONALLY SIGNIFICANT SPECIES?

The core habitat model figure (Figure E-1-4) may be used to identify general areas where habitat patch size and habitat heterogeneity (patch density) are rated as good.

6.2 WHERE ARE THE KEY HABITAT TYPES (SEASONAL REFUGES, CORRIDORS/CONNECTIVITY, MIGRATION ROUTES, CONCENTRATIONS OF REGIONALLY SIGNIFICANT SPECIES)?

The RRT determined that this REA would focus upon winter range habitat. Experts concluded that mule deer typically navigate corridors during their migration between winter and summer ranges and since summer range habitat had been excluded, there would be little movement of mule deer between the winter range habitats during the winter season. Additionally, occurrence data for the mule deer was not available across the ecoregion to assess concentrations of mule deer.

6.3 WHERE ARE CURRENT REGIONALLY SIGNIFICANT LANDSCAPE/KEYSTONE SPECIES AND THEIR HABITATS, INCLUDING SEASONAL HABITAT AND MOVEMENT CORRIDORS, AT GREATEST RISK FROM CHANGE AGENTS, INCLUDING CLIMATE CHANGE (CONNECTIVITY, SMALL POPULATION SIZE)?

The future threats to the mule deer from development are most notable in the southwestern portion of the ecoregion. Future agricultural development (Figure C-1-1) activities in the southwestern area may be a risk to mule deer through loss of habitat, especially in potential migration corridors. However, mule deer are very adaptable to agriculture. Mule deer habitat in the southwestern portion of the ecoregion is also at risk from future oil and gas extraction. Habitat in this area is also at the highest risk for future solar energy development (Figures C-1-3 through C-1-8).

6.4 WHERE ARE THE CRUCIAL WINTER AND/OR PARTURITION AREAS FOR BIG GAME SPECIES AT RISK FROM LONG-TERM HABITAT CONVERSION OR FRAGMENTATION?

Figure E-1-8 can be used to evaluate the areas within the ecoregion that are at risk from habitat conversion or fragmentation based on development activities.

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7.0 REFERENCES

Allen, J. A. 1995. Seasonal distribution and winter habitat use of female mule deer in the Copper Mountain Region, Wyoming. MS Thesis, Univ. Wyoming, Laramie, Wyoming. 126 pp.

Berger, J., K.M. Berger, and J.P. Beckmann. 2006. Wildlife and energy development: Pronghorn of the Upper Green River Basin – Year 1 Summary. Wildlife Conservation Society, Bronx, NY.

Colorado Department of Wildlife, Wildlife and Parks, North Dakota Game and Fish, Utah Division of Wildlife Resources, and Wyoming Game and Fish Department. 2008. Using the Best Available Science to Coordinate Conservation Actions that Benefit Greater Sage-Grouse Across States Affected by Oil & Gas Development in Management Zones I-II (Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming). (Unpublished report, available at http://www.ourpubliclands.org/files/upload/BestScience_2008_sagegrouse_energy.pdf.

Confluence Consulting. 2005. *Annotated Bibliography of Potential Impacts of Gas and Oil Exploration and Development on Coldwater Fisheries*. Prepared by Confluence Consulting, Inc., for Trout Unlimited, Bozeman, MT.

deVos, J. V Jr., and T. McKinney. 2007. Potential Impacts of Global Climate Change on Abundance and Distribution of Elk and Mule Deer in Western North America. Final Report to the Western Association of Fish and Wildlife Agencies. Avaialble online at http://www.createstrat.com/i/globalwarmingdoc2.pdf.

Gaines, W. L., P. H. Singleton, and R. C. Ross. 2003. *Assessing the cumulative effects of linear recreation routes on wildlife habitats on the Okanogan and Wenatchee National Forests*. U.S. Department of Agriculture, Forest Service, General Technical Report PNW-GTR-586, Portland, Oregon.

Gilbert, P. F., O. C. Wallmo, and R. B. Gill. 1970. *Effect of snow depth on mule deer in Middle Park, Colorado*. *Journal of Wildlife Management* 34:15-23.

Gucinski, H., M. H. Brooks, M. J. Furniss, and R. R. Ziemer. 2001. *Forest roads: a synthesis of scientific information*. U.S. Department of Agriculture, Forest Service, General Technical Report PNW-GTR-509, Portland, Oregon.

Heffelfinger, J. R., and T. A. Messmer. 2003. Introduction. Pages 1−11 in J. C. deVos Jr., M. R. Conover, and N. E. Headrick, editors. Mule deer conservation: issues and management strategies. Berryman Institute Press, Utah State University, Logan, USA.

Hobbs, N. T. 1989. Linking energy balance to survival in mule deer: Development and test of a simulation model. Wildl. Monograph. 101: 1- 39.

Hobbs, N. T. and R. A. Spowart. 1984. Effects of prescribed fire on nutrition of mountain sheep and mule deer during winter and spring. Journal of Wildlife Management. 48(2): 551-560. [4485].

Holloran, M. J. 2005. Greater sage-grouse (*Centrocercus urophasianus*) population response to natural gas field development in western Wyoming. PhD Dissertation, University of Wyoming, Laramie, USA.

Kie, J. G., R. T. Bowyer, B. B. Boroski, M. C. Nicholson, and E. R. Loft. 2002. Landscape heterogeneity at differing scales: effects on spatial distribution of mule deer. Ecology 83:530–544.

Lovaas, A.L. 1976. Introduction of prescribed burning to Wind Cave National Park. Wildl Soc Bul 4:69-73.

Lutz, D. W., and 7 co-authors. 2003. Impacts and changes to mule deer habitat. Pages 13–61 in J. C. deVos, Jr., M. R. Conover, and N. E. Hedrick, editors. Mule deer conservation: issues and management strategies. Berryman Institute Press, Utah State University, Logan.

McCulloch, Clay Y. 1969. Some effects of wildfire on deer habitat in pinyon-juniper woodland. Journal of Wildlife Management. 33(4): 778-784.

Monteith, K. L., V. C. Bleich, T. R. Stephenson, B. M. Pierce, M. M. Conner, R.W. Klaver, and R. T. Bowyer. 2011. Timing of seasonal migration in mule deer: effects of climate, plant phenology, and life-history characteristics. Ecosphere 2(4):art47. doi:10.1890/ES10-00096.1

Mule Deer Working Group. 2005. Western States and Provinces Mule Deer and Black-Tailed Deer Habitat Mapping Project, Western Association of Fish and Wildlife Agencies.

National Wildlife Foundation (2012). Global Warming and Sagebrush Steppe Habitat. Accessed on August 8, 2012 from http://www.nwf.org/Global-Warming/Effects-on-Wildlife-and-Habitat/ Sagebrush-Steppe.aspx.

Natural Resources Conservation Service (NRCS) 2006. Mule Deer (*Odocoileus hemionus*), Fish and Wildlife Habitat Management Leaflet, Number 28. February.

New Mexico Department of Game and Fish. 2005. Habitat Fragmentation and the Effects of Roads on Wildlife and Habitats. January.

Northwest Power and Conservation Council (2004). Lower Snake Mainstream Subbasin Plan. May. http://www.nwcouncil.org/fw/subbasinplanning/lowersnake/plan/EntirePlan.pdf

Noss, R. F., and A. Y. Cooperrider. 1994. Saving nature's legacy. Island Press, Washington, D.C.

Parker, K. L., C. T. Robbins and T. A. Hanley. 1984. Energy expenditures for locomotion by mule deer and elk. Jour. Wildl. Manage. 48:474-488.

Reeve, A. F. and F. G. Lindzey. 1991. Evaluation of mule deer winter mortality in south-central Wyoming. Wyoming Cooperative Fish and Wildlife Research Unit, Laramie, Wyoming. 147 pp.

Rosenberg, D.K., B.R. Noon, and E.C. Meslow. 1997. Biological corridors: form, function, and efficacy. BioScience 47:677-687.

Rost, G.R., and J.A. Bailey. 1979. Distribution of mule deer and elk in relation to roads. Journal of Wildlife Management 43(3):634-641.

Sawyer and Nielsen 2010, Mule Deer Monitoring in the Pinedale Anticline Project Area: 2010 Annual Report. Western Ecosystems Technology, Cheyenne, WY online at http://www.wy.blm.gov/jio-papo/papo/reports/2010annualreport_muledeer.pdf.

Sawyer, H. and F. Lindzey. 2000b. Ecology of sympatric mule deer and whitetailed deer in riparian communities of southeast Wyoming. Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming, Laramie, Wyoming. 49 pp.

Sawyer, H. and F. Lindzey. 2001. The Sublette mule deer study. Wyoming Cooperative Fish and Wildlife Research Unit, Laramie, Wyoming. 54 pp.

Sawyer, H., F. Lindzey, and D. McWhirter. 2005. Mule deer and pronghorn migration in western Wyoming. Wildlife Society Bulletin 33:1266-1273.

Sawyer, H., F. Lindzey, D. McWhirter and K. Andrews. 2002. Potential effects of oil and gas development on mule deer and pronghorn populations in western Wyoming. Transactions North American Wildlife and Natural Resource Conference 67:350-365.

Sawyer, H., R. Nielson, F. Lindzey, and L. McDonald. 2006. Winter habitat selection of mule deer before and during development of a natural gas field. Journal of Wildlife Management 70:396-403.

Stager, D. W. and D. A. Klebenow. 1987. Mule deer response to wildfire in Great Basin pinyon-juniper woodland. In: Everett, Richard L., compiler. Proceedings--pinyon-juniper conference; 1986 January 13-16; Reno, NV. Gen. Tech. Rep. INT-215. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 572-579.

Taylor, A. R., and R. L. Knight. 2003. Wildlife responses to recreation and associated visitor perceptions. Ecological Applications 13:951-963.

Trombulak, S. C., and C. A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14:18-30.

Unnasch, R.S., D. P. Braun, P. J. Comer, G. E. Eckert. 2009. *The Ecological Integrity Assessment Framework: A Framework for Assessing the Ecological Integrity of Biological and Ecological Resources of the National Park System***.** Report to the National Park Service. Version 1.0. January.

Washington Wildlife Habitat Connectivity Working Group (WHCWG). 2010. Washington Connected Landscapes Project: Statewide Analysis. Washington Departments of Fish and Wildlife, and Transportation, Olympia, WA. Available at http://waconnected.org/wp-content/themes/whcwg/docs/statewide-connectivity/2010DEC%2017%20WHCWG%20 Statewide %20Analysis%20FINAL.pdf.

Western Association of Fish and Wildlife Agencies (WAFWA) 2010. Conservation Actions to Benefit Mule Deer Affected by Energy Development. Mule Deer Working Group, Western Association of Fish and Wildlife Agencies. http://www.eastidahowindaction.org/images/Mule_Deer_Energy_Impact_Guidelines.pdf.

Wisdom, M. J., A. A. Ager, H. K. Preisler, N. J. Cimon, and B. K. Johnson. 2004a. Effects of off-road recreation on mule deer and elk. Transactions of the North American Wildlife and Natural Resources Conference 69:531-550.

Wisdom, M. J., N. J. Cimon, B. K. Johnson, E. O. Garton, and J. W. Thomas. 2004b. Spatial partitioning by mule deer and elk in relation to traffic. Transactions of the North American Wildlife and Natural Resources Conference 69:509-530.

Wyoming Game and Fish Department. 2004. Recommendations for development of oil and gas resources within crucial and important wildlife habitat: A strategy for managing energy development consistently with the FLPMA Principles of multiple use and sustained yield.

Wyoming Fish and Game. 2011. Wyoming Range Mule Deer Plan. Jun 21. http://gf.state.wy.us/web2011/Departments/Wildlife/pdfs/WRMD_PLANFINALDRAFT0000945.pdf.

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APPENDIX E-1

FIGURES

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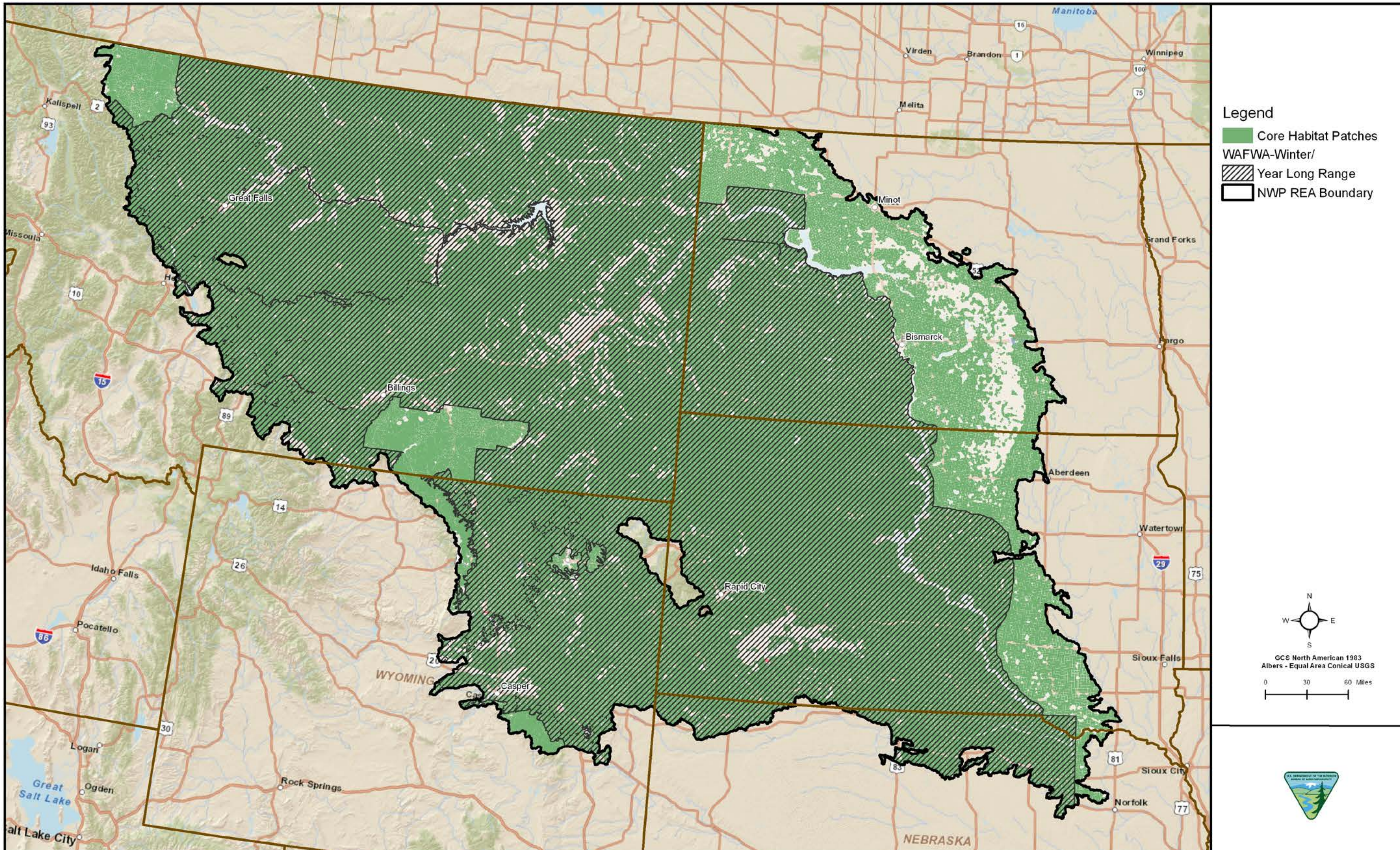

Figure E-1-1. WAFWA Mule Deer Range versus Core Habitat Patch Model for Mule Deer in Northwestern Plains

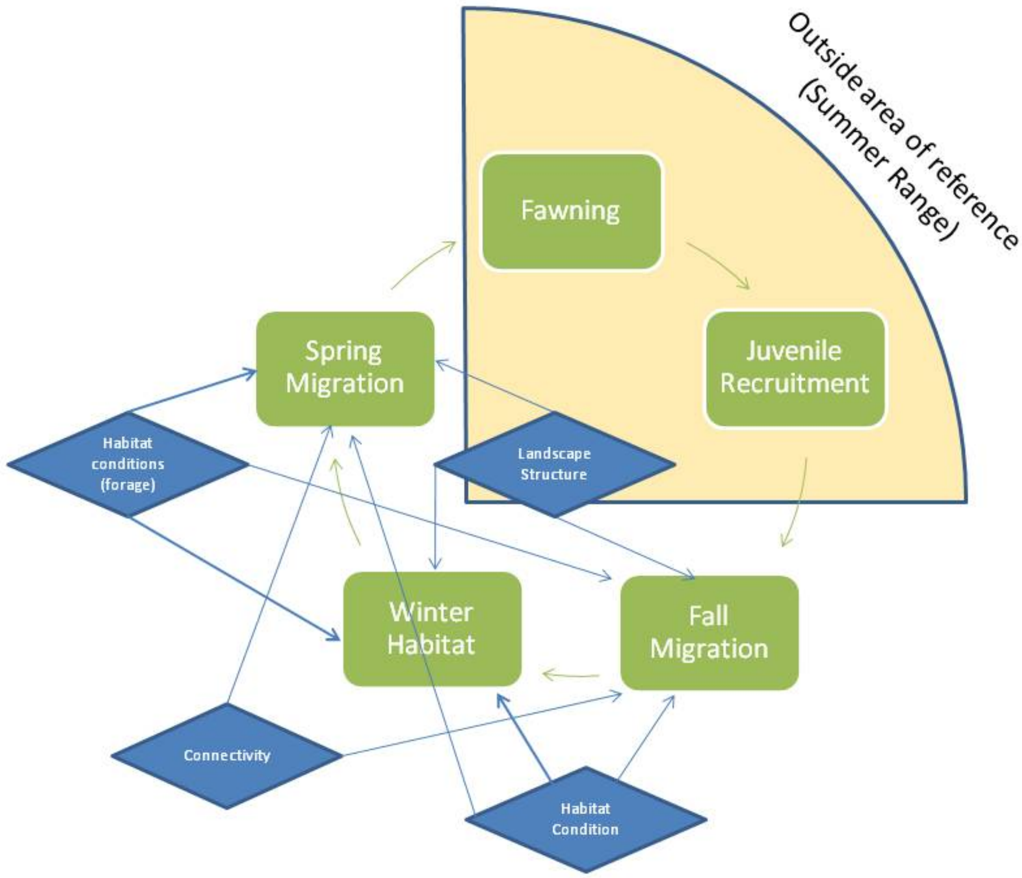

Figure E-1-2. Ecological Process Model for Mule Deer in Northwestern Plains

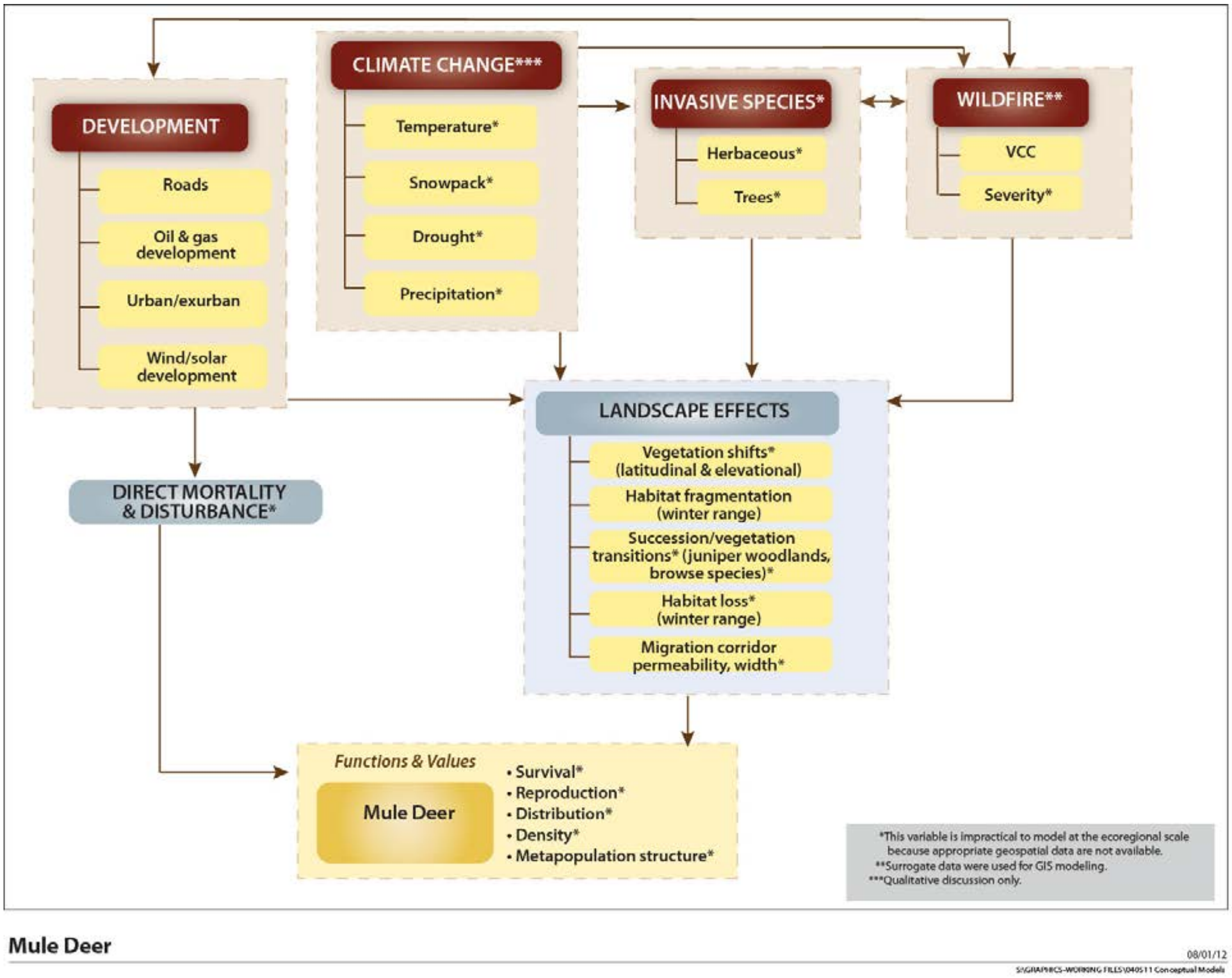

Figure E-1-3. System-Level Model for Mule Deer in Northwestern Plains

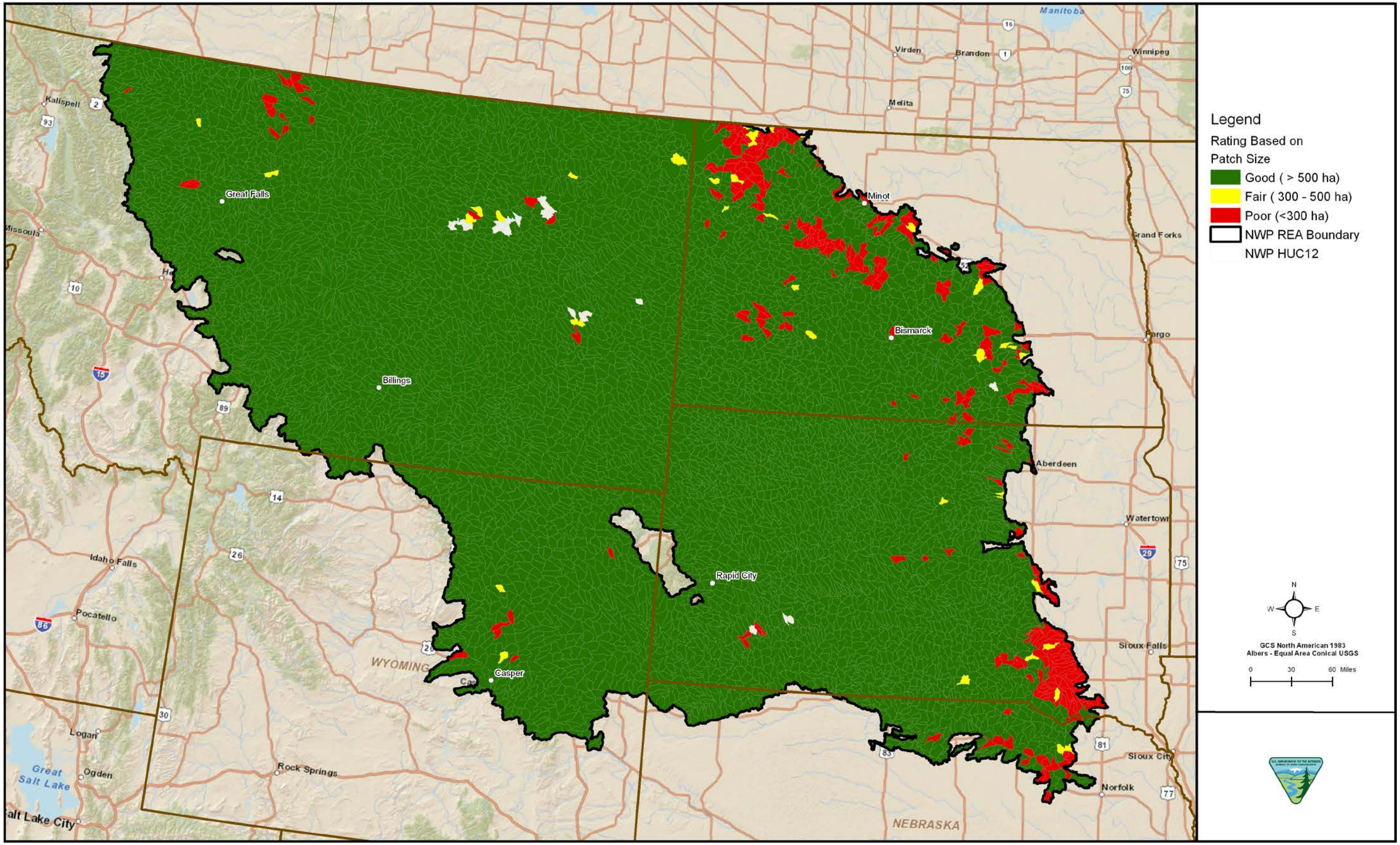

Figure E-1-4. Core Habitat Patch Size Model for Mule Deer

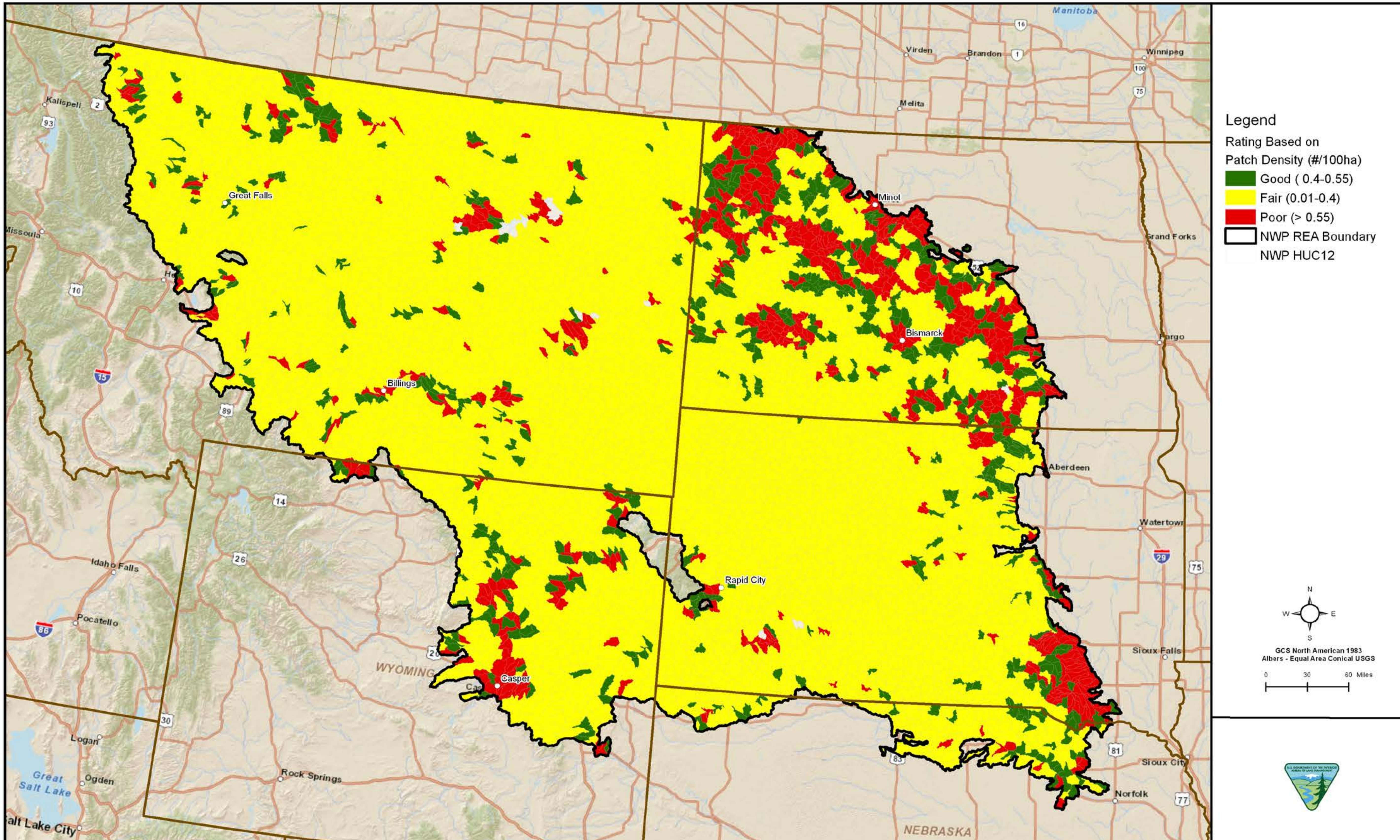

Figure E-1-5. Habitat Heterogeneity (Patch Density per 100 hectares) per Hydrologic Unit Code

