APPENDIX E-5

BIGHORN SHEEP CONSERVATION ELEMENT ANALYSIS FOR THE MIDDLE ROCKIES ECOREGION

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

During Phase 1 of this Rapid Ecoregional Assessment (REA), it was proposed that the Rocky Mountain bighorn sheep (*Ovis canadensis*) be included as part of an assemblage that would cover big game species (elk, mule deer, and bighorn sheep) of the Middle Rockies ecoregion. After evaluation of the species initially proposed for this assemblage and review of the different habitat requirements of each of these species, it was determined that bighorn sheep should be treated as a separate, single-species conservation element (CE). The Middle Rockies ecoregion is home to some of the largest populations of bighorn sheep throughout the west.

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 assemblage? and 2) what is happening to these areas? 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.

THIS PAGE INTENTIONALLY LEFT BLANK

2.0 CONSERVATION ELEMENT DESCRIPTION

Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) inhabit mountain ranges that tend to be relatively warm and arid during the summer, but experience cold, dry winters. Habitats include alpine and sub-alpine open grasslands and shrub-steppes. Sheep tend to avoid areas that have visual obstructions, such as trees or tall shrubs. They rely on the proximity of steep, rocky escape terrain, especially when lambs are young. During the lambing season, ewes select steep, inaccessible cliffs to give birth. Beyer (2008) reported that landscape ruggedness, aspect, and solar radiation index were important winter range habitat characteristics that affected population stability. Bighorn sheep within the ecoregion are common, but their recovery has been threatened by highways, habitat loss, and disease.

Seasonal migrations occur in most populations, and open grasslands and shrublands typically provide habitat for winter range. Snow and food dictate seasonal home ranges. Movement of up to 20 miles (32 kilometers [km]) between summer and winter ranges occur for Montana populations; although, if conditions permit, these sheep will live in the same area year-round (Foresman 2012). Annual precipitation on habitats ranges from about 8 to nearly 16 inches. Diets are diverse—depending on the population, diets can be dominated by grasses and sedges, browse, or forbs; forbs often contribute the greatest number of plant species eaten (Shackleton et al. 1999).

THIS PAGE INTENTIONALLY LEFT BLANK

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 winter, migration, and parturition habitat for the species was used. The goal was to obtain data to determine the current distribution and status of this species throughout the ecoregion for the critical periods. This species has been recorded in Idaho, Montana, Wyoming, and South Dakota.

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-5-1). Important datasets for bighorn sheep include the locations of crucial and severe winter range, parturition areas, and travel and migration corridors. Suitable bighorn sheep habitat models were acquired from Gap Analysis Program (GAP) and NatureServe for portions of the ecoregion (Table E-5-1). 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.

Table E-5-1. Data Sources for CE 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]
	Bighorn sheep Ranges	Western Association of Fish and Wildlife Agencies (WAFWA)	Polygon	Acquired	Yes
	WGA DSS Models	WGA Pilot Crucial Habitat	Raster	Future Dataset	No[1]
Crucial and Severe Winter Ranges	Crucial and Winter Range	ID, MT, WY, SD State Fish and Game Agencies		Aquired	No[2]
Parturition Areas	Parturition Areas	WAFWA, ID, MT, WY, SD State Fish and Game Agencies		Data Gap	No[1]
Travel Corridors	Travel Corridors	WAFWA; ID, MT, WY, SD State Fish and Game Agencies		Data Gap	No[1]
Migration Corridors	Migration Corridors	WAFWA; ID, MT, WY, SD State Fish and Game Agencies		Data Gap	No[1]

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

Because of the use of Western Association of Fish and Wildlife Agencies (WAFWA) dataset for the big game assemblage (mule deer and elk) for this REA, the Assessment Management Team (AMT) has recommended using the WAFWA bighorn sheep winter ranges dataset to develop distribution layers. The WAFWA bighorn range dataset was reviewed and found suitable for analysis at the ecoregion scale. The WAFWA winter, winter crucial, and yearlong range mapped habitat were combined to represent the winter range for bighorn sheep in the Middle Rockies. Figure E-5-1 presents the winter range distribution map, which was used to conduct the CA analyses.

THIS PAGE INTENTIONALLY LEFT BLANK

4.0 CONCEPTUAL MODELS

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 result from the CAs, and the availability of data.

4.1 ECOLOGICAL PROCESS MODEL

The ecological process model (Figure E-5-2) was developed to identify and link the key life cycle processes to specific ecological factors, or KEAs, that have the greatest potential to affect bighorn sheep habitat throughout the ecoregion. As noted in the species description, winter ranges within the ecoregion are critical habitat for the bighorn sheep. Forage quality and accessibility is a key factor in winter survival and parturition.

The model identifies the relationship between the bighorn sheep species and the ecological mechanisms that affect the species' future distribution through CAs. The key processes are identified in the model as green boxes, and, following Unnasch et al. (2009), three broad headings or categories of ecological attributes (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 landscape 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 were dependent on the data available.

4.2 SYSTEM-LEVEL MODEL

The system-level conceptual model (Figure E-5-3) 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, wildfire, and insect outbreak and disease, which are identified across the top of the figure in red. The important factors (or "drivers") affecting the abundance and distribution of bighorn sheep populations include those that impact survival, reproduction, distribution, density, and metapopulation structure. The preferred habitats are windswept grassy ridges above timberline with primarily southwestern aspects. The bighorn generally tend to avoid dense vegetation that obscures their visibility. Diseases transmitted by domestic livestock, the lack of connectivity and/or loss of genetic variability (fitness) due to habitat fragmentation, habitat loss, increased human disturbance, competition with domestic livestock, and predation on small, isolated herds are thought to be the major threats to this species (Beecham et al. 2007.)

4.2.1 Development

Human disturbance on critical winter and lambing ranges is known to adversely affect this species (Beecham et al. 2007). Roads can fragment bighorn habitat and cause effective barriers for sheep movement. Mineral exploration and extraction, road construction, harassment by low flying aircraft, and other human disturbances near lambing grounds have potential detrimental effects on Dall sheep (*Ovis dall*) populations (Nichols 1975; Hoefs and Barichello 1985; Poole and Graf 1985). Human development, especially in valley areas, may function to limit bighorn movements between occupied mountain ranges and may become a critical factor in determining their long-term conservation prospects. A commonly used minimum patch size for security habitat is 250 contiguous acres located more than 0.5 miles from an open road (Christensen et al. 1993; Leege 1984).

4.2.2 Climate Change

Climate change effects on big game species are primarily related to changes in (a) in vegetation communities, (b) fire regimes, (c) plant productivity, (d) water availability (in arid environments) and (e) the amount and persistence of snow pack affecting winter range. Rapid changes in climate have been documented to have adverse effects on bighorn sheep. Epps et al. (2004) investigated how climate change affected bighorn sheep in southern California and concluded that increased temperature and decreased precipitation in the late 1900s were important factors in bighorn sheep population extirpations in California.

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 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 cheat grass growth and the spread of other harmful invasive species, thereby converting sagebrush steppe into exotic annual grassland with less forage value. Furthermore, cheat grass 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

Wildfire threats to bighorn sheep are generally related to short-term loss of forage. Depending on fire severity and the size and timing of fires, bighorn sheep may need to migrate out of affected areas. However, within one to several vegetation periods, forage conditions are generally improved over pre-fire conditions; these effects may last for several years, depending on the vegetation community. Vegetation transitions across ecological thresholds following wildfires are often associated with loss of important habitat resources and functions for wildlife, such as foraging areas, parturition areas, or winter ranges. Thus, vegetation state and fire regime conditions are an important indicator of habitat stability for bighorn sheep.

Although wildfire can result in short-term loss of forage, fire suppression policies across the west have allowed forest succession and woody encroachment to interrupt bighorn migration corridors and encroach on their winter habitat to the extent that the carrying capacity in herd units is declining (Beecham et al. 2007). Fire suppression combined with invasive weed infestations, has negatively affected bighorn sheep habitat across the west. In some cases, prescribed fire is currently being used to restore bighorn sheep habitat.

4.2.5 Insect Outbreak and Disease

Bighorn sheep populations have experienced significant declines across their range as a result of diseases introduced from domestic livestock. They frequently experience die-offs due to pneumonia-causing *pasteurella haemolytica* (Foreyt 1989) transmitted by domestic sheep. Domestic sheep allotments in or near active bighorn sheep habitat are a major risk factor for this species. The risk of disease outbreaks resulting from contact with domestic sheep and goats is widely believed to be the most significant threat facing bighorn sheep (Beecham et al. 2007).

4.3 CHANGE AGENTS PROPOSED FOR ANALYSIS

Although numerous attributes and indicators affecting this species were initially identified in the early phases of this REA, not all are included in this analysis due to data limitations. The specific indicators that could not be modeled are identified with an asterisk on Figure E-5-3. Analyses for the invasive species and insect outbreak CAs are 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. Further information on the data gaps for indicators are discussed in the respective CA contained in Appendix C.

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

5.0 CHANGE AGENT ANALYSIS

A current status and future threat assessment for the bighorn sheep was conducted for the Middle Rockies 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, wildfire, and disease. 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 HUCs 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. 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.

5.1 CURRENT STATUS OF THE CONSERVATION ELEMENT

5.1.1 Key Ecological Attribute Selection

Table E-5-2 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 CAs. For example, encroachment by pinyon juniper stands (tree encroachment) was originally proposed as a habitat condition KEA, but the data did not support the spatial analysis requirements desired by the AMT. Instead, the horizontal visibility KEA was developed to address habitat condition.

Table E-5-2. Key Ecological Attributes Retained or Excluded

Category	Attribute	Explanation
1. Size	Minimum aggregate patch size of adequate habitat (Not necessarily contiguous but contains no barriers to movement)	Retained to show large patches of bighorn sheep habitat.
	Escape terrain (30-85% slope) (hectare [ha])	Retained to show areas that are important to bighorn sheep as escape terrain.
2. Condition	Horizontal visibility	Retained to show areas where bighorn sheep habitat is not currently affected by conifer encroachment.
	Tree encroachment (pinyon-juniper stands) meters from occupied habitat	Excluded because the data did not support the spatial analysis requirements.
	Fire regime Vegetation Condition Class (VCC)	Excluded because this KEA was not thought to be accurate in areas of bighorn sheep habitat.
3. Context	Distance to barriers (forest, highways, rivers) in meters from occupied habitat area	Retained to show barriers to bighorn sheep movement.
	Distance to development (human disturbance and human presence near critical sites)	Retained to show the anthropogenic impacts.
	Disease transmission via grazing domestic sheep	This KEA was added because the transmission of disease from domestic sheep was determined to be an important factor for bighorn sheep throughout the west.

The KEAs proposed to evaluate wildfire were excluded because the rolling review team (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 impacts of wildfire on this CE were not assessed for this REA.

Table E-5-3 identifies the KEAs, indicators, and metrics that were used to evaluate the CAs and pathways affecting this CE across the ecoregion (as illustrated in Figure E-5-3). Several indicators were used to assess the current status for bighorn sheep. The WAFWA bighorn sheep range layer was used for comparison against the size, condition, and landscape context indicators (e.g., patch size, horizontal visibility) incorporated into a GIS overlay analysis.

Table E-5-3. Bighorn Sheep Key Ecological Attributes, Indicators, and Metrics for Current Status Assessment for the Middle Rockies Ecoregion

Category	Ecological Attribute	Indicator / Unit of Measure	Metric			Data Source	Citation
			Poor = 3	Fair = 2	Good = 1		
Size	Connectivity & Context Cover Landscape Structure	Minimum aggregate patch size of adequate habitat (square kilometers [km^2])	<75 km^2	na	>75 km^2	GAP WAFWA	Hells Canyon Bighorn Restoration Committee 2004
	Escape	Escape terrain 30-85% slope (ha)	<1.6 ha	na	>1.6 ha	DEM	Hells Canyon Bighorn Restoration Committee 2004
Condition	Cover/Escape	Horizontal visibility	Forested habitat >15% of canopy closure, ag. and urban /exurban habitat	Shrubland with > 1m vegetation height, forest with 10-15% canopy closure	Upland grasslands, altered grasslands, mountain mahogany, bitterbrush, shadscale, exposed rock, barren areas, snow fields, all forest cover types with <10% canopy cover	GAP, National Land Cover Data (NLCD), LANDFIRE	Hells Canyon Bighorn Restoration Committee 2004
Landscape Context	Connectivity & Context	Distance to barriers (forest, highways, rivers) from occupied habitat area (m)	<400 m	400 – 1500 m	>1500 m	GAP Linear Feature National Hydrography Dataset (NHD)	Papouchis et al. 2001
	Connectivity & Context/ Landscape Structure	Distance to development (human disturbance and human presence near critical sites)	<400 m	400 – 1500 m	>1500 m	GAP, Topologically Integrated Geographic Encoding and Referencing (TIGER), Human Footprint	Papouchis et al. 2001
		Disease transmission via grazing domestic sheep herds (km)	<23 km	23 – 50 km	>50 km	Bureau of Land Management (BLM) domestic sheep allotment	Singer et al. 2001

na = no metric value available

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 RRT comprised of Bureau of Land Management BLM wildlife biologists and state level experts. The RRT met periodically to contribute information and to analyze input attributes and outputs 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

The minimum aggregate patch size of adequate habitat is not necessarily contiguous, but it contains no barriers to sheep movement.

The winter range for bighorn sheep in the Middle Rockies (Figure E-5-1) was used to assess patch size. The habitat patch layer was reclassified based on the patch acreage ranges and metric values between 1 and 3, as noted in Table E-5-3. 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 minimum aggregate patch size layer output is presented on Figure E-5-4.

5.1.1.2 Escape Terrain

Escape terrain for bighorn sheep was defined as habitat patches that occurred on slopes between 30 and 85 percent. Elevation data were retrieved from the U.S. Geological Survey (USGS) National Elevation Dataset (NED) website, and slopes that fell within the defined elevation range were extracted. The bighorn sheep seasonal range habitat dataset was then intersected with the extracted slope data to isolate patches that met the required slope criteria. Area calculations were completed and the data were assigned scores based on the grading criteria (as presented in Table E-5-3). This layer was converted to raster with assigned grade 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 escape terrain layer is presented on Figure E-5-5.

5.1.1.3 Horizontal Visibility

Habitat patches were assessed and graded on the basis of horizontal visibility. Many bighorn habitat studies or habitat suitability models have highlighted horizontal visibility as a key determinant of bighorn habitat. Horizontal visibility allows bighorn sheep to sight predators at a safe distance and influences how far bighorns are willing to stray from escape terrain.

Three datasets were required to support the analysis, including LANDFIRE canopy cover, GAP landcover data, and LANDFIRE existing vegetation height (EVH). To assess habitat that would qualify as having good horizontal visibility, landcover types were extracted from the GAP landcover dataset. These landcover types included upland grasslands, altered grasslands, mountain mahogany, bitterbrush, shadscale, exposed rock barren areas, snow fields, and all forest cover types. Forested types were further limited to those regions that had less than 10 percent canopy cover by using the LANDFIRE canopy cover dataset to identify the appropriate canopy cover conditions. All selected areas were further constrained to only these areas located within the bighorn sheep habitat range.

Habitats qualifying as having fair horizontal visibility were lands composed of shrublands with greater than 1 meter (m) vegetation height and all forest cover types that had 10-15 percent canopy cover. The GAP landcover dataset was used to identify these shrublands and forested lands. The shrubland cover types were limited to areas of shrublands that exceeded 1 m in height. This was accomplished by the overlay of both the selected shrubland portions of the GAP vegetation cover and LANDFIRE's existing vegetation height datasets. Forested types were limited to those regions that had 10-15 percent canopy cover by using the LANDFIRE canopy cover dataset to identify the appropriate cover conditions.

Finally, to delineate habitat areas considered to have poor horizontal visibility, forested areas with greater than 15 percent of canopy cover or areas mapped as agriculture or urban/exurban were delineated.

Each group of habitat described above was graded, based on the valuation documented in Table E-5-3, and were then combined into one raster. Zonal statistics were applied to the raster output and summarized on a watershed basis using HUC 12 identifiers. The horizontal visibility layer is presented on Figure E-5-6.

5.1.1.4 Distance to Barriers

Barriers were characterized as the minimum distance from forested regions, highways, and perennial rivers. Forested regions were extracted from GAP landcover data by isolating pixels that were classed as forest. Only forested regions having canopy cover of >80 percent were selected by using the LANDFIRE canopy cover dataset. Topologically Integrated Geographic Encoding and Referencing (TIGER) road data were used to identify roads that were classified as highways. Finally, the USGS National Hydrography Dataset (NHD) was used to extract perennial stream features. Proximity analyses were applied to all development datasets, outputs were combined, constrained to the bighorn sheep range boundaries, and then graded based on the distance criteria presented in Table E-5-2. Summary zonal statistics were applied to the graded data to generate a rating for each watershed included within the HUC 12 watershed boundary dataset. The distance to barriers layer is presented on Figure E-5-7.

5.1.1.5 Distance to Development

Human disturbance and presence was represented by trails, roads, highways, and urbanized regions. TIGER road data were used to identify trail, road, and highway features. Trails captured within the TIGER dataset represent trail features that support vehicular traffic. Urban areas were extracted from the GAP landcover dataset by isolating pixels which represented urban uses. Proximity analyses were applied to all development datasets, outputs were combined, constrained to the bighorn sheep range boundaries, and then graded based on the distance criteria presented in Table E-5-3. Summary zonal statistics were applied to the graded data to generate a rating for each watershed included within the HUC 12 watershed boundary dataset. The human disturbance and presence near critical areas layer is presented on Figure E-5-8.

5.1.1.6 Disease Transmission via Domestic Herds

The risk of disease transmitted by domestic sheep herd grazing was based on a proximity analysis of BLM domestic sheep grazing pasture allotments in relation to bighorn sheep-occupied habitat. BLM grazing pasture allotment datasets were used to identify domestic sheep grazing pasture locations. Proximity analyses were conducted based on the distances defined in Table E-5-3. The buffered areas were then intersected with the bighorn sheep range dataset and scored. Summary zonal statistics were applied to the graded data to generate a rating for each watershed included within the HUC 12 watershed boundary dataset. The disease transmission layer is presented on Figure E-5-9.

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 bighorn sheep habitat for each HUC across this ecoregion. To generate overall scores for each watershed, all scored criteria were additively combined. Each watershed has the potential of receiving a maximum score of 121 points (i.e., 7 indicators assessed, each having a grading system of 1 to 3). The summed scores were then divided by a factor of 15 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. A higher overall status score would result in a rating of poor for the HUC, indicating that there are existing CA stressors on the CE habitat based on the KEA metrics. The results of the current status analysis for the ecoregion are presented on Figure E-5-10.

The habitat patch size (Figure E-5-4) and escape terrain (Figure E-5-5) indicates that general habitat features are good within most of the winter range. However, the bighorn sheep winter range is threatened by poor horizontal visibility (Figure E-5-6) and barriers throughout most of the range (Figure E-5-7). The barriers are mostly related to the presence of forested cover (of >80%), since the distance to development (of which both datasets include roads) is rated as good. The populations of bighorn sheep that may be at greatest risk to disease transmission within the ecoregion are located in eastern Idaho (Figure E-5-9). Based on the KEA analysis, there are two large contiguous patches of bighorn sheep range in the ecoregion in which the current habitat status is rated as good (Figure E-5-10). In contrast, many smaller, discontinuous patches occur within the northwest portion of the ecoregion in which habitat conditions are rated as fair.

A summary of the current status ratings based on bighorn sheep distribution is provided in Table E-5-4. 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 miles per HUC that were rated as good, fair, or poor. The result of the current status assessment indicates that approximately one-third (32.2 percent) of the 6th level HUC watersheds that intersect the distribution layer for the bighorn sheep were rated as good. The majority (42.6 percent) of the watersheds was rated as fair, while 25.2 percent of the land area was rated as poor.

Table E-5-4. Summary of Current Status Ratings for Bighorn Sheep

Overall Rating by 6th Level HUC	Total Square Miles[a]	Percentage of Total Square Miles[a, b]
Good	9,590	32.2
Fair	12,690	42.6
Poor	7,523	25.2

[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-5-3) 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 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 bighorn sheep.

5.2.1 Development Change Agent

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

Bighorn sheep habitat does not appear to be at risk from future agricultural development (Figure C-1-1), and potential urban growth (Figure C-1-8). The primary potential risk to the bighorn sheep are most notably from oil and gas development in the southern portion of the ecoregion (Figures C-1-3 and C-1-4).

5.2.2 Climate Change

The climate CA layer was created through the results of the 2025 and 2060 USGS climate change models. These models illustrate the predicted changes in climate over time. Climate change was modeled based on a 15-km grid created for regional analysis. This analysis included a comparison of current climate patterns to future modeled climate patterns and resulted in the delta (change) output figures. Further details regarding the climate change analysis is 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 bighorn sheep in this ecoregion. Increases in populations or ranges of bighorn sheep within the region will depend on forage availability and quality, with a likely increase competition for available resources.

The NatureServe Climate Change Vulnerability Index (NSCCVI) tool was utilized to assess bighorn sheep 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/presumed stable**.** The NSCCVI tool indicated that available evidence does not suggest that abundance and/or range extent of this species within the geographical area assessed will change (increase/decrease) substantially by 2050. The assessment rating was largely based on a majority of neutral scores calculated when assessing factors that influence vulnerability, such as distribution to barriers, dispersal and movements, sensitivity to temperature and moisture changes (historical thermal/hydrological niche), and reliance on interspecific interactions to generate habitat.

6.0 MANAGEMENT QUESTIONS

The relevant MQs for the bighorn sheep CE 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. Several examples of how the REA can be used to answer MQs (as noted in Appendix A) are provided below; these examples demonstrate the functionality of the REA and provide an opportunity to discuss 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 winter range habitat model presented on Figure E-5-1, along with the analysis of habitat patch size (Figure E-5-4), can be used to define regionally significant bighorn habitat. Among these areas, an enhanced definition of the significance of the areas can be determined by using the overall current status figure (Figure E-5-9) based on relative threats.

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. Occurrence data for the species was not available across the ecoregion to assess concentrations centers.

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 primary future threats to the bighorn winter range are most notably from potential oil and gas development in the mid-south region (Figures C-1-3 and C-1-4).

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

There are two large contiguous patches of bighorn sheep range in the ecoregion in which the current habitat status is rated as good (Figure E-5-10). In contrast, many smaller, discontinuous patches occur within the northwest portion of the ecoregion in which habitat conditions are rated as fair.

THIS PAGE INTENTIONALLY LEFT BLANK

7.0 REFERENCES

Beecham, J.J. Jr., C.P. Collins, and T.D. Reynolds. (2007, February 12). Rocky Mountain Bighorn Sheep (*Ovis canadensis*): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/rockymountain bighornsheep.pdf. Accessed June 24, 2012

Beyer, A.C. 2008. Habitat Comparisons Of Historically Stable And Less Stable Bighorn Sheep Populations. M.S. thesis, Montana State University Bozeman, Montana

Christensen, A., L.J. Lyon, and J.W. Unsworth. 1993. Elk management in the Northern Region: considerations in forest plan updates or revisions. U.S. Department of Agriculture, Forest Service, General Technical Report INT-303, Ogden, Utah.

Epps C.W., McCullough D.R., Wehausen J.D., Bleich V.C., Rechel J.L. (2004) Effects of climate change on population persistence of desert-dwelling mountain sheep in California. Conservation Biology,18, 102–113.

Etchberger, R.C., P.R. Krausman, and R. Mazaika. 1989. Mountain sheep habitat characteristics in the Pusch Ridge Wilderness, Arizona. Journal of Wildlife Management 53:902-907.

Foreyt, W.J. 1989. Fatal Pasteurella haemolytica pneumonia in bighorn sheep after direct contact with clinically normal domestic sheep. Am. J. Vet. Res. 50:341-344.

Foresman, Kerry B. 2012. Mammals of Montana. Mountain Press Publishing Company; Second edition, July 25.

Hebblewhite, M. 2008. A literature review of the effects of energy development on ungulates: Implications for central and eastern Montana. Report prepared for Montana Fish, Wildlife and Parks, Miles City, MT.

Hells Canyon Bighorn Sheep Restoration Committee. 2004. The Hells Canyon Initiative: Hells Canyon bighorn sheep restoration plan. Idaho Department of Fish and Game, Lewiston, USA.

Hoefs, M. and N. Barichello. 1985. Distribution, abundance, and management of wild sheep in Yukon. Pages 16-34 *in* M. Hoefs, editor. Wild Sheep: Distribution, abundance, and management and conservation of the sheep of the world and closely related mountain ungulates. Special Report: Northern Wild Sheep and Goat Council. Whitehorse, Yukon, Canada.

Leege, T.A. 1984. Guidelines for evaluating and managing summer elk habitat in northern Idaho. Idaho Department of Fish and Game, Wildlife Bulletin Number 11, Boise.

National Wildlife Foundation 2012. Global Warming Effects on Wildlife and Habitat. http://www.nwf.org/Global-Warming/Effects-on-Wildlife-and-Habitat/Sagebrush-Steppe.aspx. Accessed on June 29.

Nichols, L. 1975. Report from Alaska. Pages 8-13 *in* J.B. Trefethan, editor. The wild sheep in North America. The Boone and Crockett Club and Winchester Press, New York, NY.

Noss, R.F. , and A.Y. Cooperrider. 1994. *Saving Nature's Legacy: Protecting and Restoring Biodiversity*. Defenders of Wildlife and Island Press, Washington, D.C.

Papouchis, C.M., F.J. Singer, and W.B. Sloan. 2001. Responses of desert bighorn sheep to increased human recreation. Journal of Wildlife Management 65(3):573-582.

Phillips, Steven. (2010) *Species' Distribution Modeling for Conservation Educators and Practitioners*. Exercise. American Museum of Natural History, Lessons in Conservation. Available at http://ncep.amnh.org/linc.

Poole, K.G. and R.P. Graf. 1985. Status of Dall's sheep in the Northwest Territories, Canada. Pages 35-42 in M. Hoefs, editor. Wild Sheep: Distribution, abundance, management and conservation of the sheep of the world and closely related mountain ungulates. Special report. North American Wild Sheep and Goat Council. Whitehorse, Yukon, Canada

Shackleton, D.M., C.C. Shank, and B.M. Wikeem. 1999. Natural history of Rocky Mountain and California bighorn sheep. In: R. Valdez and P. R. Krausman, [EDS.]. Mountain sheep of North America. Tucson, AZ, USA: University of Arizona Press. p. 78-138.

Singer, F.J., L.C. Zeigenfuss, and L. Spicer 2001. Role of Patch Size, Disease, and Movement in Rapid Extinction of Bighorn Sheep. Conservation Biology (15): 1347-1354

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.

WAFWA 2010. Conservation Actions to Benefit Mule Deer Affected by Energy Development. Mule Deer Working Group, Western Association of Fish and Wildlife Agencies.

Wakelyn, L.A. 1987. Changing habitat conditions on bighorn sheep ranges in Colorado. Journal of Wildlife Management 51 :904-912.

APPENDIX E-5

FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

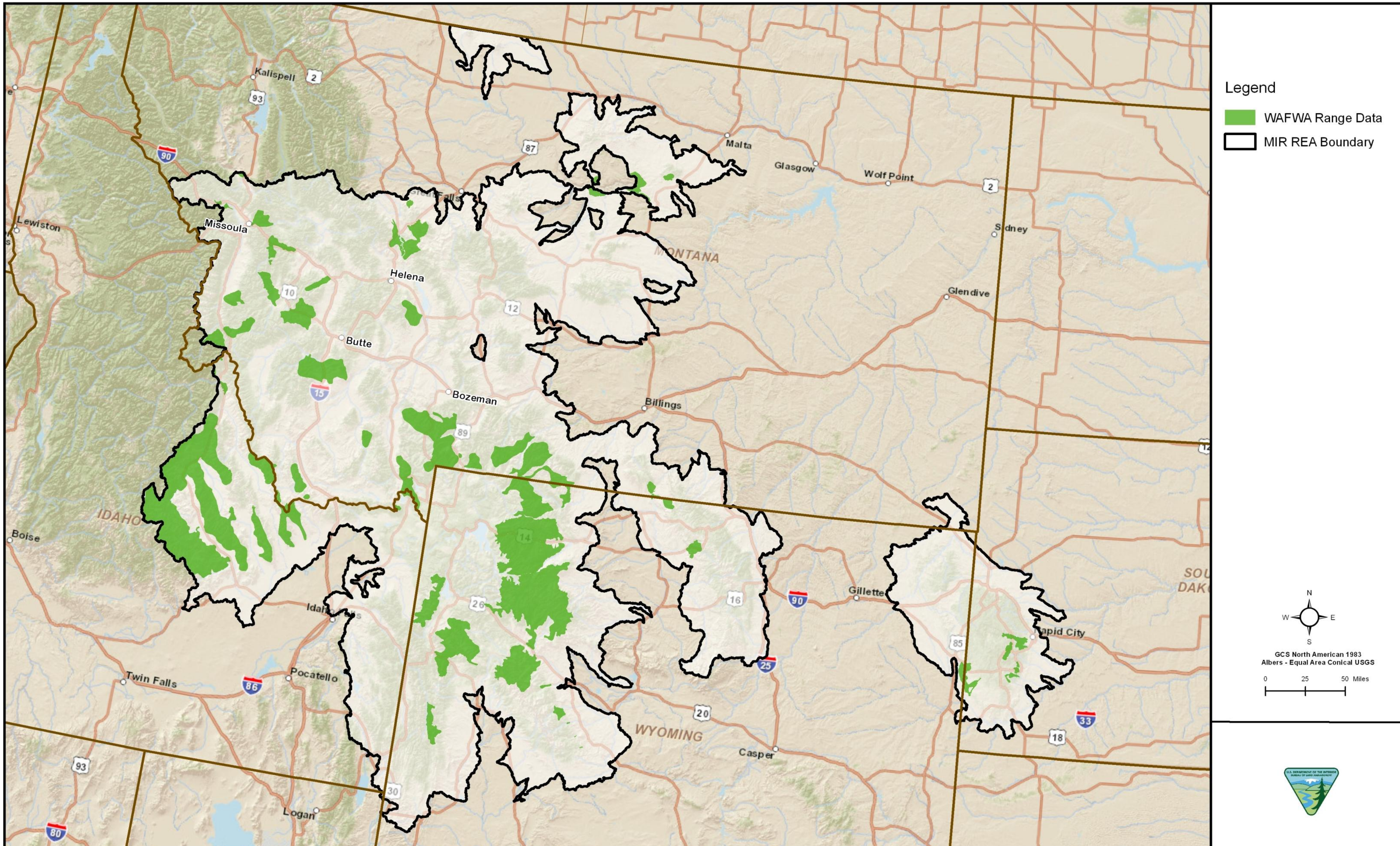

Figure E-5-1. Winter Range Distribution Map for the Bighorn Sheep

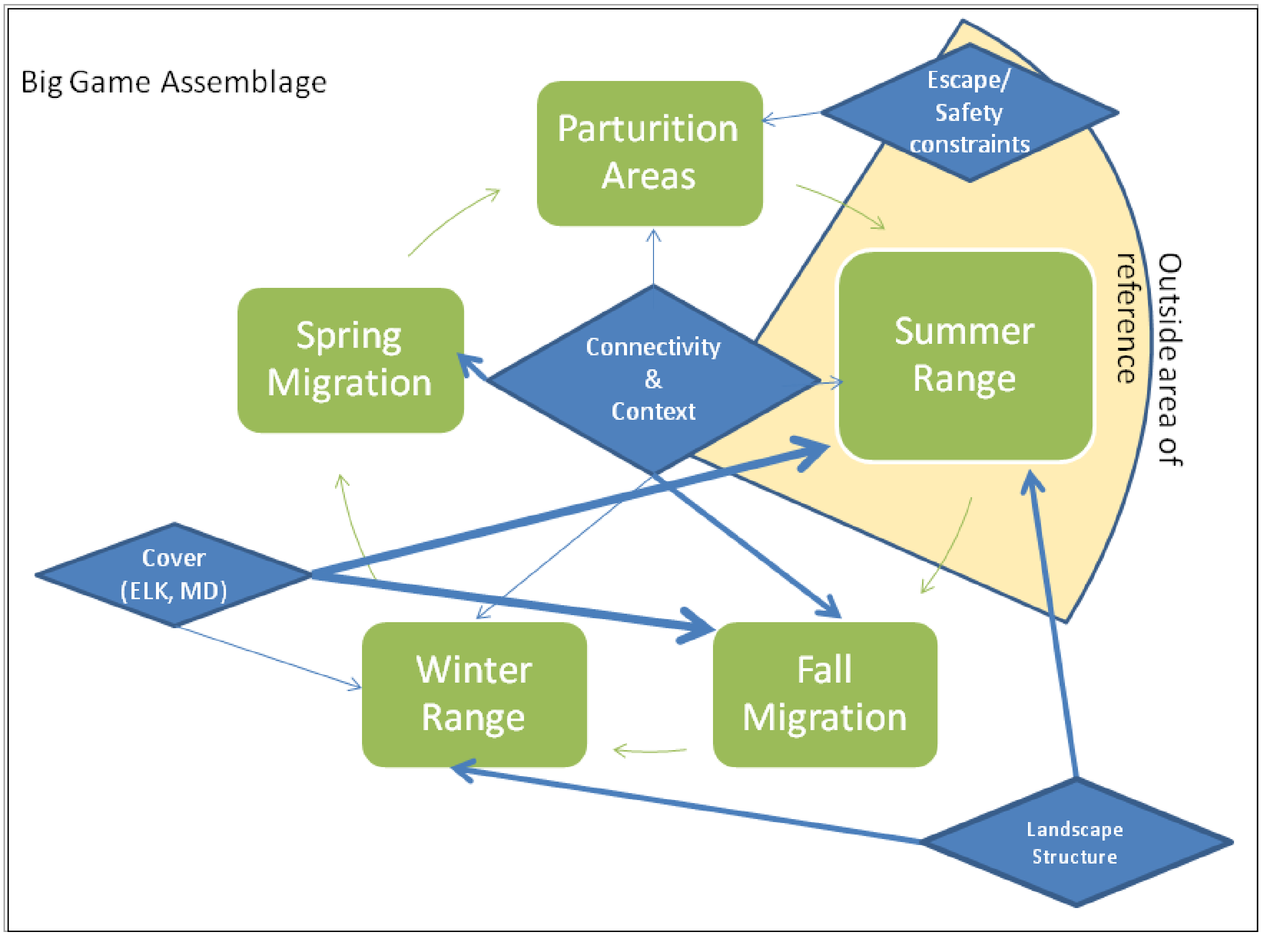

Figure E-5-2. Ecological Process Model for the Bighorn Sheep

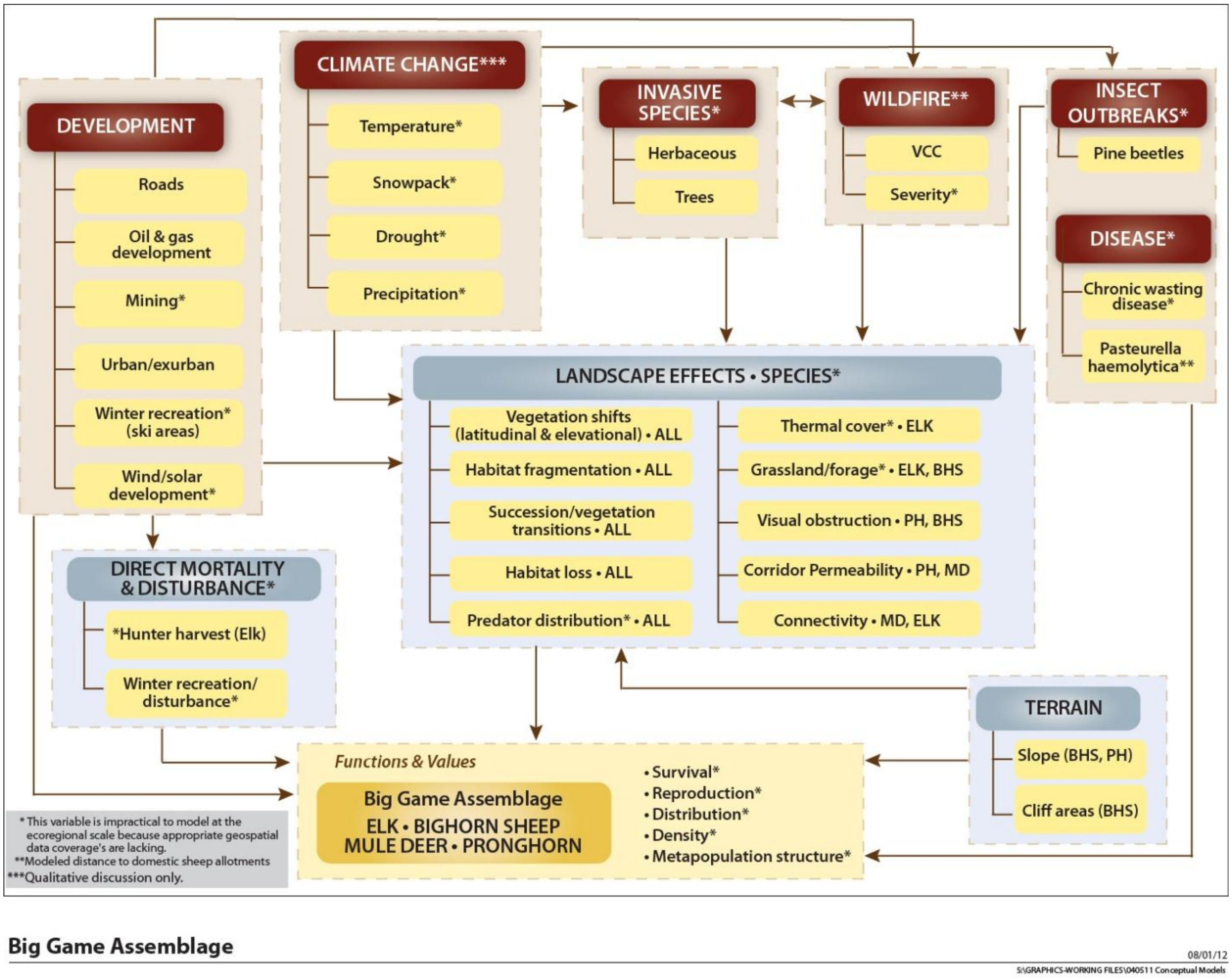

Figure E-5-3. System-Level Conceptual Model for the Bighorn Sheep

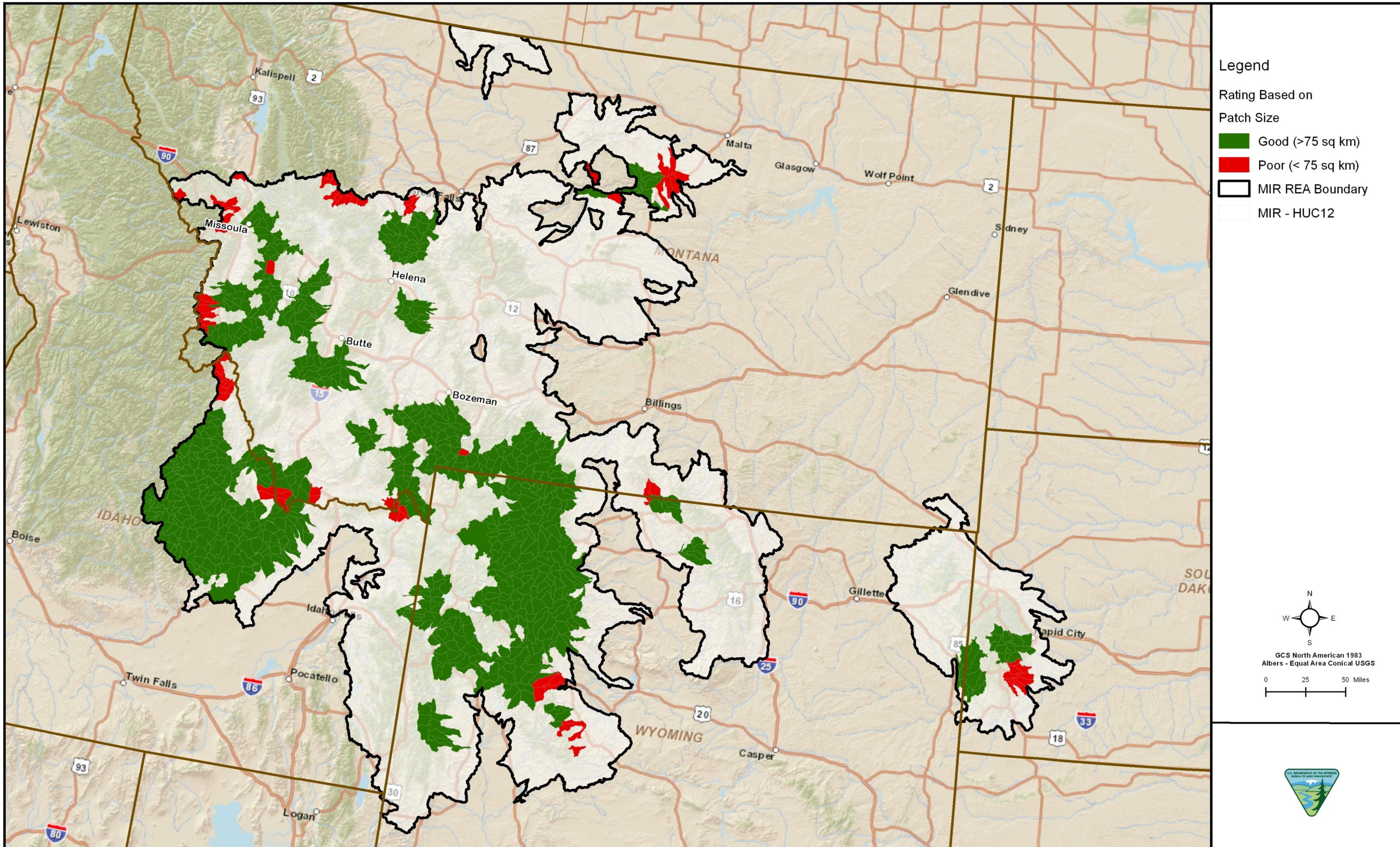

Figure E-5-4. Patch Size based on Winter Ranges for the Bighorn Sheep

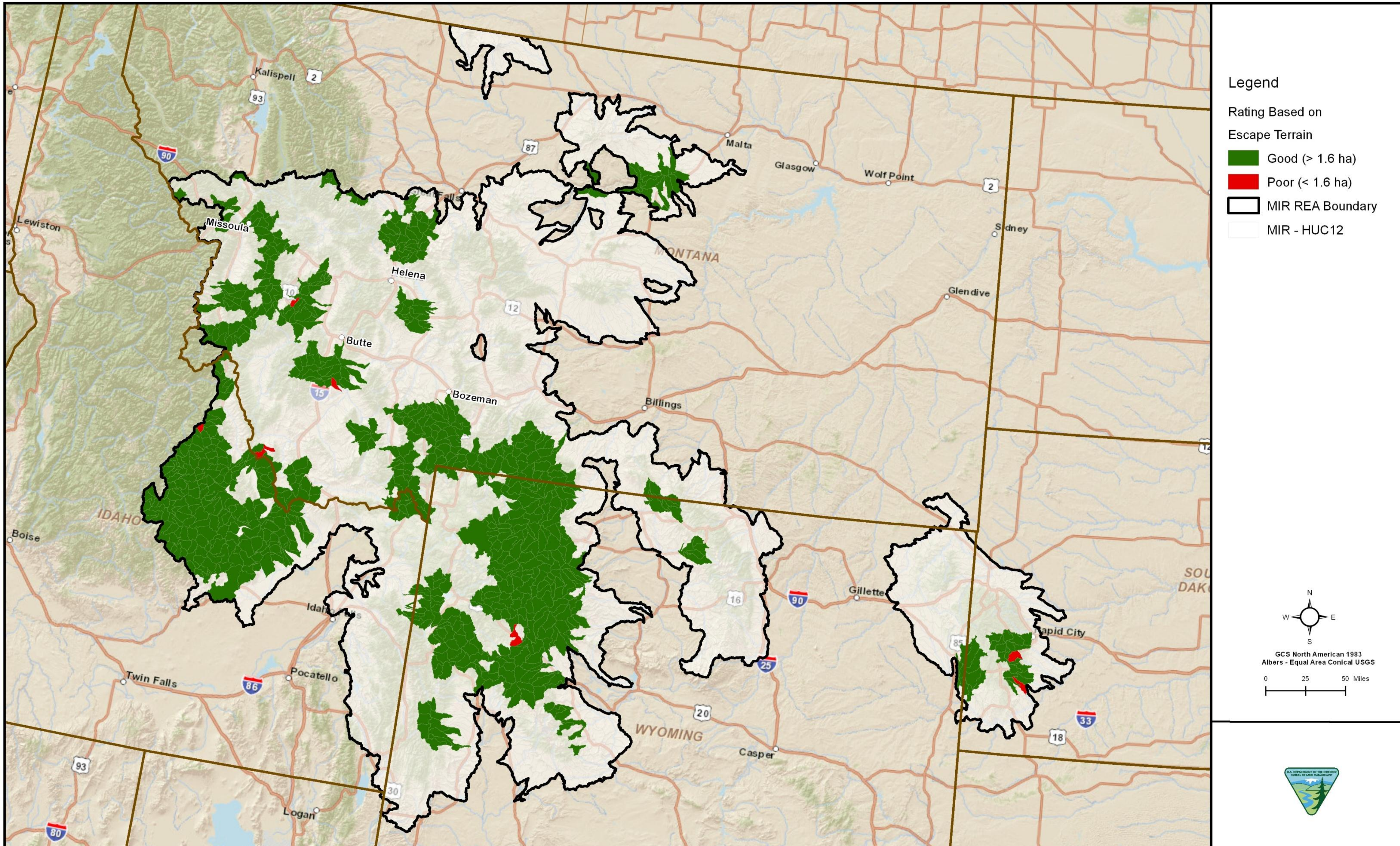

Figure E-5-5. Escape Terrain Habitat (30 to 85% Slope)