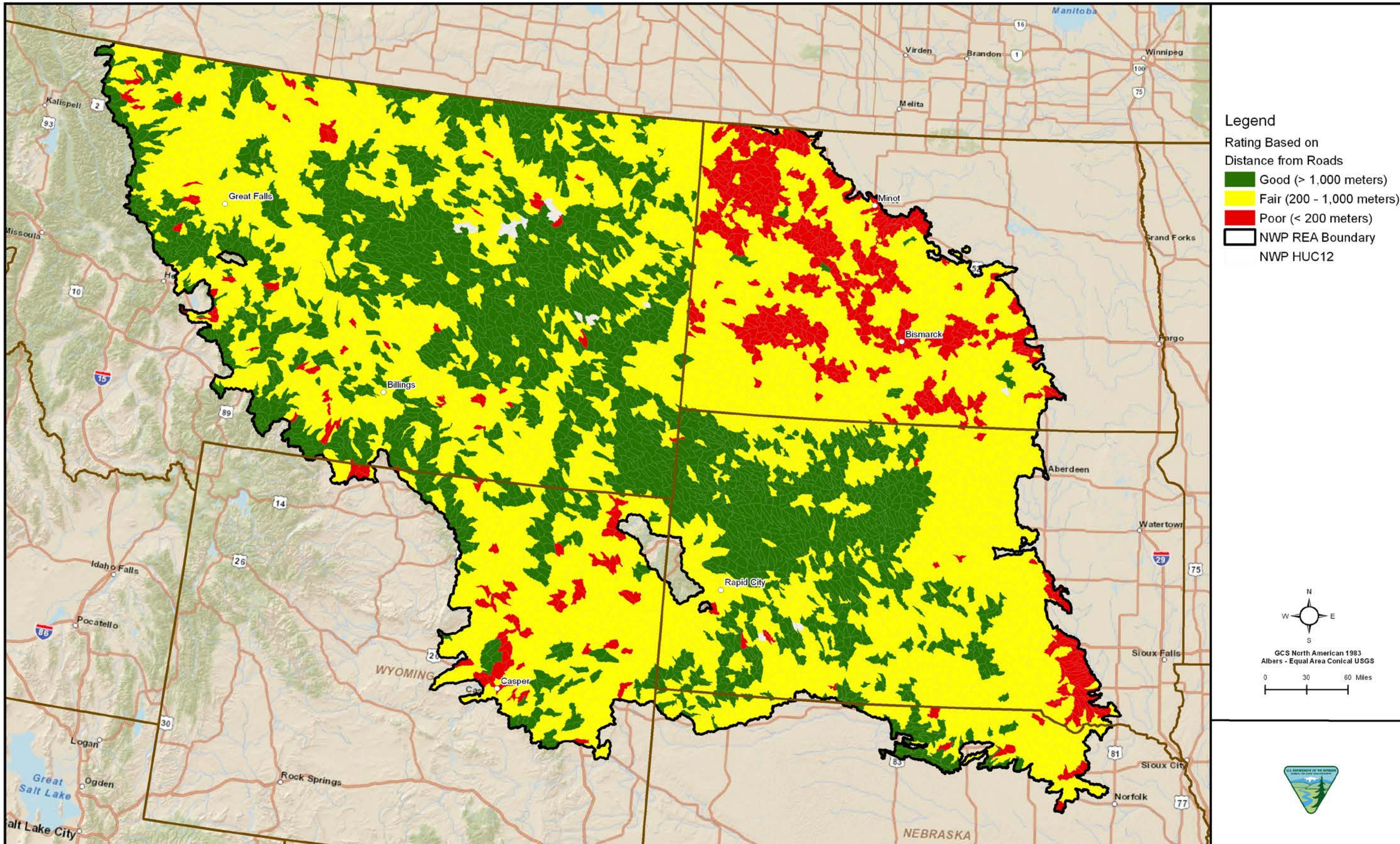

Figure E-1-6. Distance to Roads by Hydrologic Unit Code

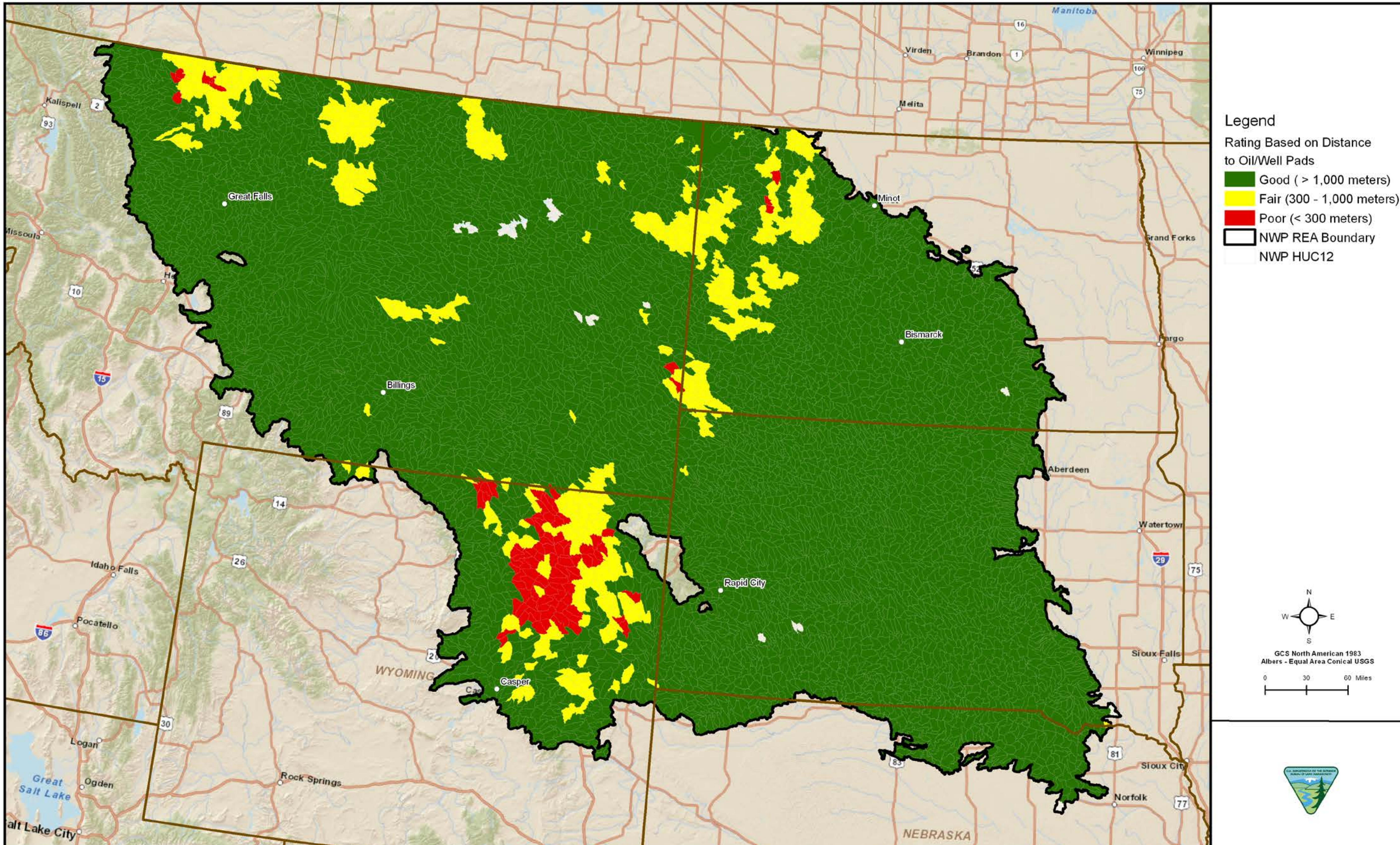
Legend
Rating Based on Distance to Oil/Well Pads
Good (> 1,000 meters)
Fair (300 - 1,000 meters)
Poor (< 300 meters)
NWP REA Boundary
NWP HUC12
GCS North American 1983
Albers - Equal Area Conical USGS
0 30 60 Miles
Great Falls
Billings
Casper
Rapid City
Bismarck
Minot
Aberdeen
Watertown
Sioux Falls
Sioux City
Norfolk
Fargo
Grand Forks
Winnipeg
Brandon
Virden
Melita
Kalispell
Missoula
Idaho Falls
Pocatello
Logan
Ogden
Salt Lake City
Great Salt Lake
Rock Springs
WYOMING
NEBRASKA
Manitoba

Figure E-1-7. Distance to Oil and Gas Development by Hydrologic Unit Code

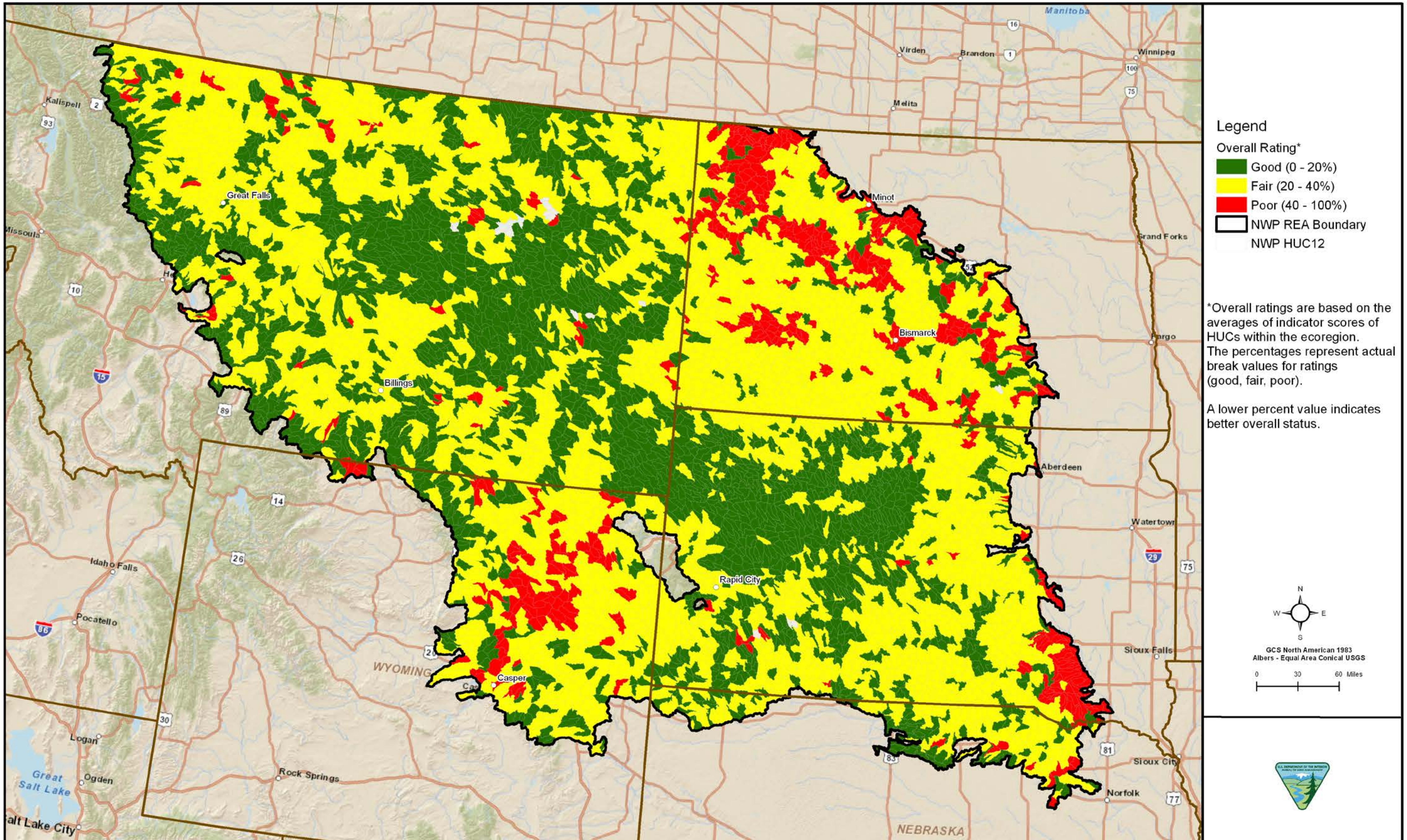

Figure E-1-8. Current Status of the Mule Deer Habitat based on Hydrologic Unit Code within the Northwestern Plains Ecoregion

ATTACHMENT A

GAP LANDCOVER CLASSES RECLASSIFIED TO WHCWG CLASSES – CURRENT STATUS ANALYSIS FOR MULE DEER

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GAP LANDCOVER CLASSES RECLASSIFIED TO WHCWG CLASSES

Agriculture	Cultivated Cropland
	Pasture/Hay
Alpine	North American Alpine Ice Field
	Rocky Mountain Alpine Bedrock and Scree
	Rocky Mountain Alpine Dwarf-Shrubland
	Rocky Mountain Alpine Fell-Field
	Rocky Mountain Dry Tundra
Dry Forest	Eastern Great Plains Tallgrass Aspen Parkland
	Harvested forest-tree regeneration
	Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland
	Middle Rocky Mountain Montane Douglas-fir Forest and Woodland
	North-Central Interior Dry Oak Forest and Woodland
	North-Central Interior Dry-Mesic Oak Forest and Woodland
	North-Central Interior Maple-Basswood Forest
	North-Central Interior Oak Savanna
	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
	Northern Rocky Mountain Ponderosa Pine Woodland and Savanna
	Northern Rocky Mountain Subalpine Woodland and Parkland
	Northwestern Great Plains - Black Hills Ponderosa Pine Woodland and Savanna
	Northwestern Great Plains Aspen Forest and Parkland
	Rocky Mountain Aspen Forest and Woodland
	Rocky Mountain Foothill Limber Pine-Juniper Woodland
	Rocky Mountain Lodgepole Pine Forest
	Rocky Mountain Poor-Site Lodgepole Pine Forest
	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
	Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland
	Southern Rocky Mountain Ponderosa Pine Woodland
	Western Great Plains Dry Bur Oak Forest and Woodland
	Western Great Plains Wooded Draw and Ravine
Grass-dominated	Central Mixedgrass Prairie
	Central Tallgrass Prairie
	Harvested forest-grass/herbaceous regeneration
	Introduced Upland Vegetation - Annual Grassland
	Introduced Upland Vegetation-Perennial Grassland and Forbland
	North-Central Interior Sand and Gravel Tallgrass Prairie
	Northern Rocky Mountain Lower Montane, Foothill and Valley Grassland
	Northern Rocky Mountain Subalpine-Upper Montane Grassland
	Northern Tallgrass Prairie
	Northwestern Great Plains Mixedgrass Prairie
	Recently burned forest
	Recently burned grassland
	Rocky Mountain Subalpine-Montane Mesic Meadow
	Southern Rocky Mountain Montane-Subalpine Grassland
	Western Great Plains Sand Prairie
	Western Great Plains Shortgrass Prairie
	Western Great Plains Tallgrass Prairie

GAP LANDCOVER CLASSES RECLASSIFIED TO WHCWG CLASSES (Continued)

Riparian	Eastern Great Plains Floodplain Systems
	Inter-Mountain Basins Greasewood Flat
	Introduced Riparian and Wetland Vegetation
	Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland
	Northwestern Great Plains Floodplain
	Northwestern Great Plains Riparian
	Rocky Mountain Lower Montane Riparian Woodland and Shrubland
	Rocky Mountain Subalpine-Montane Riparian Shrubland
	Rocky Mountain Subalpine-Montane Riparian Woodland
	Western Great Plains Floodplain
	Western Great Plains Floodplain Systems
	Western Great Plains Riparian Woodland and Shrubland
Shrub-dominated	Harvested forest-shrub regeneration
	Inter-Mountain Basins Big Sagebrush Shrubland
	Inter-Mountain Basins Big Sagebrush Steppe
	Inter-Mountain Basins Curl-leaf Mountain Mahogany Woodland and Shrubland
	Inter-Mountain Basins Mat Saltbush Shrubland
	Inter-Mountain Basins Mixed Salt Desert Scrub
	Inter-Mountain Basins Montane Sagebrush Steppe
	Introduced Upland Vegetation - Shrub
	Northern Rocky Mountain Foothill Conifer Wooded Steppe
	Northern Rocky Mountain Montane-Foothill Deciduous Shrubland
	Northern Rocky Mountain Subalpine Deciduous Shrubland
	Northwestern Great Plains Shrubland
	Recently burned shrubland
	Rocky Mountain Lower Montane-Foothill Shrubland
	Western Great Plains Sandhill Steppe
	Wyoming Basins Dwarf Sagebrush Shrubland and Steppe
Sparsely Vegetated	Disturbed, Non-specific
	Inter-Mountain Basins Active and Stabilized Dune
	Inter-Mountain Basins Cliff and Canyon
	Inter-Mountain Basins Shale Badland
	Rocky Mountain Cliff, Canyon and Massive Bedrock
	Southwestern Great Plains Canyon
	Unconsolidated Shore
	Western Great Plains Badland
	Western Great Plains Cliff and Outcrop
Urban/Developed	Developed, High Intensity
	Developed, Low Intensity
	Developed, Medium Intensity
	Developed, Open Space
	Quarries, Mines, Gravel Pits and Oil Wells
Water	Open Water (Fresh)
Wet Forest	Northern Rocky Mountain Mesic Montane Mixed Conifer Forest
	Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland

GAP LANDCOVER CLASSES RECLASSIFIED TO WHCWG CLASSES (Continued)

Wetland	Columbia Plateau Vernal Pool
	Eastern Great Plains Wet Meadow, Prairie, and Marsh
	Great Plains Prairie Pothole
	Inter-Mountain Basins Alkaline Closed Depression
	North American Arid West Emergent Marsh
	Northern Rocky Mountain Conifer Swamp
	Northern Rocky Mountain Wooded Vernal Pool
	Rocky Mountain Alpine-Montane Wet Meadow
	Rocky Mountain Subalpine-Montane Fen
	Ruderal Wetland
	Western Great Plains Closed Depression Wetland
	Western Great Plains Depressional Wetland Systems
	Western Great Plains Open Freshwater Depression Wetland

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APPENDIX E-2

GREATER SAGE-GROUSE CONSERVATION ELEMENT ANALYSIS FOR THE NORTHWESTERN PLAINS ECOREGION

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SECTION

1.0 INTRODUCTION

The greater sage-grouse (GRSG) (*Centrocercus urophasianus*) is considered an umbrella species for sagebrush-associated vertebrates (Rowland et al. 2006). Indirect effects of sagebrush habitat loss, fragmentation, and degradation are thought to have caused the extirpation of the GRSG from approximately 50 percent of its original range (Connelly and Braun 1997; Connelly et al. 2004; Schroeder et al. 2004), leading to its declaration as a candidate species for listing under the Endangered Species Act (ESA).

Management questions (MQs) pertaining to this ecoregion were identified in Task 1 and can be summarized into two primary questions: 1) where are the important areas for this species? and 2) what is happening to these areas? The central focus of these two MQs is to document the current status of selected conservation elements (CEs) at the ecoregional scale and to evaluate how this status may change over a future time period. The first step is to identify suitable habitat for the CE within the ecoregion. Then, these areas are assessed relative to current and potential future change agent (CA) threats.

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2.0 CONSERVATION ELEMENT DESCRIPTION

The GRSG is a true sagebrush obligate that relies on large, intact blocks of sagebrush as habitat and food year-round. Generally, sagebrush habitats provide critical winter range for the GRSG. However, depending on the time of year and where they are in their life cycle, GRSG move to different areas to survive. Sagebrush/grassland habitats also provide critical breeding range for the GRSG. Meadows, riparian areas, alfalfa fields, and other moist areas provide important summer range, but GRSG will use a variety of habitats at that time of year. The GRSG populations decline when sagebrush/grassland habitat is altered or fragmented by reducing or eliminating sagebrush canopy cover, seeded to introduced grass species, converted to agriculture dominated by annual grasses (e.g., cheatgrass), or altered in any way that results in significant reduction of the native grass/forb understory (Idaho Department of Fish and Game 1997).

Sagebrush and understory grasses and forb cover are key components of GRSG nesting and early brood-rearing habitat. Most GRSG nests occur under sagebrush. If sagebrush is eliminated from a large area, it will not support GRSG populations because nesting success and/or juvenile survival will also be reduced (Idaho Department of Fish and Game 1997).

Insects are a key component of GRSG brood habitat. A high-protein diet of insects is necessary for all young upland game birds during the first month of life. The best early (June to mid-July) GRSG brood habitat includes native grasses and forbs, as well as a 15-25 percent canopy coverage of sagebrush. Late summer (mid-July to September) brood range consists of a variety of habitats, including agricultural fields, meadows, and riparian areas adjacent to big sagebrush communities. In years of above average summer precipitation, late summer brood range may overlap early summer brood range. During winter, GRSG feed almost exclusively on sagebrush leaves and buds. If adequate sagebrush is available for winter food and cover, GRSG are seldom impacted by severe winter weather. Loss of sagebrush on grouse winter ranges can, however, severely reduce GRSG numbers (Idaho Department of Fish and Game 1997).

The GRSG was recently designated by the U.S. Fish and Wildlife Service (USFWS) as a candidate species under the ESA (U.S. Department of the Interior 2010). The USFWS determined protection under the ESA was warranted; however, listing the GRSG was precluded by the need to address other listings of higher priority.

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3.0 CONSERVATION ELEMENT DISTRIBUTION MODELING

To answer the MQs regarding the location of this species across the ecoregion, a variety of existing data layers representing important habitat for the species were used. The goal was to obtain data to determine the current distribution and status of this species throughout the ecoregion. The GRSG is found in four of the five states in the ecoregion (Montana, North Dakota, South Dakota, and Wyoming).

Because of its long history as a valuable upland game species, unexpected population declines in recent years, and recent addition to the federal ESA candidate list, there is an abundance of GRSG information available via various data sources such as Sagemap and eBird, as well as data provided from the Bureau of Land Management (BLM) on range and buffered lek locations (Table E-2-1). Because there has been so much focus on answering the "where" MQs related to GRSG distribution across the west, there are many different GRSG distribution maps available (including those that include priority habitats, buffered lek locations, and occupied habitats). Montana Fish, Wildlife, and Parks previously attempted to create a Maxent model of this species distribution, with limited success.

Table E-2-1. Data Sources for Conservation Element Distribution Mapping

Data Needs	Dataset Name	Source Agency	Type/Scale	Status	Use in Rapid Ecoregional Assessment (REA)
Modeled Suitable Habitat	Gap Analysis Program (GAP) Habitat Models	U.S. Geological Survey (USGS)	Raster (30 meters [m])	Acquired	No[2]
	Breeding Bird Density (BBD) Map	BLM	Polygon	Acquired	Yes
	State-Derived Core and Lek Areas	MT, WY, ND, SD State Agencies	Polygon/ Raster	Received	Yes
	Western Governors' Association (WGA) Decision Support System (DSS) Models	WGA Pilot Crucial Habitat	Raster	Future Dataset	No[2]
Occurrences	State Natural Heritage Databases	MT, WY, ND, SD Heritage Programs and Fish and Game	Point	GRSG Data Not Acquired	No
	Breeding Bird Survey	USGS	Polygon	Acquired	Yes
	eBird	Avian Knowledge Network, Partners in Flight	Point	Acquired	No[3]
Areas with Potential for Restoration of Habitat or Habitat Connectivity	Management Plan Areas	U.S. Forest Service (USFS), National Park Service (NPS), BLM, USFWS	Polygon	Not Available	No[1]
Location of Core Areas	Core GRSG	BLM	Polygon	Acquired	Yes
Location of Leks, Nesting, Brood-Rearing, and Winter Habitat	BLM 2006 Compilation of States	BLM; MT, WY, ND, SD, Fish and Game Agencies	Point 1:24k	Acquired	No[2]
Habitat Connectivity	WGA DSS Data	WGA	Polygon	Future Dataset	No[2]

[1] Data gap
[2] More representative data were selected for use.
[3] Scale is inappropriate

As a result of the variety of distribution maps available, the BLM determined that new distribution maps for GRSG for this Rapid Ecoregional Assessment (REA) would not be necessary. The BLM recommended using a combination of the existing breeding bird density (BBD) (Doherty et al. 2010) and GRSG range maps, as developed by Schroeder (2004), because these maps cross land ownerships and provide coarse-scale information about where most of the GRSG are located.

The BBD map uses maximum count of male GRSG on actual leks to develop GRSG breeding density circles for 11 states across the west (Doherty et al. 2010). This map displays GRSG breeding densities in 25, 50, 75 and 100 percent buffer circles around existing leks. More specifically, in order to identify a given proportion of the population (e.g., 25 percent) within the smallest area, the BBD map highlights those areas with the greatest lek density and highest male counts. The Rolling Review Team (RRT) recommended only using the 75 percent (8.5-kilometer [km] radius) breeding circles from this dataset. This was based on the fact that most birds nest within certain distances of leks, and the BBD map therefore provides a way to evaluate breeding and nesting seasonal habitats. Because of the sensitivity of these data, the center point of each buffered lek location was not provided and the buffered lek circles were dissolved into one polygon for the analysis.

The GRSG range map, as developed by Schroeder (2004) and updated by BLM in 2006 (henceforth referred to as the Schroeder range map), shows the current and historic distribution of potential habitat, or range. These data were initially researched and compiled by Dr. Michael A. Schroeder of the Washington State Department of Fish and Wildlife. The combination of these maps were used, because they were determined to be the best representation of all seasonal habitat usage for this species, and because these maps represent the areas of management concern that are relevant at the scale of the REA. Figure E-2-1 presents the combination of the BBD and the Schroeder range maps that were used for this analysis. Although this map is not intended to portray actual distribution of GRSG, it will be referred to as the REA GRSG distribution layer. As illustrated on this map, the majority of the Schroeder range overlaps the 75 percent buffered leks.

4.0 CONCEPTUAL MODELS

The 75 percent current BBD map and the Schroeder range map data layers formed the starting point of the CA analysis across the ecoregion, the aim of which is to understand how this species will react to the potential future impact of CAs. The current status and potential future threat analyses were based on CE-specific ecological conceptual models, selected environmental variables (Key Ecological Attributes [KEAs]) likely to be impacted by CAs, and the availability of data. The CAs initially considered in this analysis include development, climate change, invasive species, wildfire, and disease.

4.1 ECOLOGICAL PROCESS MODEL

The ecological process model (Figure E-2-2) was developed to identify and link the key life cycle processes to ecological attributes (EAs) that have the greatest potential to affect GRSG habitat throughout the ecoregion. As noted in the species description, this species requires large, intact blocks of sagebrush for all phases of their life cycle.

The key processes are identified in the model as green boxes. Following Unnasch et al. (2009), three broad headings or categories of EAs (size, condition, and context) are identified in the model as blue diamonds. Size refers to attributes related to habitat or patch size, condition refers to the condition of the habitat, and context refers to the spatial structure of the habitat. At the landscape level, the EAs under the condition category were the most challenging to spatially represent and will primarily depend on the data available.

4.2 SYSTEM-LEVEL MODEL

The system-level conceptual model (Figure E-2-3) illustrates the interactions between the CAs and the primary habitat functions of this species. The CAs for this CE, which are development, climate change, invasive species, wildfire, and disease, are identified across the top of the figure in red. The availability, suitability, and connectivity of sagebrush communities are the primary factors affecting GRSG populations.

4.2.1 Development

Development, infrastructure (roads, pipelines, transmission lines), oil and gas exploration, and wind farms in proximity to GRSG leks and winter habitat can significantly impact GRSG populations (Doherty et al. 2008; Holloran 2005; Kaiser 2006; Naugle et al. 2006; Aldridge and Boyce 2007; Harju et al. 2010). Abandonment of GRSG leks in response to power lines has been documented (Ellis 1987; Hall and Haney 1997; Braun 1998), presumably due to an increase the number of nesting raptors and ravens offerered new or alternative nesting structures (Gilmer and Wiehe 1977; Steenhof et al. 1993). Collision of GRSG with fences and transmission lines during flight has been documented (Beck et al. 2006).

Potential impacts of gas and oil development to GRSG include physical habitat loss, habitat fragmentation, spread of exotic plants, increased predation probabilities, and greater anthropogenic activity and noise resulting in displacement of individuals through avoidance behavior (Connelly et al. 2004). The GRSG leks within 0.4 km of coalbed methane (CBM) wells in northern Wyoming had fewer males per lek and lower annual rates of population growth compared to leks situated >0.4 km from a CBM well (Braun et al. 2002).

Conversion of sagebrush to pasture, cropland, or irrigated hayfields has been widely recognized as a dominant factor in the decline of GRSG populations. On the landscape scale, reducing the land cover of sagebrush communities below 25 percent of a 30-km radius (i.e., the mean home range size) has been suggested as a strong predictor of GRSG extirpations (Aldridge et al. 2008), and losses have been observed when the proportion fell below 65 percent.

Urban development results in direct loss of sagebrush ecosystem acreage, and the human disturbance associated with these developments makes even more acreage non-functional. Selection of town sites result from a variety of factors including easy access, presence of water, presence of building materials, a relatively high degree of security and safety, etc. Some residences and subdivisions (i.e., ranch/farmsteads and ranchettes) are far removed from actual incorporated towns, but have the same type of impact on the ecosystem on a smaller scale. This trend in habitat loss is continuing at an ever-expanding rate as the human population grows (Wyoming Interagency Vegetation Committee 2002). Some investigators have estimated that as much as 3-5 percent of this ecosystem may have already been negatively impacted by town and urban development (Braun 1998).

4.2.2 Climate Change

Climate change effects are expressed primarily as a range of suitable temperature and precipitation (Wisdom et al. 2011) and the frequency and duration of drought (Aldridge et al. 2008). Evers (2010) suggests that under projected climate change in the Great Basin, cooler and moister sagebrush communities (i.e., nesting and brood-rearing habitat) would decrease substantially. The synergistic effects of climate change have the potential to adversely impact GRSG habitat throughout this ecoregion. Increasing temperatures within in the region may lead to fragmentation and habitat loss. Modeling efforts suggest that the geographic range of big sagebrush (*Artemesia tridentata*) will contract significantly and move northward and upward in elevation (Shafer et al. 2001; Miller et al. Undated).

Climate change will facilitate the incursion of invasive plants and the associated changes in fire regime, which currently pose significant threats to GRSG and the sagebrush ecosystem (USFWS 2011). When sagebrush covered much of the western United States, fire helped to recycle nutrients and suppress woody invasion. However, the recent pattern of more frequent fires eventually results in vegetation shifts from sagebrush to grassland vegetation systems. Grassland systems are more vulnerable to invasive species, which also cause compounding problems for sagebrush.

Also, because many crops at northern latitudes are currently temperature-limited, warmer seasonal temperatures associated with climate change may lead to greater conversion of native shrub-steppe to tilled agriculture in the near term (Motha and Baier 2005; Stubbs 2007)

4.2.3 Invasive Species

Invasive species occurrences and fire history are often linked and have been estimated to contribute to an increase in juniper and pinyon woodlands (Miller and Tausch 2001) which are avoided by GRSG. In Wyoming big sage communities, invasion of annual grasses or weeds (e.g., cheat grass, medusahead) is the greatest threat, because these fuels increase the fire frequency from greater than 100 years to less than 10 years (Wisenant 1990). Tree establishment within sagebrush communities generally decreases forb availability due to moisture depletion (Bates et al. 2000).

Increases in the spread of non-native species such as cheatgrass, Japanese brome, and knapweed (*Centaurea* spp.) are also adversely impacting sagebrush-steppe habitat (Quigley and Arbelbide 1997). The increased fire frequency in areas with cheatgrass affects the ability of sagebrush to reestablish between fire events. Exotic plants are opportunists, and, when present, quickly increase to establish and colonize areas that have experienced soil-surface disturbance or that lack plant cover. Construction activities from mines, wells, roads, and other surface disturbance activities provide avenues for the establishment of non-native plants that degrade sagebrush ecosystems (Wyoming Interagency Vegetation Committee 2002).

A data gap exists with regard to invasive species due to the lack of large-scale, comprehensive geospatial datasets covering the ecoregion and the inability to identify suitable surrogates.

4.2.4 Wildfire

Many researchers believe fire historically (as a primary disturbance factor) had an important role in some sagebrush ecosystems, increasing the dominance of many herbaceous species while reducing the abundance and cover of woody plants.

Wildfire reduces habitat quality and quantity for GRSG (Connelly and Braun 1997; Connelly et al. 2000; Nelle et al. 2000; Fischer et al. 1996). Moderate fire return intervals (FRIs) and low-intensity fires are necessary to maintain the mixed composition of sagebrush communities for lekking, nesting, and brood rearing. The predominant impacts of wildfire are expected to occur at the vegetation community level, as sagebrush sites shift from one state to another with changes in disturbance regimes.

4.2.5 Disease

Naugle et al. (2004) reported the first West Nile virus (WNV) case in GRSG in northeast Wyoming, resulting in a 25 percent decline in survival of four populations (Naugle et al. 2004). Walker (2007) showed that GRSG chick and adult survival was significantly lower due to WNV, which resulted in declining male and female lek attendance. A highly efficient vector of WNV in North America is the mosquito (*Culex tarsalis*) (Hayes et al. 2005; Turell et al. 2005), which is thought to increase due to water development and well ponds associated with oil and gas exploration.

4.3 CHANGE AGENTS PROPOSED FOR ANALYSIS

Although numerous attributes and indicators affecting this species were initially identified in early phases of this REA, not all are included in this analysis. Analysis for invasive species and disease CAs were not included for this CE because the direct effect indicators were determined to be data gaps or because they were impractical to model at the ecoregional scale because appropriate geospatial data were not available. The specific indicators that could not be modeled are identified with an asterisk on Figure E-2-3. Further information on the data gaps for these indicators are discussed in the respective CA analysis contained in Appendix C.