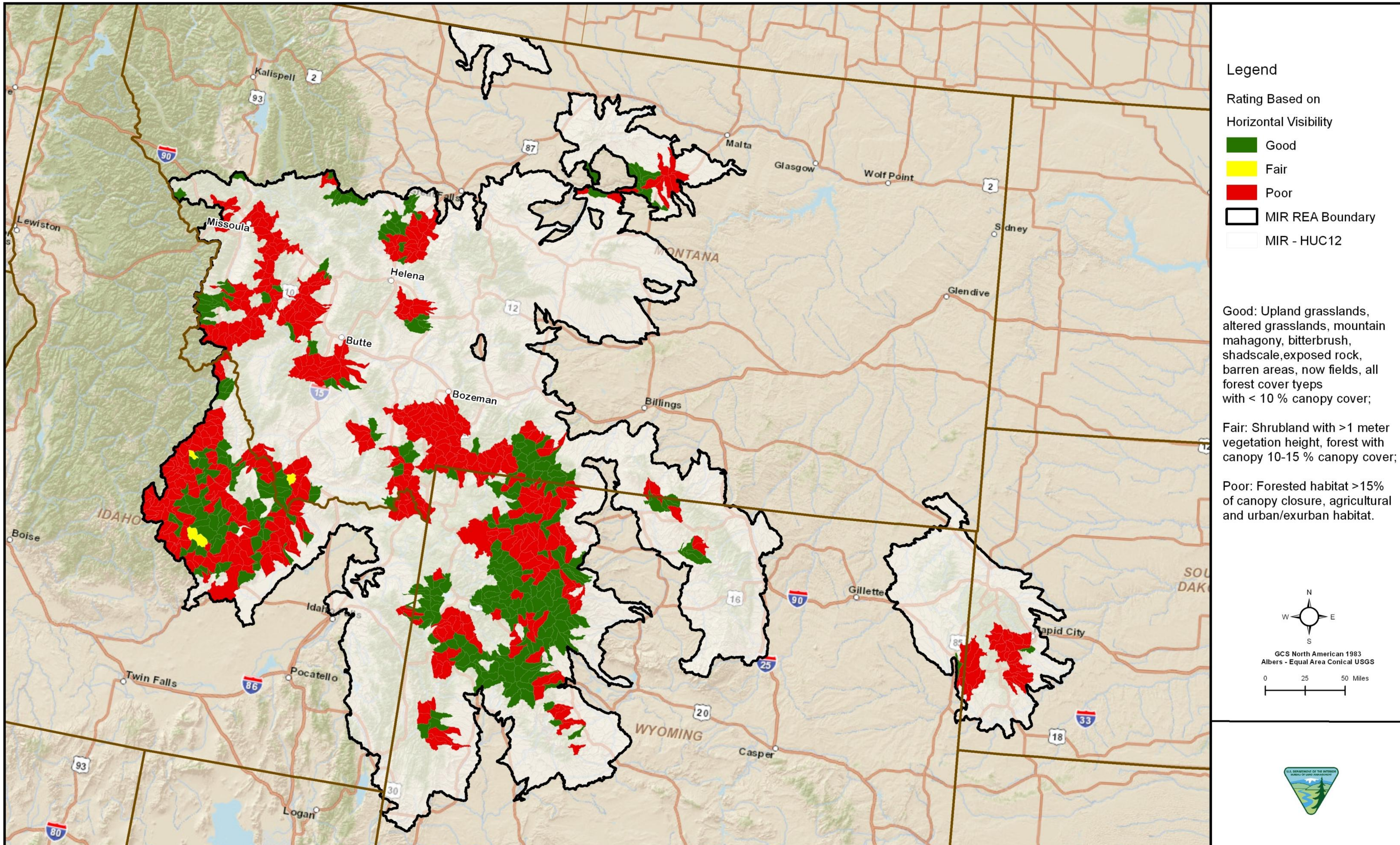

Figure E-5-6. Horizontal Visibility

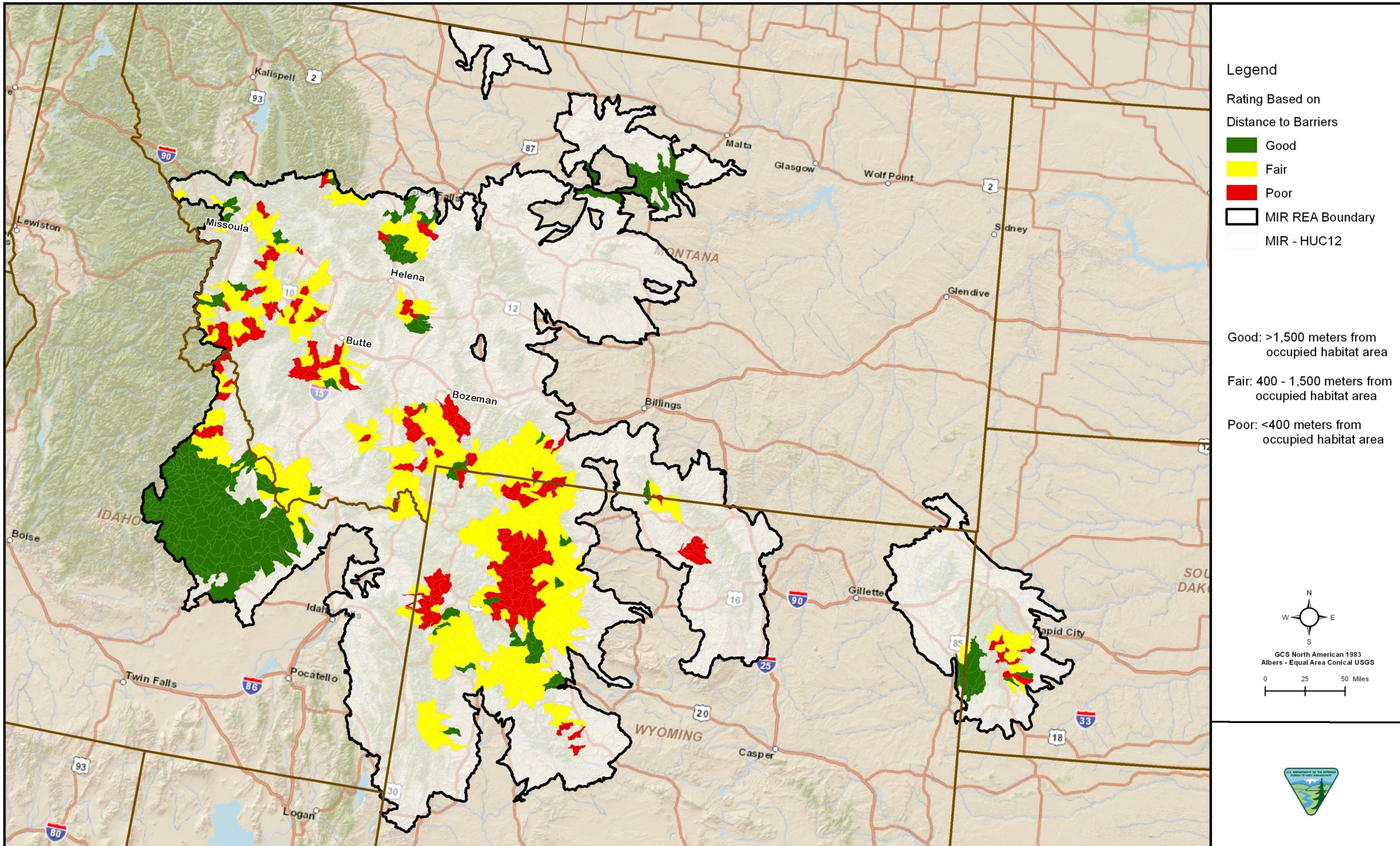

Figure E-5-7. Distance to Barriers to Bighorn Sheep

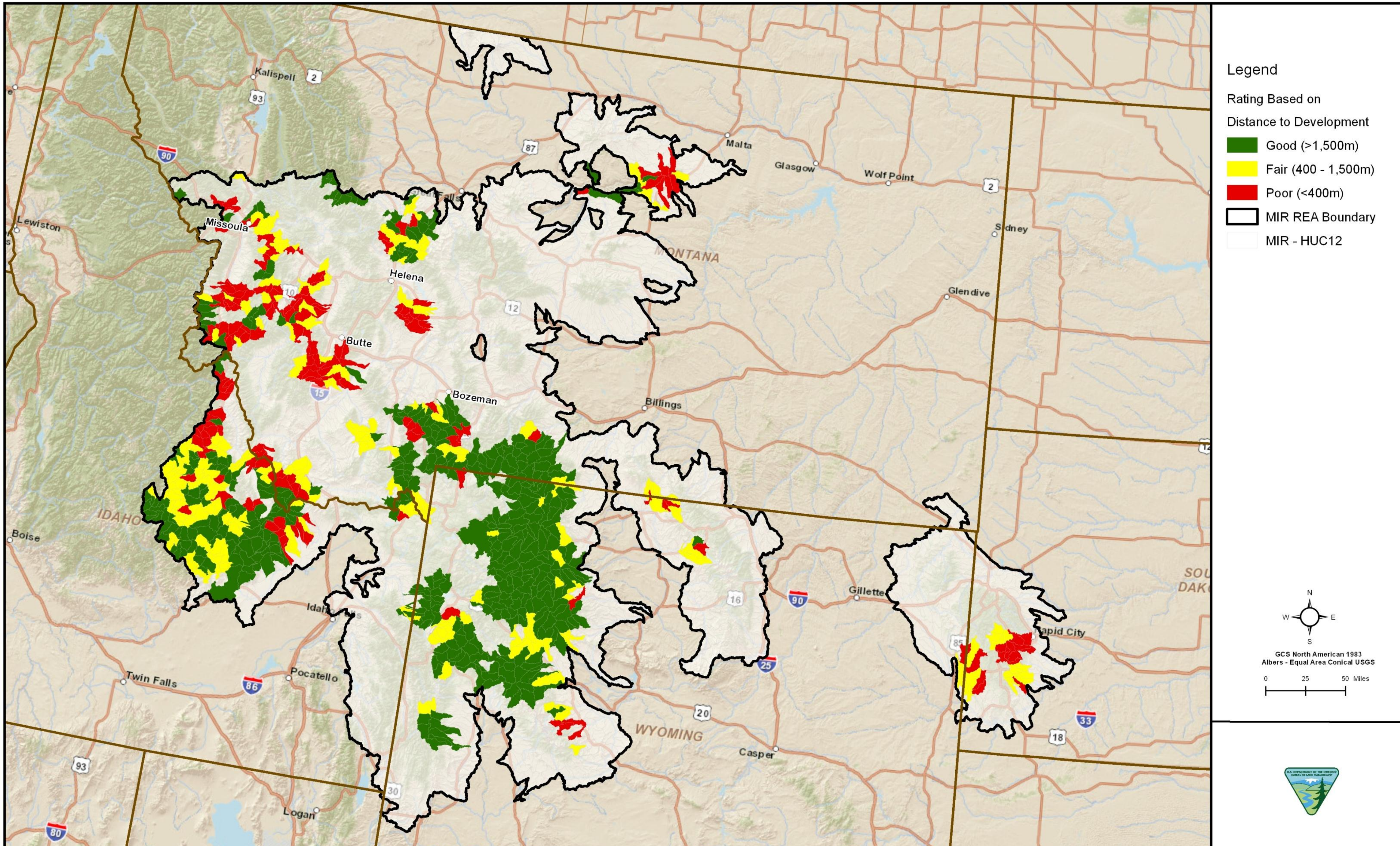

Figure E-5-8. Distance to Development

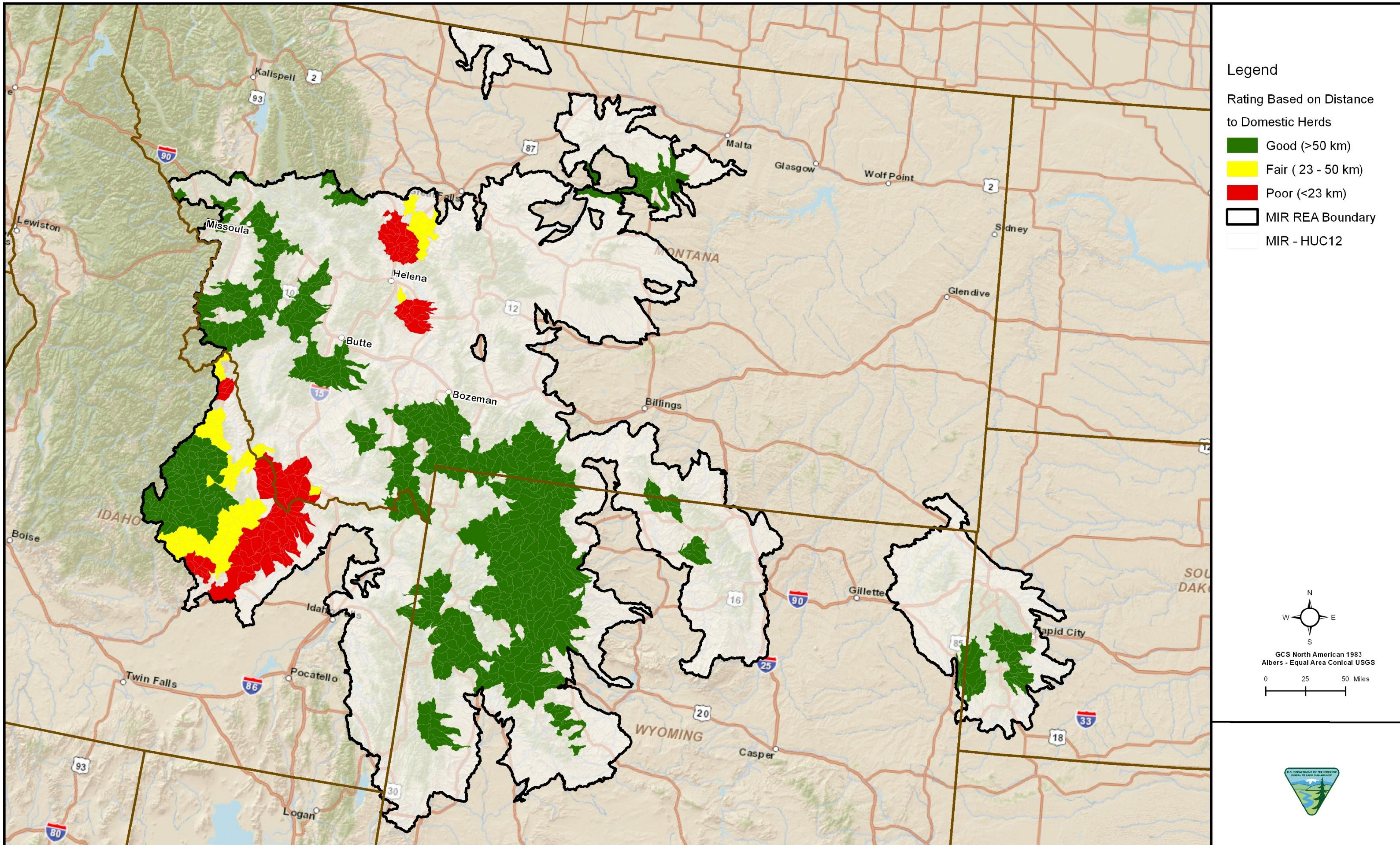

Figure E-5-9. Disease Transmission via Domestic Herds

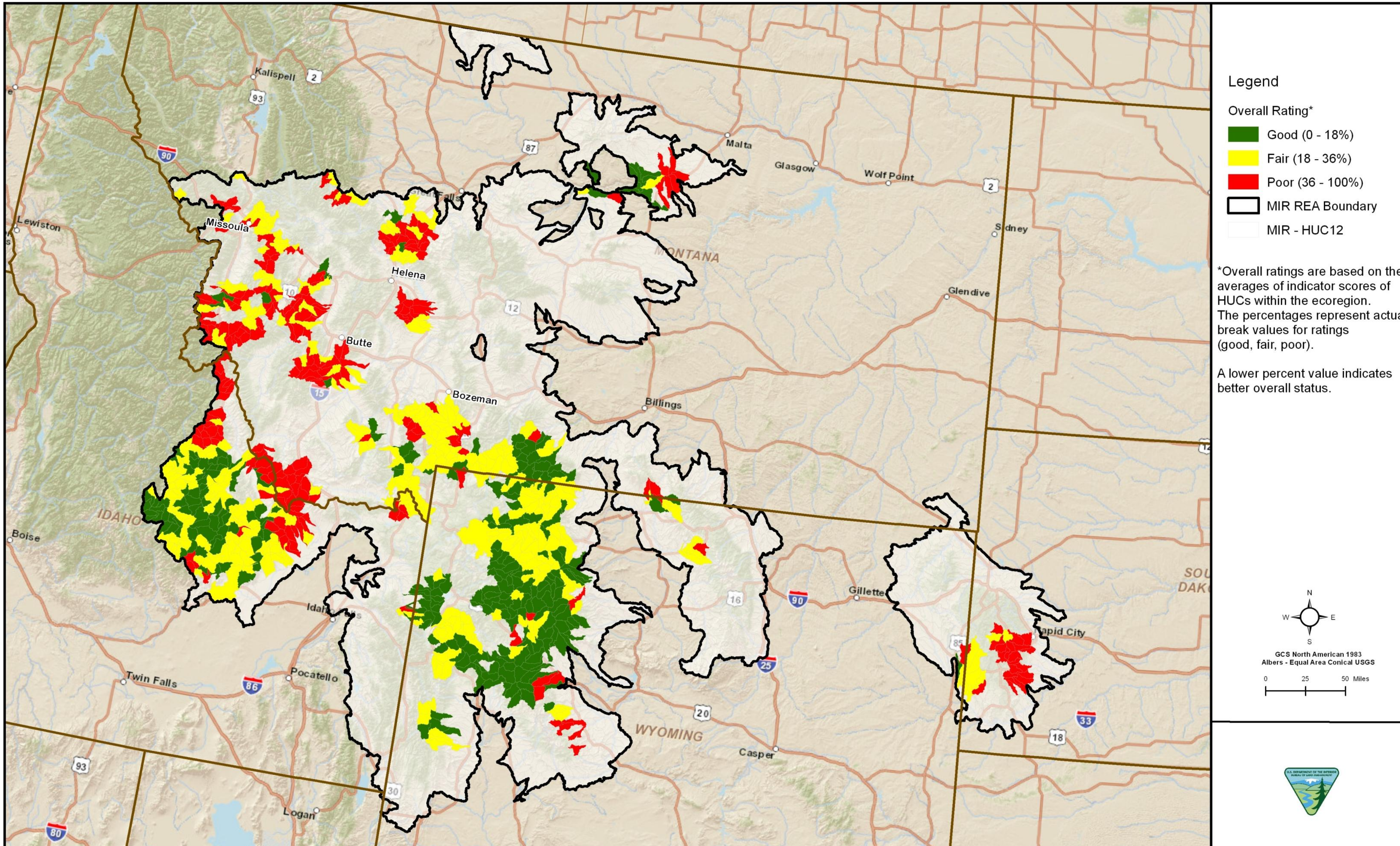

Figure E-5-10. Overall Rating for Bighorn Sheep

APPENDIX E-6

FOREST CARNIVORE ASSEMBLAGE CONSERVATION ELEMENT ANALYSIS FOR THE MIDDLE ROCKIES ECOREGION

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

NUMBER

THIS PAGE INTENTIONALLY LEFT BLANK

1.0 INTRODUCTION

The American marten (*Martes americana*), wolverine (*Gulo gulo*), and Canada lynx (*Lynx canadensis*) were selected as focal species for the Forest Carnivore Assemblage because these species are widespread and characteristic of forested ecosystems in the Middle Rockies ecoregion. Moreover, they are sensitive to landscape-level change due to their low population density, low fecundity, limited dispersal ability across open or developed habitat, and other traits that lower ecological resilience (Carroll et al. 2001).

Carnivores with the largest home range requirements, such as the grizzly bear or wolverine, have been suggested as umbrella species because the area required to support viable populations may protect sufficient habitat for other species with smaller area requirements (Noss et al. 1996). However, modeling of habitat overlap for grizzly bear, wolverine, and lynx indicates that differences in priority habitats are sufficient to warrant the integration of single-species habitat models into multi-species conservation strategies rather than basing planning on a single umbrella species (Carroll et al. 2001). Because the grizzly bear is more of a habitat generalist, and because its distribution and survival are more closely associated with direct adverse interactions with humans, the grizzly bear was defined as a single-species conservation element (CE) for this ecoregion.

Though the forest carnivores share the much of the same forested habitat, habitat requirements such as size and condition do vary from species to species. In addition, how each species interact with CAs made it difficult to come up with a standard set of key ecological attributes (KEAs) to perform a geospatial analysis suitable for all of the forest carnivores. Also, the wolverine and lynx had federally-adopted distribution data available, while the occurrence data were used to model American marten distribution using Maxent.

A variety of the management questions (MQs) apply to this assemblage. 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 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.

THIS PAGE INTENTIONALLY LEFT BLANK

2.0 CONSERVATION ELEMENT DESCRIPTION

2.1 CANADA LYNX

More than other carnivores, Canada lynx are strongly associated with a particular prey species, the snowshoe hare (Koehler and Aubry 1994; Brand et al. 1976; Brand and Keith 1979; Koehler and Brittell 1990). However, snowshoe hare populations in the Middle Rockies ecoregion do not exhibit the dramatic cycles reported in northern boreal forests. Consequently, lynx populations in this ecoregion typically consume other prey in addition to snowshoe hares.

Lynx in the Rocky Mountains select home ranges that provide a mosaic of forest stages to meet their seasonal resource needs and do not appear to migrate seasonally (Koehler and Aubry 1994; Aubry et al. 2000; Squires et al. 2010). In this region, the preferred elevation range includes mid- to high-elevation forests (range approximately 1,250 to 2,355 meters [m]). In the U.S. Rocky Mountains, suitable lynx habitat is highly fragmented on gradients of aspect and elevation and supports Canada lynx in lower densities than suitable habitats in Canada and Alaska (Koehler 1990; Koehler and Aubry 1994). Winter habitat use focuses on multistory, mature, subalpine fir-Engelmann spruce stands with high horizontal cover provided by low branches, and deep snow cover (Agee 1999; Squires et al. 2010). In summer, dense stands of lodgepole pine (an earlier successional stage of the spruce-fir forest cover type) and dense younger fir-spruce stands are preferred. This seasonal shift reflects a shift in snowshoe hare abundance between the different successional stages (Squires et al. 2010).

Maternal dens tend to be in mature or old-growth lodgepole pine, spruce, and subalpine fir stands (Koehler 1990; Koehler and Brittell 1990). Den sites must be near foraging habitat because the hunting range of females with offspring is reduced during this time (Ruediger et al. 2000). Stands of trees that provide denning habitat are not large (1 to 3 hectares) relative to home range size, but several sites should be interconnected (Koehler and Brittell 1990). Other important features of denning sites are minimal human disturbance and access to alternate den sites, as females often move kittens to areas where prey is more abundant or to avoid disturbance (Koehler and Brittell 1990). Canada lynx require cover for daily movement between foraging and denning areas, and avoid crossing openings wider than 100 m (Koehler and Aubry 1994). Average home range size in Montana and Wyoming studies ranged from 122 to 238 square kilometers (km^2) for males and 43 to 115 km^2. for females (Brainerd 1985; Aubry et al. 1999, Squires and Laurion 2000; Ruediger et al. 2000). Lynx perform long-distance movements; this includes dispersal of offspring from the maternal home range as well as occasional exploratory movements beyond the usual home range.

2.2 AMERICAN MARTEN

American martens are habitat specialists that associate closely with late-successional coniferous forests in the Rocky Mountains (Buskirk and Ruggiero 1994). Physical structure of the forest appears to be more important than species composition. Key habitat elements include the presence of snags and stumps (which are used as shelter and maternal dens), low branches, and downed logs. American martens are dietary generalists whose food resources vary by season and may include forest-dwelling small mammals and carrion in winter, and bird eggs and nestlings, insects, fish, fruit, and small mammals in summer and fall (Buskirk and Zielinski 1997). American martens generally avoid crossing openings or venturing very far from overhead cover (Buskirk and Ruggiero 1994). The American martens travel and forage on the ground, in trees, and on the surface of snow, and they make extensive use of subnivean space. American martens do not migrate seasonally, but instead may utilize different portions of their home ranges in response to seasonal availability of resources and den sites. Reports of American marten home range size vary considerably as a function of prey abundance and habitat type (Buskirk and McDonald 1989; Buskirk and Ruggiero 1994; Powell 1994; Bull and Heater 2001; O’Doherty et al. 1997; Thompson and Colgan 1987).

2.3 WOLVERINE

Wolverines are present in alpine tundra, and in boreal and montane forests in the western mountains. Banci (1994) concluded that habitat requirements were large, isolated tracts of wilderness that support a diverse prey base, and were not linked to specific plant associations or topography. At the southern edge of their distribution (including the Middle Rockies ecoregion), where suitable and unsuitable conditions exist in close proximity, wolverines selected high-elevation areas near alpine treeline where a mix of forest, meadow, and boulder fields were present, and where deep snow-cover existed during winter (Inman et al. 2012). In Idaho, wolverines used higher elevations in summer than winter, and they shifted use of cover types from whitebark pine communities in summer to lower elevation Douglas fir and lodgepole pine communities in winter (Copeland et al. 2007). Ungulate carrion is an important element in the winter diet, resulting in an association with mid-elevation forests within ungulate winter ranges, and, in many cases, is associated with wounding/mortality by hunters (Copeland et al. 2007). However, other habitat requirements including persistent snow cover at denning sites appear to influence habitat and elevation preferences (Copeland et al. 2010). Wolverines in the Greater Yellowstone Ecosystem (GYE) selected areas at elevations >2,600 m and avoided areas at elevations <2,150 m, including winter months when the majority of ungulate prey were pushed to lower elevations by deep snow (Inman et al. 2012).

Wolverine home range size greatly exceeds those of American marten and Canda lynx. In Montana, mean home range size for adult males was 422 km^2, average home range size for adult females with young was 100 km^2, and for adult females without young was 388 km^2 (Hornocker and Hash 1981). Recent studies in the GYE averaged approximately 303 km^2 for adult females and 800 km^2 for adult males (Inman et al. 2012). The wolverine has been considered sensitive to human presence based largely on the species' occurrence in remote areas and spatial separation from human infrastructure (Carroll et al. 2001). However, it is unclear whether this is a cause-effect relationship or a result of the species' preference for areas that are not suitable for human development (Copeland et al. 2007).

3.0 CONSERVATION ELEMENT DISTRIBUTION MODELING

To answer the MQs regarding the location and status of this CE across the ecoregion, a variety of existing data layers representing important habitat for the focal species were evaluated for use. The goal was to obtain data to determine the current distribution and status of each species throughout the ecoregion for critical periods.

3.1 LYNX DISTRIBUTION

Habitat data models for this species are available from Gap Analysis Program (GAP) and NatureServe (Table E-6-1), but after review it was decided these data were not adequate for the Rapid Ecoregional Assessment (REA) process. In addition, the Western Governors' Association (WGA) Wildlife Council Crucial Habitat Assessment Tool (CHAT) is being used to generate models and datasets for the ecoregion; however, no data are currently available. The National Park Service (NPS) also has data on modeled suitable habitat for the Greater Yellowstone Area and Northern Rockies. The Northern Rockies dataset only covers the northwest corner of the Middle Rockies ecoregion outside of the Greater Yellowstone Ecosystem (GYE) and modeled habitat data covering the southern portion of the ecoregion was not available from the U.S. Forest Service (USFS). Canada lynx critical habitat data are available from the U.S. Fish and Wildlife Service (USFWS).

A modeled habitat layer from USFS and a critical habitat layer from USFWS were used to map distribution. These data were readily available and published. The USFS data were the habitat data defined by Lynx Conservation Assessment and Strategy (LCAS) for use in the Northern Rockies Lynx Amendment Environmental Analysis. The USFWS data used was the designated Canada lynx critical habitat data. The modeled habitat and designated critical habitats were converted to a raster, and contiguous pixels were then grouped together.

Figure E-6-7 presents the distribution map for the lynx, which was used to conduct the CA analyses.

Table E-6-1. Data Sources for Lynx 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
	NatureServe Habitat Model	NatureServe	Polygon	Acquired	No
	State-Derived Models	ID, MT, WY State Agencies	Raster (30-90 m)	Data Gap	No
	WGA DSS Models	WGA Pilot Crucial Habitat	Raster	Future Dataset	No
	Lynx Habitat Analysis for Greater Yellowstone Area	NPS	Polygon	Acquired	No
Occurrences	State Natural Heritage Databases	Natural Heritage Programs – ID, MT, WY	Point	Acquired	No
Areas with Potential for Restoration of Habitat or Habitat Connectivity	Management Plan Areas	USFS, NPS, Bureau of Land Management (BLM), USFWS	Polygon	Acquired	Yes
Designated Critical Habitat	Canada Lynx Critical Habitat	USFWS	Polygon	Acquired	Yes
Lynx Conservation Assessment and Strategy	Canada Lynx Distribution	USFS	Raster	Acquired	Yes
Denning Areas		USFS, NPS, BLM, USFWS	Point	Data Gap	No
Travel Corridors	WGA DSS Datasets	WGA	Polygon	Future Dataset	No
	Linkage Areas	USFS	Polygon	Data Gap	No

3.2 AMERICAN MARTEN DISTRIBUTION

Table E-6-2 lists the types of data and data sources for the American marten that were proposed for use in the REA as part of the pre-assessment data identification effort in Task 2. Suitable American marten habitat models were acquired from GAP and NatureServe for portions of the ecoregion (Table E-6-2). The WGA Pilot Crucial habitat program could have data available for this species in the future, but currently there are no data available. Key data requirements include other habitat modeling efforts from states occurrences from natural heritage programs and any information on management plans or habitat restoration.

Table E-6-2. Data Sources for American Marten Conservation Element Distribution Mapping

Data Needs	Dataset Name	Source Agency	Type/Scale	Status	Use in REA
Modeled Suitable Habitat	GAP Habitat Models	USGS	Raster (30-m)	Acquired	No
	NatureServe Habitat Model	NatureServe	Polygon	Acquired	No
	State-Derived Models	ID, MT, WY State Agencies	Raster (30-90 m)	Data Gap	No
	WGA DSS Models	WGA Pilot Crucial Habitat	Raster	Future Dataset	No
Occurrences	State Natural Heritage Databases	Natural Heritage Programs – ID, MT, WY		Acquired	Yes
Areas with Potential for Restoration of Habitat or Habitat Connectivity	Management Plan Areas	USFS, NPS, BLM, USFWS		Data Gap	No

Based on the lack of available data for the ecoregion, it was was determined that Maxent modeling would be used to develop the American marten distribution map. Point occurrence data that was provided through the states' natural heritage programs or fish and game agencies was used to develop the Maxent models. Point occurrence data from observations made from 1990 to present were used to develop these models.

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, the model 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 the model to validate the accuracy of the predictions based on occurrence data and also provides various validation measures. Since 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 convert them back to a GIS format for additional processing.

Maxent models are based on observation data, which can vary greatly in distribution within a state or within states of the ecoregion; this can create some uncertainty that must be acknowledged when viewing the resulting modeled habitat and corresponding maps. Some areas of the ecoregion without observations may display modeled habitat for American marten (such as the Black Hills part of South Dakota, which is within the ecoregion and within the historical range of the CE). However, the Black Hills lost the Americal marten population in he mid- 1900s. Reintroduction of the American Marten in the Black Hillls occurred in the 1980s and 1990s (Buskirk 2002). In addition, BLM foresters have seen along the Wyoming-South Dakota state lines in the Black Hills during recent field work. Some areas of the ecoregion that have been intensively studied may also overemphasize modeled habitat. These factors, and the uncertainty in the resulting modeled habitat should be taken into consideration when viewing the modeled habitat and when using it in making management decisions.

The intent of the REA modeling effort was to identify modeled habitat of American marten. Since Maxent uses species occurrence data, the Rolling Review Team (RRT) determined that the occurrence data should be limited to 1990 – present to be consistent with timeframes used by other CEs being modeled with Maxent. Of the four states making up this ecoregion, Montana, Idaho, and Wyoming contributed the only occurrence data; South Dakota contributed none. Some of the observations from Montana were based on trapping records, and the spatial location was the center point of the township. Since this location was generalized, these records were removed from the observation being used in order to keep the spatial uncertainty of the observations as low as possible. Figure E-6-1 shows the amount of occurrence data collected for each state.

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 the American marten. 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 American marten. 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-6-3 contains the 16 environmental variables used in the Maxent model and their contribution (listed in the 'Percent Relative Contribution' column). The American marten Maxent model had Parameter-elevation Regressions on Independent Slopes Model (PRISM) precipitation and maximum temperature environmental layers as the highest contributors. 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.

Table E-6-3. Maxent Environmental Variables for American Marten

Environmental Variable	Maxent Variable Code	Percent Relative Contribution	Percent Permutation Importance
PRISM Precipitation	prsm_pres90	39	22.2
PRISM Temperature (max)	prsmmaxt90	17.5	8.3
Aspect (North/South)	aspns_mir_90	12.4	11.6
Solar Radiation (Equinox)	sri_eq_mr_90	7.5	18.6
Elevation	ned_mir_90	6.6	16.3
GAP Vegetation	gap_mir_90	5.5	1.8
Slope	slope_mir_90	22.6	6.3
Solar Radiation (Summer Solstice)	sri_ss_mr_90	2.5	7
Solar Radiation (Winter Solstice)	aspew_nwp_90	2.4	4.5
LANDFIRE Vegetation	evt_mr_90	0.9	0.4
Distance to Water	edw_nwp_90	0.9	1.1
PRISM Temperature (min)	prsmmint90	0.9	0.3
Aspect (East/West)	aspew_mir_90	0.6	0.8
Geology	geol_mir_90	0.3	0.6
Rugosity	vrm_mr_90	0.2	0
State Soil Geographic (STATSGO) Soils	soil_mir_90	0.1	0.2

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, 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 of where the predicted over expected frequency (P/E) ratio vs. logistic value crosses 1 (where the model started to do 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 where 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 pdf output detailing the moderate and optimal thresholds (Figure E-6-2). 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.

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). This method uses actual training data; therefore, 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], BLM NOC Wildlife Habitat Spatial Analysis Lab, and Montana Fish, Wildlife and Parks) determined that the WYNDD thresholds were the best to use for this REA. Table E-6-4 list the thresholds for American marten using both methods. American marten had an anomaly with the moderate threshold slightly lower than the low threshold using the WYNDD method. This occurred due to the fact that the low and moderate thresholds were being calculated using the training data, while the moderated was generated as a commonly-used Maxent statistic. Since the thresholds were to be combined (described next) it didn't require a different determination of thresholds.

Table E-6-4. Maxent Thresholds Calculated for American Marten

Method	Measurement	Threshold	Value
MT / Hirzel	Test Omission Rate (0.05)	Low	0.015
MT / Hirzel	P/E =1 (R Script)	Moderate	0.284
MT / Hirzel	Δ P/E Ratio > Δ Logistic Value (R Script)	Optimal	0.655
WYNDD	5% Training Value	Low	0.268
WYNDD	Max. Training Sen. + Spec.	Moderate	0.266
WYNDD	50% Training Value	Optimal	0.578

To establish a modeled habitat map, the Maxent model output requires a binary display of which areas are 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 American marten modeled habitat. These three thresholds were combined because it was determined to be the most representative. The Maxent output was then reclassified to show two classes, modeled and not potential habitat, as shown on Figure E-6-5.

The Maxent output distribution model (Figure E-6-6) was overlain with the observation points to visually inspect the relative accuracy of the model. 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]). The AUC for this assemblage was very high

(0.93 for the training data and 0.92 for the testing data). Threat analysis outputs were correlated to reporting units that spatially contained distribution data.

3.3 WOLVERINE DISTRIBUTION

Table E-6-5 lists the types of data and data sources for the wolverine that were proposed for use in the REA as part of the pre-assessment data identification effort in Task 2. This species has been recorded in Idaho, Montana, and Wyoming. Key data requirements for this species include other habitat modeling efforts from states or occurrences from natural heritage programs, data from the USFS, and any information on management plans or habitat restoration. Suitable wolverine habitat models were acquired from GAP and NatureServe for portions of the ecoregion (Figure E-6-19). Additional datasets were presumed to be available from the USFWS and the USFS, as the wolverine was proposed in December 2010 to be added to the list of candidates for Endangered Species Act (ESA) protection. The USFWS is evaluating the impact of climate change on denning habitat. In addition, the Western Governors' Association (WGA) Wildlife Council Crucial Habitat Assessment Tool (CHAT) is being used to generate models and datasets for the ecoregion; however, no data are currently available.

Table E-6-5. Data Sources for Wolverine Conservation Element Distribution Mapping

Data Needs	Dataset Name	Source Agency	Type/Scale	Status	Use in REA
Modeled Suitable Habitat	GAP Habitat Models	USGS	Raster (30-m)	Acquired	No
	NatureServe Habitat Model	NatureServe	Polygon	Acquired	No
	State-Derived Models	ID, MT, WY State Agencies	Raster (30-90 m)	Data Gap	No
	WGA Decision Support Systems (DSS) Models	WGA Pilot Crucial Habitat	Raster	Future Dataset	No
	Wildlife Conservation Society (WCS)	WCS	Polygon (converted raster model)	Acquired	Yes
Occurrences	State Natural Heritage Databases	Natural Heritage Programs - ID, MT, WY	Point	Data Gap	No
	WCS	WCS	Point	Data Gap	No
Ungulate Carrion (Winter Range)	Winter Ranges	Rocky Mountain Elk Foundation (RMEF), Western Association of Fish and Wildlife Agencies (WAFWA)	Polygon	Acquired	No
Areas with Potential for Restoration of Habitat or Habitat Connectivity	Management Plan Areas	USFS, NPS, WCS, USFWS	Polygon	Data Gap	No
Denning Areas		USFS, USFWS, WCS	Point	Data Gap	No

The Assessment Management Team (AMT) and state partners recommended use of data from the Wildlife Conservation Society (WCS), which and was adopted for the wolverine distribution. A logistic regression analysis based on wolverine telemetry data collected in the GYE by the WCS's Greater Yellowstone Wolverine Program was used to create a distribution layer for the wolverine.

Figure E-6-21 presents the distribution map for the wolverine, which was used to conduct the CA analyses.

THIS PAGE INTENTIONALLY LEFT BLANK

4.0 CONCEPTUAL MODELS

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

4.1 ECOLOGICAL PROCESS MODEL

The ecological process model for the forest carnivores (Figure E-6-3) was developed to identify and link the key life cycle processes to specific ecological factors, or KEAs, that have the greatest potential to affect the habitat of the Canada lynx, American marten, and wolverine throughout the ecoregion.

The key life cycle processes are identified in the model as green boxes. Following Unnasch et al. (2009), KEAs that fall under three broad headings (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. Spatially representing these KEAs at the landscape level depends on the data available to represent each category.

4.2 SYSTEM-LEVEL MODEL

The system-level conceptual model for the forest carnivore assemblage (Figure E-6-4) depicts the interactions of CAs with the primary habitat functions and values for these species, shown at the bottom of the model. The primary CAs for this CE are development, climate change, insect outbreak and disease, and wildfire, which are identified across the top of the figure in red. The most important habitat functions and values affecting abundance and status of forest carnivore populations are habitat suitability, survivorship, productivity, and connectivity. CA effects on habitat functions and values can occur through direct disturbance and mortality of individuals, or through changes to the habitat at the landscape or stand level, shown in the gray boxes.

At the landscape level, the status of forest carnivore populations depends on the availability of suitable habitat, the size and degree of fragmentation of suitable habitat blocks, and the ability of dispersing individuals to move between habitat blocks (connectivity). At the stand level, foraging habitat and den site availability are critical habitat functions, but the relevant indicators are not suited to rapid ecosystem assessment. The three species in this assemblage are represented by a generic conceptual model because they share the important landscape-level habitat functions, but they differ considerably in the details of habitat suitability and home range and dispersal requirements.

4.2.1 Development

Forest carnivores have been affected by historic and current land use, including clear-cut logging, exurban development, recreational activity, energy development, and mining activity in suitable habitat. In addition to habitat loss and conversion, these changes result in fragmentation of remaining habitat and loss of connectivity between suitable habitat patches for these regionally-significant species.

All of the carnivore species are susceptible to effects of human encroachment on montane forested habitats in the ecoregion through land cover change, land use change, direct mortality, and disturbance.

4.2.2 Climate Change

Core habitats of forest carnivores and habitat connectivity in the Rocky Mountains are vulnerable to the effects of climate change (Wasserman 2010; Gonzalez et al. 2007; Carroll 2007) through potential changes in snowpack and vegetation type gradients. Deep, persistent snow pack is a critical habitat element for Middle Rockies forest carnivores (Carroll et al. 2001), including denning habitat and dispersal habitat for wolverine (Copeland et al. 2007). Climate change scenarios predict substantial decreases in the depth and duration of average winter snowpacks and shifts of forest communities toward higher elevations and higher latitudes (IPCC 2007). Prey availability, protection from predators, and availability of habitat suitable for reproduction may shift with coniferous forest communities. The result of these changes may be increased isolation of remnant populations in high elevation montane “islands” separated by unsuitable dry forest, shrubland, and grassland habitats. Smaller, isolated carnivore populations are at risk of extinction due to genetic drift, inbreeding, and stochastic events (Gilpin and Soule 1986; Buskirk and Ruggiero 1994). Loss of connectivity for dispersing individuals may reduce opportunities for population recovery and natural recolonization, in particular for Canada lynx and wolverine in the Middle Rockies, as these populations are already at the southern edge of their current ranges and may depend on recruitment from refugia outside of the ecoregion.

4.2.3 Insect Outbreak and Disease

Insect outbreaks and forest disease organisms are integral to habitat-forming processes that affect the availability of structural elements like snag trees and coarse woody debris favored by forest carnivores. The dynamics of insect outbreaks are complex, and effects of naturally-occurring and non-native insects and disease organisms on tree health and mortality may be exacerbated by climate change in current and future scenarios. Moreover, there are complex interactions between bark beetles and wildfire, which is also subject to the influence of climate change and past management history.

4.2.4 Wildfire

Fire plays a role in forest succession and stand-level structure in the ecoregion. Montane forests have co-evolved with wildfire, which at low intensity contributes many of the structural requirements (snags and coarse woody debris) of forest carnivore habitat. The interactions of climate change (i.e., changes in temperature, precipitation, and drought patterns) with fire regime are likely to result in shifts in the size and distribution of successional conifer forest patches. Potential increases in wildfire frequency, severity, and extent in forest communities would likely result in overall loss of suitable habitat, as high severity fire is more likely to be stand-replacing.

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. Not all of the relationships identified in the system-level conceptual model were amenable to geospatial analysis in this REA because either the CA indicator was not suitable for a landscape level analysis or because data were not available to support the analysis. The indicators that could not be modeled are identified with an asterisk on Figure E-6-4. Further information on the data gaps for these effects is discussed in the respective CA analysis contained in Appendix C. Surrogate indicators were used in some cases for particular attributes of these processes. For example, mortality and disturbance effects were modeled using an anthropogenic influence layer including distance to exurban and mining developments and roads.

The specific indicators that could not be modeled are identified with an asterisk on Figure E-6-4. The analysis for the effects of climate change on this CE was only qualitatively evaluated because of the scale (15-kilometers [km]) of the CA analysis (Appendix C-5). Analyses of the effects of the insect outbreak and disease CA were not included for this CE because the direct effect indicators were impractical to model at the ecoregional scale, as appropriate geospatial data were not available (Appendix C-4).

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

5.0 CHANGE AGENT ANALYSIS

A current status and future threat assessment for the forest carnivores was conducted for the Middle Rockies 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 proposed for analysis of the current status for this CE include development and wildfire, depending on the species. The CAs that are 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 HUCs was extracted for the ecoregion. A 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 HUC (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 were calculated to determine a value associated with each watershed 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 GIS process model can then be rerun, changing necessary inputs for other CA analyses.

5.1 CURRENT STATUS OF CANADA LYNX

5.1.1 Key Ecological Attribute Selection

Table E-6-6 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 explanation provided in the table, and some were modified as a result of RRT review. For example, understanding of the effects of human development on lynx is hampered by lack of adequate information on their long-distance movements, habitat preferences, mortality factors, and population trends (Squires 2005). The Canada lynx is listed as threatened under the ESA, but unlike many other threatened or endangered species that have well-defined management needs, scientists have limited understanding of how human-caused actions may contribute to the rarity of Canada lynx within their range. Some KEAs were used in the analysis because they are important for establishing current condition of the CE, but are not directly related to CAs. For example, Native Vegetation Blocks were mapped because this species has large home range requirements.

Table E-6-6. Key Ecological Attributes Retained or Excluded for the Canada Lynx

Category	Attribute	Explanation
1. Size	Suitable habitat blocks	Retained to show size of contiguous areas.
	Native Vegetation Blocks Containing Suitable Habitat	RRT decision to exlude because adopted distribution data from federal agencies were used.
2. Condition	Wildland Fire Frequency Fire Return Interval (FRI)	Retained to show the FRI to indicate forest habitat quality.
	Mean Monthly Snowpack/Depth	Retained to show persistence and depth of snowpack during critical months of the year.
	Development (disturbance due to human land use – exurban, oil and gas wells, towers and transmission lines)	Excluded per RRT comments: anthropogenic development was less important than other CAs for lynx.
	Distance to roads	Added to anthropogenic layer per literature review and RRT comments related to risk of mortality, barrier to connectivity, and disturbance.
3. Context	Dispersal Ability Distance between large habitat blocks	Excluded because analysis scored everything as good.
	Distance between suitable habitat patches within home range (daily movements)	Excluded because analysis scored everything as good.
	Distance between suitable habitat patches; long-distance and exploratory movements	Added replaced dispersal ability between large habitat blocks to indicate distance that must be traversed by dispersing individuals.

Table E-6-7 identifies the KEAs, indicators, and metrics that were used to evaluate the current status of this CE across the ecoregion (as illustrated on Figure E-6-4). Several indicators were used to assess the current status for this CE, including size of available habitat, habitat condition, and connectivity.

Table E-6-7. Canada Lynx Key Ecological Attributes, Indicators, and Metrics for Current Status Assessment for the Middle Rockies Ecoregion

Category	Ecological Attribute	Indicator / Unit of Measure	Metric			Data Source	Citation
			Poor = 3	Fair = 2	Good = 1		
Size	Suitable Habitat Blocks	Contiguous areas adopted (km^2)	<65	65-100	>100	USFS, USFWS	Aubry et. al. 1999; Squires & Laurion 2000; Ruediger et al. 2000
Condition	Habitat Condition	Wildland Fire Frequency FRI (years)	<40	40-100	100	LANDFIRE Mean FRI	Agee 1999; Murphy (pers. Comm.)
		Mean Monthly Snowpack/Depth (centimeter [cm]) (January – March)	<13 cm in March	Present <4 months and 12 -77 cm	Present 4 months and >77 cm	National Land Cover Data (NLCD)/ National Oceanic and Atmospheric Administration (NOAA)	Carroll et al. 2001; Carroll 2007; Koehler & Aubry 1994; Squires et. al. 2010
		Distance to roads (m) *From freeways* *From Secondary Road*	 <500 <100	na	 >500 >100	Linear features	Carrol et al. 2001; professional judgement
Landscape Context	Connectivity; Long-distance and exploratory	Distance between suitable habitat blocks ≥ home range size (see size indicator) (km)	>40	15 - 40	<15	USFS, USFWS	Ruediger et al. 2000; Squires & Laurion 2000; McKelvey et. al. 1999

In most cases the metrics used to rank attribute quality were based on available scientific literature and reports, coupled with subject matter expert opinion 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 subject matter 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.

5.1.1.1 Suitable Habitat Blocks

Vegetation is a key feature that significantly affects the distribution of the Canada lynx. A vegetation data layer provides information pertaining to the foraging, breeding, and dispersal requirements of the species, Prey species (snowshoe hare and other small mammals) are closely associated with forested vegetation communities. Forested communities also provide denning habitat and vegetative cover for dispersing individuals. Stand-level vegetation data and prey distribution data that are important to the lynx's habitat selection were not available or well-suited for this REA. Therefore, the modeled habitat layer from USFS and a critical habitat layer from USFWS were applied. The modeled habitat and designated critical habitats were converted to a raster, and contiguous pixels were then grouped together. These groups were then assigned values based on the KEA metrics. The habitat block size mean values per watershed are calculated and displayed according to the KEA table. The size metric was based on data on home range sizes of female lynx in the Middle Rockies ecoregion reported in the literature and refined following RRT advice.

Figure E-6-8 presents the suitable habitat blocks for the Canada lynx.

5.1.1.2 Wildfire Frequency

Fire has been the primary natural disturbance in western subalpine forests within the range of the Canada lynx (Agee 1999). Although lynx range is included in areas with high-severity fire regimes, there is considerable range in fire return frequency on these landscapes as well as variation due to local site conditions, leading to wide variation in successional stages present. The Canada lynx uses a mosaic of successional stages ranging from dense younger stands to mature and old growth stands (Agee 1999); however, recent research indicates that winter habitat (in particular mature spruce-fir forests) may be most limiting for lynx in the ecoregion (Squires et al. 2010). Therefore, wildland fire return interval (FRI) from the LANDFIRE database was used as a surrogate indicator of forest successional condition. The FRI metric in Table E-6-7 results in higher scores for habitat with more mature forest stands. However, similar to the suitable habitat size indicator, the fire return indicator has limitations because it does not consider stand-level characteristics that influence suitability for lynx, such as small-scale interspersion of successional stages or vegetation structure.

Figure E-6-9 presents the wildfire return frequency for the Canada lynx.

5.1.1.3 Mean Monthly Snowpack/Depth

Presence of deep persistent snowpack from December through March in the Middle Rockies ecoregion was selected as an indicator of suitable habitat for the Canada lynx based on literature review and confirmed in discussion with the RRT. National Oceanic and Atmospheric Administration (NOAA) average monthly snowpack data are overlaid for months indicated in the KEA table. Areas which meet the criteria (depth and correct months) are assigned the appropriate values. The final layer contains categorical data, so the majority per watershed values are dispalayed on the map. The metrics shown in Table E-6-7 for three categories of snowpack conditions are based on break points in available data sources (National Land Cover Data [NLCD]/NOAA) and conditions that may exist in occupied habitat. Good snowpack conditions in Table E-6-7 represent the closest approximations to values reported in the literature that could be made for this analysis using these data sources.

Figure E-6-10 presents the mean monthly snowpack/depth layer for the Canada lynx.

5.1.1.4 Distance to Roads

Roads constitute a potential source of mortality, due to collision with vehicles and illegal shooting, as well as a barrier to movement due to avoidance of high traffic volumes and open areas. Areas closest to roads generally have greater human activity and therefore indicate lower habitat suitability. Distance to roads was modeled by extracting two categories from the Topologically Integrated Geographic Encoding and Referencing (TIGER) dataset (i.e., Primary/Secondary and other roads). The dataset is the TIGER all roads by county. The two roads categories are buffered according to respective KEA table entry, and an overlay is then created. Where two different categories of threat overlap (good and fair), the lower of the two scores (in this case fair) is used. Distance to roads within each HUC was calculated and ranked as good or fair; these rankings were dependent on the road type and based on metrics in the literature, professional judgment, and discussion with the RRT.

Figure E-6-11 presents the distance to roads layer for the Canada lynx.

5.1.1.5 Distance between suitable habitat blocks

The connectivity KEA reflects the need for juvenile lynx to disperse from maternal home ranges for periodic exploratory long-distance movements, which have been documented in radio-telemetry studies. Distances between the large habitat blocks are calculated and values are assigned according to the KEA table. Metrics in Table E-6-7 were derived from the literature and RRT advice.

Figure E-6-12 presents the distance between suitable habitat for assessment of the long-distance connectivity for the lynx.

5.1.2 Current Status of Habitat for the Lynx

The individual KEA analyses provide the basis for the compilation of an overarching data layer that defines the current status of lynx habitat for each HUC across the ecoregion. 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 as 1, 2, or 3, respectively, to the KEA. The KEAs were considered equally weighted in this analysis; therefore, the Quality Rank Scores were simply averaged to produce an overall threat score for each HUC.

The overall 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 score would result in a rating of poor for the HUC based on the current status KEAs. The results of the current status analysis for the lynx are presented on Figure E-6-13.

The current status of lynx populations in the western United States is not known, although surveys in the GYE and northern Rocky Mountains suggest that suitable habitat is sparsely occupied (Murphy et al. 2005; Squires et al. 2007; Squires et al. 2010). Suitable habitat blocks that would be sufficient in size to support adult female home ranges are scattered in several portions of the ecoregion (shown on Figure E-6-8). However, comparison with the map of Canada lynx habitat defined by the USFS and USFWS (Figure E-6-7) indicates that not all of the habitat blocks that scored as good with respect to size are occupied, including some habitat in the Black Hills. The current status of lynx habitat with respect to the wildland fire CA is shown on Figure E-6-9. HUCs in portions of the GYE and smaller scattered areas across the ecoregion had scores of mean FRI >100 years, whereas areas with shorter FRI (< 40 years) were concentrated in the northern portion of the ecoregion (primarily in Montana) and portions of the Bighorn Mountains. Snowpack depth and persistence are most favorable to lynx in the higher elevations of the same general areas (Figure E-6-10). With regard to habitat connectivity for long-distance movements, the best scores appear in the GYE and portions of western Montana. The overall current status of lynx habitat in the ecoregion in this assessment is good to fair within much of the GYE, western Montana, and the Big Horn Mountains in Wyoming; however, overall poor conditions were calculated in many smaller groups of watersheds (Figure E-6-13). Some of the low-scoring watersheds in this assessment occupy key corridors with the potential to connect larger, high-scoring blocks of habitat, reinforcing management concerns over connectivity for this species in this region.

A summary of the current status ratings based on the lynx distribution is provided in Table E-6-8. 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 47 percent of the 6th level HUC watersheds that intersect the lynx distribution received an overall good rating. The majority of the total square miles for this CE are still below acceptable conditions, with a combined percentage of approximately 53 percent of the total area rated fair or poor.

Table E-6-8. Summary of Current Status Ratings for the Lynx

Overall Rating by 6th Level HUC	Total Square Miles[a]	Percentage of Total Square Miles[a, b]
Good	25,988	47.1
Fair	20,563	37.3
Poor	8,630	15.6

[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 CURRENT STATUS FOR AMERICAN MARTEN

5.2.1 Key Ecological Assessment Selection

Table E-6-9 identifies the original KEAs that were proposed in Task 3 and which of these were used in the final current status analysis. Some of the KEAs were modified following RRT review, as explained in the table. Some KEAs were used in the analysis because they are important for establishing current condition of the CE but are not directly related to CAs. For example, Native Vegetation Blocks were mapped because this species has large home range requirements.

Table E-6-9. Key Ecological Attributes Retained or Excluded for the American Marten

Category	Attribute	Explanation
1. Size	Suitable habitat blocks	Retained to show size contiguous areas.
	Native Vegetation Blocks Containing Suitable Habitat	Excluded because ran habitat patch size on modeled results.
2. Condition	Wildland Fire Frequency FRI	Retained to show the FRI to indicate forest habitat quality.
	Mean Monthly Snowpack/ Depth	Retained to show persistence and depth of snowpack during critical months of the year.
	Development (distance from human land use – exurban, grazing, mining)	Retained to show effects of human development.
	Distance to roads	Added to anthropogenic layer per literature review and RRT comments related to risk of mortality, barrier to connectivity, and disturbance.
3. Context	Dispersal ability Distance between large habitat blocks	Replaced by distance between suitable habitat patches; (long-distance and exploratory movements) to indicate distance that must be traversed by dispersing individuals.
	Fragmentation of suitable habitat	Retained to show effects of forest fragmentation.
	Distance between suitable habitat patches within home range (daily movements)	Excluded because no adequate information regarding metrics was found.
	Distance between suitable habitat patches; long-distance and exploratory movements	Replaced dispersal ability between large habitat blocks to indicate distance that must be traversed by dispersing individuals.

Table E-6-10 identifies the KEAs, indicators, and metrics that were used to evaluate the CAs and pathways affecting this CE assemblage across the ecoregion (as illustrated in Figure E-6-4). Several indicators were used to assess the current status for this CE, including size of suitable habitat blocks, habitat condition, and landscape context (e.g., distance to roads, fragmentation, and connectivity). The applicable outputs were incorporated into a GIS overlay analysis.

In most cases, the metrics used to identify attribute quality were based on available scientific literature and reports, coupled with subject matter expert opinion 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 subject matter 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.

Table E-6-10. American Marten Key Ecological Attributes, Indicators, and Metrics for Current Status Assessment for the Middle Rockies Ecoregion

Category	Ecological Attribute	Indicator / Unit of Measure	Metric			Data Source	Citation
			Poor = 3	Fair = 2	Good = 1		
Size	Suitable Habitat Blocks	Contiguous areas with of model results (km^2)	<1	1 - 15	>15	Maxent	Buskirk & McDonald 1989; Powell 1994; Bull & Heater 2001; O'Doherty et al. 1997
Condition	Habitat Condition	Wildland Fire Frequency FRI (years)	<40	40-100	100	LANDFIRE Mean FRI	Agee 1999; Murphy (pers. Comm.)
		Mean Monthly Snowpack / Depth (cm) (January – March)	<13 cm in March	present <4 months and 13 -77 cm	Present 4 months and >77 cm	NLCD/ NOAA	Carroll et al. 2001; Carroll 2007; Corn & Raphael 1992; Buskirk & Ruggiero 1994; Krohn et al. 1995
		Development (Distance from human land use – exurban, grazing, mining)	<5 km	5-10 km	>10 km	Mining NLCD GAP Human Footprint	Oliff et al. 1999; Carroll et al. 2001; Kirk and Zielinski 2009
		Distance to roads (m) *From freeways* *From Secondary Road*	<500 <100	na	>500 >100	Linear features	Carrol et al. 2001; professional judgement
Landscape Context	Landscape Structure	Fragmentation of suitable habitat (% of landscape within 15 km^2 block) that is suitable habitat	>25 %	25 – 75%	>75%	Maxent	Hargis et al. 1999
	Connectivity; Long-distance and exploratory	Distance between suitable habitat blocks ≥ home range size (see size indicator) (km)	>40	5 - 40	<5	Maxent	Bull & Heater 2001

5.2.1.1 Suitable Habitat Blocks

The sizes of suitable habitat blocks were calculated from the Maxent model and ranked in 3 categories according to the metrics in Table E-6-9. Size metrics were based on home range sizes of female American marten in the Rocky Mountains as reported in the literature and refined with RRT advice.

5.2.1.2 Wildfire Return Frequency

Fire has been the primary natural disturbance in western coniferous forests (Agee 1999). Although American marten predicted suitable habitat is included in areas with high-severity fire regimes in the Middle Rockies, there is considerable range in fire return frequency on these landscapes and variation due to local site conditions, leading to wide variation in successional stages. Wildland FRI from the

LANDFIRE database was used as a surrogate indicator of forest successional condition. The FRI metrics in Table E-6-10 were assessed for 3 intervals with higher scores (good) assigned to habitat with more mature forest stands. However, similar to the suitable habitat size indicator, the fire return indicator has limitations because it does not consider stand-level characteristics that influence suitability for American marten, such as vegetation structure.

Figure E-6-9 presents the wildfire return frequency for the American marten.

5.2.1.3 Mean Monthly Snowpack / Depth

Presence of deep, persistent snowpack from December through March in the Middle Rockies ecoregion was selected as an indicator of suitable habitat for the American marten based on literature review and confirmed in discussion with the RRT. NOAA average monthly snowpack data are overlaid for months indicated in the KEA table. Areas which meet the criteria (depth and correct months) are assigned the appropriate values. The final layer contains categorical data, so the majority per watershed values are dispalayed on the map. The metrics shown in Table E-6-10 for the three categories of snowpack conditions are based on break points in available data sources (NLCD/NOAA) and conditions that may be present in occupied habitat. Good snowpack conditions in this table represent the closest approximations to values reported in the literature that could be made for this analysis using these data sources.

Figure E-6-10 presents the Mean Monthly Snowpack Presence and Depth for the American marten.

5.2.2 Development

Development was characterized in this analysis as the distance to human land use (exurban and rural development and mining). This KEA was used as an indicator to assess potential impacts from human land use, including habitat loss, barriers to connectivity, and avoidance due to disturbance.

Development data were compiled into one dataset from all applicable sources. Datasets include oil and gas wells, exurban or greater housing density, roads, transmission lines, and wind turbines. All anthropogenic layers are overlaid and distance is calculated from this layer to American marten suitable habitat. The mean distance per watershed from anthropogenic disturbance to American marten suitable habitat is displayed. Distance from development was assessed for 3 distance zones, as noted in Table E-6-10. The distance to development layer results are shown on Figure E-6-16.

5.2.2.1 Distance to Roads

Roads constitute a potential source of mortality, due to collision with vehicles, as well as a barrier to movement due to avoidance of high traffic volumes and open areas. Areas closest to roads generally have greater human activity and therefore indicate lower habitat suitability. Distance to roads was modeled by extracting two categories in the TIGER dataset (i.e., Primary/Secondary and other roads). The dataset is the TIGER all roads by county. The two roads categories are buffered according to respective KEA table entry, and an overlay is then created. Where two different categories of threat overlap (good and fair), the lower of the two scores (in this case fair) is used. Distance to roads within each HUC was calculated and ranked as good or fair; these readings were dependent on the road type, and based on metrics in the literature, professional judgment, and discussion with the RRT. The distance to roads layer results are shown on Figure E-6-17.

5.2.2.2 Fragmentation of Suitable Habitat

Fragmentation of suitable forest habitat was selected as a KEA to capture the effects of loss of forest continuity within an area that is the typical home range size of American martens. A 15-km^2 moving window analysis was run on the habitat to determine the percentage of suitable habitat. Output values were classified according to percentages in the KEA table and were assigned a good, fair, or poor value. The metric and scoring for this indicator were derived from field studies in the Uinta Mountains of Utah (Hargis et al. 1999) and include 3 categories of fragmentation (Table E-6-10). The fragmentation of suitable habitat layer results are shown on Figure E-6-18.

5.2.2.3 Distance between Suitable Habitat Blocks

The connectivity KEA reflects the need for juvenile marten to disperse from maternal home ranges for periodic exploratory long-distance movements, which have been documented in radio-telemetry studies. Distance between suitable habitat patches, as determined by the Maxent model, was used as the surrogate for connectivity. Metrics and scoring in Table E-6-10 were derived from the literature and RRT advice. The distance between suitable habitat blocks results are shown on Figure E-6-19.

5.2.3 Current Status of Habitat for the American Marten

The individual KEA analyses provide the basis for the compilation of an overarching data layer that defines the current status of American marten habitat for each HUC across the ecoregion. 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 as 1, 2, or 3, respectively, to the KEA. The KEAs were considered equally weighted; therefore, the Quality Rank Scores were simply averaged to produce an overall threat score for each HUC. The overall 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 score would result in a rating of poor for the HUC, based on the current status KEAs.

The results of the current status analysis for the American marten are displayed on Figure E-6-20. Conifer forest habitat blocks that would be sufficient in size to support adult female home ranges are scattered in several portions of the ecoregion (shown on Figure E-6-15). Comparison with the map of Maxent-predicted suitable habitat (Figure E-6-14) indicates that not all of the habitat blocks that scored good or fair with respect to size are likely to be occupied, in particular some conifer habitat in western Montana.

The current status of American marten habitat with respect to the wildland fire CA is shown on Figure E-6-9. HUCs in portions of the GYE and smaller scattered areas across the ecoregion had scores of mean FRI >100 years, whereas areas with shorter FRI (< 40 years) were concentrated in the northern portion of the ecoregion (primarily in Montana), and portions of the Bighorn Mountains. Snowpack depth and persistence are most favorable to American marten in the higher elevations of the same general areas (Figure E-6-10). HUCs that scored poor with respect to development effects were widespread throughout the ecoregion, with the exception of portions of the GYE. The fragmentation KEA (Figure E-6-18) indicated relatively few HUCs with good scores, but large portions of the ecoregion (including the GYE, western Wyoming, and western Montana) scored fair. With regard to habitat connectivity for long-distance movements, the best scores appear in the GYE and portions of western Montana (Figure E-6-19). The overall current status of American marten habitat in the ecoregion in this assessment is good to fair within much of the GYE and western Wyoming, while overall poor conditions were calculated in many watersheds in western Montana and Idaho (Figure E-6-20). Some of the low-scoring watersheds in this assessment occupy key corridors with the potential to connect larger, high-scoring blocks of habitat, reinforcing management concerns over connectivity for this species in this region.

A summary of the current status ratings based on the lynx distribution is provided in Table E-6-11. 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 one-third (31.4 percent) of the 6^{th} level HUC watersheds that intersect the marten distribution were rated as good. The majority of the habitat for this CE is considered below acceptable conditions.

Table E-6-11. Summary of Current Status Ratings for the American Marten

Overall Rating by 6th Level HUC	Total Square Miles[a]	Percentage of Total Square Miles[a, b]
Good	25,069	31.4
Fair	31,083	38.9
Poor	23,657	29.6

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

5.3 CURRENT STATUS FOR WOLVERINE

5.3.1 Key Ecological Attribute Selection

Table E-6-12 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 in the table, and some were revised based on RRT guidance. Some KEAs were used in the analysis because they are important for establishing current condition of the CE, but are not directly related to CAs. For example, Native Vegetation Blocks were mapped because this species has large home range requirements.

Table E-6-12. Key Ecological Attributes Retained or Excluded for the Wolverine

Category	Attribute	Explanation
1. Size	Suitable habitat blocks	Retained to show size of contiguous areas.
	Native Vegetation Blocks Containing Suitable Habitat	Excluded because of use of adopted distribution.
2. Condition	Wildland Fire Frequency FRI	Excluded per RRT comments. Wildland fire was not considered an important CA for wolverine habitat quality.
	Mean Monthly Snowpack/Depth	Retained to show persistence and depth of snowpack during critical months of the year.
	Development (disturbance due to human land use – exurban, transmission lines, oil and well, and towers)	Retained to show effects of human development.
	Distance to roads	Added to anthropogenic layer per literature review and RRT comments related to risk of mortality, barrier to connectivity, and disturbance.
3. Context	Dispersal ability Distance between large habitat blocks	Replaced by distance between suitable habitat patches; (long-distance and exploratory movements) to indicate distance that must be traversed by dispersing individuals.
	Fragmentation of suitable habitat	Excluded because no adequate information regarding metrics found.
	Distance between suitable habitat patches within home range (daily movements)	Analysis of daily distance traversed between habitat patches with a home range did not reveal differences across suitable habitats in the ecoregion. Attribute was revised to assess connectivity related to long-distance dispersal.
	Distance between suitable habitat patches; long-distance and exploratory movements	Replaced dispersal ability between large habitat blocks to indicate distance that must be traversed by dispersing individuals.

Table E-6-13 identifies the KEAs, indicators, and metrics that were used to evaluate the CAs and pathways affecting this CE assemblage across the ecoregion (as illustrated on Figure E-6-4). Several indicators were used to assess the current status for this assemblage. Suitable habitat size, habitat condition, and landscape context (e.g., distance to roads, distance between suitable habitat blocks) of the applicable output were incorporated into a GIS overlay analysis.

Table E-6-13. Wolverine Key Ecological Attributes, Indicators, and Metrics for Current Status Assessment for the Middle Rockies Ecoregion

Category	Ecological Attribute	Indicator / Unit of Measure	Metric			Data Source	Citation
			Poor = 3	Fair = 2	Good = 1		
Size	Suitable Habitat Blocks	Contiguous areas adopted data (km^2)	<250	250 - 350	>350	GAP	Hornocker & Hash 1981; Aubry et al. 1999; Inman et al. 2010; Copeland et al. 2010; Murphy et al. 2011
Condition	Habitat Condition	Mean Monthly Snowpack/Depth (cm) (January – mid-May)	<13 cm in May	present <4 months and 12 -77 cm	Present >4 months and >77 cm	NOAA	Aubry et al. 2007; Copeland 2008; Copeland et al. 2010; McKelvey et al. 2011; Murphy (pers. Comm.)
		Development (distance to human land use – exurban, grazing, mining)	<5 km	5-10 km	>10 km	Mining NLCD GAP Human Footprint	Murphy (pers. Comm.)
		Distance to roads (m) *From freeways & Secondary*	na	<500	>500	Linear features	Carrol et al. 2001; professional judgement
Landscape Context	Connectivity: Long-distance and exploratory	Distance between suitable habitat patches (km)	>150	60 -150	<60	GAP	Inman et al. 2012

In most cases, the metrics used to identify attribute quality were based on available scientific literature and reports, coupled with subject matter expert opinion 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 subject matter 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.

5.3.1.1 Suitable Habitat Blocks

The habitat block size KEA was used as a surrogate for availability of large, isolated tracts of wilderness required by wolverine. The sizes of suitable habitat blocks were calculated and ranked in three categories according to the metrics contained in Table E-6-13. The WCS layer is the result of a logistic regression analysis based on wolverine telemetry data collected in the GYE by the WCS's Greater Yellowstone Wolverine Program, 2001-2009. Size metrics were based on home range sizes of female wolverines in the Rocky Mountain reported in the literature and refined by RRT advice.

Figure E-6-22 presents the suitable habitat blocks for the wolverine.