Analysis for the development, wildfire, and climate change CAs are included for this CE.

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5.0 CHANGE AGENT ANALYSIS

A current status and future threat assessment for the GRSG was conducted for the ecoregion using the 12-digit Hydrologic Unit Codes (HUCs) as the analysis unit. Based on the ecological process and system-level models, KEAs were identified for the current status and future threat analyses, with a specific emphasis on the ability to measure impacts using existing geospatial data.

Because the scale of the analysis is at the HUC 12, a layer of 6^{th} level watersheds was extracted for the ecoregion. A geographic information system (GIS) process was iterated through the KEA indicators and determined the metric values associated with each watershed. In other instances, sufficient published data indicated cut-off points for these values. These values were added as an attribute to the HUC 12 layer. The final layers were created by combining the HUC 12 watersheds (with ranked KEAs) with the final suitable habitat layer and the habitat layer from the current status CA layer.

The CAs evaluated for current status include development and wildfire. The CAs evaluated for future threats include development and climate change.

5.1 CURRENT STATUS OF THE GREATER SAGE-GROUSE

5.1.1 Key Ecological Attribute Selection

Table E-2-2 identifies the original KEAs proposed in Task 3 and which of these were used in the final current status analysis. Not all of the KEAs proposed were used, based on the rationale provided. Other KEAs were used but are not directly related to CAs. For example, one of the primary problems with the CA analysis was that the 75 percent buffered lek circles were used as part of the initial distribution maps. The center of each of the circles was not provided and the circles were all dissolved together into one polygon. Many of the initial KEAs used the center point of the breeding circle as what could be referred to as the actual lek location. Because the distribution data were formatted in this manner, many of the metrics for the KEAs had to be modified. Subsequent to the initial analysis, the RRT also recommended combining the Schroeder range map with the BBD map as an additional distribution layer for the analysis.

Table E-2-2. Key Ecological Attributes Retained or Excluded for the Greater Sage-Grouse

Category	Attribute	Explanation
1. Size	a. Percent cover of sagebrush in buffered lek area and Schroeder range area	Retained to show the amount of sagebrush within each lek circle and throughout the Schroeder range.
	b. Percent of cropland in buffered lek and Schroeder range area	Retained to show the potential impact of agriculture to GRSG habitat.
	c. Sagebrush patch size	Retained to show core habitat fragmentation.
2. Condition	a. Cover type	Retained to show the relative quality of the cover types around habitat.
	b. Vegetation condition class (VCC)	This KEA was excluded because of the uncertainty associated with the use of VCC in shrub and grassland systems.
3. Context	a. Edge density, ratio of edge to interior	This KEA was excluded because the analysis was too large to complete at an ecoregional scale and patch size was a similar analysis.
	b. Patch density	This KEA was excluded because the analysis was too large to complete at an ecoregional scale.
	c. Oil and gas well density (within 11.3 square miles)	This KEA was excluded because the KEA listed below completes the same analysis with a smaller, more conservative assessment.
	d. Oil and gas well density (1 square mile)	Retained to show the oil and gas well density relative to the spatial location of buffered leks (smaller moving window).
	e. Road density	Retained to show the density of roads relative to buffered leks and GRSG range.
	f. Distance to highways	Retained to show the proximity of major highways relative to buffered lek locations and GRSG range.
	g. Presence of power lines	Excluded because this KEA was combined with the KEA listed below.
	h. Distance to towers and power lines	Retained to show proximity of power lines and towers to buffered leks and GRSG range.
	i. Percent of combined breeding circle and range area in agriculture	Included as part of percent of cropland in buffered lek area and GRSG range.
	j. Human density	Retained to show the proximity of populated areas.
	k. Annual precipitation	Excluded because precipitation is an indirect indicator for GRSG relative to habitat condition. Also, data not adequate scale for analysis.

Table E-2-3 identifies the KEAs, indicators, and metrics that were used to evaluate the CA and pathways affecting this CE. For each of the KEAs listed in Table E-2-2, a discussion of the indicator, metric, metric rank and value, data source(s), and references is provided. Several indicators were used to assess the current status for this CE. This table was limited to size, condition, and landscape context based on spatially available attributes and key factors affecting GRSG in this ecoregion. For this CE, metrics used were equally weighted when evaluating the overall current status of the CE.

Table E-2-3. Greater Sage-Grouse Key Ecological Attributes, Indicators, and Metrics

Category	Ecological Attribute	Indicator/Unit of Measure	Metric			Data Source	Citation
			Poor = 3	Fair = 2	Good = 1		
Size	Lek Quality	Sagebrush density (% cover of sagebrush)	< 20%	20%-65%	> 65%	GAP/ National Land Cover Database (NLCD)	Aldridge et al. 2008
		Cropland proximity	>65%	20%-65%	<20%	GAP/ NLCD	Aldridge et al. 2008
	Core Habitat Patch Size	Patch size (hectares [ha])	< 500	500-4000	>4000	GAP/ NLCD	Wisdom et al. 2011
Condition	Quality Community Composition Landscape Structure Habitat Condition	Cover type	Cultivated fields Woodlands Other Landcover types (water, human landuse)	Scrub-willow; Sagebrush savannas with trees	Small sagebrush (e.g., low, black); forb-rich mosaics of low and tall sagebrush Riparian meadows; Large, woody, tall sagebrush (e.g., big, silver, and three-tip) trees	GAP/ NLCD	Crawford et al. 2004
Landscape Context	Connectivity Habitat Condition	Oil and gas well pad density (quantity per square mile)	> 7	1 - 7	< 1	Oil & Gas Wells	Naugle et al. 2006
		Road density (km/square kilometer [km^2])	> 0.112	0.087-0.112	< 0.087	Linear Features	Wisdom et al. 2011
		Distance to highway (km)	< 5	5-8	> 8	Linear Features	Wisdom et al. 2011
		Distance to towers and power lines (km)	< 8.5	8.5-21	> 21	Tower layer file	Hall and Haney 1997; Wisdom et al. 2011
		Human density (persons/km^2) within buffered leks and range areas in agriculture	> 31	4 – 31	< 4	Census Topographically Integrated Geographic Encoding and Referencing (TIGER), Core Areas & Census	Wisdom et al. 2011

In most cases, the metrics used to identify attribute quality were based on available publications, coupled with expert analysis and professional judgment in association with data-driven metrics. The evaluation of the indicators and metrics used was carried out through the establishment of a GRSG RRT comprised of BLM wildlife biologists and state-level GRSG experts. The RRT met periodically to contribute information and to analyze input attributes and outputs that were derived from various forms of spatial analyses in GIS. This process enabled the RRT to determine the efficacy of attributes, indicators, and metrics, as well as to ascertain the accuracy of each step of the modeling process.

Similar efforts of developing ecological attribute tables have been provided by Oliver (2006), the Uinta Basin Adaptive Resource Management Local Working Group (UBARM 2006), and O'Brien (2007). Definitions for rankings of indicators were adapted from UBARM (2006) as follows:

- Poor: Allowing the indicator to remain in this condition for an extended period will make restoration or prevention of extirpation of GRSG practically impossible (e.g., it will be too complicated, costly, and/or uncertain to reverse the alteration).
- Fair: The indicator lies outside of its range of acceptable variation and requires human intervention for maintenance. If unchecked, GRSG will be vulnerable to serious degradation.
- Good: The indicator is functioning within its range of variation, although it may require some human intervention for maintenance.

Each of the analyses described below were initially completed for the entire ecoregion rather than on only the distribution layer (BBD and Schroeder range). Upon completion of each analysis, the distribution layer was dropped onto the completed KEA analysis layer as a mask for display of the analysis. Completing each analysis in this manner allowed every pixel to retain its original value from the original analysis. All of the CA layers for this CE are presented showing the attributes by pixel because it was the only way to show the level of detail necessary for interpretation at the ecoregional scale.

5.1.1.1 Sagebrush Density

This KEA was designed to show the amount or density of sagebrush across the REA GRSG distribution area through the evaluation of the amount of habitat classified as sagebrush. Because each of the buffered lek circles had an 8.5-km radius, a moving window analysis (with a window radius of 8.5 km) was completed on all Gap Analysis Program (GAP) vegetation data labeled as sagebrush. The moving window analysis was then extracted to the REA GRSG distribution map, and if greater than 65 percent of the moving window contained sagebrush, it was rated as good. The pixels within the REA GRSG distribution map extent were assigned values between 1 and 3 (Table E-2-3) based on the percent cover within the moving window analysis area. The sagebrush density layer, based on percent sagebrush cover, is presented on Figure E-2-4.

5.1.1.2 Cropland Proximity

This KEA was included to identify the amount of cropland across the REA GRSG distribution. Land use cover data from GAP was used to identify cropland. A moving window analysis was completed for this analysis with the same moving window size as the previous KEA. If less than 20 percent of the CE distribution area contained pixels that were labeled as cropland, the pixels were rated as good. The pixels of the REA GRSG distribution map were assigned values between 1 and 3 (Table E-2-3) based on the percent cropland within each area. The percent cropland is presented on Figure E-2-5.

5.1.1.3 Sagebrush Patch Size

This KEA was included to assess habitat fragmentation by identifying the larger patches of sagebrush relative across the CE distribution. This analysis was initially completed for the entire ecoregion, and all of the GAP vegetation types classified as any type of sagebrush were reclassified into one layer for this analysis. A GIS tool was used to group contiguous 30-meter (m) pixels. This tool assigns each pixel group unique values, and a value is then assigned to the pixels based on the size of the group that they are located in. The REA GRSG distribution layer was then dropped over the previously assigned pixels to show the patches assigned as good, fair, or poor. While it is recognized that sagebrush areas are naturally patchy, this indicator identifies those larger blocks of sagebrush that are naturally patchy. The sagebrush patch size layers are presented on Figure E-2-6.

5.1.1.4 Cover Type

The quality and composition of cover types is important for all GRSG lifecycles. This KEA was included to attempt to classify the quality and community composition of the cover types across the REA GRSG distribution map. The GAP vegetation layers were used to complete this analysis. The vegetation layers were reclassified into three classes. The class rated as good contains small sagebrush, with a mosaic of low and tall sagebrush; riparian meadows; and large, woody, tall sagebrush (e.g. big, silver, and three-tip). The class rated as fair contains scrub-willow, sagebrush savannahs with minor tree encroachment. The class rated as poor contains cultivated fields and woodlands. Each pixel was assigned values between 1 and 3 based on the definitions listed above. The REA GRSG distribution map was then dropped over the cover type analysis as a mask to display the cover types of the REA GRSG distribution map labeled as good, fair, and poor. The cover type layers are presented on Figure E-2-7.

5.1.1.5 Oil and Gas Well Density

Oil and gas wells have the potential to negatively affect GRSG and associated habitat. This KEA was developed to analyze the potential impact of energy development on GRSG. Use of this indicator was based on the assumption that increased levels of oil and gas development near known GRSG leks and range could influence breeding and other behaviors. The metric values for this indicator were based on Holloran (2005) and evaluated GRSG leks relative to natural gas wells in western Wyoming. Holloran categorized each lek based on the total number of producing wells within 3.1 miles of the lek. His research used fewer than five wells as the control (minimal gas field-related disturbance), leks with 5-15 wells as lightly impacted, and leks with more than 15 wells as heavily impacted.

The analysis completed for this REA used a moving window to identify the density of oil and gas wells relative to the REA GRSG distribution map. The moving window was 1 square mile in size. Pixels were assigned values between 1 and 3 (Table E-2-3) based on the number of oil or gas wells within the 1 square mile moving window; the REA GRSG distribution map was then dropped over the analysis to display areas on the distribution map as good, fair, or poor relative to their proximity to oil and gas wells. Figure E-2-8 presents the results of the oil and gas well pad density analysis.

5.1.1.6 Road Density

KEAs defined to assess landscape context evaluate the quality of the landscape immediately surrounding an ecological system in order to provide an assessment of the potential threats to GRSG habitat. Both improved and unimproved roads compact soil and vegetation, increasing surface runoff. Road rights of way are often inroads for exotic species colonization points, and unimproved roads contribute to wind and water-borne sedimentation.

Roadway data were extracted from selected geographic and cartographic information from the U.S. Census Bureau's Topologically Integrated Geographic Encoding and Referencing (TIGER) database. For this REA, the criterion used was the All Roads County-based shapefile (U.S. Census Bureau 2012).

The analyses used a 1-square-kilometer (km^2) moving window to show the density of roads relative to the REA GRSG distribution map areas. Pixels were assigned values between 1 and 3 (Table E-2-3) based on the road density (km/km^2) analysis using values described in Wisdom et al. (2011). Figure E-2-9 presents the road density evaluation.

5.1.1.7 Distance to Highways

A second indicator was used to assess potential anthropogenic impacts from roadways. This KEA assesses the distance to highways relative to REA GRSG distribution. For this analysis, pixels were assigned values of 1, 2, or 3 (Table E-2-3) based on their distance (km) from highways. The REA GRSG distribution map was then dropped over these pixels to display the good, fair, and poor values across the REA GRSG distribution map. Figure E-2-10 presents the distance to highways data layer.

5.1.1.8 Distance to Towers and Power lines

The presence of towers and power line infrastructure is considered in this assessment as an indicator associated with decreased lek success, higher mortality, and poor landscape structure (fragmentation). For example, abandonment may increase if leks are repeatedly disturbed by raptors perching on power lines near leks (Ellis 1984), or by noise and human activity associated with energy development during the breeding season. Additionally, deaths resulting from collisions with power lines were an important source of mortality for sage-grouse in southeastern Idaho (Beck et al. 2006). Three potential factors associated with towers could decrease GRSG numbers or lek use: 1) raptors, especially immature golden eagles (*Aquila chrysaetos*), hunt more efficiently from perches such as towers and may harass or take adult grouse near or on leks; 2) common ravens (*Corvus corax*) may use the towers as perches and nest sites, and may prey on eggs and young of GRSG near leks; and 3) GRSG may respond to towers as potential raptor perch sites and thus abandon or decrease their use of a lek from which towers can be seen (Rowland 2004).

Wisdom (2011) found different tolerance distances between transmission lines and cellular towers. He indicated that this difference could be due to the fact that cellular towers are associated with more intense human development and are concentrated along major highways and within and near larger towns.

Transmission line data were obtained for major utility lines within this ecoregion. These transmission lines are generally greater than 115 kilovolts (kV) and tie major power plants to the electrical grid. Data for minor transmission lines (e.g., neighborhood electrical lines, etc.) were not available for use in this analysis.

The values for this indicator were derived from two different studies based on distances of leks from power lines and cellular towers. Hall and Haney (1997) found that leks located less than 3 km from utility lines had declining population trends; Wisdom et al. (2011) found GRSG populations within 12 km of cellular towers were extirpated, while areas greater than 21 km from cellular towers were occupied. The concern with the towers and power lines in both of these studies was related to raptor predation on leks, collisions, electromagnetic radiation, and associations with human developments. Because the center of each of the lek circles was not provided, it was necessary to calculate the radius of each buffered lek circle (which turned out to be 8.5 km). Therefore, in order to cover both of the referenced studies, the metric of less than 8.5 km was used for the poor category. The metric for the good category was greater than 21 km (based on the Wisdom et al. [2011] study), and the metric for the fair category (8.5 to 21 km) was a combination of both studies. The raster layer used for this KEA included a combination of cellular towers and wind turbine towers combined with the power line layer. Figure E-2-11 presents the distance to towers and power lines evaluation.

5.1.1.9 Human Density

Human population growth is an indicator of landscape context and is used as a surrogate indictor for the potential impacts associated with increased human access. Human land use, including tillage agriculture, historic grazing management, urban and exurban development, roads and power line infrastructure, and even recreation have contributed both individually and cumulatively to lower numbers of sage-grouse across the range (Knick et al. 2011).

Housing data for the spatial locations were used to estimate number of people per square mile. The number of houses was used per location and then multiplied by 2.58, representing the national average people per household number. Pixels were then assigned values of 1, 2, or 3 (Table E-2-3) based on the human population density analysis. The REA GRSG distribution map was then dropped over the pixels to display the good, fair, and poor ratings for the human density analysis. Figure E-2-12 presents the human density data layer.

5.1.2 Current Status of Habitat for the Greater Sage-Grouse

The individual KEA analyses provide the basis for the compilation of an overarching data layer that defines the current status of the GRSG habitat for each HUC across this ecoregion. A method of aggregating scores was used to summarize overall threats with regard to GRSG habitat quality. Individual indicators can identify areas of potential risk to GRSG populations, but aggregated scores can provide important information with relation to areas where this species might encounter multiple threats.

In order to create a current status layer, an overall score for each pixel across the ecoregion was calculated by summing the values of each pixel from each analysis. For this CE, the metrics were equally weighted when evaluating the overall current status. Each watershed has the potential to receive a maximum score of 27 points (i.e., 9 indicators assessed, each having the potential for a maximum score of 3). The summed scores were then divided by a factor of 9 to yield a value between 1 and 3. This final overall score was then ranked as poor, fair, or good based on the natural breaks method, which seeks to reduce the variance within classes while maximizing the variance between classes. The overall current status layer for GRSG is presented on Figure E-2-13. The result of the overall analysis is also presented based on HUC 12 and is displayed on Figure E-2-14.

The current status analysis indicates there are some existing concerns associated with several areas of the ecoregion (Figure E-2-14). The size attributes indicate several areas are threatened by lower patch size (Figure E-2-6) and a low percentage of sagebrush (Figure E-2-4), particularly in the northernmost part of the ecoregion. The anthropogenic features that contribute most to the ecoregion as a whole are the distances from highways (Figure E-2-10) and power line infrastructure (Figure E-2-11). A summary of the current status ratings based on the CE distribution is provided in Table E-2-4. The CE distribution layer was used to calculate the total number of square miles of CE habitat and a percentage of the total number of square mile per HUC that were rated as good, fair, or poor. The results of the current status assessment indicate that nearly 65 percent of the 6th level HUC watersheds that intersect the GRSG distribution received an overall good or fair rating.

Table E-2-4. Summary of Current Status Ratings for the Greater Sage Grouse

Overall Rating by 6th Level HUC	Total Square Miles[a]	Percentage of Total Square Miles[a, b]
Good	21,389	22.4
Fair	40,201	42.2
Poor	33,697	35.4

[a] These values include only the area of HUCs that intersect with the CE distribution layer.
[b] Values rounded to one decimal place.

5.2 FUTURE THREAT ANALYSIS

The system-level model (Figure E-2-3) was used to create a series of intermediate layers that are primarily based on the geospatial data available on the future projections for the development and climate change CAs. Future threats were evaluated for development for a short-term time horizon (5 to 10 years) and for climate change for a long-term time horizon (50-year; 2050 to 2069).

Because of the inherent inaccuracies of the temporal scale of the future data, it is only possible to infer information pertaining to a subjective future period, rather than a specific time period, for some of these attributes. However, because of the limits placed on these data outputs, it is fair to assume that this model predicts the overall future potential for these attributes within this ecoregion. It is an upper limit of potential growth and should therefore be carefully applied to future estimates of the effect on GRSG populations.

5.2.1 Development Change Agent

Future spatial data for development was limited to the potential for future energy development, modeled urban growth, and future potential agricultural development, as discussed in the development CA analysis presented in Appendix C-1.

The greatest threats from future agricultural and potential energy development are to the GRSG populations in the southernmost areas of the ecoregion. These areas may become critical resources for the species in the ecoregion because the current sagebrush cover and patch size are rated higher (good to fair) here than other areas to the north. GRSG habitat throughout this ecoregion is at high risk from future potential energy development. In particular, energy development that occurs in sagebrush habitat particularly threatens GRSG habitat.

5.2.2 Climate Change Future Threats

The climate change CA layer will be created through the results of the 2025 and 2060 USGS climate change models. These models should document areas that may be negatively and positively affected by climate change. Climate change was modeled based on a 15-km grid created for regional analysis based on a comparison of current climate patterns to future modeled climate patterns resulting in the delta (change) output figures. Further details regarding the climate change analysis are provided in Appendix C-5.

The climate change modeling conducted for this REA shows that the Northwestern Plains could experience a temperature increase of between 1.9 to 2.3 degrees Celsius (°C) (Figure C-5-7). For this species, the predicted temperature changes in summer appear most relevant (Figure C-5-10). Increases will significantly increase evapotranspiration rates and reduce the water content of dead vegetation and litter. Both conditions will likely increase water stress in plants and provide more flammable materials for wildfires.

The general precipitation pattern for the Northwestern Plains ecoregion show a large annual precipitation increase in the southeastern area of the ecoregion, and a moderate increase across the rest of the ecoregion (Figure C-5-1). A modeled shift in precipitation to earlier in the season (March and April), combined with increased temperatures during the May-June and July-August seasons, suggests that the sagebrush habitat in areas such as the Powder River Basin may experience more frequent wildfires.

The dependence of the species on sagebrush through all seasonal periods has been well documented. The presence of early greening forbs (broad-leafed flowering plants) improves hen nutrition during this pre-laying season, which increases nest initiation, hatching success, and chick survival. Tall, dense, residual grass (previous year's growth) in nesting habitat improves hatching success. During the summer months, as forbs and other food plants mature and dry out, GRSG seek areas still supporting green vegetation. Sagebrush stands closely associated with riparian areas provide important security cover, and are used during loafing and roosting periods. During the fall, forbs and insects decrease in availability, so the amount of sagebrush in the diet increases. Fall habitats are those used during migration to winter areas, the timing of which depends on temperatures and snow depth. During the winter, the primary requirement of GRSG is sagebrush exposed above the snow. Winter habitat may be limited in deep snow areas (Cagney et. al 2010).

The NatureServe Climate Change Vulnerability Index (NSCCVI) tool was utilized to assess GRSG vulnerability to the effects of climate change. Using annual raster datasets from NatureServe to perform climate change calculations in ArcGIS (through the Predicted Temperature 2040-2069 (Fahrenheit [F]) and the Predicted Hamon actual evapotranspiration to potential evapotranspiration (AET : PET) Moisture Metric 2040-2069 datasets), the NSCCVI calculator was applied and produced an index score of moderately vulnerable. The NSCCVI tool indicated that available evidence suggests the abundance and/or range extent of this species within the geographical area assessed is likely to decrease by 2050. The assessment rating was largely based on a majority of neutral and somewhat increased vulnerability scores calculated when assessing factors that influence vulnerability, such as distribution to relative barriers, dispersal and movements, reliance on interspecific interactions, and genetic factors.

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6.0 MANAGEMENT QUESTIONS

The relevant MQs for the GRSG would include those defined as part of the Landscape Species/Species Richness category. The overall MQ was: Where are the key habitat types (seasonal, refuges, corridors/connectivity, migration routes, concentrations of regionally significant species, etc.) for landscape species, keystone species, regionally significant species, and regionally significant suites of species? This MQ was considered in implementing the GIS analyses. Emphasis was placed on the spatial relationship of attributes mentioned in the MQs and the distribution map for the CE. Specific MQ examples for the REA were developed in Task 1 and are presented in Appendix A. Several of these MQs are discussed below to demonstrate the functionality of the REA and to provide an opportunity to discuss significant data gaps that were identified during the REA.

6.1 WHERE ARE AREAS THAT HAVE POTENTIAL FOR RESTORING REGIONALLY SIGNIFICANT SPECIES HABITAT OR HABITAT CONNECTIVITY FOR REGIONALLY SIGNIFICANT SPECIES?

The BBD map (Figure E-2-1) was developed by the BLM using count data at leks to delineate high-abundance population centers that contain 25, 50, 75, and 100 percent of the known breeding population. The Schroeder range map also indicates the habitat necessary to sustain the species year round. Several KEAs were selected to evaluate suitable habitat size and conditions of existing breeding areas within the ecoregion. The size attributes indicate that several existing leks are threatened by lower patch size (Figure E-2-9) and a low percentage of sagebrush (Figure E-2-4), particularly in the northernmost part of the ecoregion. The overall combined assessment of the current habitat conditions for the CE by BBD and Schroeder range is presented on Figure E-2-14 and can be used to identify potential areas for restoration.

6.2 WHERE ARE CURRENT REGIONALLY SIGNIFICANT LANDSCAPE/KEYSTONE SPECIES AND THEIR HABITATS, INCLUDING SEASONAL HABITAT AND MOVEMENT CORRIDORS, AT GREATEST RISK FROM CHANGE AGENTS, INCLUDING CLIMATE CHANGE (CONNECTIVITY, SMALL POPULATION SIZE)?

The results of the climate change modeling conducted for this REA show that the Northwestern Plains could experience a temperature increase of between 1.9 to 2.3°C. (Figure C-5-7). The general precipitation pattern for the Northwestern Plains ecoregion shows a large annual precipitation increase in the southeastern area of the ecoregion, and a moderate increase across the rest of the ecoregion (Figure C-5-1). A modeled shift in precipitation to earlier in the season (March and April), combined with increased temperatures during the May-June and July-August seasons, suggests that the sagebrush habitat in areas such as the Powder River Basin may experience more frequent wildfires.

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7.0 REFERENCES

Aldridge, C.L., and M.S. Boyce. 2007. Linking occurrence and fitness to persistence: a habitat-based approach for Greater Sage-Grouse. Ecological Applications 17:508-526.

Aldridge, C.L., S.E. Nielsen, H.L. Beyer, M.S. Boyce, J.W. Connelly, S.T. Knick, and M.A. Schroeder. 2008. Range-wide patterns of greater sage-grouse persistence. Diversity and Distributions 14: 983-994.

Bates, J. D., R. F. Miller, and T. Svejcar. 2000. Understory vegetation response and nitrogen cycling following cutting of western juniper. J. Range Manage. 53:119-126.

Beck, J. L., K. P. Reese, J. W. Connelly, and M. B. Lucia. 2006. Movements and survival of juvenile greater sage-grouse in southeastern Idaho. Wildlife Society Bulletin 34:1070–1078.

Braun, C. E. 1998. Sage-grouse declines in western North America: what are the problems? Proceedings of the Western Association of State Fish and Wildlife Agencies 78:139-156.

Braun, C.E., O.O. Oedekoven, and C.L. Aldridge. 2002. Oil and gas development in western North America: effects on sagebrush steppe avifauna with particular emphasis on sage grouse. In *Transactions North American Wildlife and Natural Resources Conference,* 337-349. Washington, DC: Wildlife Management Institute.

Cagney, Jim, Everet Bainter, Bob Budd, Tom Christiansen, Vicki Herren, Matt Holloran, Benjamin Rashford, Mike Smith, Justin Williams. 2010. *Grazing Influence, Management and Objective Development in Wyoming's Greater Sage-Grouse Habitat with Emphasis on Nesting and Early Brood* Rearing. University of Wyoming Extension, Laramie, WY. Publication B-1203, March 2010. http://www.wyomingextension.org/agpubs/pubs/B1203.pdf.

Connelly, J. W., and C. E. Braun. 1997. Long-term changes in sage-grouse Centrocercus urophasianus populations in western North America. Wildlife Biology 3/4:123-128.

Connelly, J. W., A. D. Apa, R. B. Smith, and K. P. Reese. 2000. Effects of predation and hunting on adult sage-grouse Centrocercus urophasianus in Idaho. Wildlife Biology 6:227-232.

Connelly, J.W., S.T. Knick, M.A. Schroeder, and S.J. Stiver. 2004. *Conservation assessment of greater sage-grouse and sagebrush habitats.* Cheyenne, Wyoming: Western Association of Fish and Wildlife Agencies.

Crawford, J. A. R.A. Olson, N.E.. West, J.C. Mosley, M.A.. Schroeder, T.D. Whitson, R.F. Miller, M.A. Gregg, and C.S. Boyd 2004. Ecology and management of sage-grouse and sage-grouse habitat. J. Range Manage. 57: 2-19.

Doherty, K. E., D. E. Naugle, B. L. Walker, and J. M. Graham. 2008. Greater sage-grouse winter habitat selection and energy development. Journal of Wildlife Management 72:187-195.

Doherty, Kevin E., D. E. Naugle, and B. L. Walker. 2010a. Greater sage-grouse nesting habitat: the importance of managing at multiple Scales. Journal of Wildlife Management 74(7):1544–1553.

Doherty K.E., J.D. Tack, J.S. Evans, and D.E. Naugle. 2010b. Breeding densities of greater sage-grouse: A tool for range-wide conservation planning.

Ellis, K. L. 1984. Behavior of lekking sage-grouse in response to a perched golden eagle. Western Birds 15:37-38.

Ellis, K. L. 1987. Effects of a new transmission line on breeding sage-grouse at a lek in northwestern Utah. In J. Roberson, chairman. Fifteenth Sage-grouse Workshop Transactions of the Western States Sage-grouse Committee, Western Association of Fish and Game Agencies.

Evers, L. 2010. Modeling sage-grouse habitat using a state and transition model Ph.D. Disertation, Oregon State University, Corvallis, OR.

Fischer, R. A., K. P. Reese, and J. W. Connelly. 1996. An investigation on fire effects within xeric sage-grouse brood habitat. Journal of Range Management 49(3):194-198.

Gilmer, D. S., and J. M. Wiehe. 1977. Nesting by ferruginous hawks and other raptors on high voltage power line towers. Prairie Naturalist 9(1):1-10.

Hall, F., and E. Haney. 1997. Distribution and trend of sage-grouse (Centrocercus urophasianus) in relation to overhead transmission lines in northeastern California. Draft. California Department of Fish and Game.

Harju, Seth M., Matthew R. Dzialak, Renee C. Taylor, Larry D. Hayden-Wing, and Jeffrey B. Winstead. 2010. Thresholds and Time Lags in Effects of Energy Development on Greater Sage-Grouse Populations. Journal of Wildlife Management 74(3):437-448.

Hayes, E.B., Komar, N., Nasci, R.S., Montgomery, S.P., O'Leary, D.R., Campbell, G.L., 2005. *Epidemiology and transmission dynamics of West Nile virus disease*. Emerging Infectious Diseases 11, 1167–1173.

Holloran, M.J. 2005. Greater Sage-Grouse (Centrocercus urophasianus) Population Response to Natural Gas Field Development in Western Wyoming. Doctoral Dissertation, University of Wyoming, Laramie, WY.

Idaho Department of Fish and Game 1997. Idaho Sage-grouse Management Plan 1997. August. Boise, ID. Available at https://research.idfg.idaho.gov/wildlife/ Wildlife%20Technical%20Reports/ Sage%20Grouse%20Management%20Plan%201997.pdf

Kaiser RC. 2006. Recruitment by Greater Sage-Grouse in Association with Natural Gas Development in Western Wyoming. Masters thesis, Department of Zoology and Physiology, University of Wyoming, Laramie.

Knick S.T., S.E. Hanser, R.F. Miller, D.A. Pyke, M.J. Wisdom, S.P. Finn, E.T. Rinkes and C.J. Henny. 2011. Ecological Influence and Pathways of Land Use in Sagebrush. Pp. 203-251 in S.T. Knick and J.C. Connelly (editors), *Greater Sage-Grouse: ecology and conservation of a landscape species and its habitats*. Studies in Avian Biology (vol. 38), University of California Press, Berkley, CA.

Miller, R.F., S.T. Knick, D.A. Pyke, C.W. Meinke, S.E. Hanser, M.J. Wisdom, and A.L. Hild. Undated. Characteristics of Sagebrush Habitats and Limitations to Long-Term Conservation. Unpublished manuscript; accepted for publication in a special volume of "Studies in Avian Biology" (C.D. Marti, ed.).

Miller, R.F. and R.J. Tausch. 2001. *Role of fire in juniper and pinyon woodlands: a descriptive analysis*. Tall Timbers Research Station Miscellaneous Publication No. 11:15-30.