5.3.1.2 Mean Monthly Snowpack / Depth

Presence of deep, persistent snowpack from December through mid-May in the Middle Rockies ecoregion was selected as an indicator of suitable habitat for the wolverine based on literature review and confirmed in discussion with the RRT. NOAA average monthly snowpack data are overlaid for months indicated in the KEA table. Areas which meet the criteria (depth and correct months) are assigned the appropriate values. The final layer contains categorical data, so the majority per watershed values are dispalayed in the map. The metrics shown in Table E-6-13 for the three categories of snowpack conditions are based on break points in available data sources (NLCD/NOAA) and conditions that may be present in occupied habitat. Good snowpack conditions in this table represent the closest approximations to values reported in the literature that could be made for this analysis using these data sources.

Figure E-6-23 presents the Mean Monthly Snowpack Presence and Depth for the wolverine.

5.3.1.3 Disturbance due to Human Land Use

Development was characterized in this analysis as the distance to human land use (exurban and rural development and mining). This KEA was used as an indicator to assess potential impacts from human land use, including habitat loss, barriers to connectivity, and avoidance due to disturbance.

Development data were compiled into one dataset from all applicable sources. Datesets include oil and gas wells, exurban or greater housing density, roads, transmission lines, and wind turbines. All anthropogenic layers are overlaid and distance is calculated from this layer to American marten suitable habitat. The mean distance per watershed from anthropogenic disturbance to American marten suitable habitat is displayed. Distance from development was assessed for 3 distance zones, as noted in Table E-6-13. The distance to development layer results are shown on Figure E-6-16.

5.3.1.4 Distance to Roads

Roads constitute a potential source of mortality, due to collision with vehicles and illegal shooting as well as a barrier to movement due to avoidance of high traffic volumes. Areas closest to roads generally have greater human activity and therefore indicate lower habitat suitability. Distance to roads was modeled by extracting freeways and secondary roads from the TIGER dataset. Road categories are buffered according to respective KEA table entry, and an overlay is then created. Where two different categories of threat overlap (good and fair), the lower of the two scores (in this case fair) is used. Distance to roads within each HUC was calculated and ranked as good or fair based on metrics in the literature, professional judgment, and discussion with the RRT.

Figure E-6-24 presents the distance to roads for the wolverine.

5.3.1.5 Distance between Suitable Habitat Blocks

The connectivity KEA reflects the need for juvenile wolverines to disperse from maternal homes. Distance between suitable habitat patches, as determined by Maxent modeled data, was used as a surrogate for connectivity. Metrics and scoring contained in Table E-6-13 were derived from the literature and RRT recommendations.

Figure E-6-25 presents the distance between large suitable habitat blocks for the wolverine.

5.3.2 Current Status of Habitat for the Wolverine

The individual KEA analyses provide the basis for the compilation of an overarching data layer that defines the current status of wolverine habitat for each HUC across this ecoregion. 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 as 1, 2, or 3, respectively to the KEAs. The KEAs were considered equally weighted; therefore, the Quality Rank Scores were simply averaged to produce an overall threat score for each HUC. The overall 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 score would result in a rating of poor for the HUC based on the current status KEAs.

The results of the current status analysis for the wolverine are presented on Figure E-6-26. Distribution data were analyzed to determine patches sufficient in size to support adult female wolverine home ranges. These areas were widely distributed in the ecoregion (as shown on Figure E-6-21). Comparison with the map of defined suitable habitat (Figure E-6-22) indicates that many of the habitat blocks that scored good or fair with respect to size are likely to be within areas of persistent snowpack depth and are most favorable to wolverines in the higher elevations of the ecoregion, including the GYE, portions of western Montana, and the Bighorn Mountains (Figure E-6-23). HUCs that scored poor with respect to development effects were widespread throughout the ecoregion with the exception of portions of the GYE. The overall current status of wolverine habitat in this ecoregion in this assessment is good to fair within much of the GYE, western Wyoming, western Montana, and Idaho, while overall poor conditions were calculated in many watersheds in western Montana and Idaho (Figure E-6-26). Some of the low-scoring watersheds in this assessment occupy key corridors with the potential to connect larger, high-scoring blocks of habitat, reinforcing management concerns over connectivity for this species in this region.

A summary of the current status ratings based on the wolverine distribution is provided in Table E-6-14. 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 one-third (30.7 percent) of the 6th level HUC watersheds that intersect the wolverine distribution were rated as good. The majority of the habitat for this CE is considered below acceptable conditions.

Table E-6-14. Summary of Current Status Ratings for the Wolverine

Overall Rating by 6th Level HUC	Total Square Miles[a]	Percentage of Total Square Miles[a, b]
Good	18,712	30.7
Fair	24,023	39.4
Poor	18,287	30.0

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

5.4 FUTURE THREAT ANALYSIS

The KEAs, indicators, and metrics used to evaluate the CA analysis for the future threats potentially affecting this CE across the ecoregion are presented in Appendix C-1 (development) and Appendix C-5 (climate change). These KEAs were used to create a series of intermediate layers based on the geospatial data that was available. The evaluation presented here is on a qualitative level; 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 the populations of the forest carnivore species.

5.4.1 Future Threat Analysis for the Lynx

Future threats for the Canada lynx were evaluated for development and climate change for long-term change (50-year; 2050 to 2069). Future spatial data for development was limited to potential energy development areas and modeled urban growth, as discussed in the development CA analysis presented in Appendix C-1. Climate change was modeled based on a 15-km grid created for regional analysis. This analysis included 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.

5.4.1.1 Development Change Agent

Spatial data for future threats to Canada lynx habitat included urban development (urban, exurban, and rural development) in undeveloped or underdeveloped regions. This development category includes expansion of roadways that are projected under reasonably foreseeable development scenarios in areas of intact habitat that are isolated from existing infrastructure. Figure C-1-8, Future Urban Growth Potential, illustrates the risk to lynx habitat based on the future urban, exurban, and rural development potential risk maps.

A comparison of the distribution map for Canada lynx (Figure E-6-7) with the future urban growth map (Figure C-1-8) indicates there is little overlap between the two, primarily because defined lynx habitat is generally at higher elevations and far from existing and projected urban, exurban, and rural development centers.

Canada lynx are at some risk to exurban development, in addition to land uses such as recreational use of wildlands and logging that were not included in this analysis. The results of expanding human development may include forest habitat loss, disturbance, and illegal shooting and trapping. The scale of this analysis did not identify any particular areas of concern where anticipated future human development overlaps with defined lynx habitat; however, more localized analysis of anticipated development overlap with lynx distribution may be possible, including the use of results of recent field surveys in the GYE and northern Rockies (Murphy et al. 2005; Squires et al. 2007; Squires et al. 2010) that provide important insights into fine-scale habitat preferences. Analysis at a finer scale will help to identify localized areas of greatest potential threats.

5.4.1.2 Climate Change

Canada lynx are vulnerable to climate change because of their dependence on snowpack during extended periods in winter/early spring, and persistence of boreal/subalpine forest types. The climate CA layer was created from the results of the 1980-1999 baseline and 2050-2069 predicted future climate models with the intention of documenting areas that may be negatively and positively affected by future climate change, as described in detail in Appendix C-5. Precipitation and temperature were analyzed annually and in five time periods within the year. Of particular interest to Canada lynx are the winter months during which snowpack accumulates (November-February and March-April), and summer months when drought and high temperatures occur (July-August). Additionally, snow water equivalent (SWE) for the month of April was analyzed as a surrogate variable to approximate late winter changes in snow pack depth.

Modeled future conditions for winter precipitation indicate that the amount could remain unchanged across the ecoregion during the analysis period, but there could be some localized increases and decreases (see Appendix C-5 for details). Temperature during the winter months may increase overall across the ecoregion by between 1.1 to 3 degrees Celsius (°C), with greater increases (3 to 5°C) at higher elevations. April SWE indicates that the most northern ranges in this ecoregion may remain unchanged, while western ranges in Montana and some ranges in Wyoming west into Idaho could experience significant decreases. Most-affected areas include the Absaroka Range, the Wind River Range, the Beartooth Mountains, and the Bighorn Range. These conditions may affect depth and persistence of snowpack in lynx habitats; significant decreases may affect the ability of lynx to utilize otherwise suitable habitat and may result in range shifts.

During the summer period predictions also vary by region, with the potential for significant decrease in precipitation in some areas. Temperature trends during the summer months indicate increases from 3.1 to 5°C at middle elevations and 5.1 to 8.7°C at higher elevations. These increases will likely increase water stress in forests and provide more fuel load for wildfires. This trend could indirectly affect the range of lynx in the ecoregion if it leads to elevational shifts in suitable conifer forest habitat, or other deleterious effects on forest habitat associated with increased fire frequency/severity or increased insect/pest outbreaks.

Results of climate change modeling in this analysis corroborate other efforts to predict effects of future climate change on lynx. Gonzalez et al. (2007) reviewed a range of IPCC future climate scenarios and modeling of vegetation using the MC1 dynamic global vegetation model, finding that a protected 3.9°C + 0.7°C warming of annual average temperatures and changes in precipitation in the period 1990-2100 may decrease snow cover suitable for lynx by 10 to 20 percent across the continental United States and Canada. Adequate snowpack and the extent of boreal/subalpine forest may shift toward relatively cooler areas, shifting lynx habitat northward as much as 200 km. Lynx populations at the southern periphery of the species' distribution, including the Middle Rockies, are in vulnerable areas that could lose potential lynx habitat in the long term.

5.4.2 Future Threat Analysis for the American Marten

Future threats for the American marten were evaluated for development and climate change for long-term change (50-year; 2050 to 2069). Future spatial data for development was limited to potential energy development areas and modeled urban growth, as discussed in the development CA analysis presented in Appendix C-1. Climate change was modeled based on a 15-km grid created for regional analysis. This analysis included 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 is provided in Appendix C-5.

5.4.2.1 Development

Spatial data for future threats to American marten habitat included development (urban, exurban, and rural development) in undeveloped or underdeveloped regions. This development category includes expansion of roadways that are projected under reasonably foreseeable development scenarios in areas of intact habitat that are isolated from existing infrastructure.

A comparison of the modeled suitable habitat map for American marten (Figure E-6-14) with the future urban growth map (Figure C-1-8) indicates there is low risk because modeled habitat is far from existing and projected urban, exurban, and rural development centers.

Although the scale of this analysis did not identify any particular areas of concern where future human development overlaps with modeled American marten habitat, American marten are potentially at risk to these effects where there is overlap or close proximity. In addition to expanding exurban development and associated road systems, recreational use of wildlands and logging, (which were not included in this analysis) may affect American marten's ability to occupy these areas due to forest habitat loss, disturbance, and trapping.

5.4.2.2 Climate Change

American marten are vulnerable to climate change because of their dependence on snowpack during extended periods in winter/early spring. In addition, the decline of boreal/subalpine forest types resulting from climate change will reduce American marten habitat. The climate CA layer was created from the results of the 1980-1999 baseline and 2050-2069 predicted future climate models with the intention of documenting areas that may be negatively and positively affected by future climate change, as described in detail in Appendix C-5. Precipitation and temperature were analyzed annually and in five time periods within the year. Of particular interest to American marten are the winter months during which snowpack accumulates (November-February and March-April), and summer months when drought and high temperatures occur (July-August). Additionally, SWE for the month of April was analyzed as a surrogate variable to approximate late winter changes in snow pack depth.

Modeled future conditions for winter precipitation indicate that the amount could remain unchanged across the ecoregion during the analysis period, but there could be some localized increases and decreases (see Appendix C-5 for details). Temperature during the winter months may increase overall across the ecoregion by between 1.1 to 3°C, with greater increases (3 to 5°C) at higher elevations. April SWE indicates that the most northern ranges in this ecoregion may remain unchanged, while western ranges in Montana and some ranges in Wyoming west into Idaho could experience significant decreases. The most-affected areas include the Absaroka Range, the Wind River Range, the Beartooth Mountains, and the Bighorn Range. These conditions may affect depth and persistence of snowpack in lynx habitats; significant decreases may affect the ability of American marten to utilize otherwise suitable habitat and may result in range shifts.

During the summer period, predictions also vary by region, with the potential for significant decreases in precipitation in some areas. Temperature trends during the summer months indicate increases from 3.1 to 5°C at middle elevations and 5.1 to 8.7°C at higher elevations. These increases will likely increase water stress in forests and provide more fuel load for wildfires. This trend could indirectly affect the range of American marten in the ecoregion if it leads to elevational shifts in suitable conifer forest habitat, or other deleterious effects on forest habitat associated with increased fire frequency/severity or increased insect pest outbreaks.

5.4.3 Future Threat Analysis for the Wolverine

Future threats for the wolverine were evaluated for development and climate change for long-term change (50-year; 2050 to 2069). Future spatial data for development was limited to potential energy development area and modeled urban growth, as discussed in the development CA analysis presented in Appendix C-1. Climate change was modeled based on a 15-km grid created for regional analysis. This analysis included 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. A NatureServe Climate Change Vulnerability Index (NSCCVI) score was calculated for the wolverine to represent the overall vulnerability of the wolverine to future climate change.

5.4.3.1 Development

Spatial data for future threats to wolverine habitat included urban development (urban, exurban, and rural development) in undeveloped or underdeveloped regions. This development category includes expansion of roadways that are projected under reasonably foreseeable development scenarios in areas of intact habitat that are isolated from existing infrastructure.

A comparison of the distribution map for wolverine (Figure E-6-21) with the future urban growth map (Figure C-1-8) indicates there is low potential risk, primarily because defined wolverine habitat is generally at higher elevations and far from existing and projected urban, exurban, and rural centers.

Although the scale of this analysis did not identify any particular areas of concern where future human development overlaps with wolverine distribution, wolverine may still be at risk to these effects where there is overlap or close proximity. In addition to expanding exurban development and associated road systems, winter recreational use of wildlands and logging (which were not included in this analysis), may affect the wolverine's ability to occupy these areas due to habitat loss, disturbance, barriers to connectivity for dispersing individuals, shooting, and trapping.

5.4.3.2 Climate Change

Wolverine are vulnerable to climate change because of their dependence on snowpack during extended periods in winter/early spring. The climate CA layer was created from the results of the 1980-1999 baseline and 2050-2069 predicted future climate models with the intention of documenting areas that may be negatively and positively affected by future climate change, as described in detail in Appendix C-5. Precipitation and temperature were analyzed annually and in five time periods within the year. Of particular interest to wolverine are the winter months during which snowpack accumulates (November-February and March-April), and summer months when drought and high temperatures occur (July-August). Additionally, SWE for the month of April was analyzed as a surrogate variable to approximate late winter changes in snow pack depth.

Modeled future conditions for winter precipitation indicate that the amount could remain unchanged across the ecoregion during the analysis period, but there could be some localized increases and decreases (see Appendix C-5 for details). Temperature during the winter months may increase overall across the ecoregion by between 1.1 to 3°C, with greater increases (3 to 5°C) at higher elevations. April SWE indicates that the most northern ranges in this ecoregion may remain unchanged, while western ranges in Montana and some ranges in Wyoming west into Idaho could experience significant decreases. The most-affected areas include the Absaroka Range, the Wind River Range, the Beartooth Mountains, and the Bighorn Range. These conditions may affect depth and persistence of snowpack in wolverine habitats; significant decreases may affect the ability of the wolverine to utilize otherwise suitable habitat and may result in range shifts.

During the summer period, predictions also vary by region, with the potential for significant decreases in precipitation in some areas. Temperature trends during the summer months indicate increases from 3.1 to 5°C at middle elevations and 5.1 to 8.7°C at higher elevations. These increases will likely increase water stress in forests and provide more fuel load for wildfires. This trend could indirectly affect the range of wolverine in the ecoregion if it leads to elevational shifts in suitable conifer forest habitat, or other deleterious effects on forest habitat associated with increased fire frequency/severity or increased insect pest outbreaks.

Other efforts to model the effects of future climate change on wolverine over larger portions of their range are available (Peacock 2011; McKelvey et al. 2011). McKelvey et al. (2011) modeled snow cover within the Columbia, Upper Missouri, and Upper Colorado River Basins and predicted that contiguous areas of spring snow may become smaller and more isolated over time, but large (>1,000 km^2) contiguous areas of wolverine habitat may persist within this study area throughout the 21st century. Among the areas that were predicted to retain snow cover during the 21st century were northwestern Montana and the GYE. However, dispersal modeling over this broad study area indicated that habitat isolation at or above levels associated with genetic isolation of populations may become widespread, leading to the prediction that wolverine populations will become smaller and more isolated. This is a concern for wolverines in this ecoregion because it is not known whether wolverine populations in this ecoregion can persist without recruitment from adjacent ecoregions.

5.4.3.3 NSCCVI

A NSCCVI score was calculated for the wolverine to represent the overall vulnerability of the assemblage to future 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 **Extremely Vulnerable.** The NSCCVI tool indicated that available evidence suggests the abundance and/or range extent of this species within the geographical area assessed is extremely likely to to substantially decrease or disappear by 2050. The assessment rating was largely based on a majority of somewhat increase and greatly increase vulnerability scores calculated when assessing factors that influence vulnerability, such as distribution to barriers, 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 genetic factors.

6.0 MANAGEMENT QUESTIONS

The relevant MQs for the forest carnivore assemblage 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. Several examples of how the REA can be used to answer MQs (as noted in Appendix A) are provided below; these examples demonstrate the functionality of the REA and provide an opportunity to discuss 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?

For each species in this assemblage, the maps of suitable habitat and the distribution maps could be used to identify suitable, currently unoccupied habitat. The maps of overall score for habitat quality (Figures E-6-13, E-6-20, and E-6-26), in conjunction with local information on site-specific land use and other conditions, could be used to identify areas with greatest restoration potential.

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

Actual corridors used by dispersing forest carnivores are not known, but key habitat types can be predicted from the maps of suitable habitat and the maps of overall habitat quality. Areas of concentration of forest carnivores are not well known in this ecoregion, and would require more extensive field survey efforts.

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 full range of maps and analyses for forest carnivores can be used to answer this complex MQ with respect to current and future development. The models created in this REA were designed to address the effects of development CAs on forest carnivores with spatial output for current conditions. Future development CA threats are described and mapped in the Development CA appendix (Appendix C-1) and are qualitatively discussed with reference to forest carnivore species in previous sections of this appendix. Similarly, climate change is discussed qualitatively in this appendix.

THIS PAGE INTENTIONALLY LEFT BLANK

7.0 REFERENCES

Agee, J.K. 1999. Distribution ecology of North American boreal forest and associated northern mixed subalpine forests. Pages 39-82 in L.F. Ruggiero, K.B. Aubry, S.W. Buskirk, G.M. Koehler, C.J. Krebs, K.S. McKelvey, and J.R. Squires, eds. Ecology and conservation of lynx in the United States. RMRS-GTR-30WWW. USDA Forest Service Rocky Mountain Research Station.

Aubry, K.B., L.F. Ruggiero, G.M. Koehler, and J.R. Squires 1999. Ecology of Canada lynx in southern boreal forests. Pages 373-396 in L.F. Ruggiero, K.B. Aubry, S.W. Buskirk, G.M. Koehler, C.J. Krebs, K.S. McKelvey, and J.R. Squires, eds. Ecology and conservation of lynx in the United States. RMRS-GTR-30WWW. USDA Forest Service Rocky Mountain Research Station.

Aubry, K. B., G. M. Koehler, J. R. Squires. 2000. Ecology of Canada lynx in southern boreal forests. Pages 373-396 in Ruggiero et al., Ecology and Conservation of Lynx in the United States. University Press of Colorado, Boulder, Colorado.

Aubry, K.B., K.S. McKelvey, and J.P. Copeland. 2007. Distribution and broadscale habitat relations of the wolverine in the contiguous United States. Journal of Wildlife Management 71:2147-2158.

Banci, V. 1994. Wolverine. Pages 99-127 in L.F. Ruggiero, K.B. Aubry, S.W. Buskirk, L.J. Lyon, and W.J. Zielinski. Technical editors. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine. USDA Forest Service General Technical Report RM-254. USDA Forest Service Rocky Mountain forest and Range Experiment Station, Fort Collins, CO.

Brainerd, S. M. 1985. Reproductive ecology of bobcats and lynx in western Montana. University of Montana, Missoula.

Brand, C.J., L.B. Keith, and C.A. Fischer. 1976. Lynx responses to changing snowshoe hare densities in central Alberta. Journal of Wildlife Management 40(3):416-428.Brand, C. J., and L. B. Keith. 1979. Lynx demography during a snowshoe hare decline in Alberta. Journal of WildlifeManagement 43:827-849.

Brand, C. J. and L. B. Keith. 1979. Lynx demography during a snowshoe hare decline in Alberta. Journal of Wildlife Management 43:827-849.

Bull, E.L. and T.W. Heater. 2001. Home range and dispersal of the American marten in northeastern Oregon. Northwestern Naturalist 82:7-11.

Buskirk, S.W. and L.L. McDonald. 1989. Analysis of variability in home-range size of the American marten. Journal of Wildlife Management 53(4):997-1004.

Buskirk, S.W. and L.F. Ruggiero. 1994. American Marten. Pages 7-37 in L.F. Ruggiero, K.B. Aubry, S.W. Buskirk, L.J. Lyon, and W.J. Zielinski. Eds. The scientific basis for conservation of forest carnivores: American marten, fisher, lynx, and wolverine the western United States. GTR RM-254. USDA Forest Service.Buskirk, S.W. and W.J.Zielinski. 1997. American Marten (*Martes Americana*) ecology and conservation. Pages 17-22 in J.E. Harris and C.V. Ogan, eds. Mesocarnivores of northern California: biology, management, and survey techniques. Workshop Manual. August 12-15, 1997. Humboldt State University, Arcata, CA. the Wildlife society, California North Coast Chapter.

Buskirk, S.W. 2002. Conservation Assessment for the American Marten in the Black Hills National Forest, South Dakota and Wyoming

Carroll, C. 2007. Interacting effects of climate change, landscape conversion, and harvest on carnivore populations at the range margin: marten and lynx in the northern Appalachians. Conservation Biology 21:1092-1104.

Carroll, C., R.F. Noss, and P.C. Paquet. 2001. Carnivores as focal species for conservation planning in the Rocky Mountain region. Ecological Applications 11(4):961-980.

Copeland, J.P., J.M. Peerk, C.R. Groves, W.E. Melquist, K.S. McKelvery, G.W. McDaniel, C.D. Long, and C.E. Harris. 2007. Seasonal habitat associations of the wolverine in central Idaho. Journal of Wildlife Management 71:2201-2212. Copeland, J.P., K.S. McKelvey, K.B. Aubry, A. Landa, J. Persson, R.M. Inman, J. Krebs, E. Lofroth, H. Golden, J.R. Squires, A. Magoun, M.K. Schwartz, J. Wilmot, C.L. Ccopeland, R.E. Yates, I. Kojhola, and R. May. 2010. The bioclimatic envelope of the wolverine (*Gulo gulo* spp.): do climatic constraints limit its geographic distribution? Canadian Journal of Zoology 88(3):233-246.

Copeland, J.P. and R.E. Yates. 2008. Wolverine population assessment in Glacier National Park: comprehensive summary update. USDA Forest Service, Rocky Mountain Research Station, Missoula, MT. 15 pp.

Corn, J.G. and M.G. Raphael. 1992. Habitat characteristics at marten subnivean access sites. Journal of Wildlife Management 56:442-448.

Gilpin, .E. and M.E. Soule. 1986. Minimum viable populations: processes of species extinction. in M.E. Soule, ed. Conservation biology: the science of scarcity and diversity. Sunderland, MA:Sinauer Associates.

Gonzalez, P., R.P. Neilson, K.S. McKelvey, J.M. Lenihan, and R.J. Drapek. 2007. Potential impacts of climate change on habitat and conservation priority areas for *Lynx Canadensis* (Canada Lynx). Report to Watershed, Fish, Wildlife, Air, and Rare Plants Staff; National Forest System; Forest Service; USDA. Washington, D.C. and NatureServe, Arllington, VA. Report from The Nature Conservancy, Arlington, VA.Hargis, C.D., J.A. Bissonette,a nd D.J. Turner. 1999. The influence of forest fragmentation and landscape pattern on American martens. Journal of Applied Forestry 36(1):157-172.

Hargis, C. D., J. A. Bissonette, and D. L. Turner. 1999. The influence of forest fragmentation and landscape pattern on American martens. Journal of Applied Ecology 36:157–172.

Hirzel AH, Le Lay G, Helfer V, Randin C, Guisan A. 2006. Evaluating the ability of habitat suitability models to predict species presences. Ecol Model 199:142–152.

Hornocker, M.G. and H.S. Hash 1981. Ecology of the wolverine in northwestern Montana. Canadian Journal of Zoology 59:1286-1301

IPCC (Intergovernmental Panel on Climate Change). 2007. Climate Change 2007: the Physical Science Basis. Contribution of Working Group I to the fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press.

Inman R.M., Packila M., Inman K., Aber B., Spence R., McCauley D. 2010. Greater Yellowstone wolverine program. Unpublished report, Wildlife Conservation Society. Ennis, Montana.

Inman, R. M., Packila, M. L., Inman, K. H., Mccue, A. J., White, G. C., Persson, J., Aber, B. C., Orme, M. L., Alt, K. L., Cain, S. L., Fredrick, J. A., Oakleaf, B. J. and Sartorius, S. S. 2011, Spatial ecology of wolverines at the southern periphery of distribution. The Journal of Wildlife Management, 76: 778–792.

Inman, R.M., M.L. Packila, K.H. Inman, A.J. McCue, G.C. White, J. Persson, B.C. Aber, M.L. Orme, K.L. Alt, S.L. Cain, J.A. Fredrick, B.J. Oaklead, and S.S. Sartorius. 2012. Spatial ecology of wolverines at the southern periphery of distribution. Journal of Wildlife Management 76(4):778-792.

Kirk, T.A. and W.J. Zielinski. 2009. Developing and testing a landscape habitat suitability model for the American marten (*Martes americana*) in the Cascades mountains of California. Landscape Ecology. DOI 10.1007/s10980-009-9349-5

Koehler, G.M. 1990. Population and habitat characteristics of lynx and snowshoe hares in north central Washington. Canadian Journal of Zoology 68:845-851.

Koehler, G. M. and J. D. Brittell. 1990. Managing spruce-fir habitat for lynx and snowshoe hares. Journal of Forestry 88(10):10-14.

Koehler, G.M., and K.B. Aubry. 1994. Chapter 4: Lynx. Pages 74-98 in American Marten, Fisher, Lynx, and Wolverine in the Western United States, L.F. Ruggiero, K.B. Aubry, S.W. Buskirk, L.J. Lyon, W.J. Zielinski, eds. U.S. Forest Service, Gen. Tech. Rpt. RM- 251.

Krohn, W.B., K.D. Elowe, and R.B. Boone. 1995. Relations among fishers, snow, and martens: development and evaluation of two hypotheses. The Forestry Chronicle 71(1):97-105.

McKelvey, K.S., J.P. Copeland, M.K. Schwartz, J.S. Littell, K.B. Aubry, J.R. Squires, S.A. Parks, M.M. Elsner, and G.S. Mauger. 2011. Climate change predicted to shift wolverine distributions, connectivity,a nd dispersal corridors. Ecological Applications 21(8):2882-2897.

Murphy, K., T. Potter, J. Halfpenny, K. Gunther, T. Jones, and P. Lundberg. 2005. The elusive Canada lynx. Yellowstone Science 13(2):7-15.

Murphy, K., J. Wilmot, J. Copeland, D. Tyers, J. Squires, R. M. Inman, M. L. Packila, D. McWhirter. 2011. Wolverine conservation in Yellowstone National Park: Final report. YCR-2011-02. National Park Service, Yellowstone National Park, Yellowstone Center for Resources, Yellowstone National Park, Wyoming.

Noss, R.F., H.B. Quigley, M.G. Hornocker, T. Merrill, and P.C. Paquet. Conservation biology and carnivore conservation in the Rocky Mountains. 1996. Conservation Biology 10(4):949-963.

O'Doherty, E.C., L.F. Ruggiero, and S.E. Henry. 1997. Home-range size and fidelity of American martens in the rocky Mountains of southern Wyoming. Pages 123-134 in G. Proulx, H.N. Bryant, and P.M. Woodard, editors. Martes: taxonomy, ecology, techniques, and management. Provincial Museum of Alberta, Edmonton, Alberta, Canada.

Oliff, S.T., K. Legg, B. Kaeding, eds. 1999. The effects of winter recreation on wildlife of the Greater Yellowstone Area: a literature review and assessment, draft report. A report to the Greater Yellowstone coordinating Committee. Yellowstone National Park, WY.

Peacock, S. 2011. Projected 21st century climate change for wolverine habitats within the contiguous United States. Environmental Research Letters 6: 014007.

Powell. R. A. 1994. Structure and spacing in Martes populations. Pages 10 1-2 1in S. W Buslurk, A. S. Harestad M. G. Raphael, and R. A. Powell, eds.Martens, sables, and fishers: Biology and conservation. Cornell UniversityPress, Ithaca, NY.