Motha, R. P., & Baier, W. 2005. *Impacts of present and future climate change and climate variability on agriculture in the temperate regions: North America*. Climatic Change, 70, 137–164.

Naugle, D.E., B.L. Walker, and K.E. Doherty. 2006. Sage-Grouse Population Response to Coal-Bed Natural Gas Development in the Powder River Basin: Interim Progress Report on Region-wide Lek-Count Analysis. University of Montana, Bozeman, MT.

Nelle, P.J., K.P. Reese, and J. W. Connelly. 2000. Long-term effects of fire on sage-grouse habitat. Journal of Range Management 53:586-591.

O'Brien, M. O. 2007. A Survey of Greater sage-grouse (Centrocercus urophasianus) Early Brood Rearing, Summer-Late Brood-rearing, and Winter Habitat Integrity in Six Utah Sage Grouse Use Areas. Grand Canyon Trust with Rachel Barton-Russell.

Oliver, G. V. 2006. Greater sage-grouse (Centrocercus urophasianus) ecological integrity table. Utah Division of Wildlife Resources, Salt Lake City, Utah. 22 pp.

Quigley, T.M., and S.J. Arbelbide, 1997. An assessment of ecosystem components in the interior Columbia Basin and portions of the Klamath and Great Basins: Volume 1. USDA For. Serv. Gen. Tech. Rep. PNW-GTR-405. Portland, OR. 4 vol. (Quigley, T.M., tech. Ed., The Interior Columbia Basin Ecosystem Management Project: Scientific Assessment).

Rowland, M.M. 2004. Effects of management practices on grassland birds: Greater Sage-Grouse. Northern Prairie Wildlife Research Center, Jamestown, ND. Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/literatr/grasbird/grsg/grsg.htm (Version 12AUG2004).

Rowland, M.M., Wisdom, M.J., Suring, L.H. & Meinke, C.W. 2006. *Greater sage-grouse as an umbrella species for sagebrush associated vertebrates*. *Biological Conservation*, 129, 323–335.

Schroeder, M.A., C.L. Aldridge, A.D. Apa, J.R. Bohne, C.E. Braun, S.D. Bunnell, J.W. Connelly, P.A. Deibert, S.C. Gardner, M.A. Hilliard, G.D. Kobriger, S.M. McAdam, C.W. McCarthy, J.J. McCarthy, D.L. Mitchell, E.V. Rickerson, and S.J. Stiver. 2004. *Distribution of sage-grouse in North America.* Condor 106:363-376.

Shafer, S.L., P.J. Bartlein, and R.S. Thompson. 2001. Potential changes in the distributions of western North America tree and shrub taxa under future climate scenarios. *Ecosystems* 4:200−215.

Steenhof, K., M.N. Kochert, and J.A. Roppe. 1993. *Nesting by raptors and common ravens on electrical transmission line towers*. Journal of Wildlife Management 57:271-281.

Stubbs, M 2007. *Land conversion in the Northern Plains*. Congressional Research Service Report for Congress, Order Code RL33950. Published on 5 Apr 2007.

Turell, M.J., Dohm, D.J., Sardelis, M.R., O'Guinn, M.L., Andreadis, T.G., Blow, J.A., 2005. *An update on the potential of North American mosquitoes (Diptera: Culicidae) to transmit West Nile virus*. Journal of Medical Entomology 42, 57–62.

Uinta Basin Adaptive Resource Management Local Working Group (UBARM). 2006. Uinta Basin Greater Sage-grouse (Centrocercus urophasianus) Local Conservation Plan. Utah State University Extension, Jack H. Berryman Institute, and Utah Division of Wildlife Resources Unpublished Report. Salt Lake City, Utah. Unpublished Report.

Unnasch, R.S., D. P. Braun, P. J. Comer, G. E. Eckert. 2009. *The Ecological Integrity Assessment Framework: A Framework for Assessing the Ecological Integrity of Biological and Ecological Resources of the National Park System*. Report to the National Park Service. Version 1.0. January.

U. S. Census Bureau. 2012. 2012 TIGER/Line Shapefiles. U.S. Census Bureau, Geography Division, Geographic Products Branch Created: August 16, 2012 Last Revised: August 28, 2012.

USFWS 2011. Greater Sage-grouse Fact Sheet. Prairie Mountain Region. Accessed on August 12, 2012 from http://www.fws.gov/mountain-prairie/species/birds/sagegrouse/GreaterSageGrouseFactSheet2011.pdf.

Whisenant, S. G. 1990. *Changing fire frequencies on Idaho's Snake River Plains: ecological and management implications*. Pages 4–10 in E. D. McArthur, E. M. Romney, S. D. Smith, and P. T. Tueller, editors.

Wisdom, M.J., C.W. Meinke, S.T. Knick, and M.A Schroeder. 2011. Factors associated with extirpation of sage-grouse. Page 451-472 in S.T. Knick and J.W. Connelly (editors). Greater sage-grouse: ecology and conservation of a landscape species and its habitats. Studies in Avian Biology 38. University of California press, Berkeley, California, USA.

Wyoming Interagency Vegetation Committee. 2002. Wyoming Guidelines for Managing Sagebrush Communities with Emphasis on Fire Management. Wyoming Game and FishDepartment and Wyoming BLM. Cheyenne, WY. 53 pp. Available at http://www.blm.gov/pgdata/etc/medialib/blm/wy/wildlife/docs.Par.8891.File.dat/fsbfiremgmtguidelines.pdf.

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APPENDIX E-2

FIGURES

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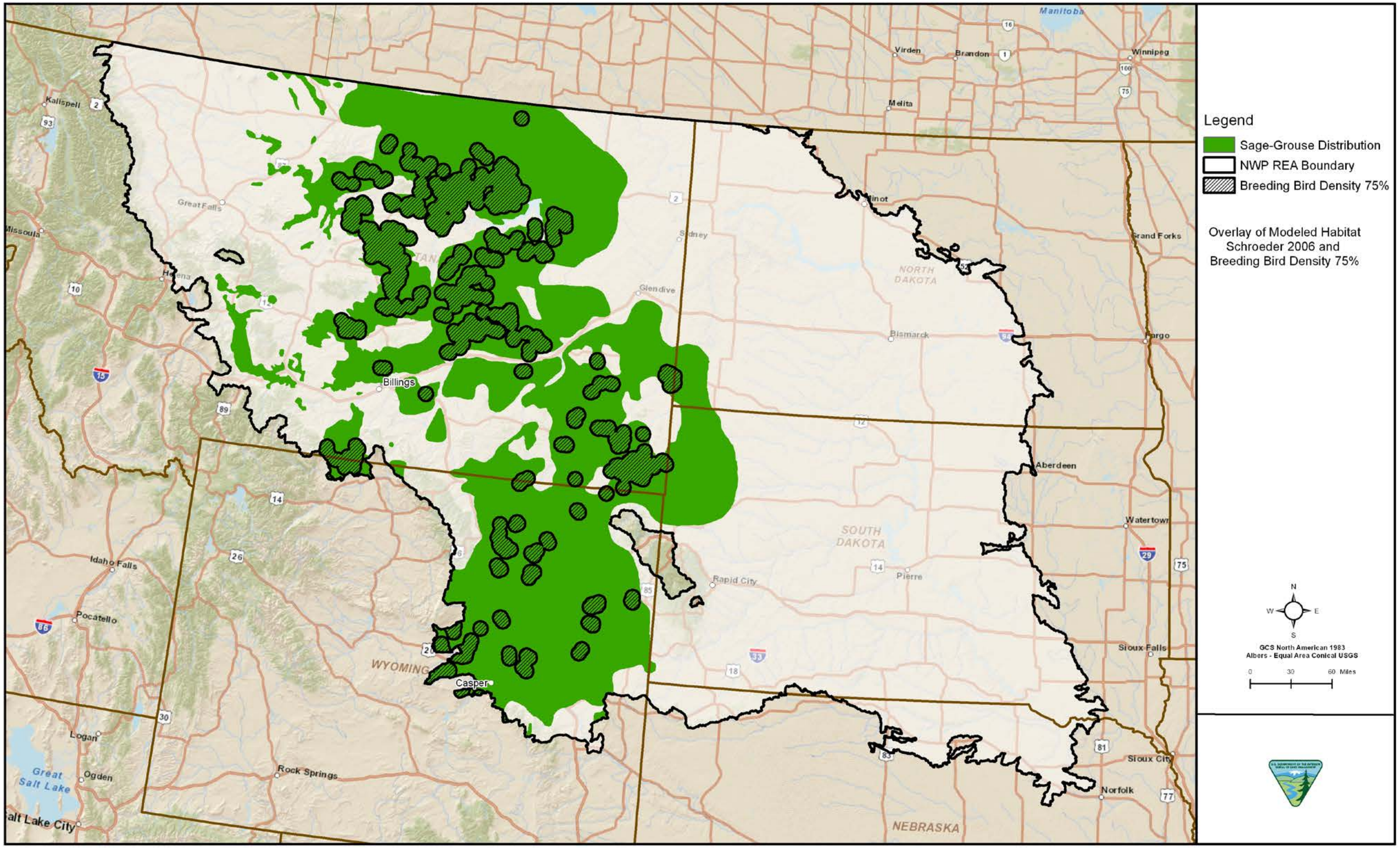

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Figure E-2-1. Breeding Bird Distribution Map for Greater Sage-Grouse in the Northwestern Plains

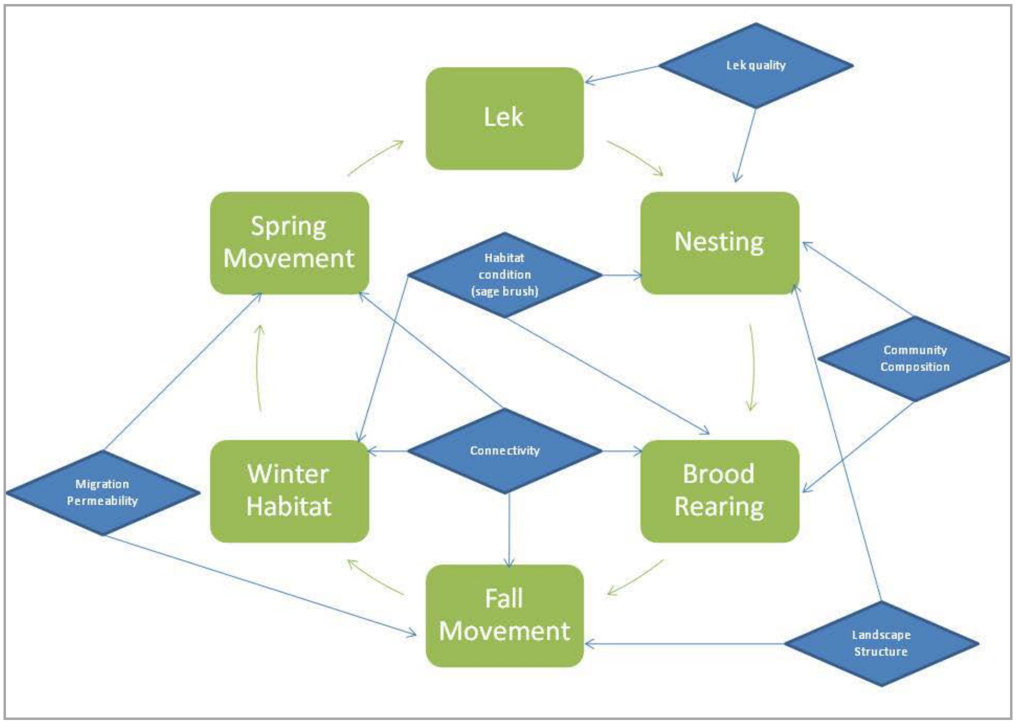

Figure E-2-2. Greater Sage-Grouse Ecological Process Model

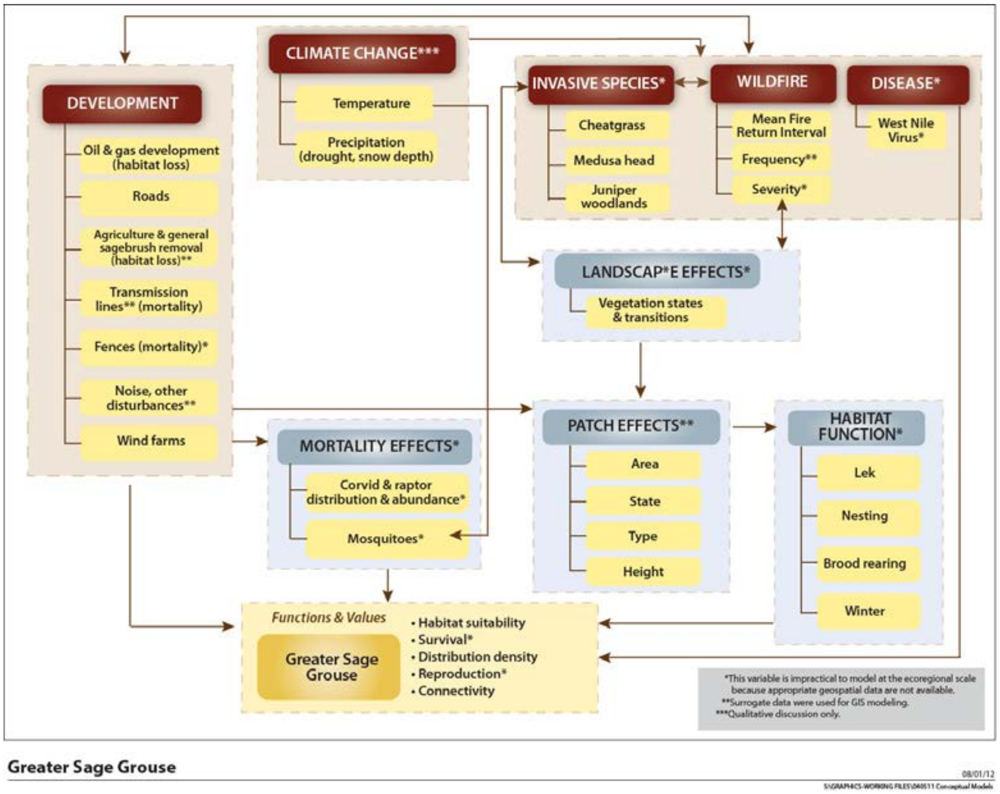

Figure E-2-3. Greater Sage-Grouse System-Level Conceptual Model

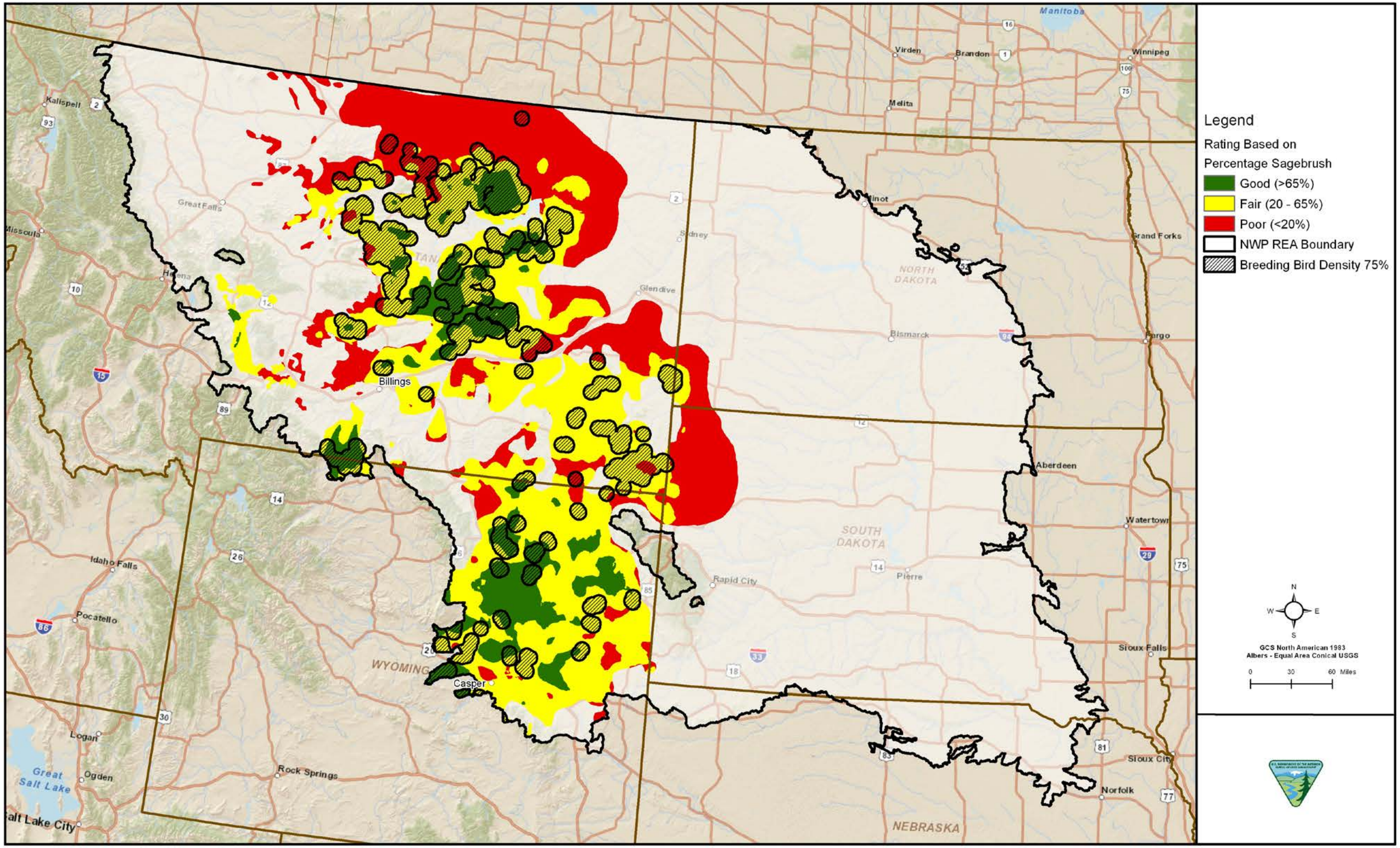

Figure E-2-4. Breeding Circle Persistence (Percentage Cover of Sagebrush)

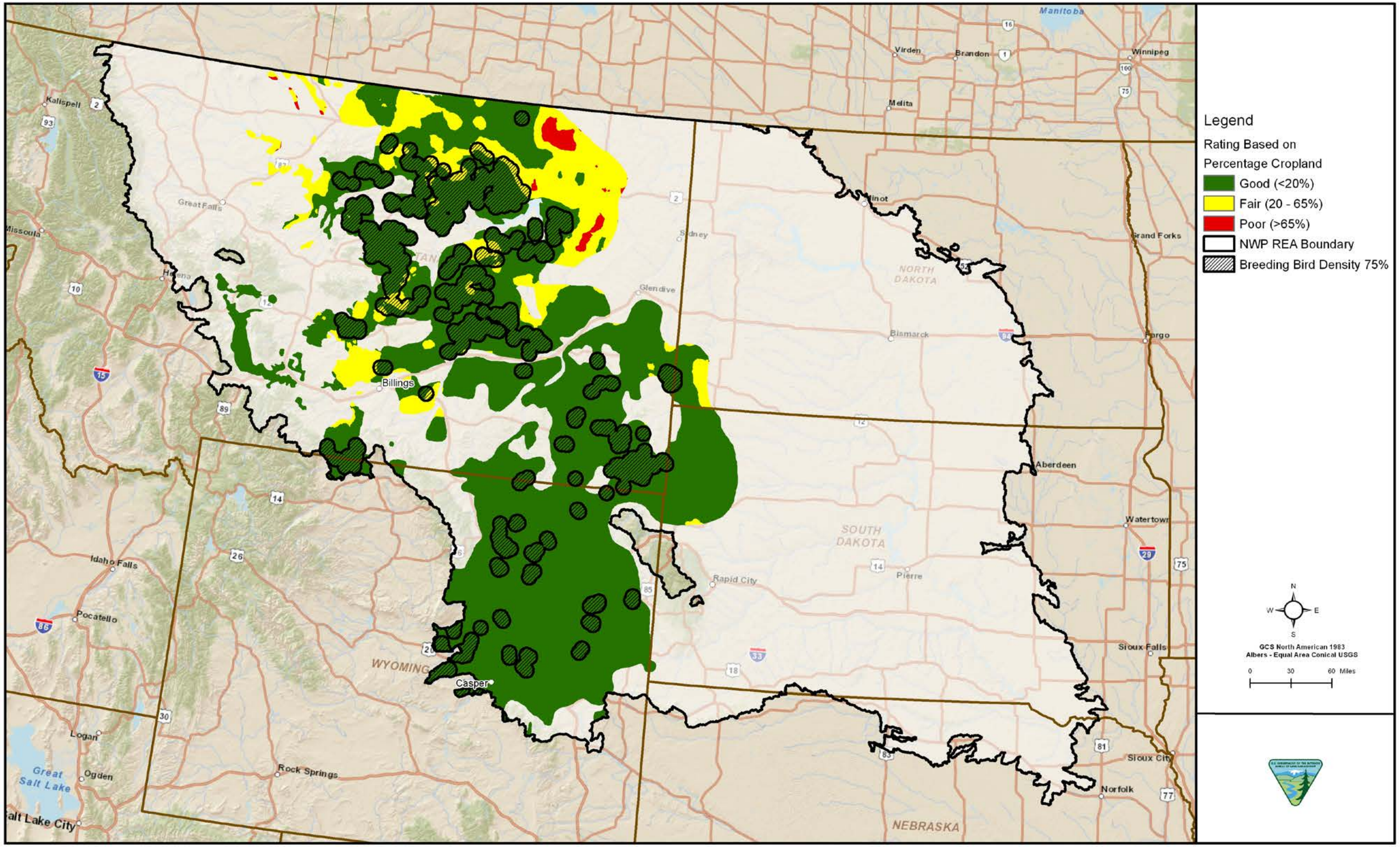

Figure E-2-5. Breeding Circle Persistence (Percentage Cover of Cropland)

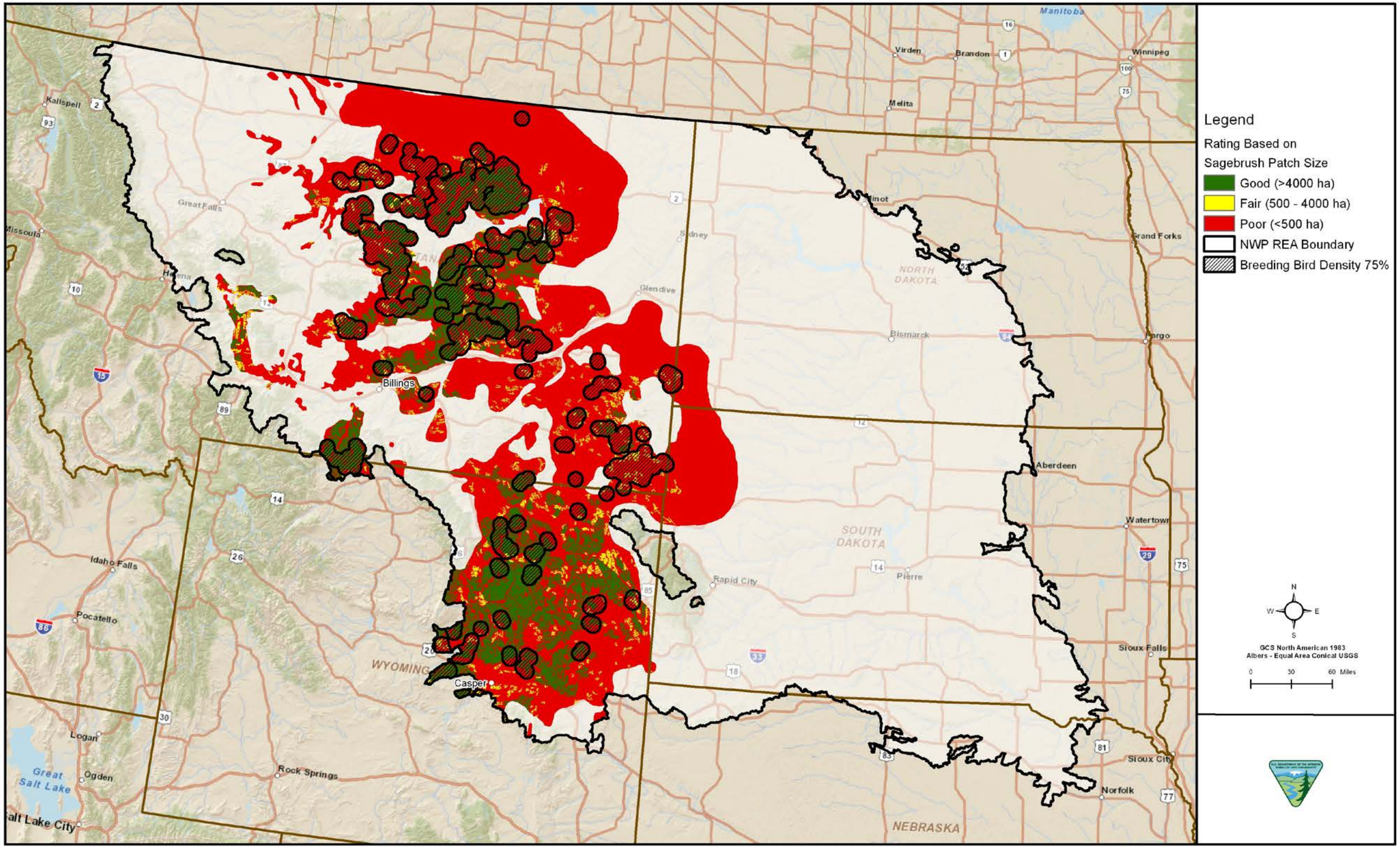

Figure E-2-6. Core Habitat Fragmentation (Sagebrush patch size)

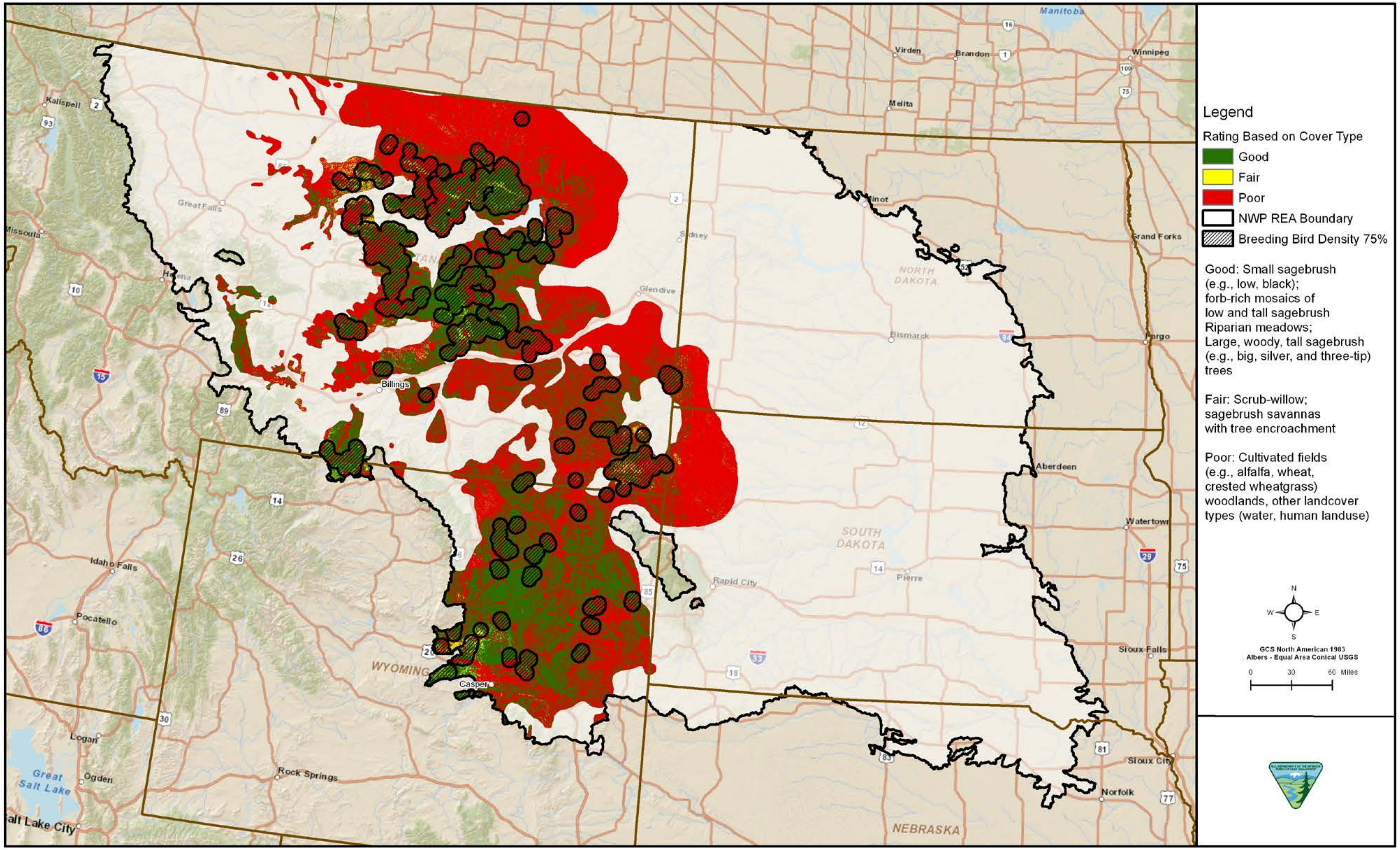

Figure E-2-7. Cover Type

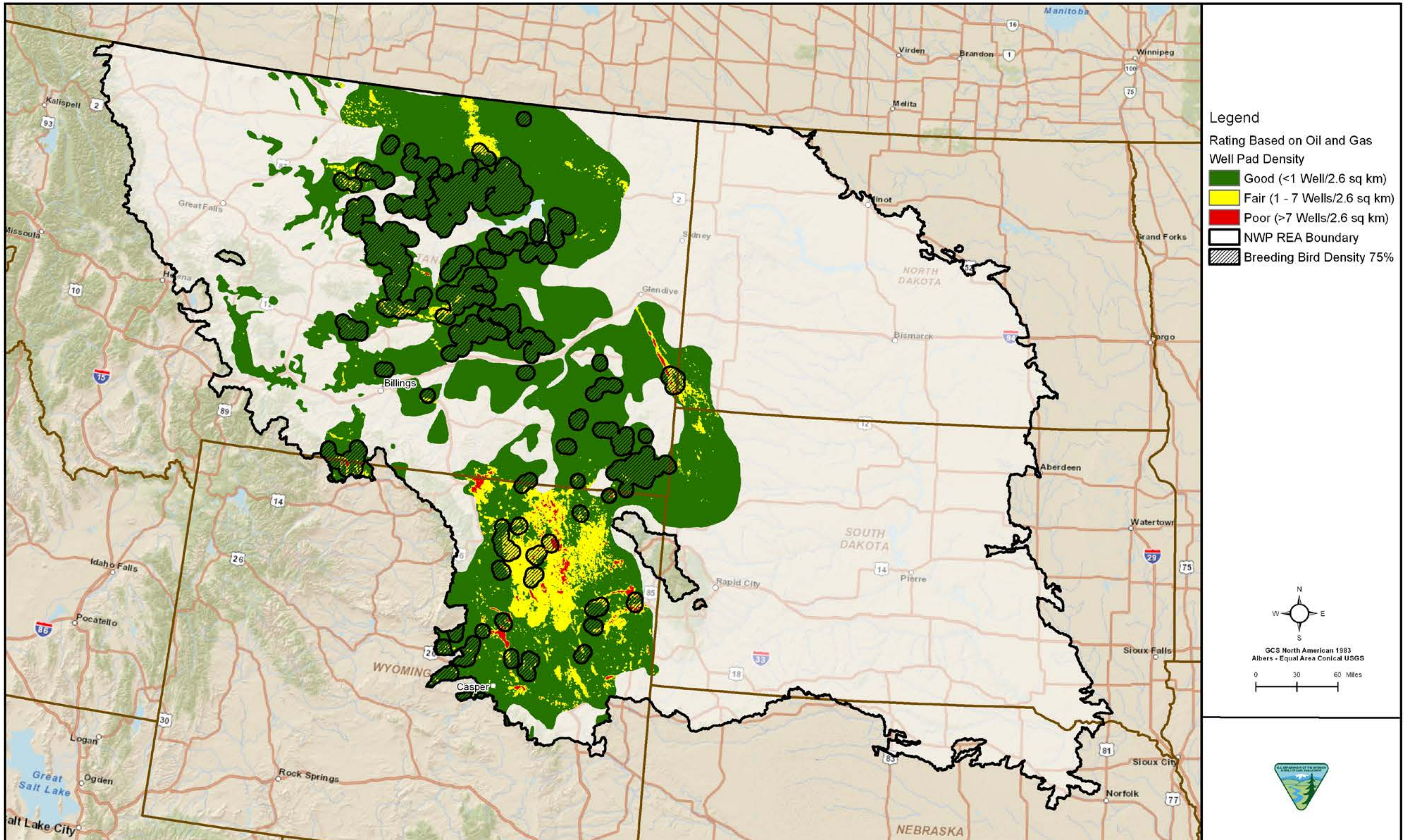

Figure E-2-8. Oil and Gas Well Pad Density (quantity per 1 square mile)

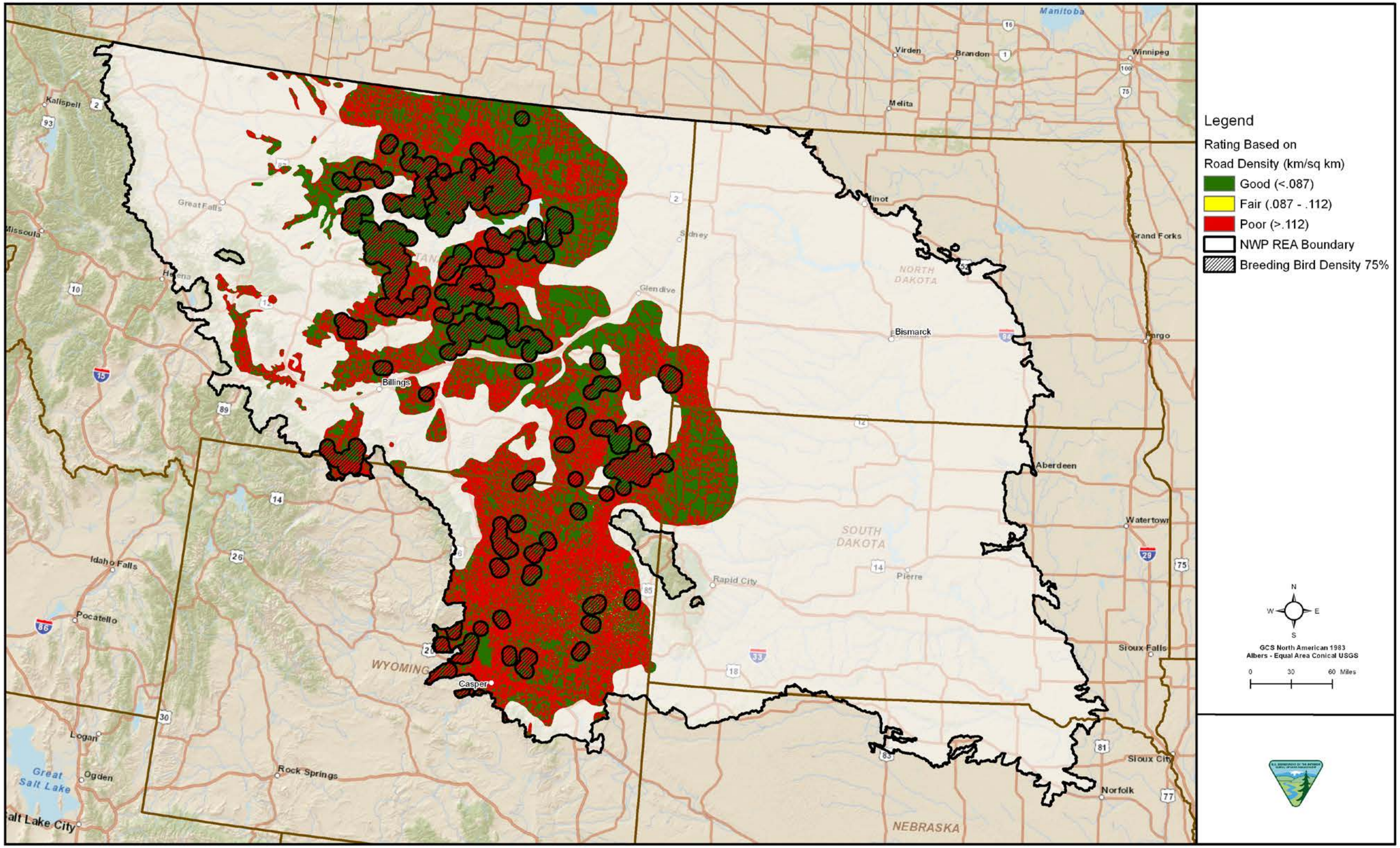

Figure E-2-9. Road Density (km/km^2)

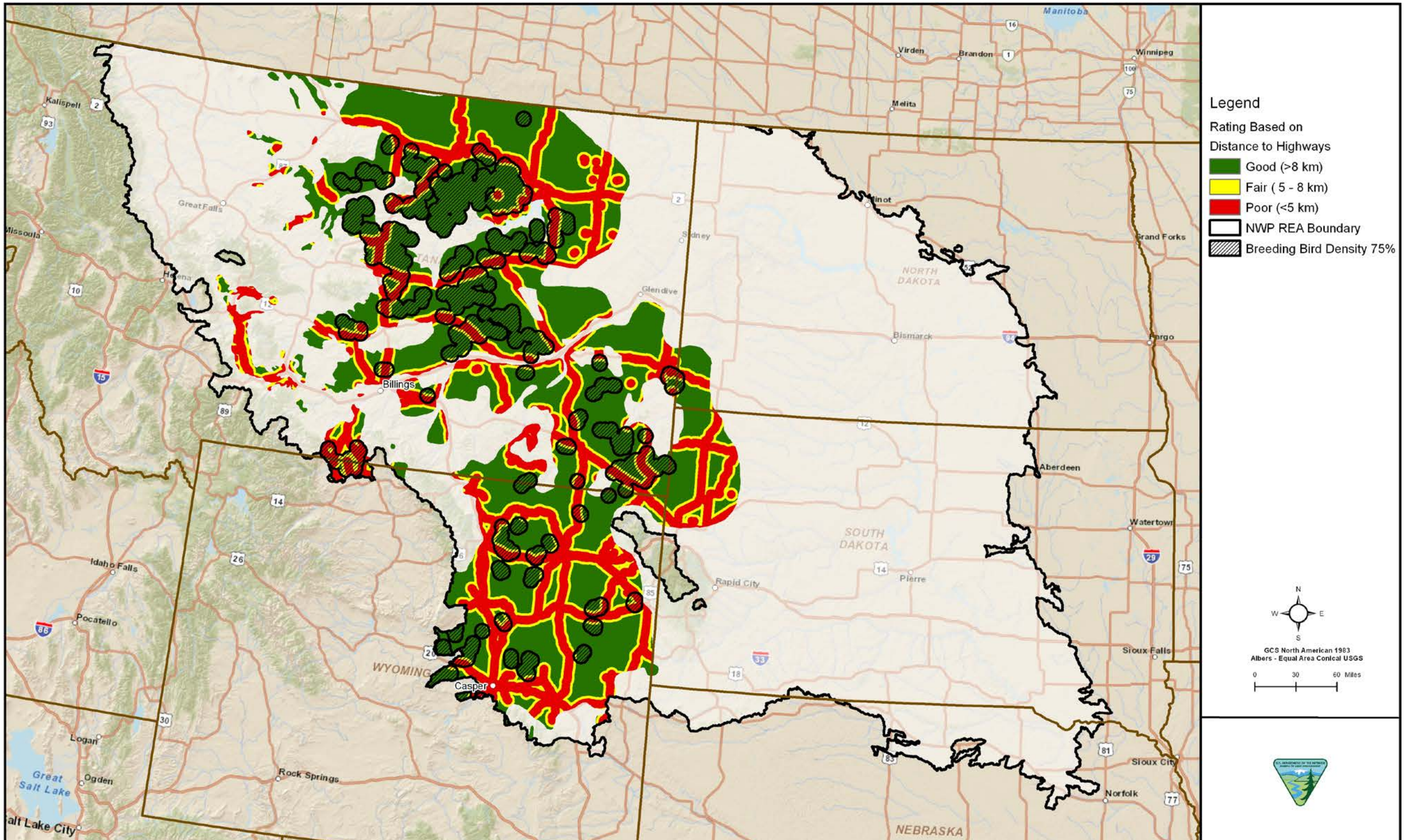
Legend
Rating Based on
Distance to Highways
Good (>8 km)
Fair (5 - 8 km)
Poor (<5 km)
NWP REA Boundary
Breeding Bird Density 75%
GCS North American 1983
Albers - Equal Area Conical USGS
0 30 60 Miles

Figure E-2-10. Distance to Highways

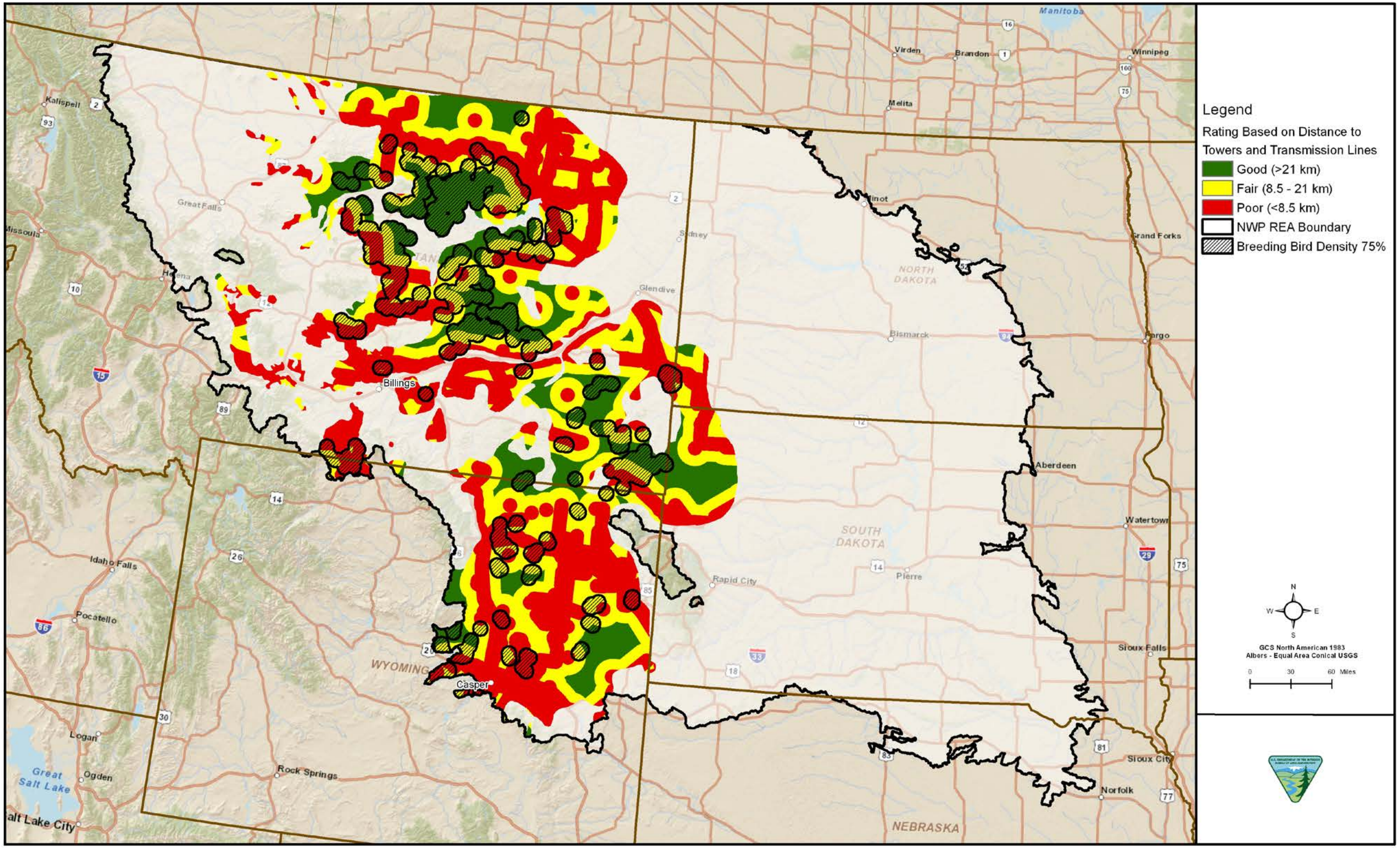

Figure E-2-11. Distance to Towers and Transmission Lines

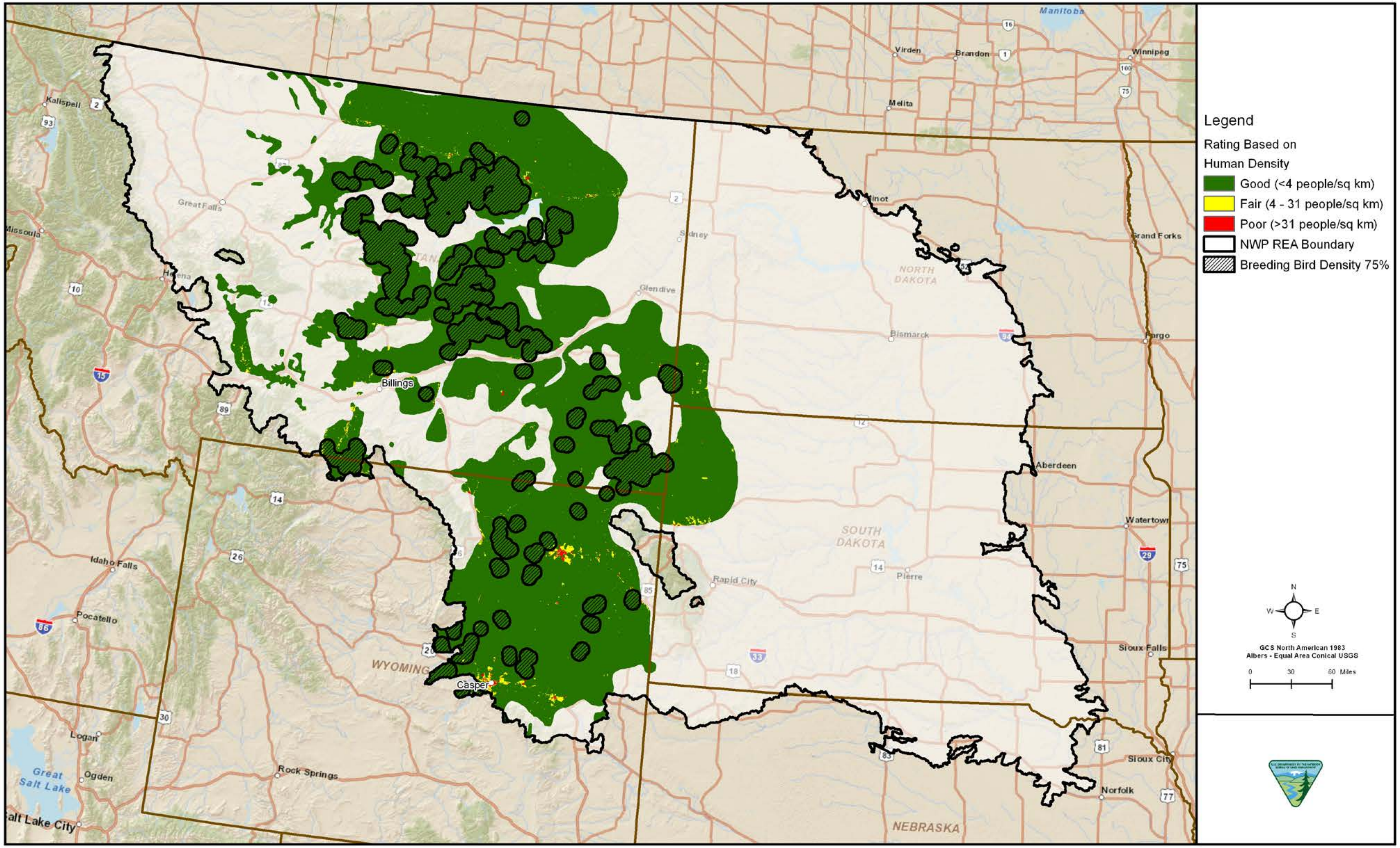

Figure E-2-12. Human Density

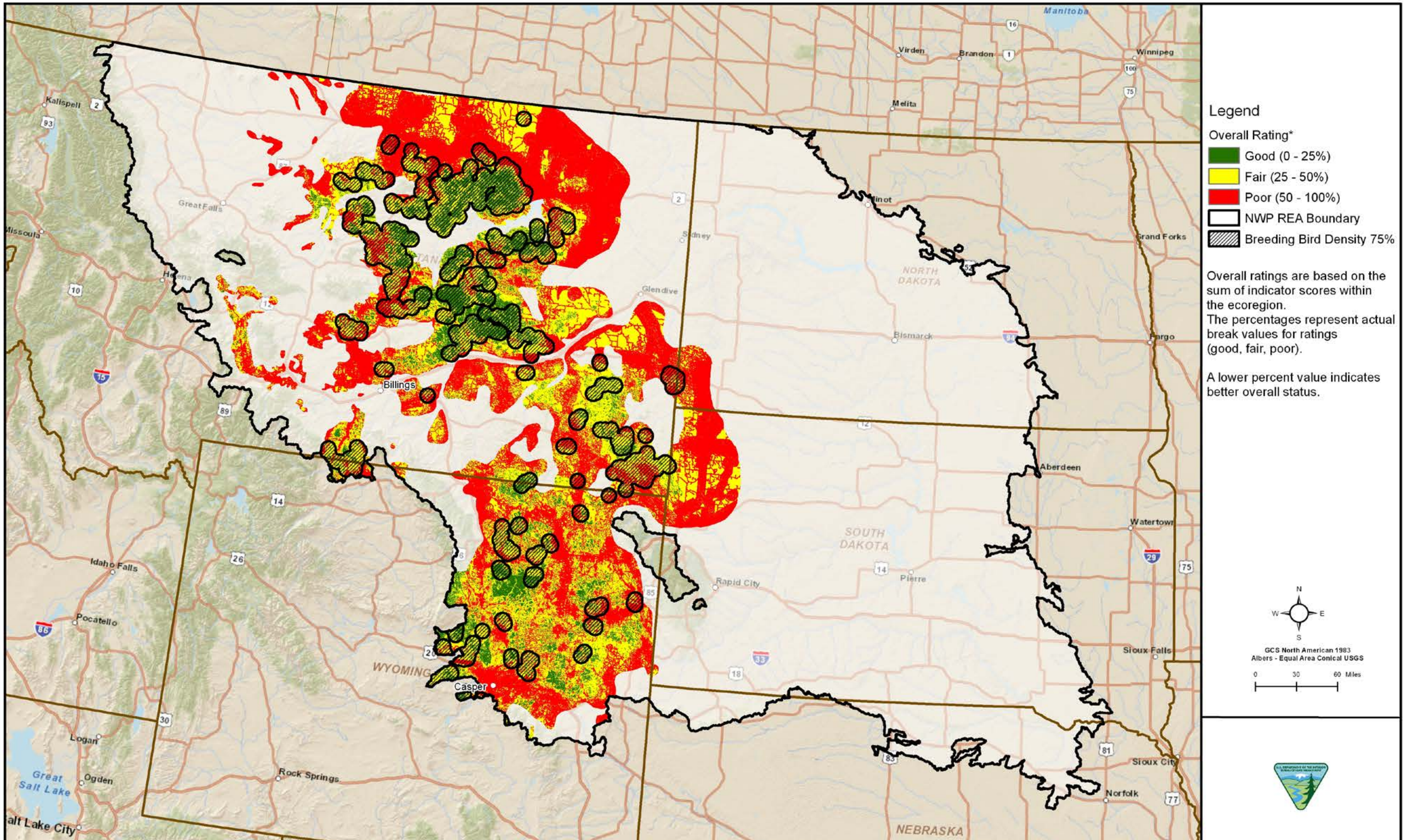

Figure E-2-13. Current Habitat Status

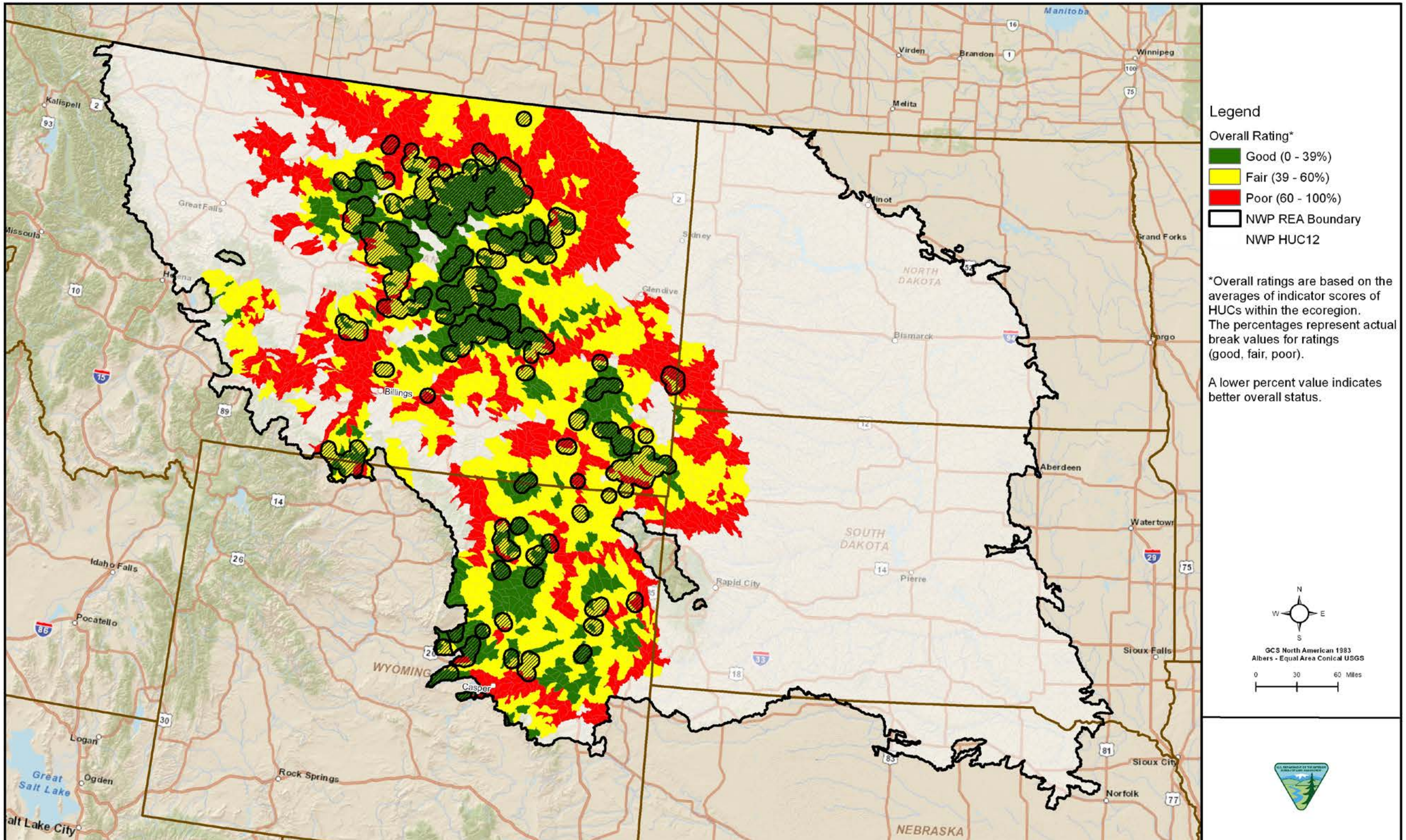

Figure E-2-14. Current Habitat Status by Hydrologic Unit Code

APPENDIX E-3

GOLDEN EAGLE CONSERVATION ELEMENT ANALYSIS FOR THE NORTHWESTERN PLAINS ECOREGION

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1.0 INTRODUCTION

The golden eagle (*Aquila chrysaetos*) occurs year-round in the Northwestern Plains (Kochert et al. 2002). Its status in the ecoregion likely reflects the status of the species on a larger scale, due in part to the dispersal of immature and non-breeding adults from outside the region to and throughout the Northwestern Plains. In the western United States, the population of golden eagles has been conservatively estimated to be approximately 27,392 individuals. Despite this relatively high estimate, the population of golden eagles in the western United States is believed to be declining (Good et al. 2004). Due to management concerns and potential declining numbers, the golden eagle was defined as a species of concern for this Rapid Ecoregional Assessment (REA).

A variety of the management questions (MQs) apply to this conservation element (CE). Many of the MQs can be summarized into two primary questions: 1) where are the important areas for this assemblage? and 2) what is happening to these areas? The central focus of these two MQs is to document the current status of the golden eagle at the ecoregional scale and to evaluate how this status may change over a future time period. The first step is to identify suitable habitat for the CE within the ecoregion. Then, these areas are assessed relative to current and potential future change agent (CA) threats.

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2.0 CONSERVATION ELEMENT DESCRIPTION

The golden eagle is one of the widest ranging raptor species in the world, occupying the majority of the Northern Hemisphere. Despite its broad range, the species is declining throughout the world due to habitat loss. Although a generalist, specific habitat requirements must be met for the golden eagle to thrive. In the western United States, the golden eagle occupies habitat at elevations ranging from 4,000-10,000 feet (ft), with occasional nesting occurrences above 10,000 ft (Good et al. 2004). The species generally nests on cliff faces with varying aspect and height, but the golden eagle will also nest in trees along riparian corridors, occasionally on man-made structures (e.g. telephone poles), or on the ground. In one area in northeastern Wyoming, 86 percent of golden eagle nests were located in trees. Where tree nesting occurs, eagles generally select locations in the upper third of large trees on the edge of riparian areas that are associated with open grassland vegetation. Tree nesting has been documented in both deciduous and coniferous trees (Menkens and Anderson 1987).

Golden eagles are habitat generalists and, as such, are likened to vegetation communities through prey populations. The communities associated with the species are primarily limited in the Northwestern Plains to open grassland and sagebrush steppe habitat. Golden eagles are considered generalist predators; however, they rely mostly on mammals, particularly rabbits and ground squirrels (Kochert et al. 2002), with prairie dogs also recorded as locally important (Mollhagen et al. 1972).

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3.0 CONSERVATION ELEMENT DISTRIBUTION MODELING

The Maxent modeling program was used to determine the distribution of the golden eagle in the ecoregion. This model uses various geospatial environmental variables (i.e. climate variables, elevation, vegetation layer, etc.) and species occurrence data to determine the distribution of a species within a given area. The Maxent distribution layer was required for use in the assessment as a boundary to limit the output to those areas where golden eagles are currently nesting.

3.1 DATA IDENTIFICATION

Table E-3-1 lists the types of data and data sources that were proposed for use in the REA as part of the pre-assessment data identification effort. Suitable habitat models, point occurrence data, nest sites, and sensitive habitat data were proposed for use in defining distribution of the golden eagle in this ecoregion.

Table E-3-1. Data Sources for Conservation Element Distribution Mapping

Data Needs	Dataset Name	Source Agency	Type/Scale	Status	Used in REA
Modeled Suitable Habitat	Gap Analysis Program (GAP) Habitat Models	U.S. Geological Survey (USGS)	Raster (30-m)	Acquired	No[3]
	NatureServe Habitat Model	NatureServe	Polygon	Acquired	No[3]
	State-Derived Models	ID, MT, WY, SD State Agencies	Raster	Not Acquired	No[3]
	Western Governors' Association (WGA) Decision Support System (DSS) Models	WGA Pilot Crucial Habitat	Raster	Future Dataset	No[1]
Point Occurrences	State Natural Heritage Databases	Natural Heritage Programs – ID, MT, WY, SD	Point	Acquired	No[2]
	eBird	Avian Knowledge Network	Point	Acquired	No[3]
	Breeding Bird Survey	USGS	Polygon	Acquired	No[3]
	Christmas Bird Count	Audubon	Point	Acquired	No[3]
Sensitive Areas	Audubon Important Bird Areas	Audubon	Polygon	Acquired	No[2]
	Bird Conservation Areas	Partners in Flight	Polygon	Not Acquired	No[2]
Nest Sites	Nests and Roosting Areas	BLM, ID, MT, WY, SD State Fish and Game Agencies	Point	Acquired	Yes

[1] Data gap
[2] Scale is inappropriate
[3] More representative data were selected for use

An evaluation of the available data was conducted to determine which data would be used for the Maxent modeling. State-derived distribution models for the golden eagle were not available for all states within the ecoregion. There is also a Western Governors' Association (WGA) Wildlife Council Crucial Habitat Assessment Tool (CHAT) underway that could generate models and datasets for the ecoregion; however, no data were currently available. In some cases, data were acquired, but it was determined that other data were more representative for use in the REA (e.g., Christmas Bird Count, Breeding Bird Surveys).

The Bureau of Land Management (BLM) determined that nest site location data were the preferential data type to be assessed in the distribution model. Nest site location data were obtained from each state for use in a Maxent distribution model. Data attributes varied widely from nest data to mortality data (i.e., road kills) and were inconsistent both on an interstate and intrastate basis. In several cases, states only provided nest location data with no further attributes associated with the data. Additionally, the data varied greatly in accuracy, with some data providing an estimate of the spatial quality of the data collection method. This attribute information was used to further remove data that appeared to show poor spatial accuracy.

The initial datasets provided by the state agencies reflected a variety of spatial attributes, so some data culling and aggregation was required to create a uniform dataset.

3.2 DISTRIBUTION MAPPING METHODS

Maxent modeling consists of using presence-only species occurrence data and a series of environmental raster layers (soil, temperature, elevation, etc.) to attempt to determine modeled habitat. During a model run, the species occurrence data are compared to the individual values within the environmental raster layers to evaluate the commonality among observations (training the model). Once these commonalities are established, it can expand beyond locations of occurrences to find suitable locations based on the commonalities between data. The Maxent model output is a value between 0-1; the higher the number the higher the modeled area suitability. Maxent also allows for testing of the model to validate the accuracy of the predictions based on occurrence data and also provides various validation measures. Because Maxent is a standalone tool, geographic information system (GIS) process models were used to extract, project, and format the data into required formats for the model inputs and also to convert them back to a GIS format for additional processing.

The intent of the REA modeling effort was to identify modeled habitat of breeding golden eagles within the ecoregion. Since Maxent uses species occurrence data, the Rolling Review Team (RRT) determined that the nest location data should be limited to 1990-present to be consistent with timeframes used by other CEs being modeled with Maxent. This significantly limited our data, but increased the likelihood of capturing active or recently-active nest site locations. Furthermore, because of the potential for multiple counting of a given nest site within the Maxent model, duplicate records (based on spatial coordinates) were removed from the occurrence (nesting) dataset. The total number of observations for golden eagle nests in the ecoregion was 638. Figure E-3-1 shows individual state contribution of occurrences to the Maxent model.