Ruediger, B., J. Claar, S. Gniadek, B. Holt, L. Lewis, S. Mighton, B. Nanaey, G. Patton, T. Rinaldi, J. Trick. A. Vandehey, F. Wahl, N. Warren, D. Wenger, and A. Williamson.2000. Canada lynx conservation assessment and strategy, 2nd edition. USDA Forest Service, USDI Fish and Wildlife Service, USDI Bureau of Land Management, and USDI National Park Service. Forest Service Publication #R1-00-53. Missoula, Montana. 142 pp.

Squires, J.R. 2005. Conservation challenges of managing lynx. Yellowstone Science 13(2):10-11

Squires, J.R. 2007. Hierarchical den selection of Canada lynx in western Montana. Journal of Wildlife Management 72(7):1497-1506.

Squires, J.R. and T. Laurion. 2000. Lynx home range and movements in Montana and Wyoming: preliminary results. Pages 337-349 in L.F. Ruggiero, K.B. Aubry, S.W. Buskirk, G.M. Koehler, C.J. Krebs, K.S. McKelvey, and J.R. Squires, editors. Ecoclogy and conservation of lynx in the United States. University Press of Colorado, Boulder, CO.

Squires, J.R., N.J. Decesare, J.A. Kolbe, and L.F. Ruggiero. 2010. Seasonal resource selection of Canada lynx in managed forests of the northern Rocky Mountains. Journal of Wildlife Management 74(8):1648-1660.

Thompson, I.D. and P.W. Colgan. 1987. Numerical responses of martens to a food shortage in northcentral Ontario. Journal of Wildlife Management 51:824-35.

Unnasch, R.S., D.P. Braun, P.J. Comer, and 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.

Wasserman, T.N., S.A. Cushman, M.K. Schwartz, and D.O. Wallin. 2010. Spatial scaling and multi-model inference in landscape genetics: *Martes americana* in northern Idaho. Landscape Ecology 25:1601-1612.