The raster output from the Maxent model provides cell values that provide information regarding the probability of modeled habitat. Several iterations of the model were run to determine the best fit for golden eagles. The main Maxent parameter that was modified was regularization. This parameter helps push the analysis out to areas without occurrence data so that the model is not over-trained on areas with closely clustered occurrence data. Montana Fish, Wildlife, and Parks had previously carried out numerous Maxent modeling efforts and were able to assist in the determination of the Maxent output format that best described presence/absence raster data for the golden eagle. The resulting Maxent output consists of data values ranked 0-1. The higher the value, the higher the suitability based on the environmental layers used.

The Maxent modeling software generates output files that describe which environmental variables contributed the most to generating the output model. Table E-3-2 contains the 16 environmental variables used in the Maxent model with their contribution listed in the 'Percent Relative Contribution' column. The golden eagle Maxent model had State Soil Geographic (STATSGO) soils, rugosity, and elevation environmental layers as the highest contributors. Because most golden eagle nesting occurs on rocky outcrops and cliffs, these environmental variables should be the most important in locating these areas across the ecoregion. Reviewing which layers contribute the most and least may allow the Maxent model to be fine-tuned by removing low-contributing environmental layers; however, for the purposes of this REA, this was not done.

The next step was to separate the Maxent output into groups that best describe various thresholds between low, moderate, and optimal suitability. Through the advice of Montana Fish, Wildlife, and Parks and the BLM National Operations Center (NOC) Wildlife Habitat Spatial Analysis Lab at the BLM NOC, two possible methods were proposed for determining thresholds.

The first method was based on modeling done by Montana Fish, Wildlife, and Parks, which utilized a method that used validation generated by the Maxent model to determine where the model passed different thresholds. This method, based on work by Hirzel (Hirzel et al. 2006), focused on the location at which the predicted over-expected frequency (P/E) ratio vs. logistic value crosses 1 (where the model started to perform better than random selection). This threshold became the moderate suitability threshold. The optimal threshold was determined by analyzing the P/E vs. logistic value curve for the location at which the increase in P/E is greater than the increase in logistic value. To help in determining these values, the BLM NOC Wildlife Habitat Spatial Analysis Lab wrote an ‘R’ script that was used to analyze the background predictions generated by Maxent. The R script generated a portable document format (PDF) output detailing the moderate and optimal thresholds (Figure E-3-2). The lowest suitability threshold was determined by calculating the 5 percent test omission rate. The test omission rate is another validation comma-separated file created by the Maxent software.

Table E-3-2. Maxent Environmental Variables for Golden Eagle

Environmental Variable	Maxent Variable Code	Percent Relative Contribution	Percent Permutation Importance
STATSGO Soils	soil_nwp_90	33.7	11.5
Rugosity	vrm_nwp_90	19.8	5.3
Elevation	ned_nwp_90	14.6	21.2
Parameter-elevation Regressions on Independent Slopes Model (PRISM) Temperature (max)	prsm_maxt90	7.4	17.7
GAP Vegetation	nwp_gap_90	6.4	3.5
Slope	slope_nwp_90m	3.7	14.1
LANDFIRE Vegetation	evt_nwp_90	3.5	2.7
Geology	lith_nwp_90	3.3	2.5
Distance to Water	edw_nwp_90	2.1	5.4
PRISM Precipitation	prsm_prcp90	2.1	8
Solar Radiation (Summer Solstice)	sri_ss_nwp_90	1	0
Aspect (N/S)	aspns_nwp_90	0.9	2.3
Solar Radiation (Winter Solstice)	sri_ws_nwp_90	0.7	1.1
Aspect (E/W)	aspew_nwp_90	0.5	1.5
Solar Radiation (Equinox)	sri_eq_nwp_90	0.3	1.3
PRISM Temperature (min)	prsm_mint90	0.1	1.8

The second method was based on Maxent modeling by the Wyoming Natural Diversity Database (WYNDD). The low and optimal suitability thresholds were calculated from the sample prediction comma-separated file generated by the Maxent modeling. The thresholds were calculated by ranking the logistic prediction of the samples used to train the model using the 5th percentile (low suitability) and 50th percentile (optimal suitability). Since this method uses actual training data, the thresholds are based on real data and everything below the 5th percentile will be classified as unsuitable. The moderate threshold was the ‘Maximum training sensitivity plus specificity’ calculated by the Maxent software.

Based on two methods of determining thresholds, the modeling team (Science Applications International Corporation [SAIC]; Spatial Lab; and Montana Fish, Wildlife, and Parks) determined the WYNDD thresholds (Figure E-3-3) to be the most appropriate break in the values for the golden eagle distribution model. The WYNDD model provided an output based on very low probability, low probability, moderate probability, and optimal probability of distribution. This model insured that all breeding eagles were included in the data layer. Table E-3-3 lists the thresholds for the golden eagle for both methods.

Table E-3-3 Maxent Thresholds Calculated for Golden Eagle

Method	Measurement	Threshold	Value
MT / Hirzel	Test Omission Rate (0.05)	Low	0.008
MT / Hirzel	P/E =1 (R Script)	Moderate	0.225
MT / Hirzel	Δ P/E Ratio > Δ Logistic Value (R Script)	Optimal	0.715
WYNDD	5% Training Value	Low	0.09
WYNDD	Max. Training Sen. + Spec.	Moderate	0.215
WYNDD	50% Training Value	Optimal	0.46

To establish a modeled habitat map, the Maxent model output requires a binary display of what is modeled habitat and which areas did not result in a Maxent output. The RRT decided that combining the low, moderate, and optimal thresholds would be the best representation of golden eagle modeled habitat. These three thresholds were combined because it was the most inclusive. The Maxent output was then reclassified to show two classes, modeled and not potentially modeled habitat, as shown on Figure E-3-4.

The Maxent output distribution model (Figure E-3-4) was overlain with the nest site location points to visually inspect the relative accuracy of the model. Knowledge of the species' natural history and the nest location data was used to infer the initial quality of the modeled output. The RRT, consisting of state and BLM specialists, reviewed the accuracy of the model based on their experience, regional knowledge, and the validation output generated by Maxent, such as area under the curve (AUC). Threat analysis outputs were correlated to reporting units that spatially contained distribution data.

4.0 CONCEPTUAL MODELS

The current and potential future threat analyses were based on CE-specific ecological conceptual models, selected environmental variables (key ecological attributes [KEAs]) likely to be impacted by CAs, and the availability of data. CAs considered in this CE analysis include development and climate change.

4.1 ECOLOGICAL PROCESS MODEL

The ecological process model (Figure E-3-5) was developed to identify and link the key life cycle processes to specific ecological factors, or KEAs, that have the greatest potential to affect golden eagle habitat throughout the ecoregion.

The key processes are identified in the model as green boxes and, following Unnasch et al. (2009), three broad headings or categories of EAs (size, condition, and context) are identified in the model as blue diamonds. Size refers to attributes related to habitat or patch size, condition refers to the condition of the habitat, and context refers to the spatial structure of the habitat. At the landscape level, the EAs under the condition category will be the most challenging to spatially represent and will primarily depend on the data available.

4.2 SYSTEM-LEVEL MODEL

The system-level conceptual model (Figure E-3-6) illustrates the interactions between the CAs and the primary habitat functions of this species. The three primary CAs for this CE are development, climate change, and wildfire, which are identified across the top of the figure in red. The important factors (or "drivers") affecting the abundance and distribution of golden eagle populations include those that impact territorial occupancy, productivity, and survivorship.

Although numerous attributes and indicators affecting this species were initially identified in the early phases of this REA, not all were included in this analysis. For some of the CAs, it was determined that either the attribute or indicator was not suitable for a landscape-level analysis or data were not available to support the analysis. The specific indicators that could not be modeled are identified with an asterisk on Figure E-3-6. Further information on the data gaps for these indicators is discussed in the respective CA analyses contained in Appendix C.

4.2.1 Development

The effect of human disturbance on golden eagle nesting remains largely understudied. The primary anthropogenic features likely affecting golden eagle populations are roads, wind turbines, transmission lines, and energy production and exploration activities (gas, oil, coal).

Roads play an important and complex role in the life history of golden eagles. Areas containing higher road densities are avoided as nest site locations by golden eagles (Steenhof et al. 1993). Roads not only increase mortality through collision with vehicles, but are often spatially associated with transmission lines, further increasing the likelihood of mortality. However, transmission lines offer suitable hunting perches and nest site locations.

The impacts of industrial development on golden eagles have not all been well documented, although power lines and wind turbines represent known sources of increased mortality (Anderson and Estep 1988; LaRoe et al. 1995; Harness and Wilson 2001). Wind turbines and transmission lines do not necessarily affect distribution of the species, but are likely to increase mortality through electrocution and collision, thereby affecting habitat suitability (Delong 2004). Research in North America from the early 1960s to 1995 showed, in particular, that electrocution by power lines was the second greatest cause of mortality among golden eagles (LaRoe et al. 1995). Of 1,428 electrocuted raptors documented from 1986 to 1996 throughout the western United States, 748 (52 percent) were golden eagles. Electrocution is a serious factor affecting mortality in golden eagles. Sub-adult eagles occupy marginal habitat consisting of higher transmission line densities in areas that adult eagles tend to avoid (Delong 2004).

Although collisions with wind turbines are relatively high in some areas, attributing distance between wind turbines and golden eagle habitat is a difficult correlation to consider. In the Altamont Pass Wind Resource Area in California, a search for bird carcasses from 1998 to 2002 led to estimates of 67 golden eagles killed annually by the 5,400 wind turbines installed in that area (Smallwood and Thelander 2008). Hunt et al. (1997) assigned relatively arbitrary (<20 kilometers (km) for sub-adults; <30 km for adults) values to distance and found no significant difference at the scale used in the analysis. For the purpose of this REA, it seems prudent to use a more conservative approach in determining appropriate distance analysis between wind turbines and golden eagle habitat.

In areas experiencing oil and gas development, golden eagles may nest in close proximity to wells and compressors. To date, no research has been conducted to determine whether noise levels from compressors influences re-occupancy of nests or nesting success. Research on the influence of weapons testing noise on bald eagles in Maryland did not suggest any impact on nest success and productivity (Brown et al. 1999). Coal mining activities have been known to affect breeding populations of golden eagles (Platt 1984). Nests monitored at a coal mine site in Wyoming resulted in nesting failure for two eagle nests immediately adjacent to mining activities (Platt 1984; Delong 2004). Research on noise impacts on bald eagles in Arizona suggests that noise around nest sites is less important than other forms of human disturbance (Grubb and King 1991). However, no research has specifically investigated the impact of continuous noise on patterns of nest territory re-occupancy in golden or bald eagles. Although oil and gas activities were considered prior to analysis, the RRT determined that the potential effect from oil and gas development was probably minimal, as suggested by previous research (Grubb and King 1991). This dataset was eliminated from the analysis.

Agricultural activities greatly affect golden eagle distribution (Marzluff et al. 1997; Beecham and Kocher 1975; Smith and Murphy 1973; McGahan 1968). As predators, eagle habitat is closely related to prey species. The primary prey species of the golden eagle inhabit predominately natural areas of shrubsteppe and grassland vegetation. Agricultural activities in these areas severely limit both habitat use by golden eagles and prey species habitat quality. Golden eagles are less likely to occupy grassland and sagebrush habitat fragmented by cropland (Delong 2004). A summary of golden eagles studies by Delong (2004) stated that in areas where agricultural land was available as habitat, eagles were sometimes present but not prevalent. Conversion of golden eagle habitat to agriculture will reduce the prey base for eagles and thus reduce the value of those areas as golden eagle habitat. Marginal habitat is occasionally used by breeding individuals if nest site locations are available and suitable alternative prey sources exist (Martzluff et al. 1997).

Hydrological features, such as rivers and streams, often influence the nest locations of raptor species (e.g. peregrine falcons). Golden eagles, however, do not appear to be limited in their distribution by this feature. Although distance to hydrological features has been considered in golden eagle studies, no correlation has been drawn between the two. It is likely that hydrology for other raptor species is closely associated with prey, rather than a direct requirement of a raptor. This has been intentionally omitted from the golden eagle model.

4.2.2 Climate Change

Climate change is one of the significant potential threats that could affect golden eagle populations over time. Although there is a paucity of information on golden eagles and climate change in the Northwestern Plains, numerous studies from outside the region address some key relationships among prey abundance and climate, as well as the risks golden eagle nesting and brood-rearing that likely apply throughout most of the species' distribution.

For golden eagles nesting at high elevations, the effect of temperature change on reproduction is important in determining nesting success. Steenhof et al. (1997) investigated the joint influence of climate and jackrabbit abundance on nesting success of the golden eagle based on 23 years of data, and observed that climate variables and jackrabbit abundance were found to often interact in their effects on the productivity of golden eagles. In that same study, jackrabbit abundance was positively correlated with the proportion of golden eagle pairs that laid eggs, the proportion of pairs that were successful, and mean brood size at fledging. Facka et al. (2010) reported the collapse of black-tailed prairie dog populations in the Chihuahuan Desert in relation to a drought. In southwestern Idaho, Smith and Johnson (1985) found reproductive success in the townsend ground squirrel to be related to the availability of a fresh growth of grasses and ultimately to the amount of rainfall in the preceding fall and early winter. Jackrabbits also experience cyclical increases and decreases in abundance; however, these cyclical patterns are more complex and, in one study (Lightfoot et al. 2010), did not appear related to rainfall.

Steenhof et al. (2007) reported that winter severity negatively influenced the number of golden eagles that laid eggs the following spring, and that the number of hot days during the brood-rearing season negatively influenced both the percentage of pairs that successfully fledged young and mean brood size at fledging. The amount of snowfall present at nest sites dictates the ability of breeding eagles to rear young. Breeding pairs occupying nest sites in areas that receive annual snowfall greater than 500 centimeters (cm) do not reproduce, presumably because of remnant snow cover at nest sites (Delong 2004). In years of heavy snowfall (>500 cm) successful reproduction is substantially diminished.

4.2.3 Wildfire

Throughout the ecoregion, fire is an important factor in affecting vegetation communities and prey populations. Although fire plays a part in short-term effects on breeding populations, there is no correlation between fire and long-term effects on golden eagles. Increased temperature, leading to wildfires and destruction of natural habitat, is a significant detrimental effect of climate change. Despite the potential negative effects associated with wildfire, positive effects to the golden eagle are also associated with wildfire. Fire has the potential to eliminate forested habitats and create clearings that golden eagles can use as alternative habitat, similar to habitat currently occupied by the species in its natural range in California and the eastern United States. Generalist species such as the golden eagle are readily adaptable, and, despite the potential negative short-term effects on the breeding population, it is likely that the species would reoccupy historical home ranges once the habitat has recovered (Kochert et al. 1999).

4.3 CHANGE AGENTS PROPOSED FOR ANALYSIS

Although numerous attributes and indicators affecting this species were initially identified in early phases of this REA, not all are included in this analysis. Analysis for the wildfire and invasive species CAs were not included for this CE because the direct effect indicators were determined to be data gaps, or because they were impractical to model at the ecoregional scale because appropriate geospatial data were not available. Climate change was analyzed using a qualitative approach, due to the scale of the climate change data. If possible, surrogate indicators that are available or better suited to geospatial analysis were used. The specific indicators that could not be modeled are identified with an asterisk on Figure E-3-6. Further information on the data gaps for these indicators is discussed in the respective CA analysis contained in Appendix C.

Analysis for the development and climate change CAs are included for this CE.

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5.0 CHANGE AGENT ANALYSIS

A current status and future threat assessment for the golden eagle was conducted for this ecoregion using the 12-digit Hydrologic Unit Codes (HUCs) as the analysis unit. Based on the ecological process and system-level models, KEAs were identified for the current status and future threat analyses, with a specific emphasis on the ability to measure impacts using existing geospatial data. Development and wildfire were evaluated as current status CAs for the golden eagle. The CAs evaluated for future threats include development and climate change.

Because the scale of the analysis is at the HUC 12 level (6^{th} level watershed), this layer was extracted for the ecoregion. GIS processes were iterated through the KEA indicators and determined the metric values associated with the 6^{th} level watershed for some of the attributes. In other instances, sufficient published data indicated cut-off points for these values. These values were added as an attribute to the HUC 12 layer. The intermediate CA layers were then combined to form a single layer outlining the current status or future threat status for each HUC.

5.1 CURRENT STATUS OF THE GOLDEN EAGLE

Table E-3-4 identifies the original KEAs that were proposed in Task 3 and which of these were used in the final current status analysis. Not all of the KEAs proposed were used, based on the rationale provided. Other KEAs were used but are not directly related to CAs. For example, the KEA initially selected to assess the wildfire CA was the Fire Regime and vegetation condition class (VCC) provided by the USGS (LANDFIRE 2010). Upon evaluation of the condition classes, the RRT did not agree that the attribute was a good indicator of golden eagle habitat. For this reason, the potential risk of wildfire on golden eagle habitat could not be evaluated as part of the REA.

Table E-3-4. Key Ecological Attributes Retained or Excluded

Category	Key Ecological Attribute		Explanation
1. Size	a.	Extent of Suitable Habitat Patches	Retained to show the large patches of shrubsteppe and grassland habitat.
2. Condition	a.	Fire Regime and VCC	Excluded per RRT comments. VCC is not considered a good indicator of habitat quality for the golden eagle.
	b.	Nesting Location Quality – Annual Snowfall	Excluded per RRT comments. Snowfall is more of an indicator of distribution than an indicator of a CA. Closely related to climate change.
3. Context	a.	Connectivity	Excluded per RRT comments. Connectivity pertains more to migratory populations than to nesting populations.
	b.	Road Density	Retained to show the anthropogenic risks.
	c.	Distance to Anthropogenic Features	Retained to show the potential effect of transmission lines on golden eagle mortality.
	d.	Distance to Mining Activities	Excluded per RRT comments. Mining activity is not perceived to be a major CA to golden eagles.

Table E-3-5 identifies the KEAs, indicators, and metrics that were used to evaluate the CAs and pathways affecting this CE across the ecoregion, (as illustrated on Figure E-3-6). Several indicators were used to create a series of intermediate layers that are primarily based on the development CA and the geospatial data that was available.

Table E-3-5. Golden Eagle Key Ecological Attributes, Indicators, and Metrics for Current Status Assessment for the Northwestern Plains Ecoregion

Category	Ecological Attribute	Indicator / Unit of Measure	Metric			Data Source	Citation	Weight
			Poor = 3	Fair = 2	Good = 1			
Size	Foraging Habitat	Extent of Suitable Habitat (% of HUC [a])	0- 32 [a]	33 - 69 [a]	70 - 100 [a]	GAP	Marzluff et al. 1997; Beecham and Kocher 1975; Smith and Murphy 1973; McGahan 1968	0.700
Landscape Context	Landscape Structure	Road Density (roads/square kilometer [km^2])	>10	5 - 9	<5	Linear Feature	Steenhof et al. 1993; Professional Judgment	0.075
		Distance to Transmission Lines (km)	<1	1 - 5	>5	Transmission Line Locations/ BLM	Delong 2004; Professional Judgment	0.075
		Distance to Wind Turbines (miles)	<10	10 – 16	>16	Wind Turbine Towers	Hunt et al. 1998; U.S. Fish and Wildlife Service (USFWS) Eagle Conservation Plan Guidelines	0.150

[a] Based on natural breaks for the GAP vegetation range for this ecoregion.

5.1.1 Key Ecological Attribute Data Analysis for Current Status

For each of the KEAs listed in Table E-3-5, a discussion of the indicator, metric, metric rank and value, data source(s), and references is provided. Four indicators were used to assess the current status for the golden eagle. This table was limited to size and landscape context based on spatially available attributes and key factors affecting golden eagles in this ecoregion.

In most cases, the metrics used to identify attribute quality were based on available publications, coupled with expert analysis and professional judgment in association with data-driven metrics. This process was carried out through the establishment of a golden eagle RRT comprised of BLM wildlife biologists and state-level golden eagle experts. The RRT met periodically to contribute information and to analyze input attributes and outputs that were derived from various forms of spatial analyses in GIS. This process enabled the RRT to determine the efficacy of attributes, indicators, and metrics, as well as to ascertain the accuracy of each step of the modeling process. Weights were attributed to each metric in order to provide an overall score for all metrics combined, based on the reporting unit.

5.1.1.1 Foraging Habitat

Vegetation is one of the key features that most significantly affects the distribution of the golden eagle. A vegetation data layer provides information pertaining to the breeding and feeding requirements for the species, nesting habitat, and prey species availability. Prey species (e.g., blacktailed jackrabbit, ground squirrel, etc.) are closely associated with open vegetation communities (i.e., grasslands and shrubsteppe). Vegetation data are also useful in identifying eagle nesting locations. Although eagle nests are closely associated with rocky cliffs, the species also nests in riparian systems that border open grassland vegetation in the Northwestern Plains.

Foraging habitat was selected as a key indicator of prey availability for golden eagles. Reliable prey distribution data were not available; therefore, golden eagle habitat was used as a surrogate. The data source for the foraging habitat data layer was the 2001 Level 2 Gap Analysis Program (GAP) landcover data. The GAP Level 2 data attribute extraction was part of an iterative process that aided in determining the best combination of Level 2 data that reflected actual habitat use by golden eagles and their prey. These attributes were determined through literature reviews and biological knowledge of the species. Some attributes (i.e., conifer dominated forest and woodland) were included in this layer despite their lack of direct use by golden eagles in foraging activity because they were noted to be an important habitat resource for golden eagles in certain areas, specifically with regard to nesting (Baglien 1975; Seibert et al. 1976). In areas where conifers are adjacent to shrubland or grassland habitat, golden eagles use these areas as nesting and foraging habitat (Seibert et al. 1976). Table E-3-6 provides the Level 2 raster attributes that were extracted for this analysis.

Table E-3-6. GAP Level 2 Codes and Descriptions Extracted for the Golden Eagle Foraging Habitat Layer

Level 2 Code	Level 2 Description
32	Cliff, canyon and talus
33	Bluff and badland
45	Conifer dominated forest and woodland (xeric-mesic)
46	Conifer dominated forest and woodland (mesic-wet)
51	Alpine and avalanche chute shrubland
52	Scrub shrubland
53	Steppe
57	Sagebrush dominated shrubland
58	Deciduous dominated shrubland
71	Alpine grassland
72	Montane grassland
73	Lowland grassland and prairie (xeric-mesic)

The extent of suitable habitat was analyzed in relation to individual HUC units. The 12-digit HUC was used as the CE reporting unit for all species, and in the case of the golden eagle, it was also used as the analysis unit. This was the result of a lack of consistent information with regard to home range size in relation to the golden eagle. Past research has shown that home range sizes for breeding golden eagles range from 1.9 square kilometers (km^2) to as high as 92 km^2 (DeLong 2004). This indicator required a method for defining the metric values. The reporting unit (percentage of habitat in the HUC) was used as the determinant boundary, and the data derived from the reporting unit was used to determine the importance of habitat size within the 12-digit HUC. The natural breaks (Jenks) method of determining break points for low (32 percent), medium (69 percent), and high (100 percent) percentages per HUC using the spatial statistics created in ArcGIS was used to determine these metrics. Foraging habitat was assigned the highest weight (70 percent) based on its relative importance to breeding and foraging golden eagles (Table E-3-5). Figure E-3-7 shows the foraging habitat ranking by HUC.

5.1.1.2 Roads Density

The effect of roads within golden eagle habitat acts in a complex relationship with regard to foraging and mortality. Despite the potential for increased foraging habitat along roadways, the RRT attributed roads to high mortality rates based on the mortalities commonly associated with traffic collision and illegal shooting. Additionally, areas of greater road densities indicate greater human activity and are therefore a probable indication of lower nesting suitability.

Road density models were created in ArcGIS based on the number of roads per km^2. Topographically Integrated Geographic Encoding and Referencing (TIGER) data for all road types were used to create this layer, which was then clipped to this ecoregion boundary. The limitations of the TIGER data are discussed in Appendix C-1. The variation in road attributes among states precluded an efficient method of selecting roads by size and/or type.

The roadway density (number of roadways per km^2) within the HUC was calculated, and relative rank as good, fair, or poor, (as noted in Table E-3-5), was assigned. The metrics used for this indicator were derived from Steenhof et al. 1993 and professional judgment. If the road density was less than 5 roads per km^2, then the HUC was ranked as good and received a metric score of 1. If the road density was between 6 and 9 roads per km^2, then a rating of fair with a metric score of 2 was assigned. If the road density was 10 roads or greater per km^2, then a rating of poor with a metric score of 3 was assigned. Road density was assigned one of the lowest weight ratings (7.5 percent). The RRT determined that although road densities are a risk to golden eagles, some positive associations can also be attributed to this KEA.

The road density analysis was reported in relation to individual HUC units (Figure E-3-8). The 12-digit HUC was used as the analysis unit and reporting unit for this metric.

5.1.1.3 Distance to Transmission Lines

Transmission lines play a role similar to roads in the life history of the golden eagle in the western United States. They are important to the species as a foraging perch in areas with few trees, yet they are responsible for high mortality rates through electrocution (Boeker and Nickerson 1975, DeLong 2004). Electrocution is a serious factor affecting mortality in golden eagles, but it has less of an effect on species distribution. Sub-adult eagles occupy marginal habitat consisting of higher transmission line densities in areas that adult eagles tend to avoid (Delong 2004). Therefore, distance to transmission lines is considered in this assessment as an indicator associated with higher mortality and poor landscape structure.

Transmission line data were obtained for major utility lines within this ecoregion. These transmission lines are generally greater than 115 kilovolts (kV) and tie major power plants to the electrical grid. Minor transmission lines (e.g., neighborhood electrical lines, etc.) were not available for use in this analysis.

Transmission line information with regard to the assigning of metrics was difficult to obtain. Therefore, after review of the literature, the RRT experts determined an appropriate distance to transmission lines for use in this metric. The Euclidean distance tool in ArcGIS was used to derive the distance calculations for this attribute and its associated metrics. Distance in km to transmission lines within the HUC was calculated, and relative rank as good, fair, or poor (as noted in Table E-3-5) was assigned. Transmission line density was assigned one of the lowest weight ratings (7.5 percent). The RRT determined that the risk of this attribute on the golden eagle was similar in many aspects to the road density analysis and should therefore be assigned a similar weight.

The transmission line analysis was reported in relation to individual HUC units. The 12-digit HUC was used as the analysis unit for this metric. This was the result of a lack of available information with regard to the effect of transmission line distance to golden eagle nesting habitat. The output from this analysis is shown on Figure E-3-9.

5.1.1.4 Distance to Wind Turbines

Wind turbines are an important factor affecting golden eagle mortality (Hunt et al. 1995, Hunt 2002) and can therefore be used to define the integrity of the landscape structure for this CE. The U.S. Fish and Wildlife Service (USFWS) and its partners have developed a “Draft Eagle Conservation Plan Guidance” (USFWS 2011) that outlines the current relationship between golden eagle mortality and wind turbine prevalence. The guidance document provided the basis for the metrics for this indicator.

The USFWS provided a compiled dataset for wind turbine locations and test towers throughout the United States. These data were clipped to this ecoregion, and point occurrence data were limited to wind turbines for use in this analysis. Distance in miles to wind turbines within the HUC was calculated, and relative rank as good, fair, or poor, (as noted in Table E-3-5) was assigned. The wind turbine KEA was assigned a weight of 15 percent because of the high rate of mortality for golden eagles inhabiting areas currently occupied by wind turbines, but the indicator was not given a greater weight overall because wind turbine locations are currently limited to smaller areas within the ecoregion. As wind turbines increase throughout golden eagle habitat, they will likely have a significantly greater effect on the overall population of golden eagles. Figure E-3-10 presents the results of this model.

5.1.2 Current Status of Habitat

The individual KEA analyses provide the basis for the compilation of an overarching data layer that defines the current status of golden eagle habitat of each 12-digit HUC across this ecoregion. A method of aggregating scores was used to summarize overall current status with regard to golden eagle habitat quality. Individual CAs can identify areas of potential risk to golden eagle populations, but aggregated scores can provide important information with relation to areas where golden eagles might encounter multiple CAs.

In order to create a current status data layer, an overall score for each HUC unit was calculated. Based on each KEA rating of good, fair, or poor, an HUC quality rank score was subsequently assigned to the KEA. If the KEA rating was good, then the HUC quality rank score of 1 was assigned (Table E-3-7). In some cases, the KEA was assigned a varying weighting factor based on varying levels of importance of each KEA (as noted in Table E-3-5). The HUC quality rank score was then multiplied by the weighting factor for the KEA, and the total score was averaged (Table E-3-8).

Table E-3-7. Hydrologic Unit Code Quality Ranking Scores

HUC Quality	Rank
Good	1
Fair	2
Poor	3

Table E-3-8. Example of the Weighted Method of Scoring for 12-Digit Hydrologic Unit Code

Threat	HUC Quality Rank	Weight	Score
Foraging Habitat	3	0.700	2.1
Roads	2	0.075	0.15
Transmission Lines	1	0.075	0.075
Wind Turbines	2	0.150	0.3
Overall Threat Score (Averaged)			0.656

The overall threat score for each HUC was assigned a current habitat quality rating of good, fair, or poor, based on the natural breaks method. A higher overall threat score would result in a rating of poor for the HUC, indicating that there are existing threats to the eagle habitat based on the KEA metrics.

The results of the current status analysis for the ecoregion are presented on Figure E-3-11. The current overall status of the golden eagle is fairly stable across its entire distribution range, with a slight decline in population in the western United States (USFWS 2011). In the western half of this ecoregion, significant habitat currently exists to sustain good populations of breeding golden eagles. Figure E-3-7 indicates that the majority of the ecoregion maintains suitable habitat for golden eagles, with large areas in western North Dakota, southeastern South Dakota, west-central Montana and the Golden Triangle (MT) indicating potential habitat loss. The effect of roads on golden eagles in this ecoregion is minimal, generally localized around larger population centers, and does not pose a current substantial threat to populations across the ecoregion (Figure E-3-8). Transmission lines exist throughout large portions of this ecoregion, and Figure E-3-9 shows a substantial extent of the ecoregion as fair with regard to these lines. However, because the transmission lines themselves are relatively small (spatially) in relation to the ecoregion, it is likely that the effect from transmission lines on breeding populations of golden eagles will have less of an effect than that which is displayed on this figure. Only a small portion of the ecoregion exists in areas where proximity to transmission lines is a substantial threat. The threat of wind turbines in this ecoregion is a concern for localized golden eagle populations (Figure E-3-10). Wind turbine threats represent a substantial portion of this ecoregion and are a current threat to the golden eagle population in western Montana, northeastern Wyoming, northern Nebraska, western North Dakota, central North Dakota, western South Dakota, and central South Dakota. Because the Nebraska population of golden eagles is fairly small, the threat of wind turbines is probably greatest in this state. The overall current status of the golden eagle in this ecoregion in the context of this assessment is good to fair (Figure E-3-11). It is important to note that the locations receiving the lowest scores in this assessment are those areas in close proximity to urban areas and areas of substantial agricultural activity (e.g., Golden Triangle). The majority of the western portion of this ecoregion is inhabited by golden eagles and provides suitable habitat for the species.

A summary of the current status ratings based on the CE distribution is provided in Table E-3-9. The CE distribution layer was used to calculate the total number of square miles of CE habitat and a percentage of the total number of square miles per HUC that were rated as good, fair, or poor. The results of the current status assessment indicate that approximately 64 percent of the 6th level HUC watersheds that intersect the golden eagle distribution received an overall good rating. Approximately one-third of the HUCs were rated as fair or poor.