APPENDIX E-6

FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

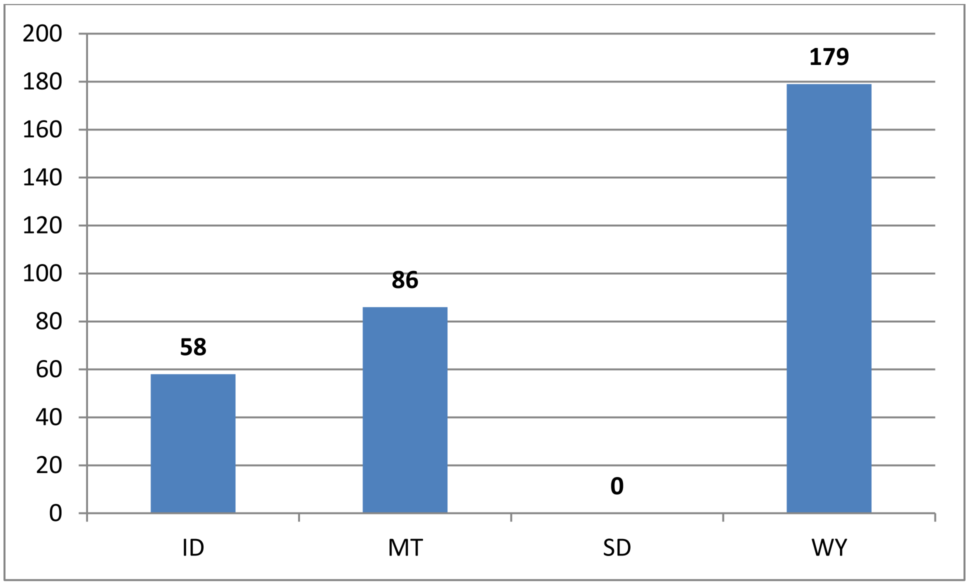

Figure E-6-1. Individual State Contribution to Marten Observations

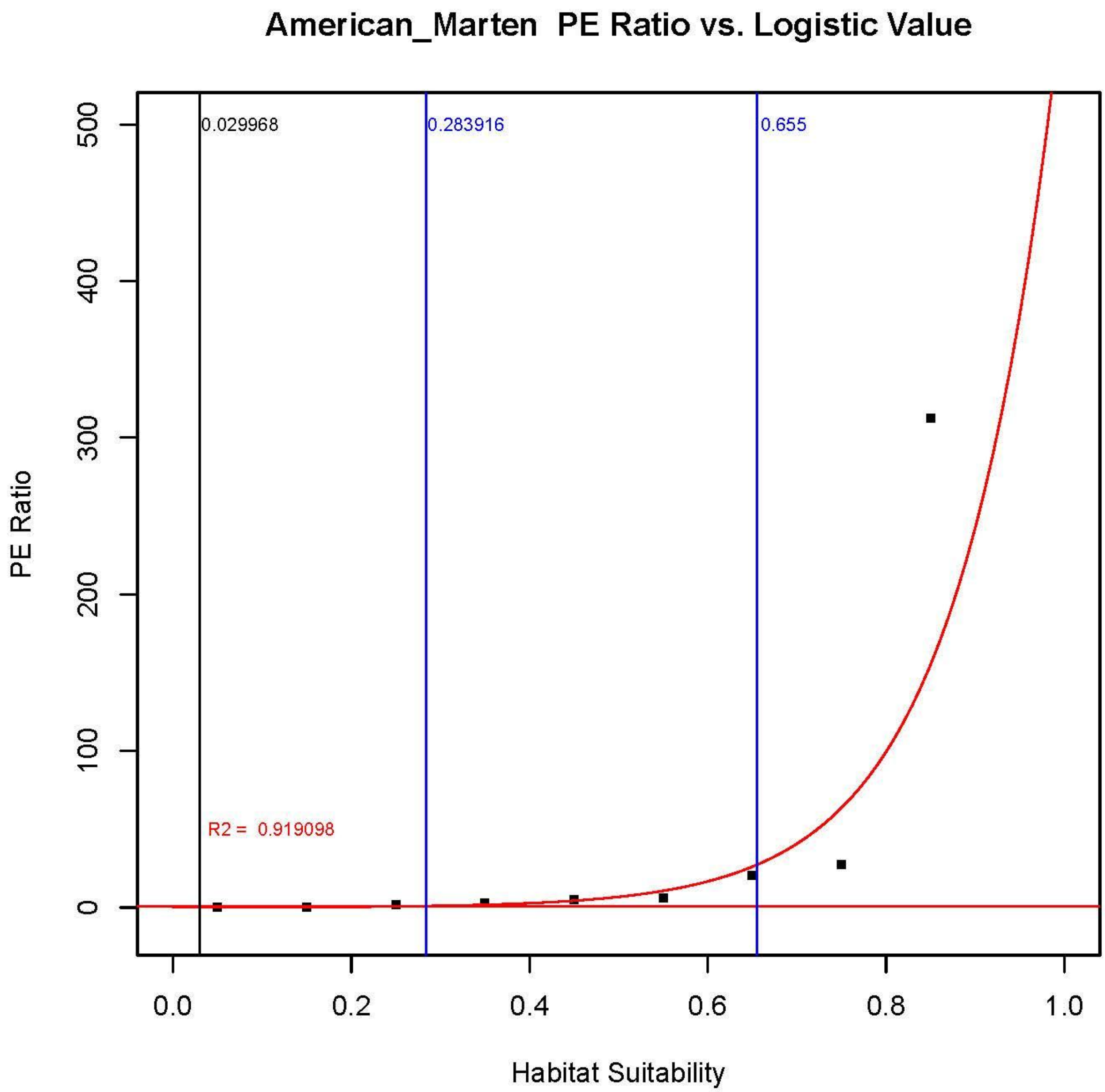

Figure E-6-2. R script PDF Output for American Marten in the MIR Ecoregion

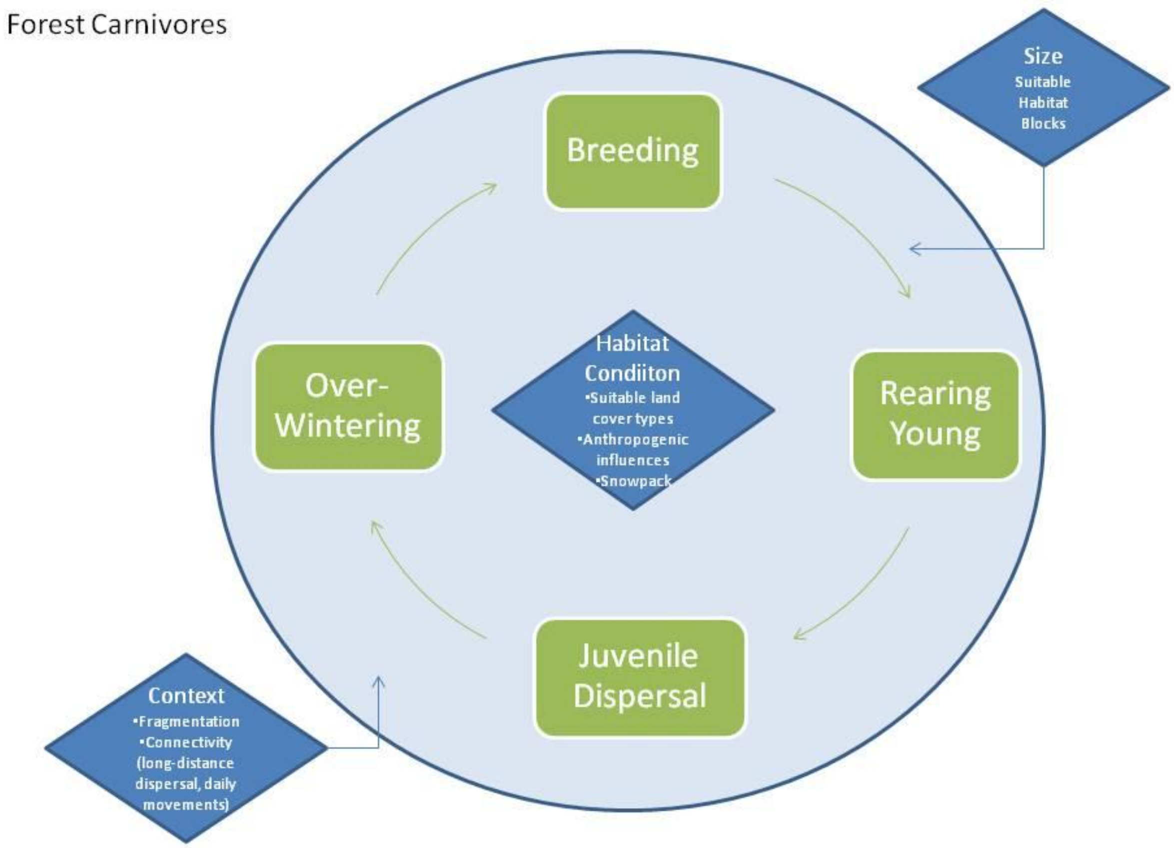

Figure E-6-3. Forest Carnivore Assemblage Ecological Process Model

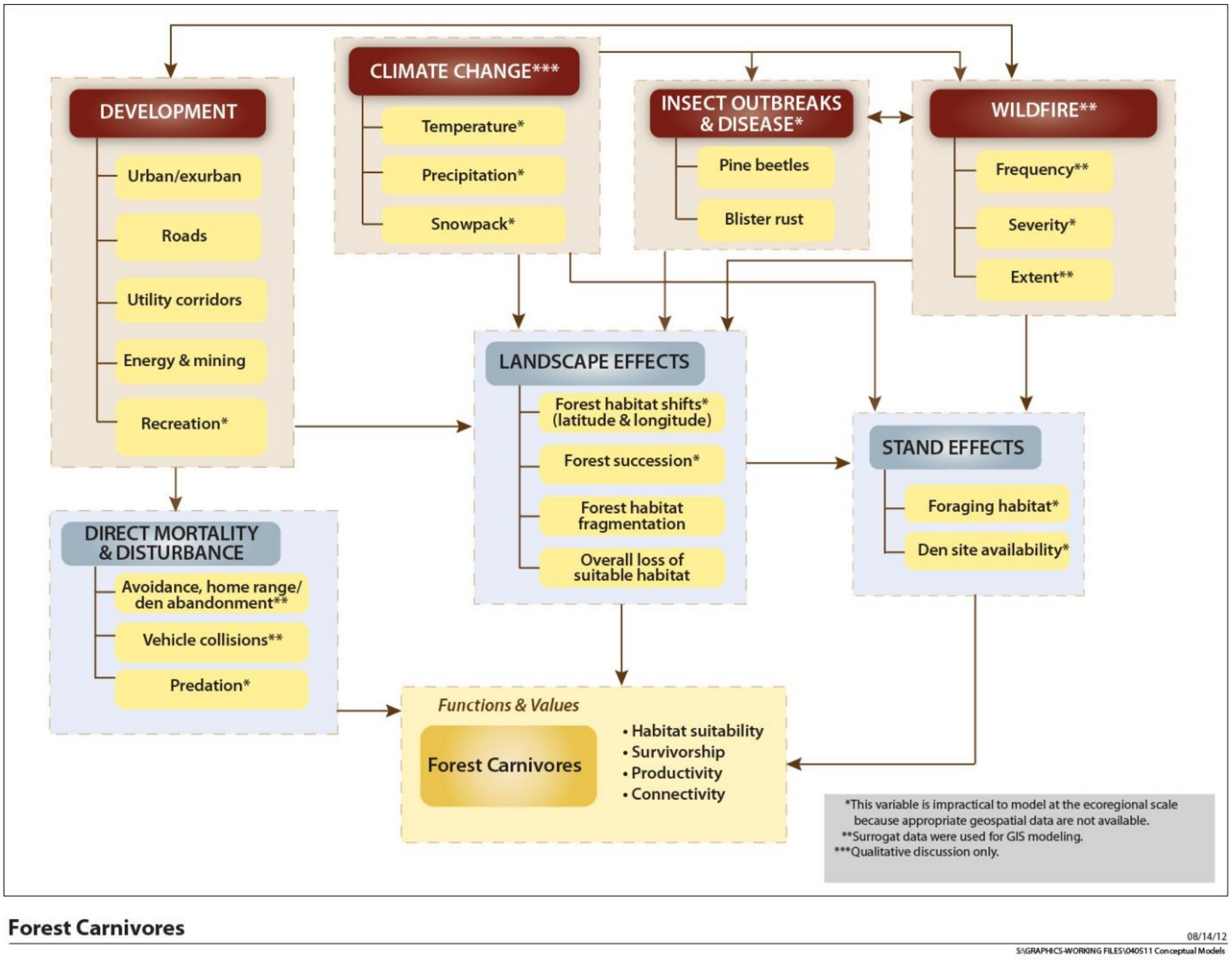

Figure E-6-4. Forest Carnivore Assemblage System-Level Conceptual Model

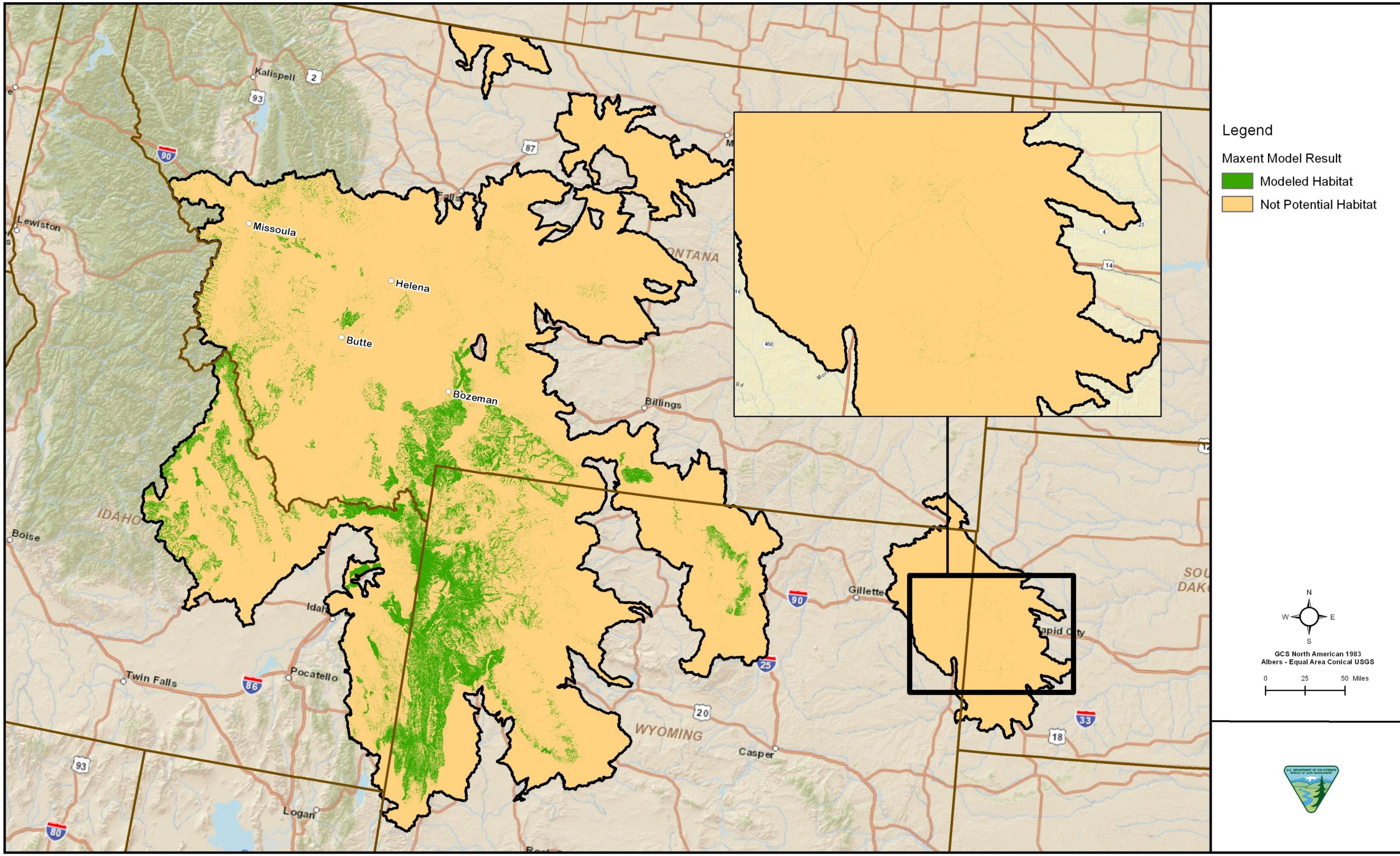

Figure E-6-5. Maxent American Marten Modeled Results

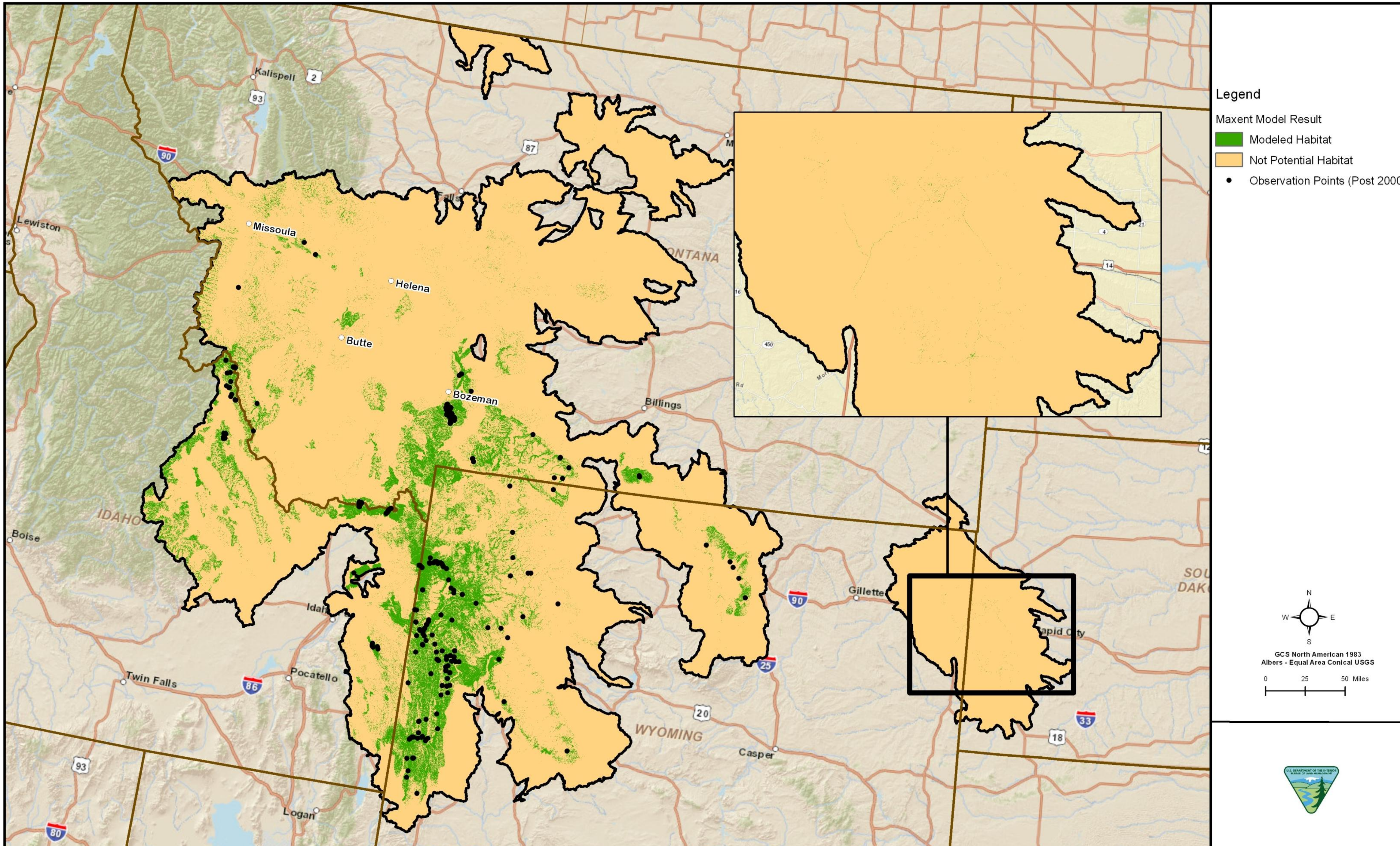

Figure E-6-6. Maxent American Marten Modeled Results with Point Observations

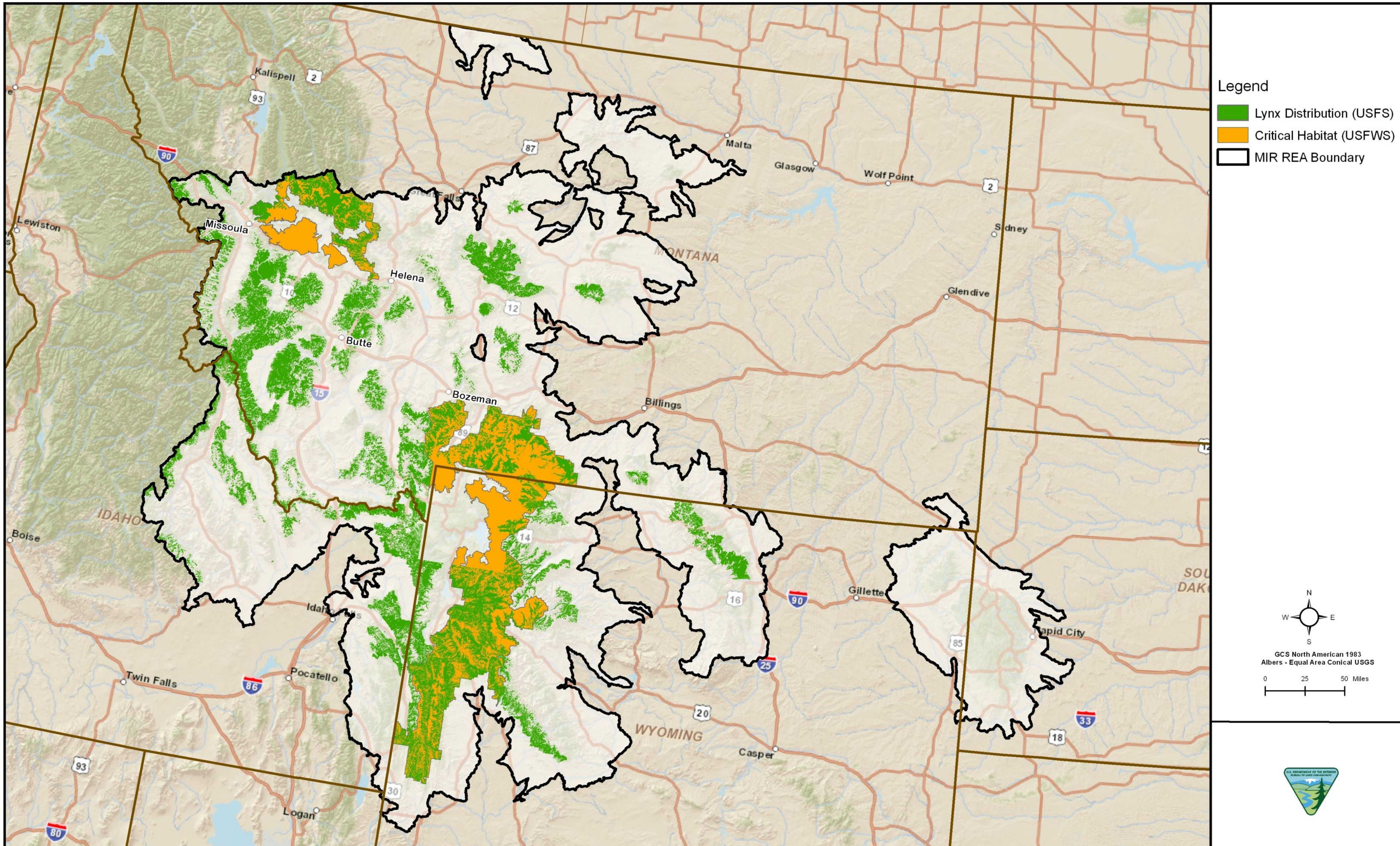

Figure E-6-7. Lynx CE Distribution

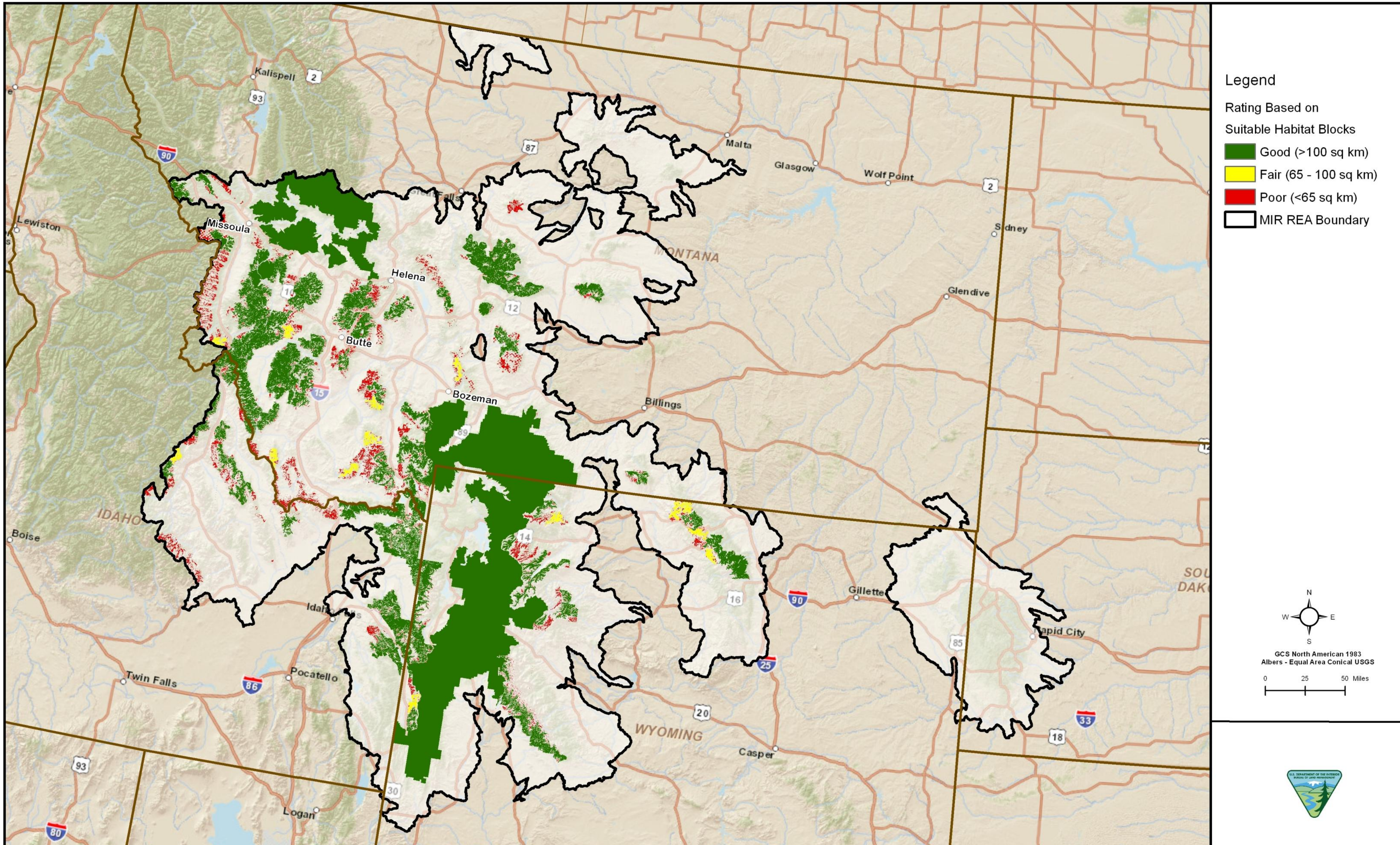

Figure E-6-8. Lynx Suitable Habitat Blocks

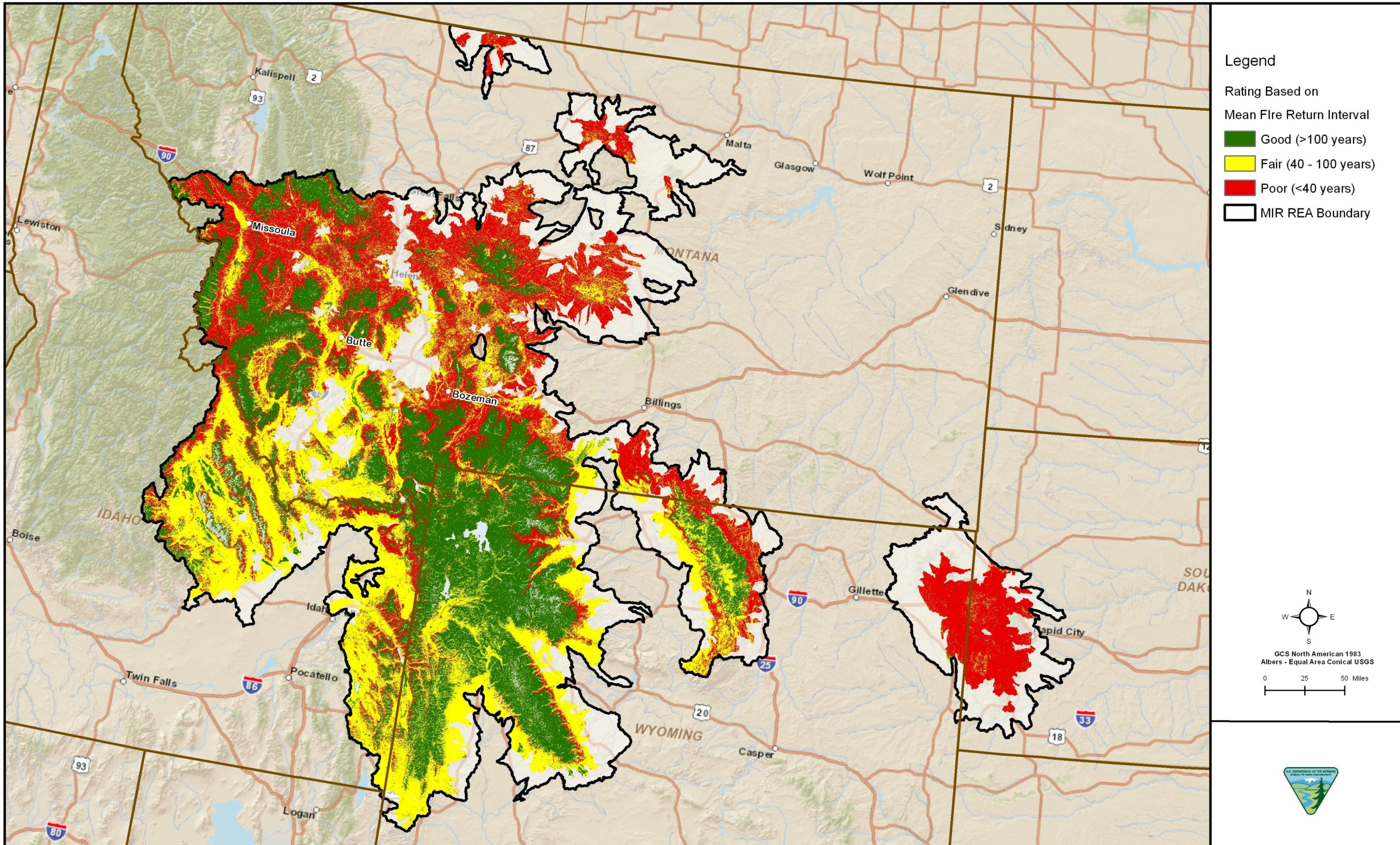

Figure E-6-9. American Marten and Lynx Mean Fire Return Interval

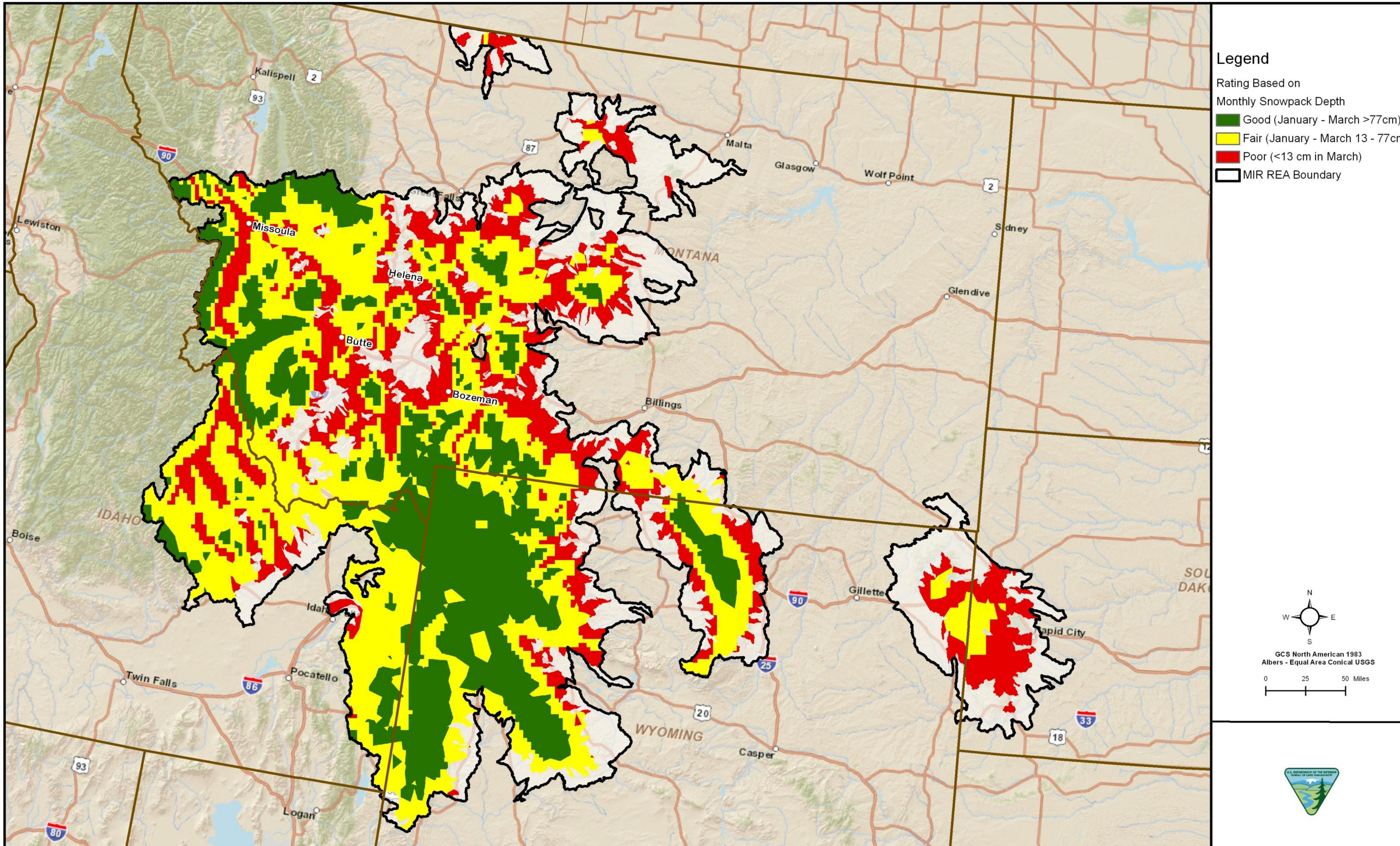

Figure E-6-10. American Marten and Lynx Mean Monthly Snowpack/Depth

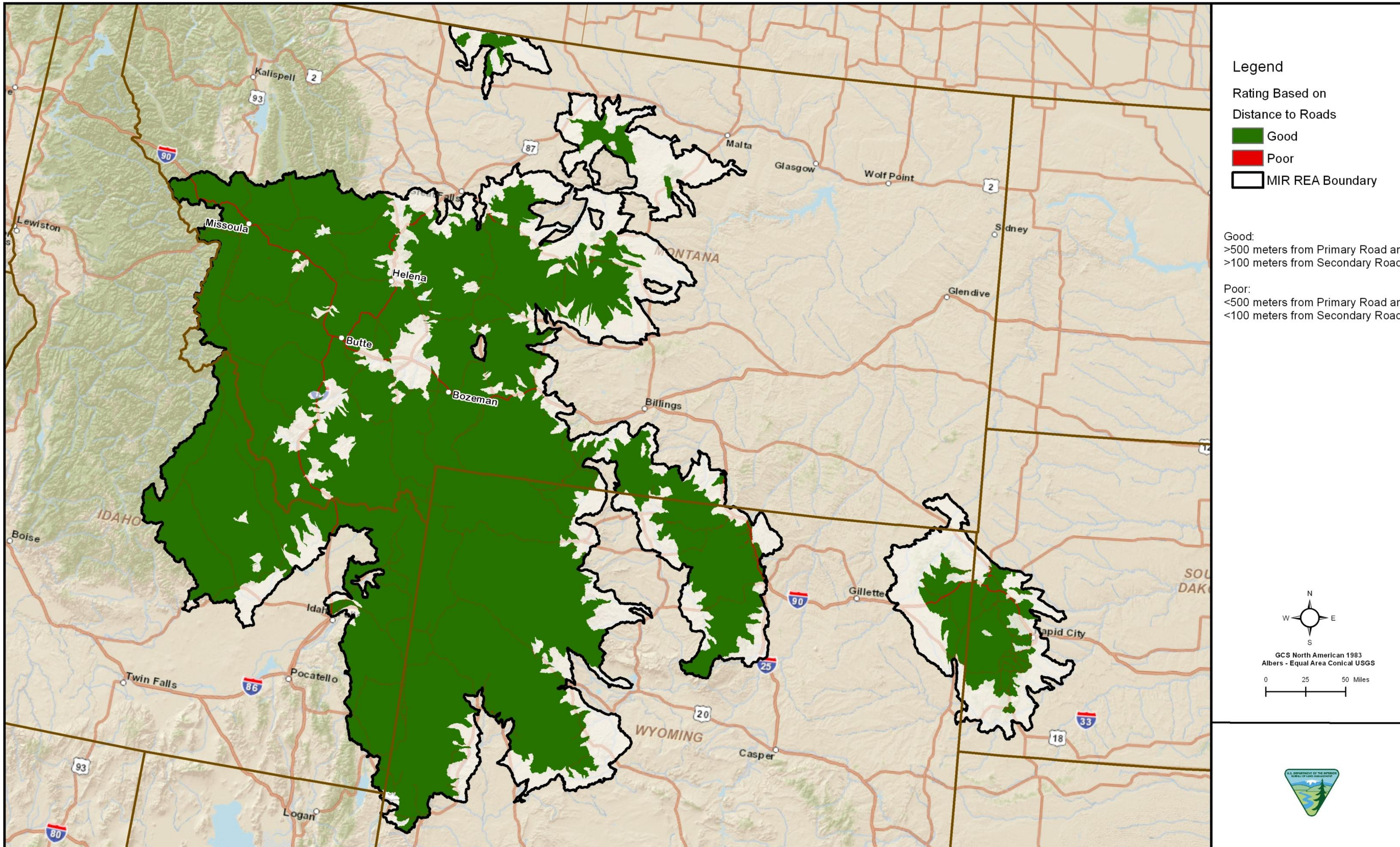

Figure E-6-11. Lynx Distance to Roads