Table E-3-9. Summary of Current Status Ratings for the Golden Eagle

Overall Rating by 6th Level HUC	Total Square Miles [a]	Percentage of Total Square Miles [a, b]
Good	118,288	64.0
Fair	46,129	25.0
Poor	20,469	11.1

[a] These values include only the area of HUCs that intersect with the CE distribution layer.
[b] Values rounded to one decimal place.

5.2 FUTURE THREAT ANALYSIS

The system-level model (Figure E-3-6) was used to create a series of intermediate layers that are primarily based on the geospatial data that was available on the future projections for the development CA and climate change CA. Future threats were evaluated for development for a short-term time horizon (5-10 years) and for climate change for a long-term time horizon (50-year; 2050 to 2069).

Because of the inherent inaccuracies of the temporal scale of the future data, it is only possible to infer information pertaining to a subjective future period (rather than to a specific time period) for some of these attributes. However, because of the limits placed on these data outputs, it is fair to assume that this model predicts the overall future potential for these attributes within this ecoregion. It is an upper limit of potential growth and should therefore be carefully applied to future estimates of their effect on golden eagle populations.

5.2.1 Development Change Agent

Future spatial data for development was limited to the future potential for energy development, modeled urban growth, and potential agricultural development, as discussed in the development CA analysis presented in Appendix C-1. KEAs used to define future threats from development are presented in Appendix C-1.

5.2.1.1 Agricultural Growth

Agricultural activities are detrimental to golden eagle distribution, and, as human populations increase, it is expected that the demands of a larger human population will require additional agriculture.

Because no future agricultural models exist for use within this ecoregion, a model was created using surrogate data to derive potential agricultural areas. STATSGO data were used to determine potential agricultural soil types. The appropriate soil types for use in this classification are types 1 through 4, which are shown on Figure C-1-1 in Appendix C-1. No specific future time period was considered in this analysis (e.g., 2025 or 2060). Alternatively, this analysis considered the maximum potential for future agricultural areas within this ecoregion.

Figure C-1-1, Future Agricultural Potential, shows the results of the analysis, indicating potential habitat loss due to potential future agricultural land development. In this ecoregion, most of the agricultural areas (current and future) lie beyond the golden eagle distribution layer. There is potential for small changes in the distribution of breeding golden eagles in some areas, but overall, the population is likely to remain unaffected.

5.2.1.2 Future Growth of Urban Areas

Urban growth affects golden eagle habitat with impacts similar to those of agricultural activities. In this ecoregion, a small portion of the area that is inhabited by golden eagles is currently in close proximity to urban/suburban populations. Urban growth, as noted by increasing population trends, impacts a variety of species; the golden eagle may be susceptible to habitat loss in near-term and long-term temporal periods.

The Integrated Climate and Land Use Scenarios (ICLUS) model is a universally accepted model, created by the U.S. Environmental Protection Agency (USEPA) for use in future climate change modeling, that provides spatial data that can be used to determine the future extent of urban areas for various time periods. The model uses U.S. Census data to predict urban growth. The ICLUS future urban extent for the year 2060 was used in this analysis. This corresponds more closely to the data and scenarios used to perform the foraging habitat and wind turbine analyses than to a near-term time period. The ICLUS urban area footprint for 2060 was used to calculate the proximity to golden eagle distribution areas. Figure C-1-2, Future Urban Growth Potential, shows the results of the analysis.

Golden eagle habitat areas in this ecoregion are mainly affected by urban growth in the major urban centers (e.g. Rapid City, South Dakota; Sheridan, Wyoming; Bozeman, Montana; etc.). However, these areas are minimal in size with regard to the distribution extent of the golden eagle and are unlikely to greatly affect the population of the golden eagle in this ecoregion. The possible exception to this would be localized populations within the immediate vicinity of these urban centers.

5.2.1.3 Oil Production Potential

Oil production potential was not characterized in this analysis as a current threat to golden eagles. Although oil production activities were considered prior to analysis, the RRT determined that the potential effect from current oil well locations was minimal, as suggested by previous research (Grubb and King 1991). Other CAs associated with disturbance to golden eagles (e.g. road proximity, transmission lines, etc.) were assessed in the current analysis, but unavailable for assessment in the future analysis.

The future analysis characterized the future potential for oil development rather than oil well locations (Figure C-1-4). These larger oil development areas can be used to qualitatively assess the potential effect of future oil production activities. Although these areas are based on oil density data, the application of these data to future potential well site activity is unknown. Therefore, a carefully considered approach should be taken when assessing the effect of potential oil production areas on golden eagle populations.

Most of the golden eagle populations in the ecoregion will likely remain unaffected by oil production. The majority of potential oil production is limited to northeastern Wyoming. However, this region represents a large part of Wyoming that is characterized as golden eagle habitat. In this ecoregion, there is potential for a negative effect on golden eagle populations in northeastern Wyoming, eastern Montana, and western North Dakota; however, the overall distribution of the species is expected to remain unaffected by oil production. The oil production potential in Wyoming appears to indicate the strongest potential effect on golden eagle populations. The South Dakota golden eagle habitat appears to be at the highest risk from this CA in the western part of the state.

It is important to note that the Energy Policy and Conservation Act (EPCA) oil and gas data used in this assessment are based on the maximum potential for oil and gas reserves within this ecoregion. As a result, these data are likely over-represented in these figures, and care should be taken in assessing the effects of oil and gas production within the constraints of this analysis.

5.2.1.4 Natural Gas Production Potential

Natural gas production potential was not characterized in this analysis as a current threat to golden eagles. Although gas production activities were considered prior to analysis, the RRT determined that the potential effect from current gas well locations was minimal, as suggested by previous research (Grubb and King 1991). Other CAs associated with disturbance to golden eagles (e.g. road proximity, transmission lines, etc.) were assessed in the current analysis, but were unavailable for assessment in the future analysis.

The future analysis characterized potential gas production areas rather than gas well locations (Figure C-1-3). These larger gas production extents could be used to qualitatively assess the potential risk to habitat from future potential for gas development activities. Although future potential for natural gas is based on gas density data, the application of these data to future potential well site activity is unknown. Therefore, a carefully considered approach should be taken when assessing the effect of potential gas production areas on golden eagle populations.

Most of the golden eagle populations in the ecoregion will likely remain unaffected by gas production in this ecoregion. Future potential natural gas development is mostly limited to northeastern Wyoming. The potential risk from this CA is greatest in this area since this area represents the largest part of Wyoming that includes golden eagle habitat. Golden eagle habitat in north-central Montana appears to be at higher risk from future natural gas development activities.

5.2.1.5 Solar Energy Potential

The effect of solar photovoltaic arrays on golden eagles is similar in function to the effects of any anthropogenic disturbance. Future solar energy development is not likely to directly affect the golden eagle through higher mortality rates, but it could be responsible for displacing prey habitat or suitable nesting habitat. The USFWS considers any anthropogenic disturbance as a potential threat to golden eagles (USFWS 2011), and treats all renewable energy resources as a similar threat to the species. Because spatial distribution of a solar array is the key factor affecting golden eagles, a reliable assessment from the available National Renewable Energy Laboratory (NREL) model (Figure C-1-6) is difficult and can only be generalized for the purposes of this analysis.

The slope and elevation associated with the western portion of this ecoregion is likely to eliminate substantial areas from future solar energy development. Similarly, golden eagles utilize the more rugged areas of the ecoregion as habitat. This, coupled with the golden eagle distribution across the ecoregion, increases the potential for limited interactions. However, in areas where foothills and less-rugged mountainous terrain exist, there is potential for habitat displacement. The most likely areas for potential effect from solar energy in this ecoregion are Northeastern Wyoming, northwestern Nebraska, and the Black Hills and surrounding areas in South Dakota.

5.2.1.6 Wind Turbine Potential

The USFWS wind turbine data contained attribute information for current and future wind turbine locations. However, the future turbine locations dataset was very limited in number, as most turbines will presumably be erected in the very near future. Therefore, an alternative dataset was used to determine the potential areas for erecting wind turbines over a long-term period. The potential future wind development layer was based on the availability of suitable wind speeds.

Data characterized by the NREL was used to create a potential future potential wind development data layer. A full description of the methods and processes implemented to create this data layer and its corresponding scoring system can be found in Appendix C-1.

The potential threats to golden eagle habitat based on future wind energy development are presented on Figure C-1-7. Higher elevations within this ecoregion are more susceptible to the threat of wind turbine development due to the higher wind speed levels within these areas. However, limited accessibility may affect the distribution of wind turbines at higher elevations, limiting the range of wind turbine distribution to lower elevation mountainous regions. Throughout the mountainous regions of this ecoregion, many of these areas are inhabited by nesting golden eagles. There is substantial potential for a negative effect on golden eagles as a result of the placement of wind turbines in these areas. Although this assessment is primarily qualitative, the spatial distribution of the golden eagle and mid-level elevation wind turbine potential overlap is apparent. There is potential for a substantial negative effect on golden eagle populations within the western portion of this ecoregion if wind turbine production increases in these areas. The southeastern most range of the golden eagle distribution layer shows a substantial potential for increased risk to wind turbine development. This area is currently on the fringe of suitable golden eagle habitat and wind turbine development in this area could result in a substantial disturbance to golden eagle populations.

5.2.1.7 Overall Development Change Agent Future Threats

The future overall score was compiled by averaging the values associated with each of the two energy types: renewable and fossil fuels. Future potential agriculture and urban areas were characterized as binary functions, and further assessment of these attributes based on the values associated with each was not possible in this analysis.

A future potential fossil fuel energy development layer was created to address the MQs associated with future fossil fuels production. This layer was created by averaging the EPCA oil data layer with the EPCA gas data layer (Figure C-1-5).

Most of the golden eagle populations in the ecoregion will likely remain unaffected by fossil fuel development. The majority of future potential fossil fuel development is limited to northeastern Wyoming. In this ecoregion, there is potential for some effect on golden eagle populations in Wyoming, but the overall distribution of the species is expected to remain unaffected by fossil fuel development.

A future potential renewable energy development layer was created to address the MQs associated with future renewable energy development. This layer was created by averaging the NREL wind speed data layer with the NREL solar energy data layer (Figure C-1-8).

This output layer gives equal weighting to potential wind and solar energy development areas, and could therefore mischaracterize the effects of each. Unlike oil and gas, wind and solar energy are not necessarily closely associated with one another spatially. Photovoltaic solar arrays threaten the species by their effect on habitat availability. Solar arrays are diverse in scope and size, and it is therefore difficult to create a clear correlation between habitat loss and solar energy production. The potential substantial effect of wind turbines on the mortality of golden eagles is directly correlated. In areas in which wind turbine production overlaps golden eagle distributions, substantial mortality can be attributed to wind turbines (Hunt et al. 1995; Hunt 2002). As a result, it might be beneficial for managers to consider wind and solar energy development as separate entities when determining the effects of renewable resources on golden eagles.

Because of the intricacies involved in the assessment of renewable energy production with regard to golden eagle populations, a limited approach must be taken in this analysis. The majority of golden eagle habitat is rated at a moderate risk to renewable energy development. Because of the large area represented as moderate risk, it is important to consider these areas as having the potential for a considerable long-term effect on golden eagle populations.

5.2.2 Climate Change Future Threats

5.2.2.1 Ecoregion Climate Change Analysis

From a climate change perspective, the relationship between temperature, precipitation, and prey species of the golden eagle is the factor that most effects the species distribution, and to some extent, nesting success. Based on the analysis conducted for the ecoregion (as presented in Appendix C-5), there are potential climate change conditions that could dramatically affect localized populations of golden eagles, especially at high elevations within the ecoregion.

The golden eagle predominately preys on a variety of small mammals, but throughout most of its western range, the black-tailed jackrabbit is its prey base. A constant overall increase in temperature (1.9 degrees Celsius [°C]-2.3°C) is expected across the golden eagle range within the Northwestern Plains. Temperature increases over time resulting from climate change will most likely result in increases in wildfire potential, which will directly affect golden eagle prey availability. Across this ecoregion, annual precipitation is predicted to be highly variable around the 2060 timeframe. Most of the region is expected to experience a mild increase (25-75 millimeters [mm]) in annual precipitation, or no annual change in precipitation. Several small pockets of increased annual dry periods (decrease to 51 mm) are expected to occur in the Bighorn and Laramie Mountains in Wyoming. Increased annual precipitation (76 to 155 mm) is expected in the southeast corner of the ecoregion along the Missouri River and on the eastern edge of the Black Hills National Forest. The annual variation in the areas adjacent to the Black Hills is not substantial with regard to its effect on overall prey availability. However, small population shifts in black-tailed jackrabbits are likely to occur. Bronson and Tiemeier (1959) found substantial shifts in populations of black-tailed jackrabbits in areas of decreased precipitation. Jackrabbits alternatively used habitat that was located along the periphery of river and stream drainages. Populations increased dramatically in these areas and even reached carrying capacity in some locations.

Golden eagles could potentially adapt in various ways to climate change. A very likely scenario would be a shift in nesting periods. As snowfall decreases in April and milder spring periods occur more regularly, it is likely that golden eagles will begin to nest earlier, especially in mountainous regions where snowfall is expected to decrease. A geographical response from golden eagle populations is also possible on a macro and micro level. The entire breeding population of golden eagles could potentially shift northward, increasing the overall population in Canada and Alaska. More likely, there will be a substantial micro-population shift. Golden eagles maintain numerous nest sites within a breeding season home range (Beecham and Kochert 1975). It is possible that golden eagles will simply increase the number of nest sites within these home ranges to take advantage of microclimates within current home ranges. Eagles might simply nest at higher elevations or move to areas near hydrological features where temperatures are lower.

Climate change presents many different issues relating to golden eagle foraging and nesting. However, it remains difficult to draw conclusions from the data presented in this REA. Climate change models are highly variable and often difficult to predict. In this case, the resolution of the spatial data is an important factor to consider. Additionally, the golden eagle is a highly mobile species that is uninhibited by most man-made and geographical features. Like all raptor species, golden eagles are highly adaptable and often able to compensate for climatic variation.

5.2.2.2 NSCCVI

The NatureServe Climate Change Vulnerability Index (NSCCVI) tool was utilized to assess golden eagle vulnerability to the effects of climate change. Using annual raster datasets from NatureServe to perform climate change calculations in ArcGIS (through the Predicted Temperature 2040-2069 [Fahrenheit (F)] and the Predicted Hamon ratio of actual evapotranspiration to potential evapotranspiration [AET : PET] Moisture Metric 2040-2069 datasets), the NSCCVI calculator was applied and produced an index score of not vulnerable/increase likely. The NSCCVI tool indicated that available evidence suggests the abundance and/or range extent of this species within the geographical area assessed is likely to increase by 2050. The assessment rating was largely based on a majority of neutral and somewhat decreased vulnerability scores calculated when assessing factors that influence vulnerability, such as dispersal and movements, sensitivity to changes in historical thermal niche, dependence on ice or snow-cover habitats, reliance on interspecific interactions to generate habitat, and dietary versatility.

6.0 MANAGEMENT QUESTIONS

The relevant MQs for the golden eagle include those defined as part of the Landscape Species/Species Richness category. The overall MQ was: Where are the important regionally significant terrestrial features, functions, and services across the ecoregional landscape? This MQ was considered in implementing the GIS analyses. Emphasis was placed on the spatial relationship of attributes mentioned in the MQs and the distribution map for the CE. Specific MQ examples for the REA were developed in Task 1 and are presented in Appendix A. Several of these MQs are discussed below to demonstrate the functionality of the REA and to provide an opportunity to discuss significant data gaps that were identified during this REA.

6.1 WHERE ARE THE HABITATS THAT SUPPORT BREEDING GOLDEN EAGLES?

The response to this MQ was required to perform all additional analyses and data comparisons for the golden eagle. The Maxent distribution model is presented on Figure E-3-4. While there are potential limitations to the quality of this model, all efforts were made to accurately describe the distribution of breeding golden eagles within the ecoregion.

6.2 WHERE ARE THE KEY HABITAT AREAS THAT SUPPORT REGIONALLY SIGNIFICANT CONCENTRATIONS OF GOLDEN EAGLES?

The Maxent distribution model was able to determine the overall distribution of the golden eagle within the ecoregion. This model created a probability range of potential golden eagle distribution areas that ranged from 0-1. In this analysis, the output value was limited to areas that provided potential for golden eagle distribution; however, it could easily be reclassified to create revised thresholds for areas likely to contain large populations, based purely on the environmental variables associated with the Maxent model. Similarly, the analysis used to create the current status of golden eagles by 12-digit HUC provides this result. Figure E-3-11, which portrays the current overall score, specifically answers this MQ by scoring HUCs within golden eagle distribution areas.

6.3 WHERE ARE THE AREAS THAT HAVE POTENTIAL FOR RESTORING GOLDEN EAGLE HABITAT OR HABITAT CONNECTIVITY, CURRENTLY AND IN THE FUTURE?

Several of the figures present data layers that could be used to answer this MQ. Habitat quality is identified both as a sum and individually across the ecoregion. These attributes can be analyzed by managers at the 12-digit HUC level to determine areas that are preferential for restoring golden eagle habitat based on their proximity to good quality habitat.

6.4 WHERE ARE REGIONALLY SIGNIFICANT GOLDEN EAGLE HABITAT AREAS AT GREATEST RISK FROM CHANGE AGENTS, INCLUDING CLIMATE CHANGE (CONNECTIVITY, SMALL POPULATION SIZE), DISTURBANCE, OR DEVELOPMENT?

The full range of figures and analyses in the golden eagle section of this REA can be used to answer this complex MQ. The models created throughout this process were created to directly address the effects of CAs on the golden eagle. All of the CAs were addressed spatially and described in detail in this section, and all of the CAs were spatially attributed to the distribution of the golden eagle. Climate change is addressed separately because of data issues, but the spatial relationship between climate change and golden eagle distribution is described in detail.

6.5 WHERE ARE AREAS OF EXISTING, PLANNED, AND POTENTIAL FUTURE DEVELOPMENT, INCLUDING ROADS (BASED ON EXISTING WILDLAND-URBAN INTERFACE LITERATURE, INCLUDING THEOBALD AND OTHERS)?

The effect of CAs on future populations of golden eagles was limited by data availability, but in most cases, surrogate data were available for use in this analysis. Therefore, although the data were limited in quality, assumptions could still be made to address this MQ. The future CA figures in Appendix C provide a spatial display of the effects of these future CAs on areas in which golden eagles occur.

6.6 WHICH CORE CONSERVATION ELEMENTS ARE THREATENED BY SOD-BUSTING, ENERGY DEVELOPMENT, GRAVEL MINING, FRAGMENTATION, LOSS OF CONNECTIVITY, AND OTHER DEVELOPMENT PRESSURES?

This MQ was addressed in the future CA analysis. The results of the analysis indicate that agricultural activity, urban growth, and wind turbines could have a potential negative effect on future golden eagle populations in some areas.

7.0 REFERENCES

Anderson, R.L. and J.A. Estep. 1988. Wind energy development in California: impacts, mitigation, monitoring, and planning. Calif. Energy Commis., Sacramento, CA. 12 p.

Baglien, J.W. 1975. Biology and habitat requirements of the nesting Golden Eagle in southwestern Montana. M.S. thesis. Montana State University, Bozeman, Montana. 63 pages.

Beecham, J. J., and M. N. Kochert. 1975. Breeding biology of the Golden Eagle in southwestern Idaho. Wilson Bulletin 87:506-513.

Boeker, E. L., and P. R. Nickerson. 1975. Raptor electrocutions. Wildlife Society Bulletin 3:79-81.

Bronson, F. H. and Tiemeier, O. W. 1959. The relationship of precipitation and black-tailed jack rabbit populations in Kansas. Ecology 40: 194-198.

Brown, B.T., G.S. Mills, C. Powels, W.A. Russell, G.D Therres, J.J. Pottie. 1999. The Influence of Weapons-Testing Noise on Blad Eagle Behavior. J. Raptor Res. 33(3):227-232.

DeLong, J. P. 2004. Effects of management practices on grassland birds: Golden Eagle. Northern Prairie Wildlife Research Center, Jamestown, ND. Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/literatr/grasbird/goea/goea.htm (Version 28MAY2004).

Facka, A. N., Roemer, G. W., Mathis, V. L., Kam, M. and Geffen, E. (2010), Drought Leads to Collapse of Black-Tailed Prairie Dog Populations Reintroduced to the Chihuahuan Desert. The Journal of Wildlife Management, 74: 1752–1762. doi: 10.2193/2009-208.

Good, R. E., R. M. Nielson, H. H. Sawyer, and L. L. McDonald. 2004. Population level survey of Golden Eagles (*Aquila chrysaetos*) in the western United States. Final report prepared by Western EcoSystems Technology, Inc. U. S. Fish and Wildlife Service, Arlington, VA.

Grubb, T.G. and R.M. King. 1991. Assessing human disturbance of breeding bald eagles with classification tree models. Journal of Wildlife Management 55:500-511.

Harness, R. E., and K. R. Wilson. 2001. Electric-utility structures associated with raptor electrocutions in rural areas. Wildlife Society Bulletin 29: 612-623.

Hirzel A. H., G. Le Lay, V. Helfer, C. Randin, and A. Guisan. 2006. Evaluating the ability of habitat suitability models to predict species presences. Ecological Modeling 199, 142-152.

Hunt, W. G., R. E. Jackman, T. L. Brown, J. G. Gilardi, D. E. Driscoll, and L. Culp. 1995. A pilot Golden Eagle population study in the Altamont Pass Wind Resource Area, California. Report to National Renewable Energy Laboratory, Subcontract No. XCG-4-14200, Predatory Bird Research Group, University of California, Santa Cruz, California. 224 pages.

Hunt, W. G., R. E. Jackman, T. L. Brown, D. E. Driscoll, and L. Culp. 1997. A population study of Golden Eagles at the Altamont Pass Wind Resource Area: second year progress report. Report to National Renewable Energy Laboratory, Subcontracts XAT-5-15174-01 and XAT-6-16459-01, Predatory Bird Research Group, University of California, Santa Cruz, California. 93 pages.

Hunt, W. G., R. E. Jackman, T. L. Brown, D. E. Driscoll, and L. Culp. 1998. A population study of golden eagles in the Altamont Pass Wind Resource Area: population trend analysis 1997. Report to National Renewable Energy laboratory, Subcontract XAT-6-16459-01. Predatory Bird Research Group, University of California, Santa Cruz.

Hunt, W. G. 2002. Golden Eagles in a perilous landscape: predicting the effects of mitigation for wind turbine blad strike mortality. Report to the California Energy Commission. University of California, Santa Cruz, CA.

Kochert, M. N., K. Steenhof, L. B. Carpenter, and J. M. Marzluff. 1999. Effects of fire on Golden Eagle territory occupancy and reproductive success. Journal of Wildlife Management 63:773-780.

Kochert, M. N., K. Steenhof, C. L. McIntyre, and E. H. Craig. 2002. Golden Eagle (*Aquila chrysaetos*). *In* A. Poole and F. Gill (eds.), The Birds of North America, No. 684. The Birds of North America, Inc., Philadelphia, Pennsylvania.

LANDFIRE 2010. LANDFIRE 1.1.0 Vegetation Condition Class layer. U.S. Department of the Interior, Geological Survey. [Online]. Available: _http://landfire.cr.usgs.gov/viewer/ [2010, October 28].

LaRoe, E.T., G.S. Farris, C.E. Puckett, P.D. Doran and M.J. Mac (Eds.). 1995. Our living resources: a report to the nation on the distribution, abundance and health of U.S. plants, animals and ecosystems. U.S. Department of the Interior, National Biological Service, Washington, D.C. 530 pp.

Lightfoot, D. C., A.D. Davidson, C. M. McGlone, and D. G. Parker. 2010. Rabbit abundance relative to rainfall and plant production in Northern Chihuahuan desert grassland and shrubland habitats. Western North American Naturalist 70: 490-499.

McGahan, J. 1968. Ecology of the golden eagle. Auk 85:1-12.

Marzluff, J. M., S. T. Knick, M. S. Vekasy, L. S. Schueck, and T. J. Zarriello. 1997. Spatial use and habitat selection of Golden Eagles in southwestern Idaho. Auk 114:673-687.

Menkens, G. E., Jr., and S. H. Anderson. 1987. Nest site characteristics of a predominantly tree-nesting population of Golden Eagles. Journal of Field Ornithology 58:22-25.

Mollhagen, T. R., R. W. Wiley, & R. L. Packard. 1972. Prey remains in Golden Eagle nests: Texas and New Mexico. J. Wildl. Mgmt. 36: 784-792.

Platt, S. W. 1984. Energy development and raptor populations on and adjacent to the Black Butte Coal Company mine permit area. Unpublished progress report. Black Butte Coal Company, Point of Rocks, Wyoming. 71 pages.

Seibert, D. J., R. J. Oakleaf, J. M. Laughlin, and J. L. Page. 1976. Nesting ecology of Golden Eagles in Elko County, Nevada. Technical Note. U.S. Department of the Interior, Bureau of Land Management. 17 pages.

Smallwood, K.S. and C.G. Thelander. 2008. Bird mortality at the Altamont Pass Wind Resource Area, California. *Journal of Wildlife Management* 72:215-223.

Smith, D. G., and J. R. Murphy. 1973. Breeding ecology of raptors in the eastern Great Basin of Utah. Brigham Young Univ., Provo. Sci. Bull. Biol. Ser. 18, No. 3. 76pp.

Smith, G.W. and D.R. Johnson. 1985. Demography of a Townsend ground squirrel population in southwestern Idaho. Ecology 66:171-178.

Steenhof, K., M. N. Kochert, and J. A. Roppe. 1993. Nesting by raptors and ravens on electrical transmission line towers. Journal of Wildlife Management 57:271-281.

Steenhoff, K., M.N. Kochert, and T.L. McDonald. 1997. Interactive effects of prey and weather on Golden Eagle reproduction. J. Anim. Ecol. 66:350-362.

Unnasch, R.S., D. P. Braun, P. J. Comer, G. E. Eckert. 2009. *The Ecological Integrity Assessment Framework: A Framework for Assessing the Ecological Integrity of Biological and Ecological Resources of the National Park System***.** Report to the National Park Service. Version 1.0. January.

USFWS 2011. Draft Eagle Conservation Plan Guidance. U.S. Fish & Wildlife Service. January 2011. http://www.fws.gov/windenergy/docs/ECP_draft_guidance_2_10_final_clean_omb.pdf

APPENDIX E-3

FIGURES

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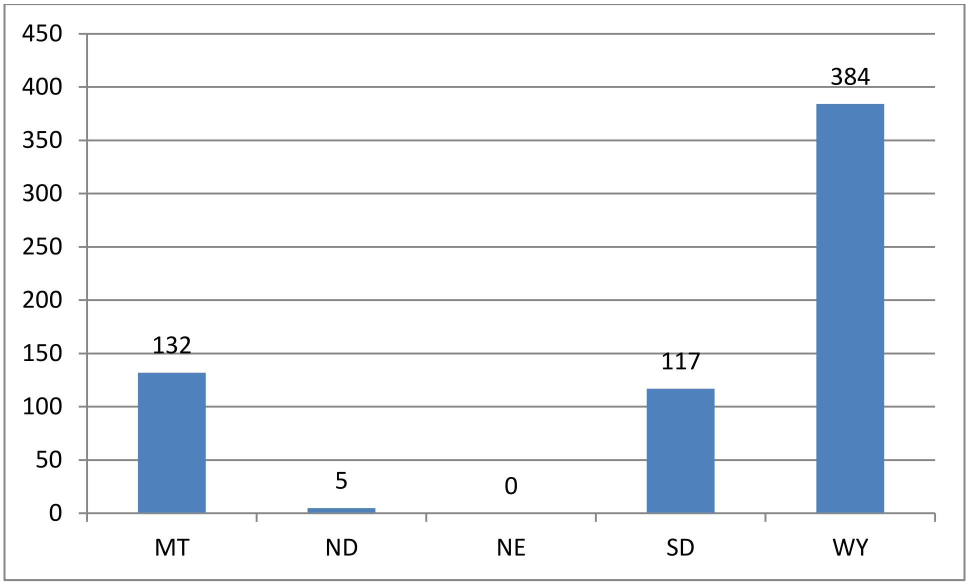

Figure E-3-1. Golden Eagle Nest Observations Used in Maxent Habitat Model for Northwestern Plains Ecoregion

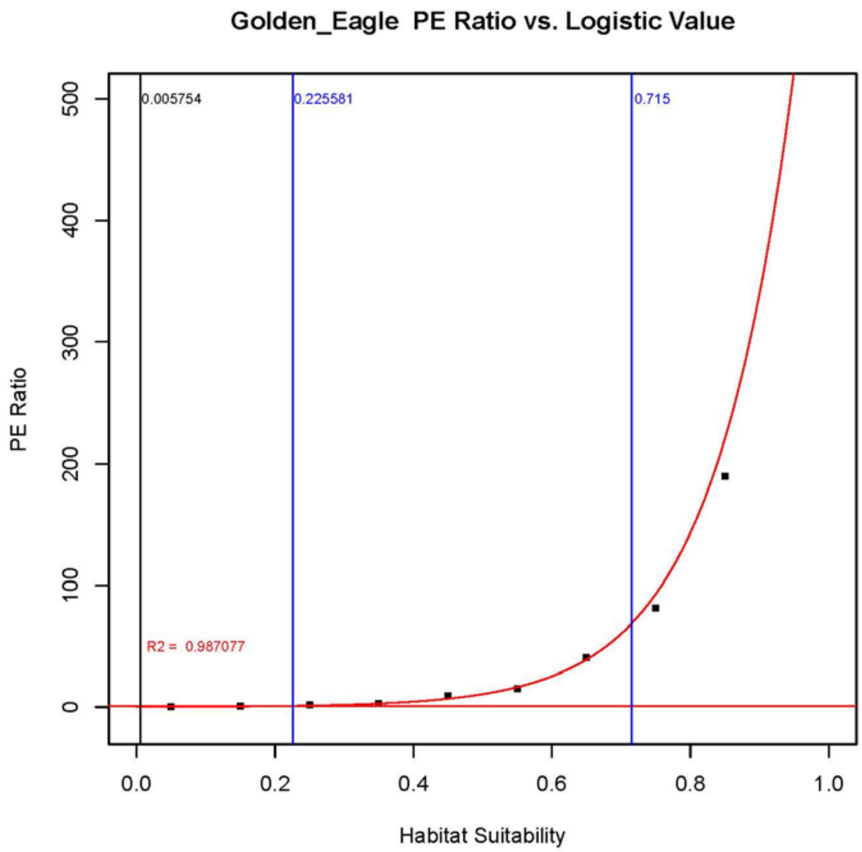

Figure E-3-2. R-Script Output for Golden Eagle Maxent Habitat Model

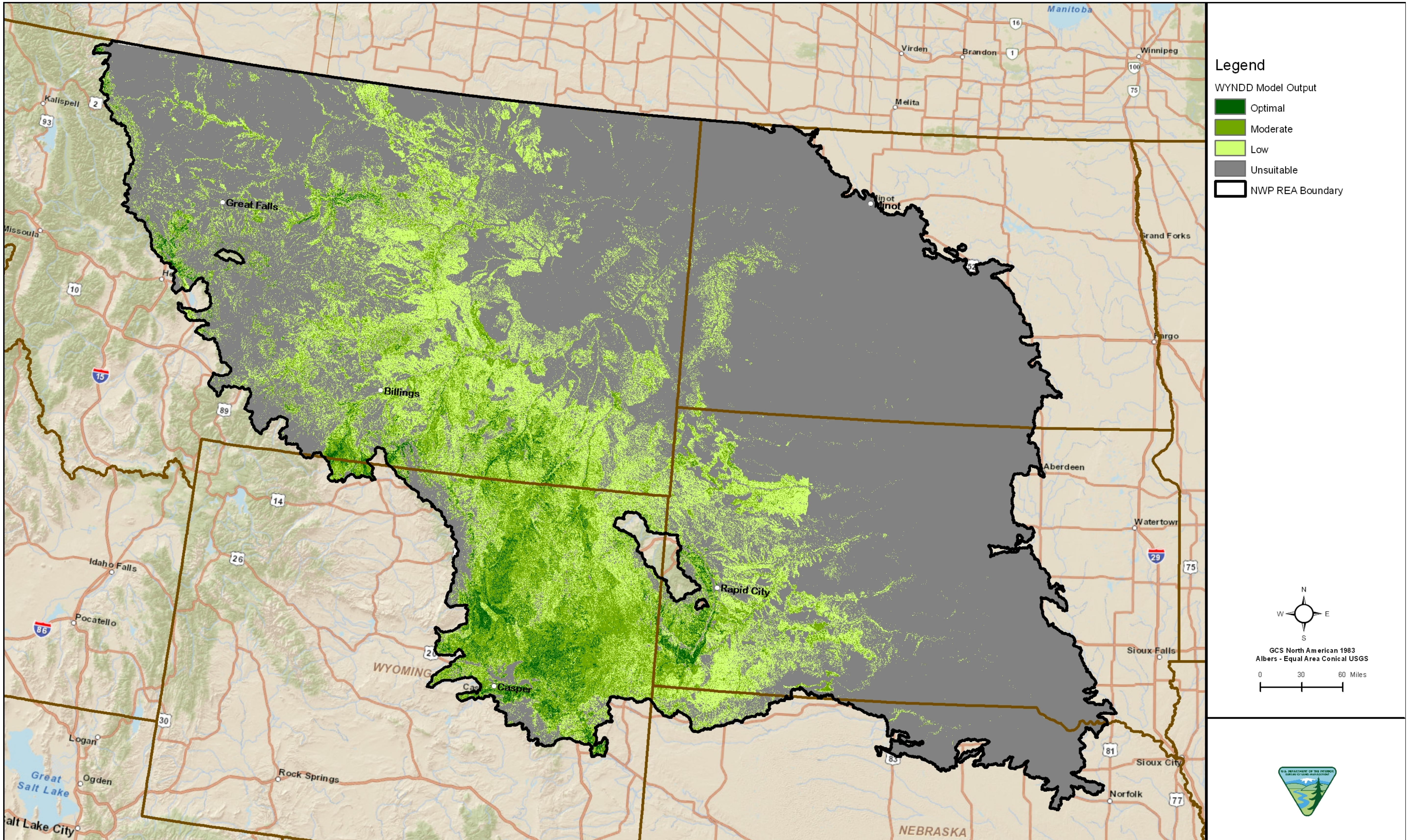

Figure E-3-3. Wyoming Natural Diversity Database Habitat Model for the Golden Eagle

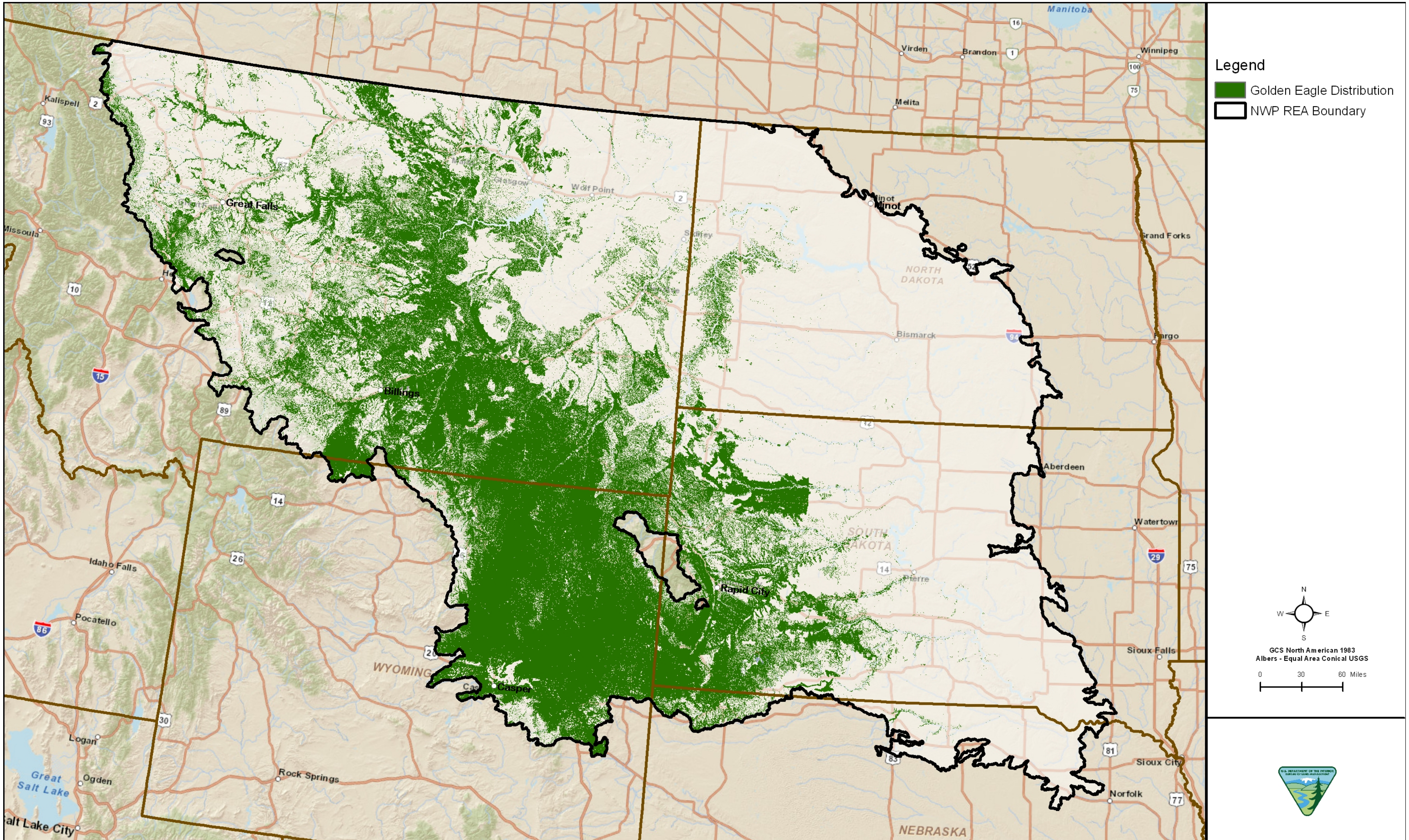

Figure E-3-4. Maxent Habitat Model for the Golden Eagle

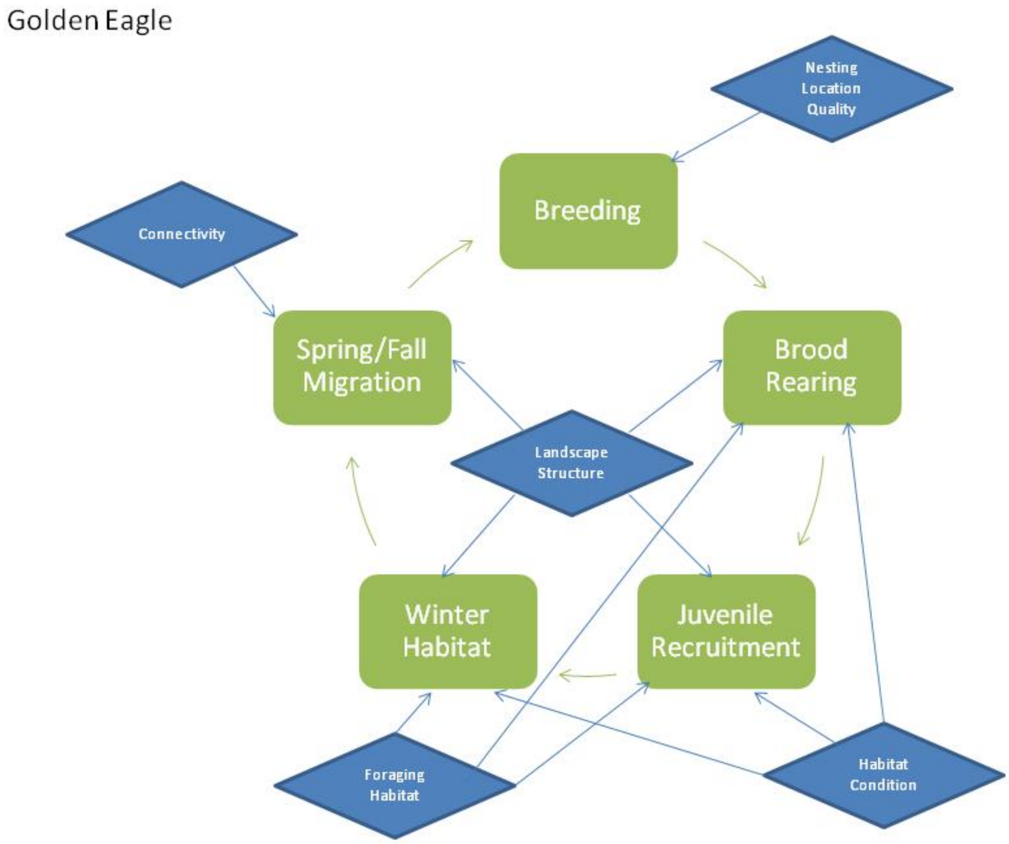

Figure E-3-5. Ecological Process Model for the Golden Eagle

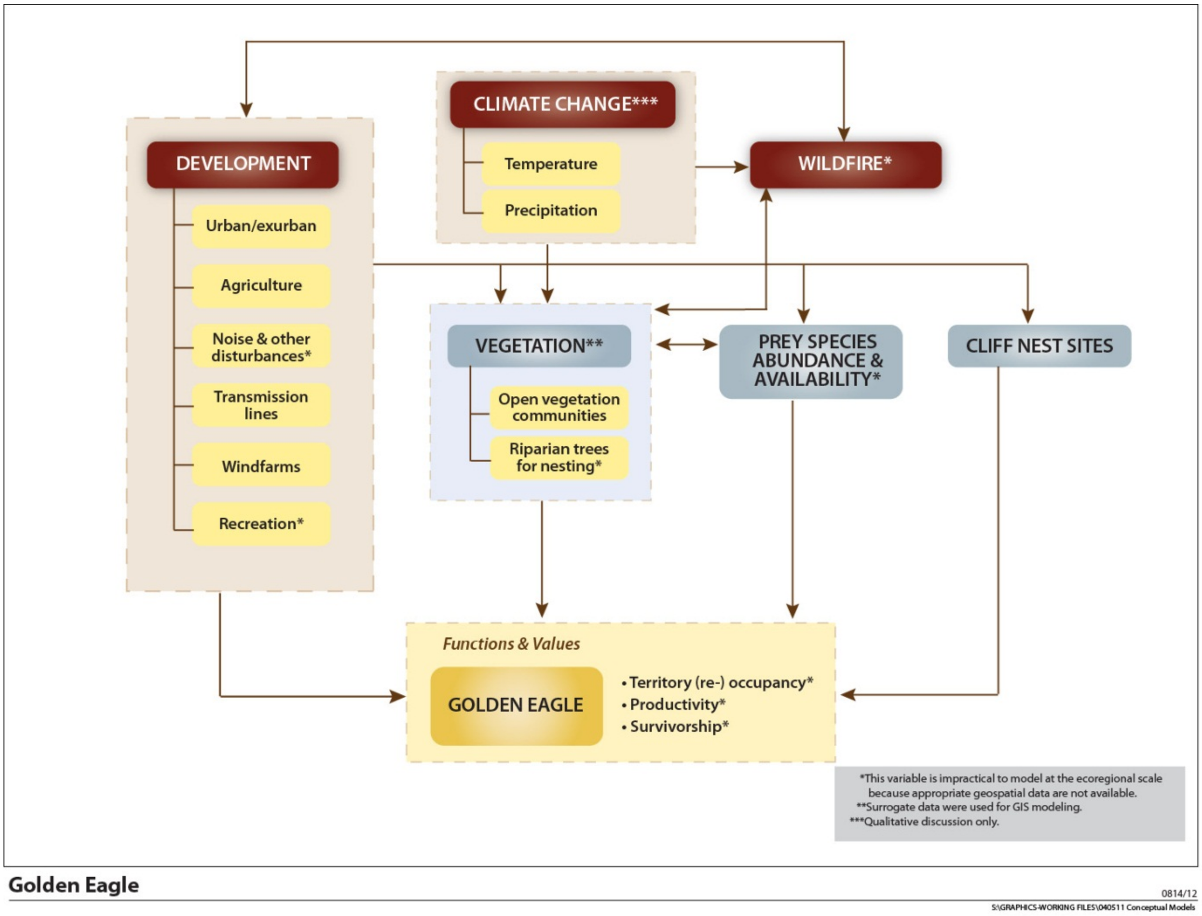

Figure E-3-6. System-Level Conceptual Model for the Golden Eagle

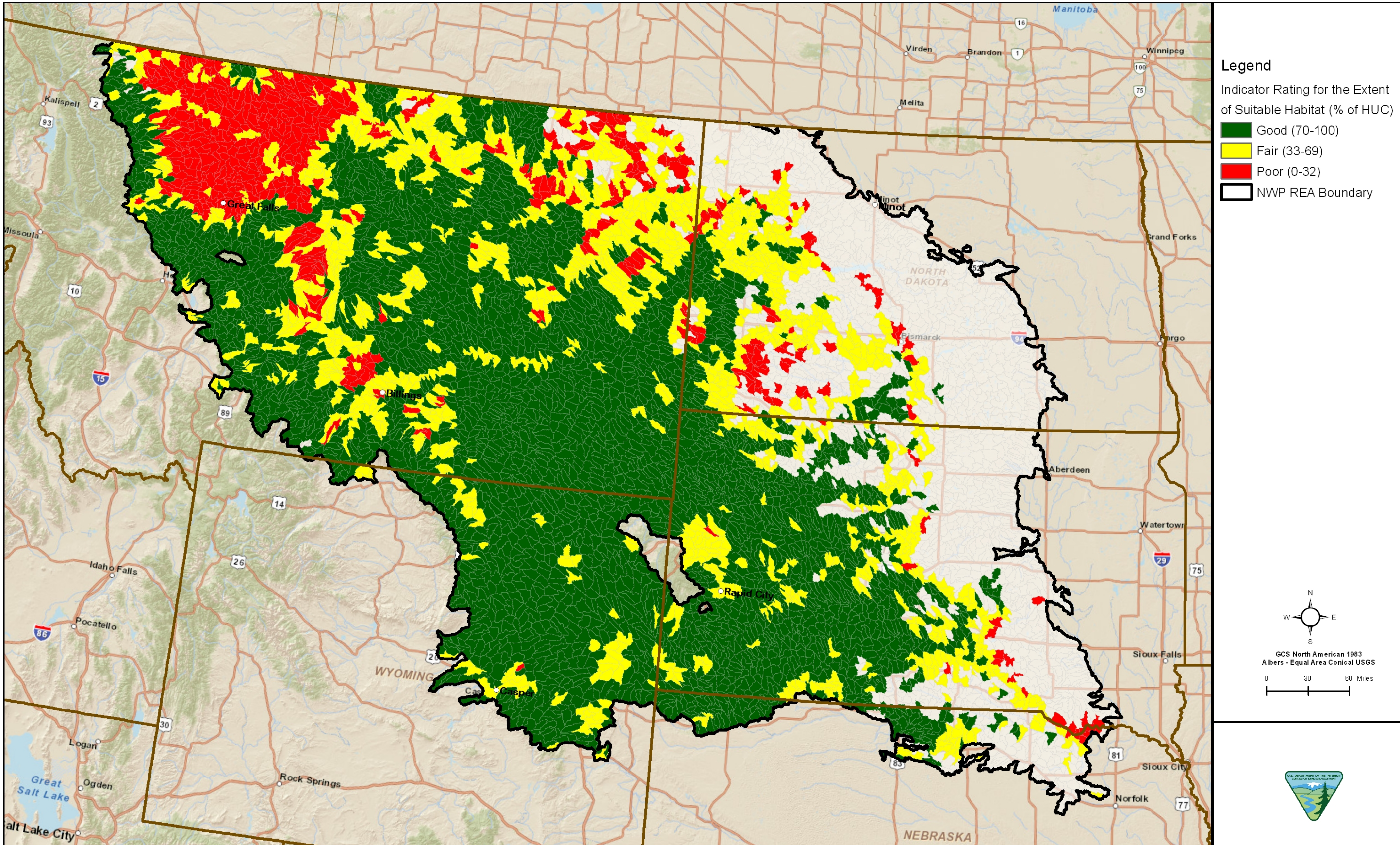

Figure E-3-7. Foraging Habitat of Golden Eagle in Northwestern Plains Ecoregion

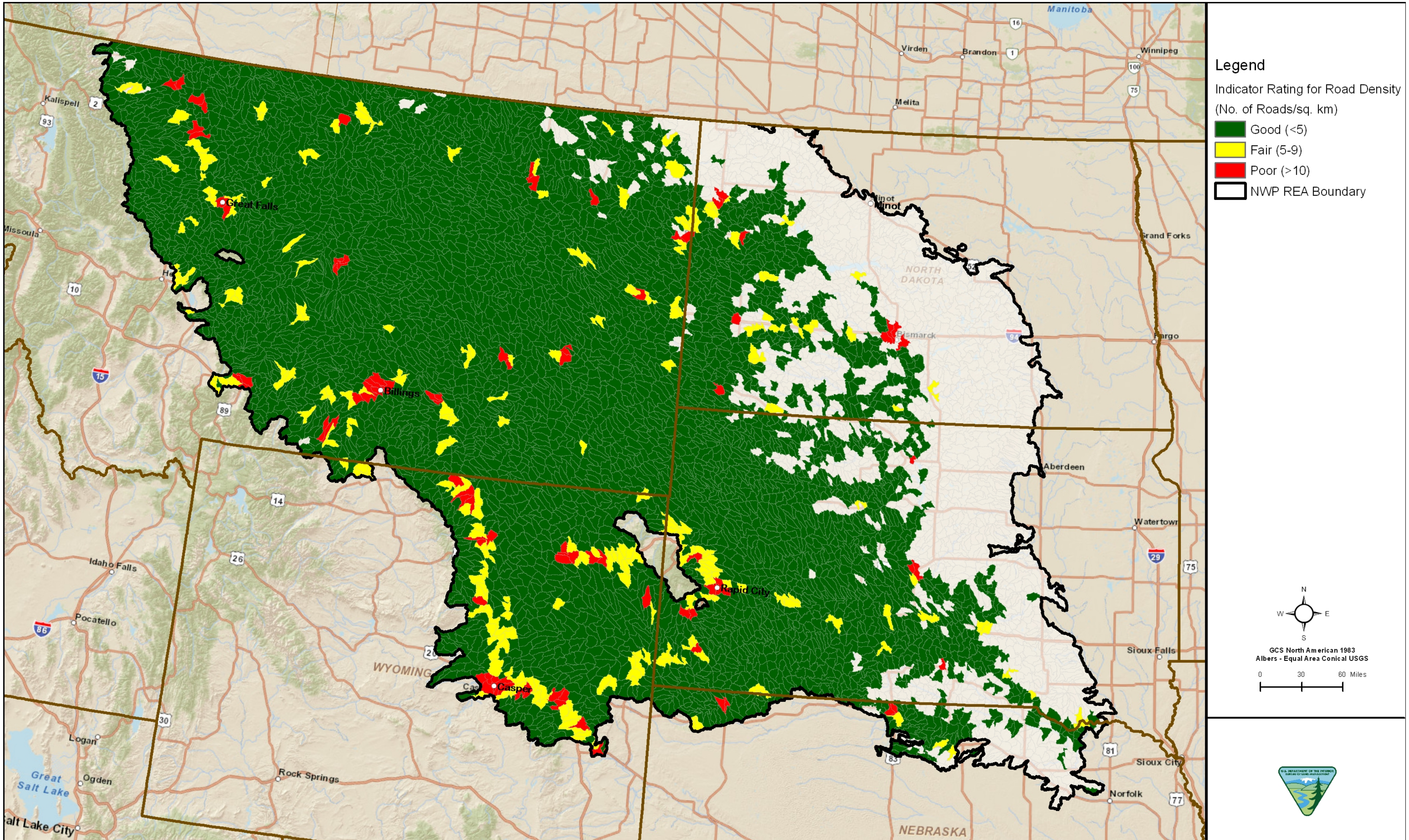

Figure E-3-8. Road Density

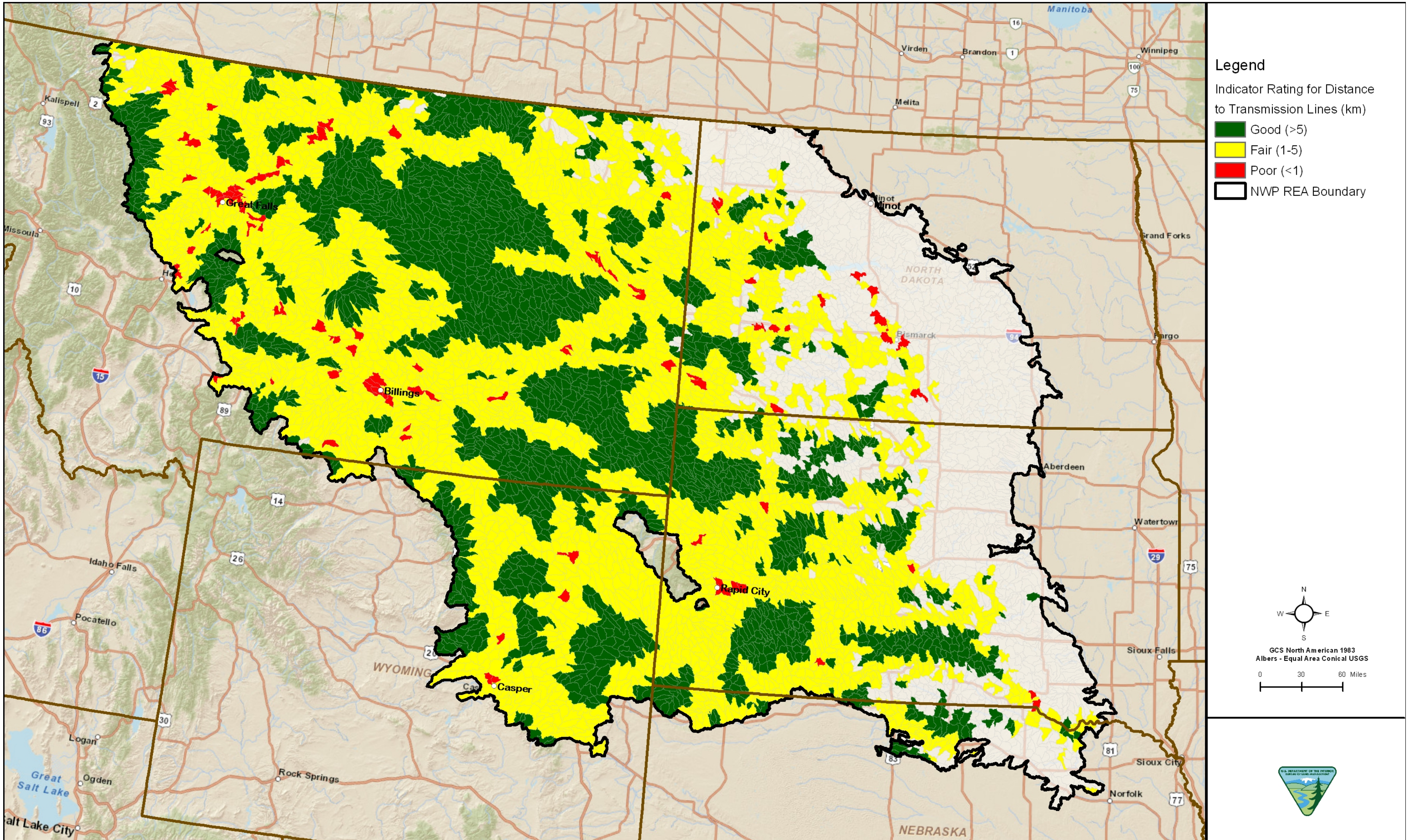

Figure E-3-9. Transmission Line Proximity

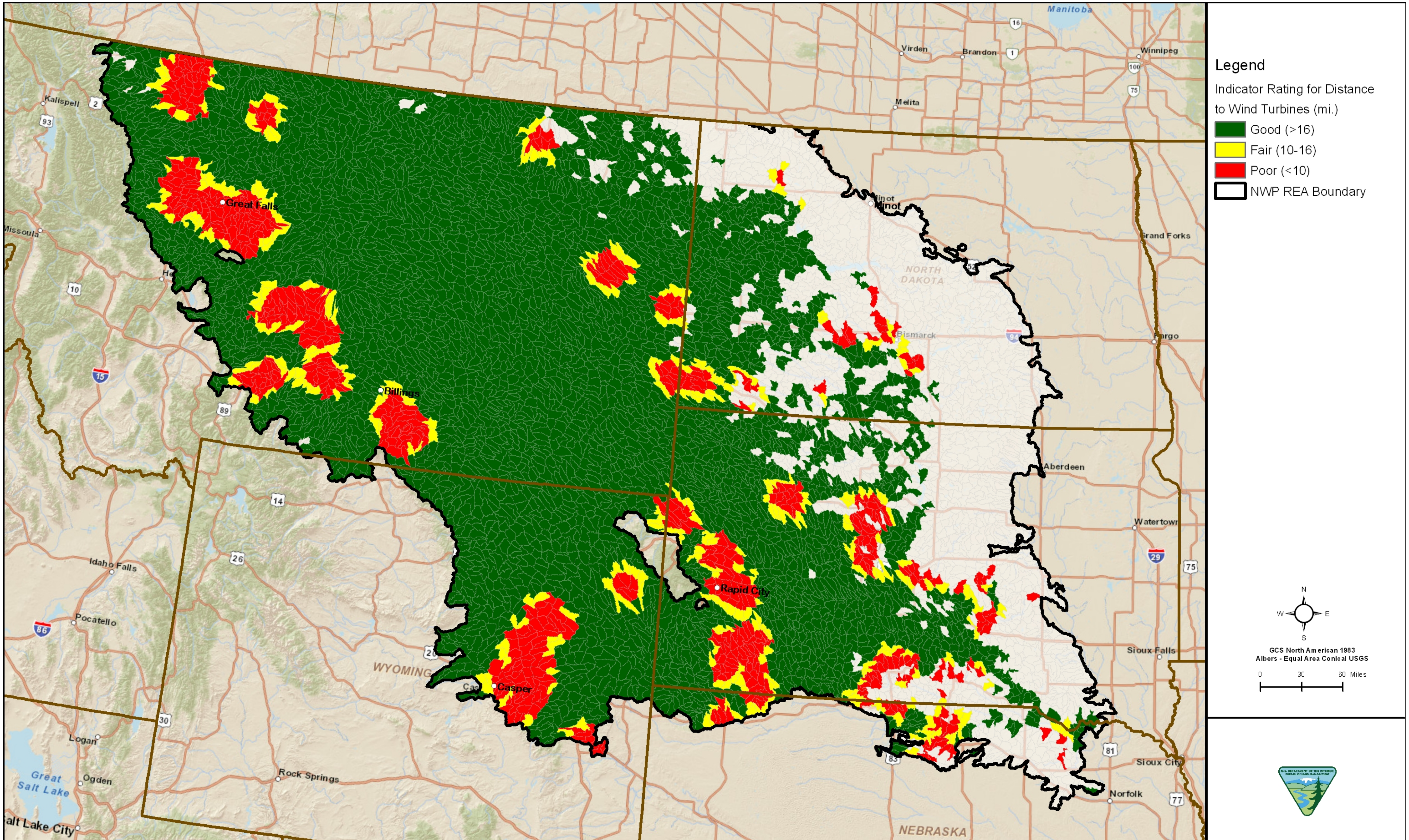

Figure E-3-10. Wind Turbine Proximity

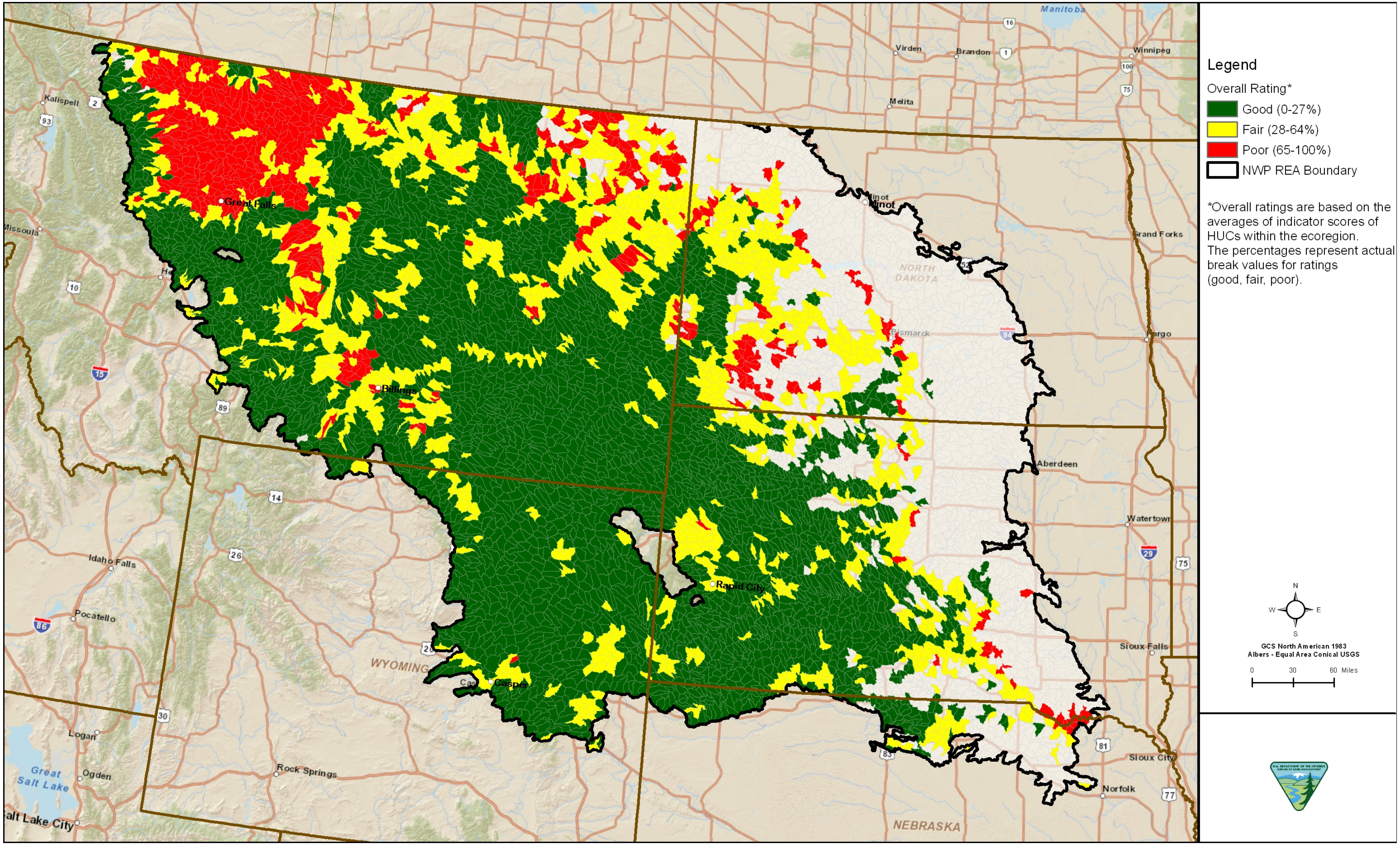

Figure E-3-11. Overall Current Status Score for the Golden Eagle Analysis