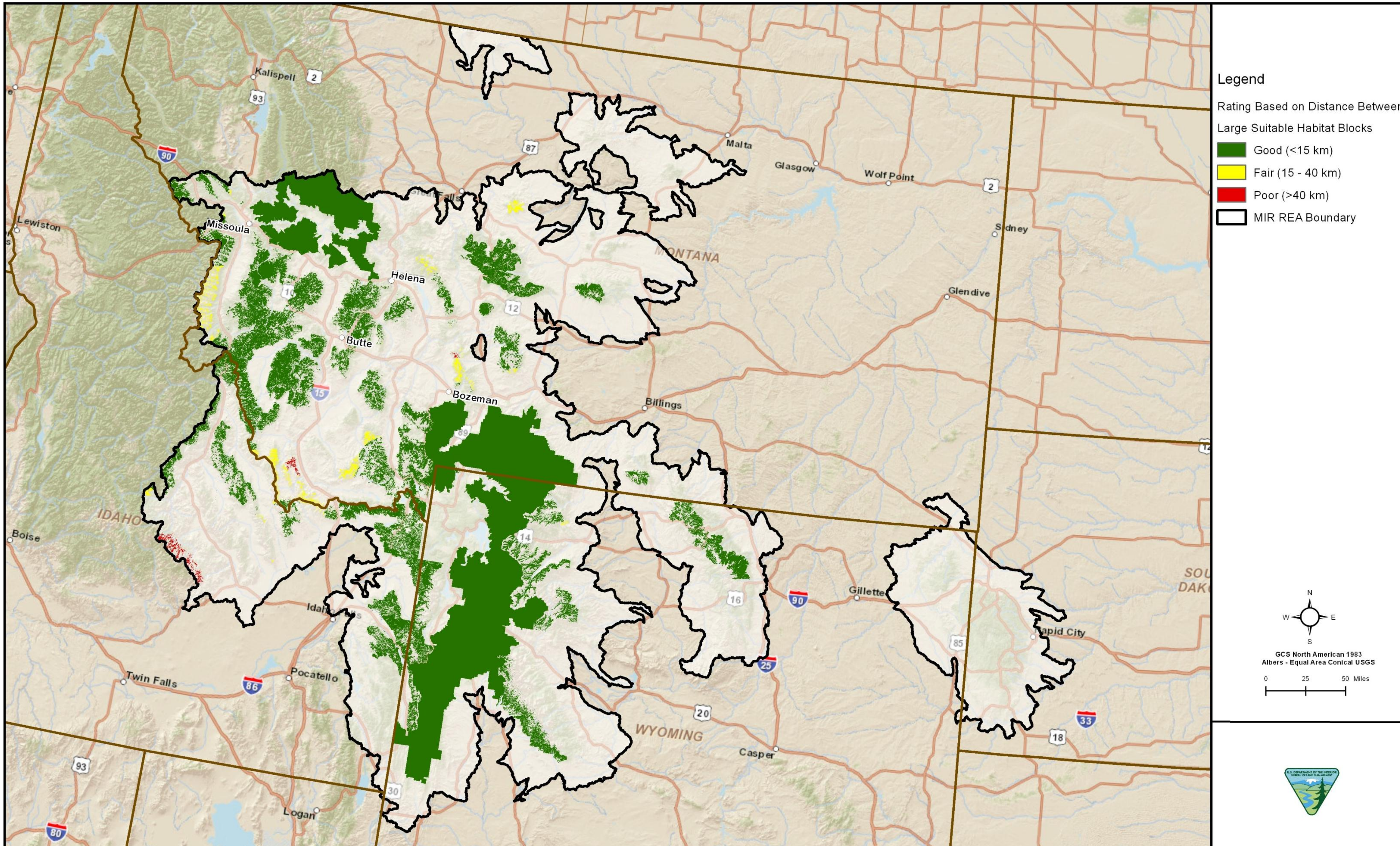

Figure E-6-12. Lynx Distance Between Large Suitable Habitat Blocks

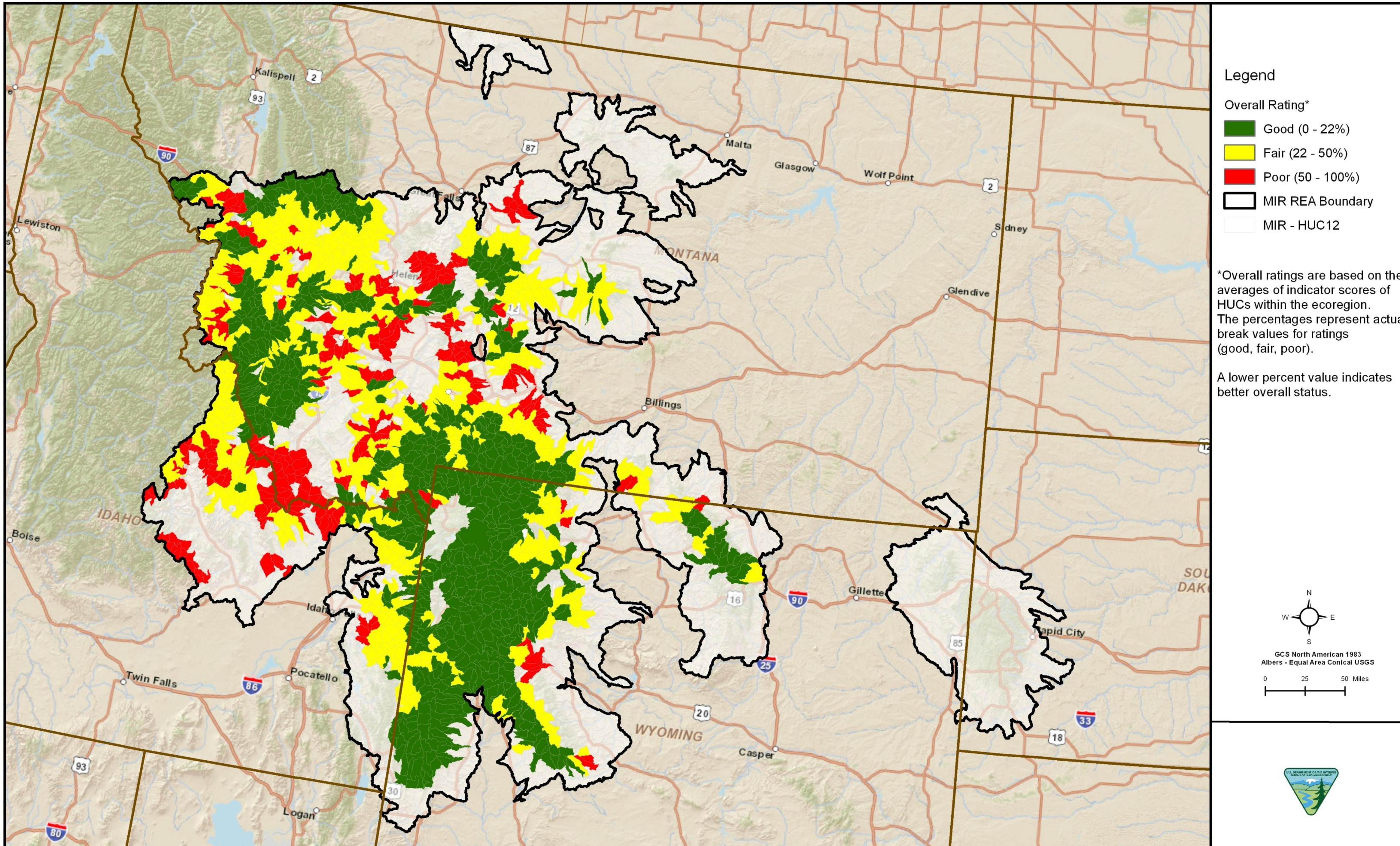

Figure E-6-13. Lynx Current Status of Habitat

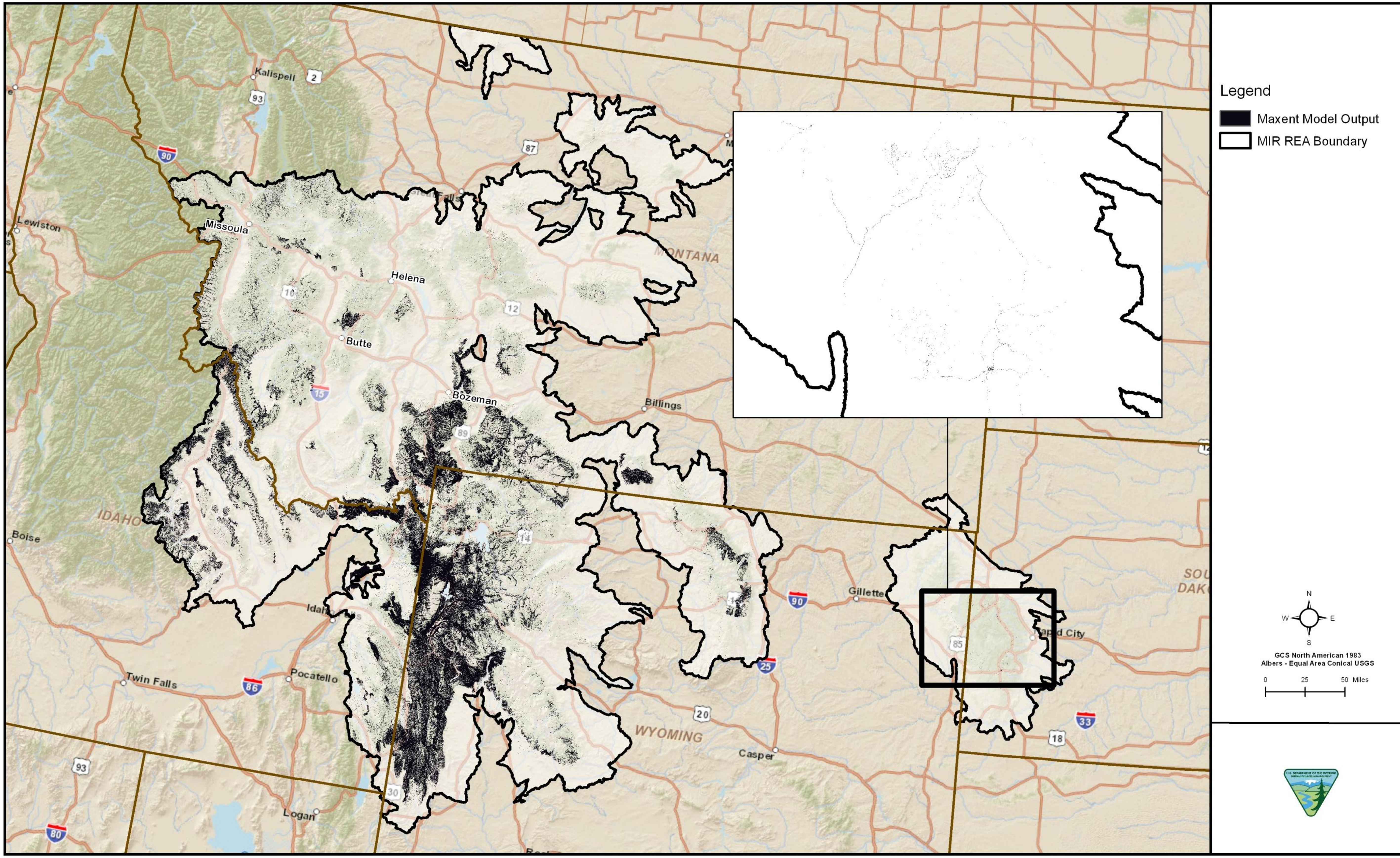

Figure E-6-14. American Marten Conservation Element Distribution

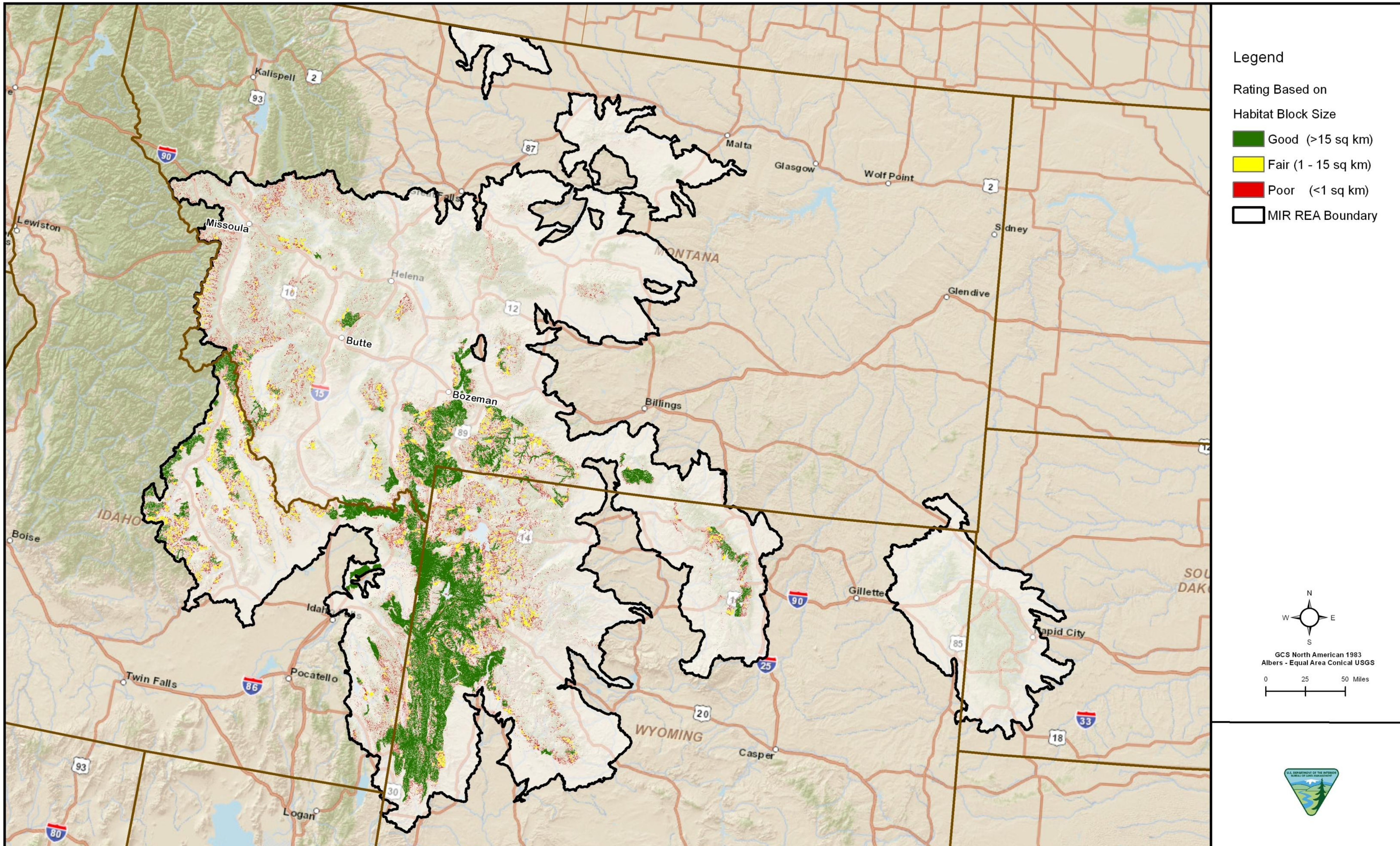

Figure E-6-15. American Marten Suitable Habitat Blocks

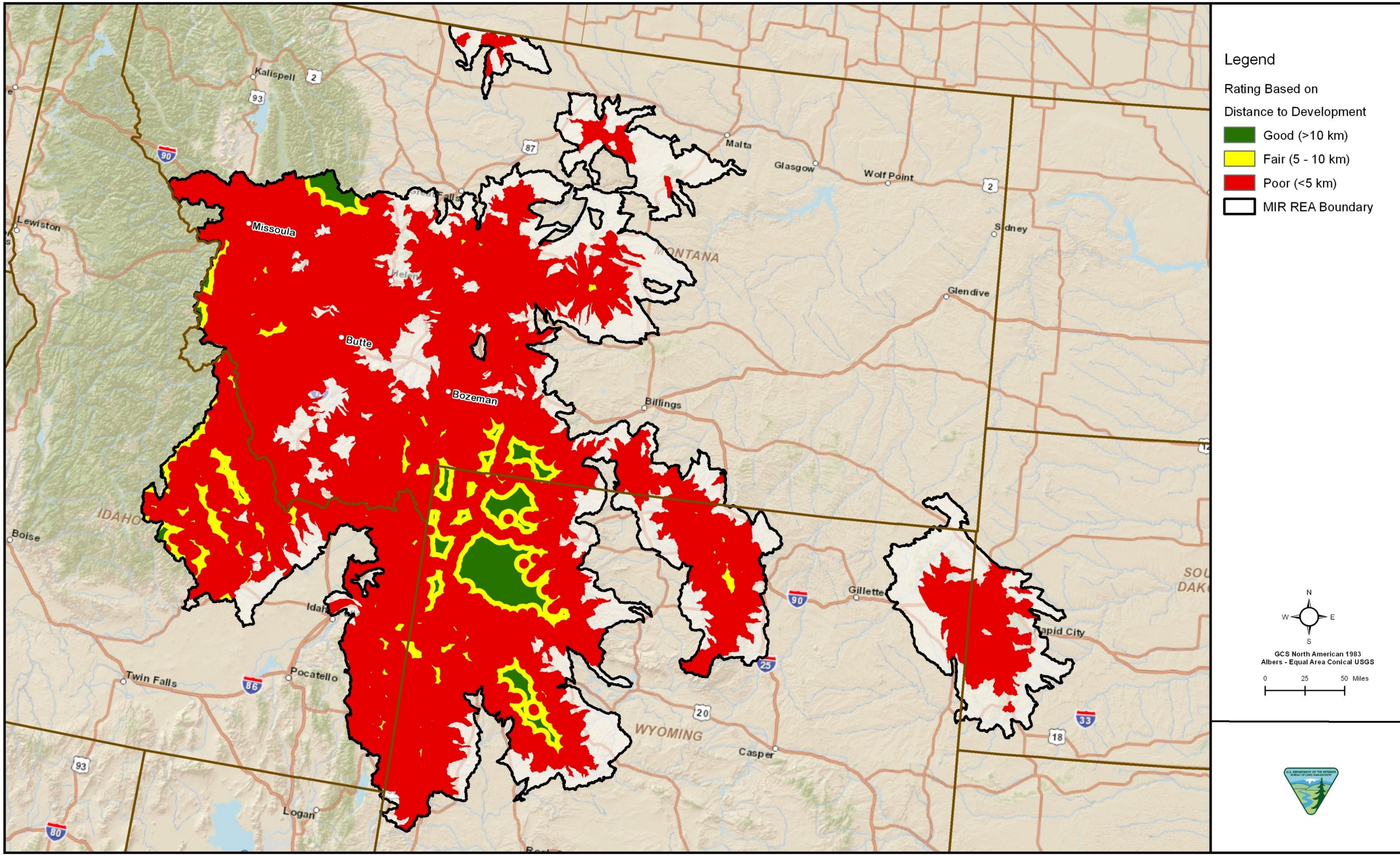

Figure E-6-16. American Marten and Wolverine Distance to Development

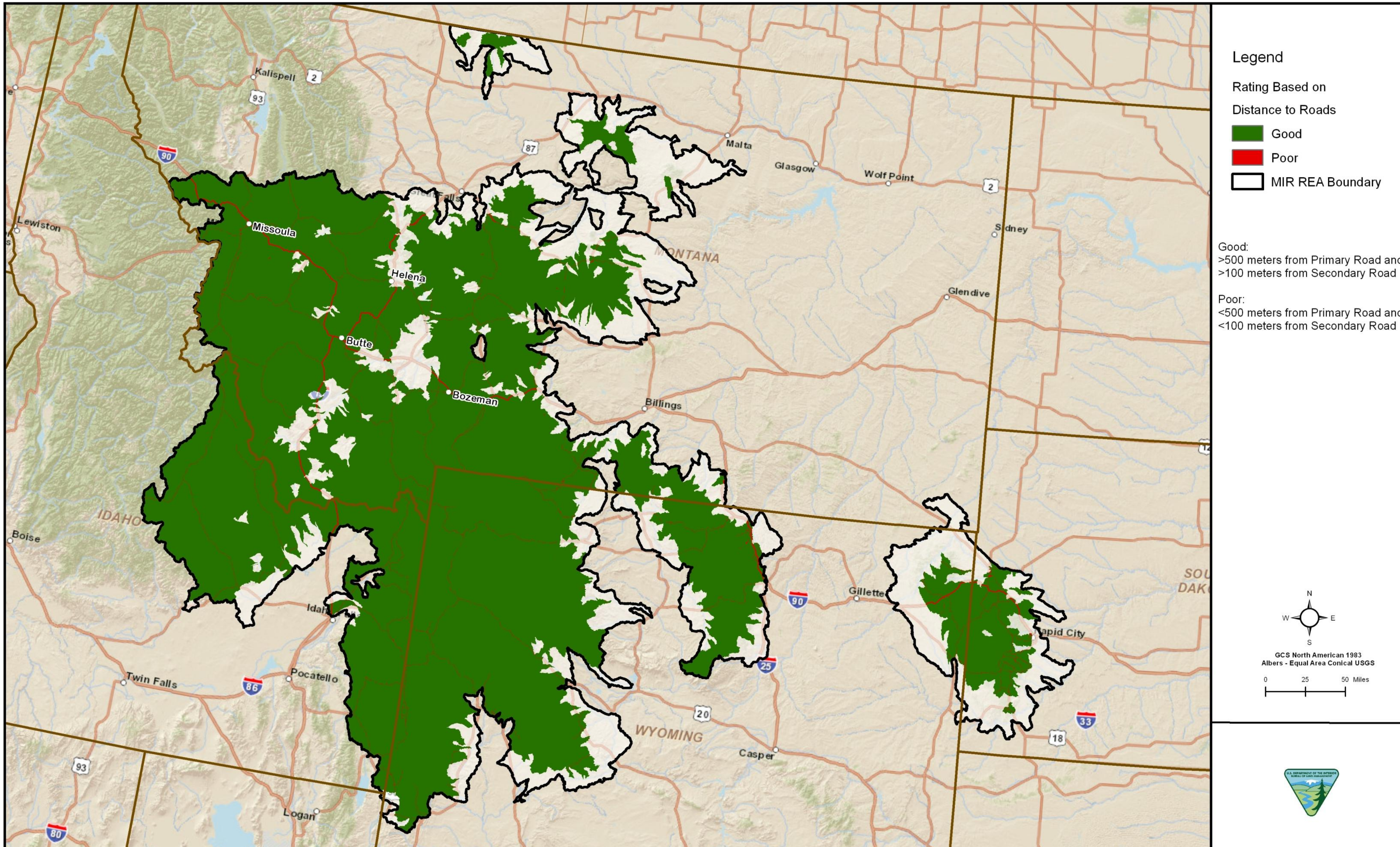

Figure E-6-17. American Marten Distance to Roads

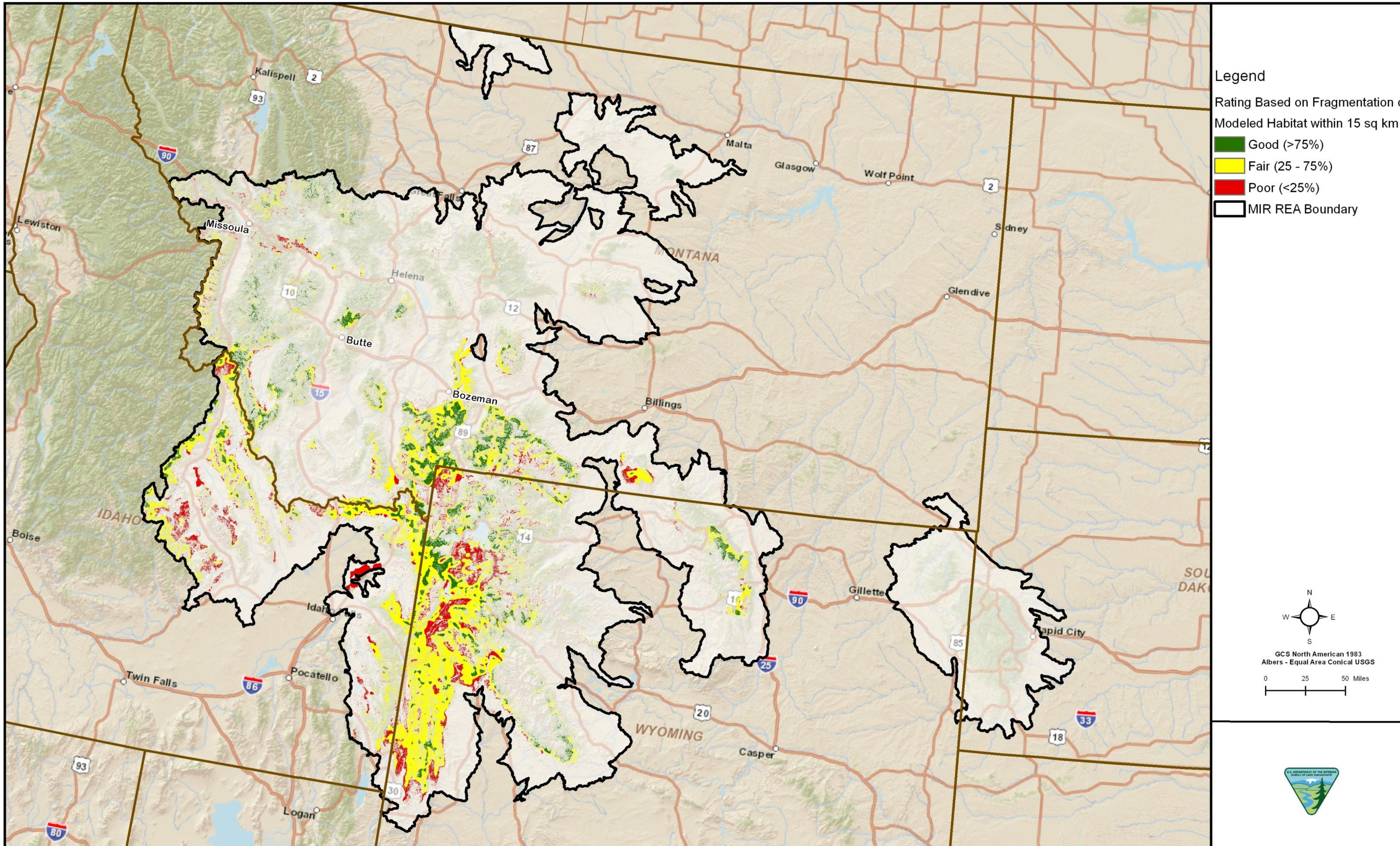

Figure E-6-18. American Marten Fragmentation of Suitable Habitat

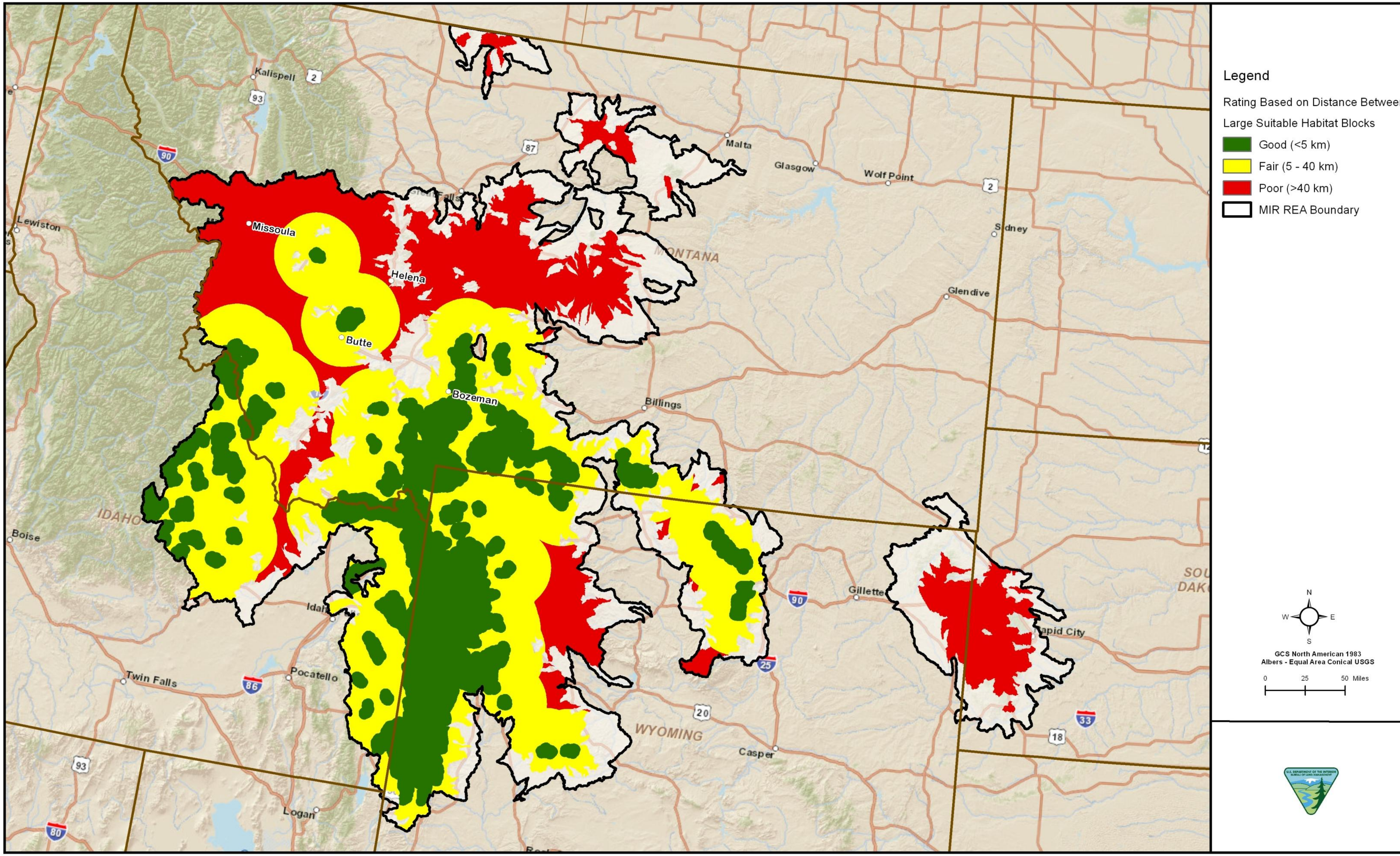

Figure E-6-19. American Marten Distance Between Large Suitable Habitat Blocks

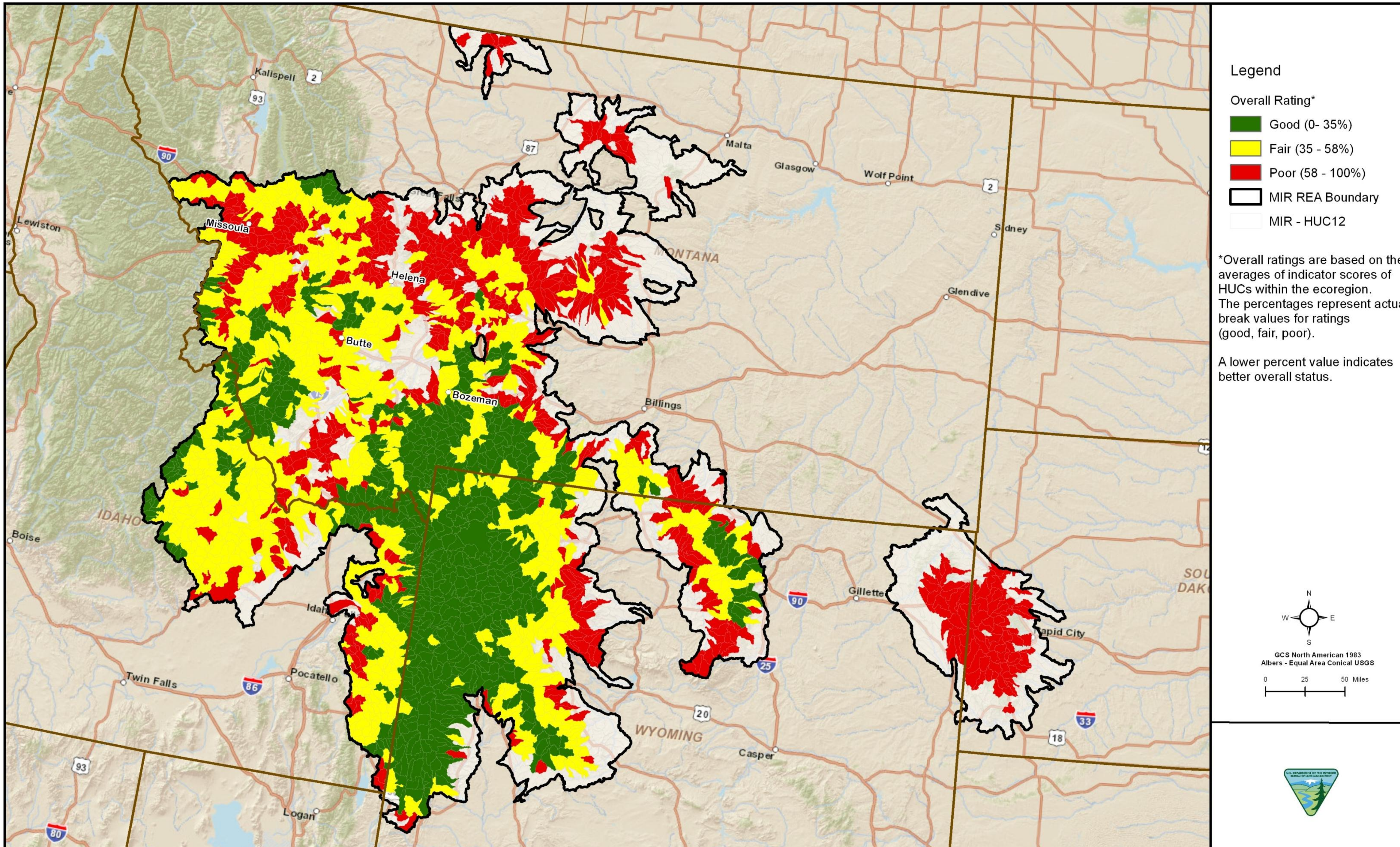

Figure E-6-20. American Marten Current Status of Habitat

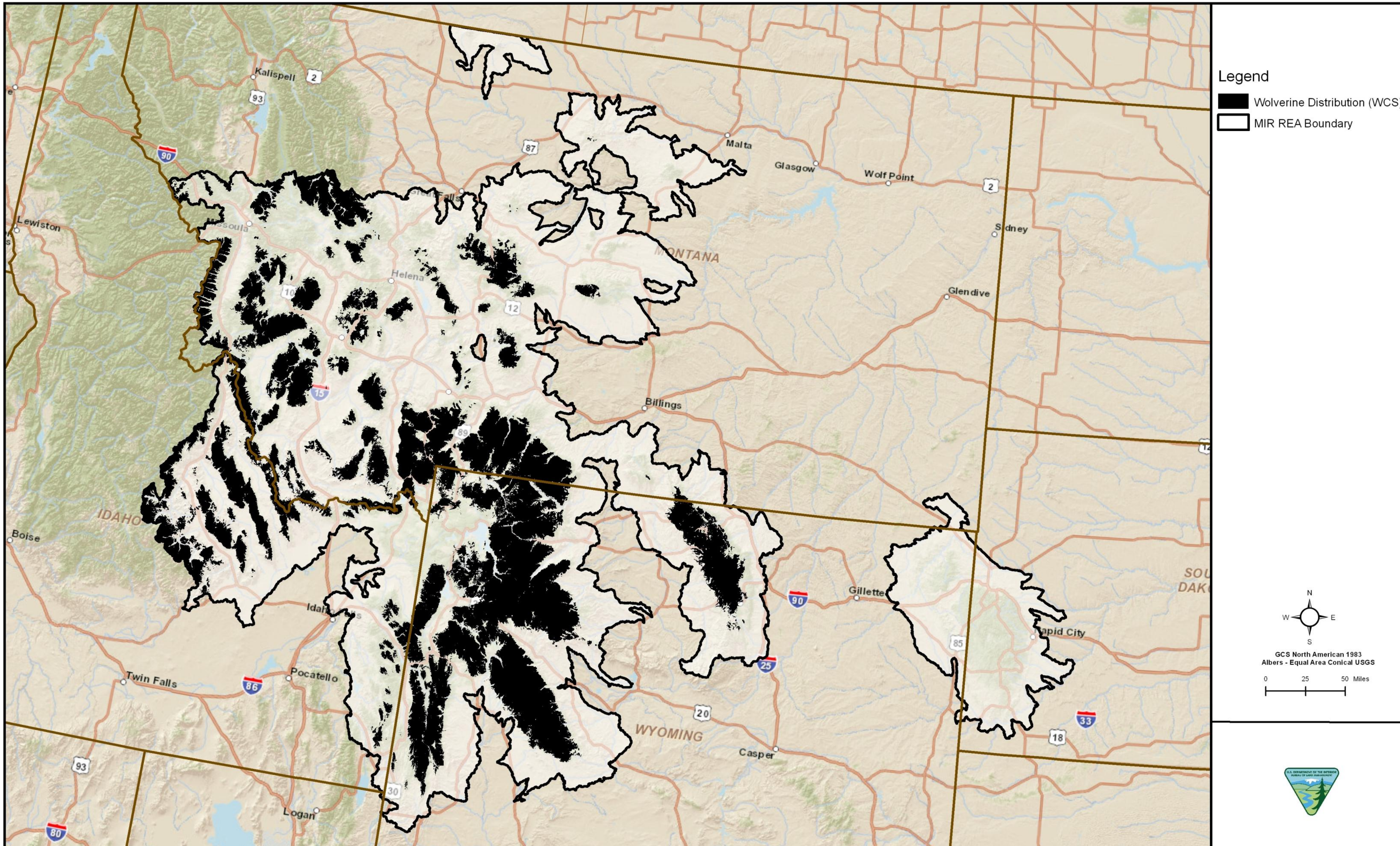

Figure E-6-21. Wolverine CE Distribution

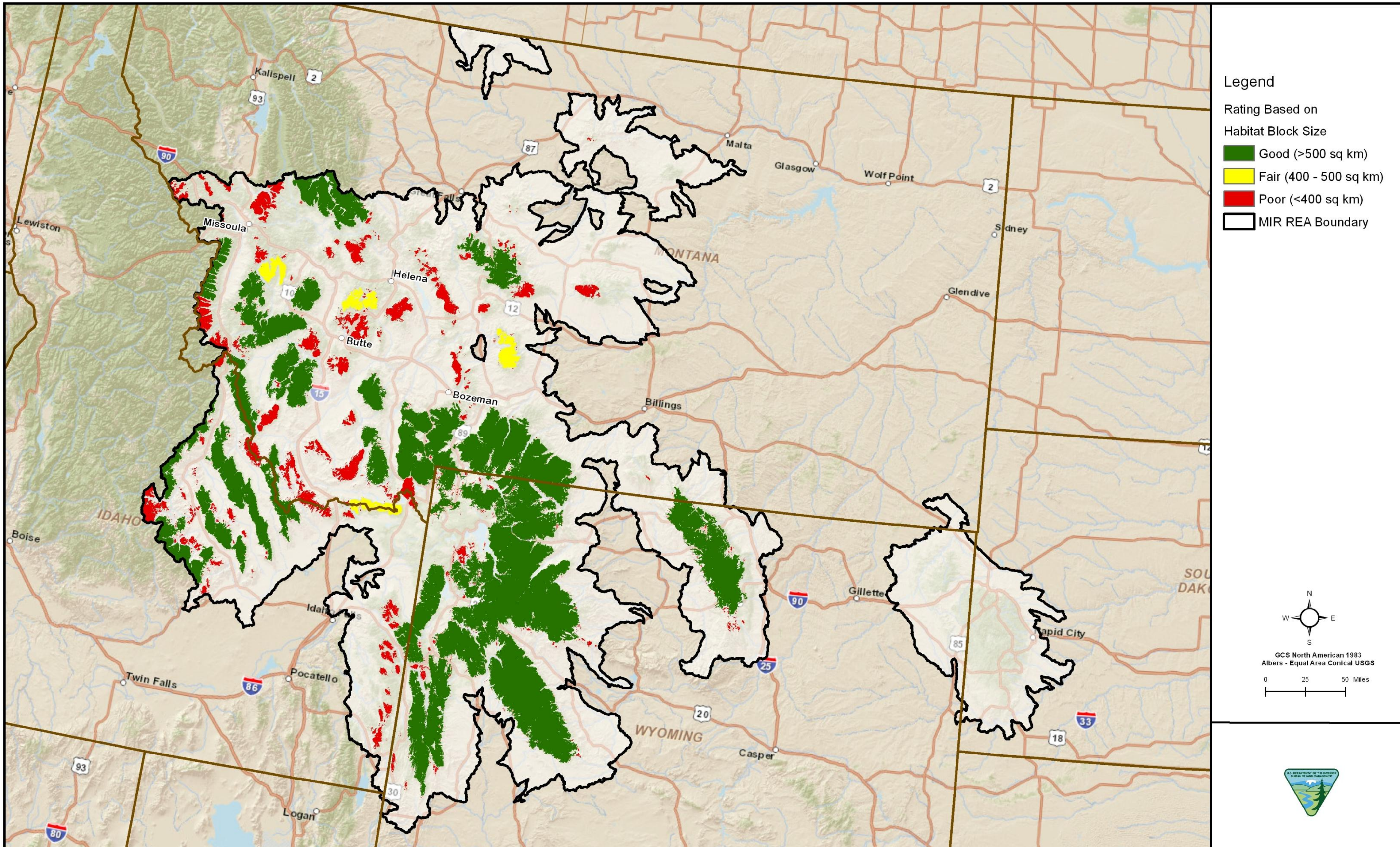

Figure E-6-22. Wolverine Suitable Habitat Blocks

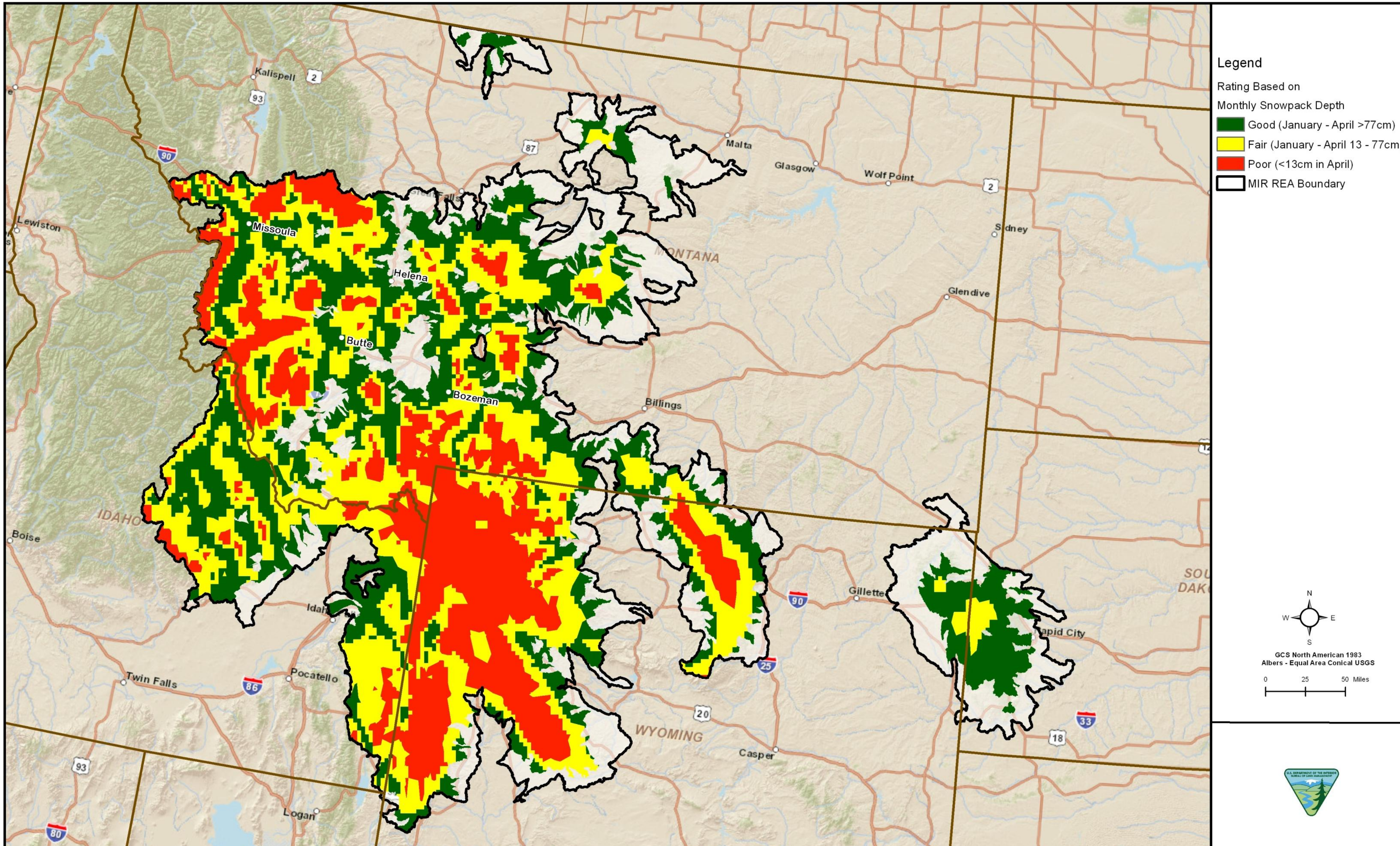

Figure E-6-23. Wolverine Mean Monthly Snowpack/Depth

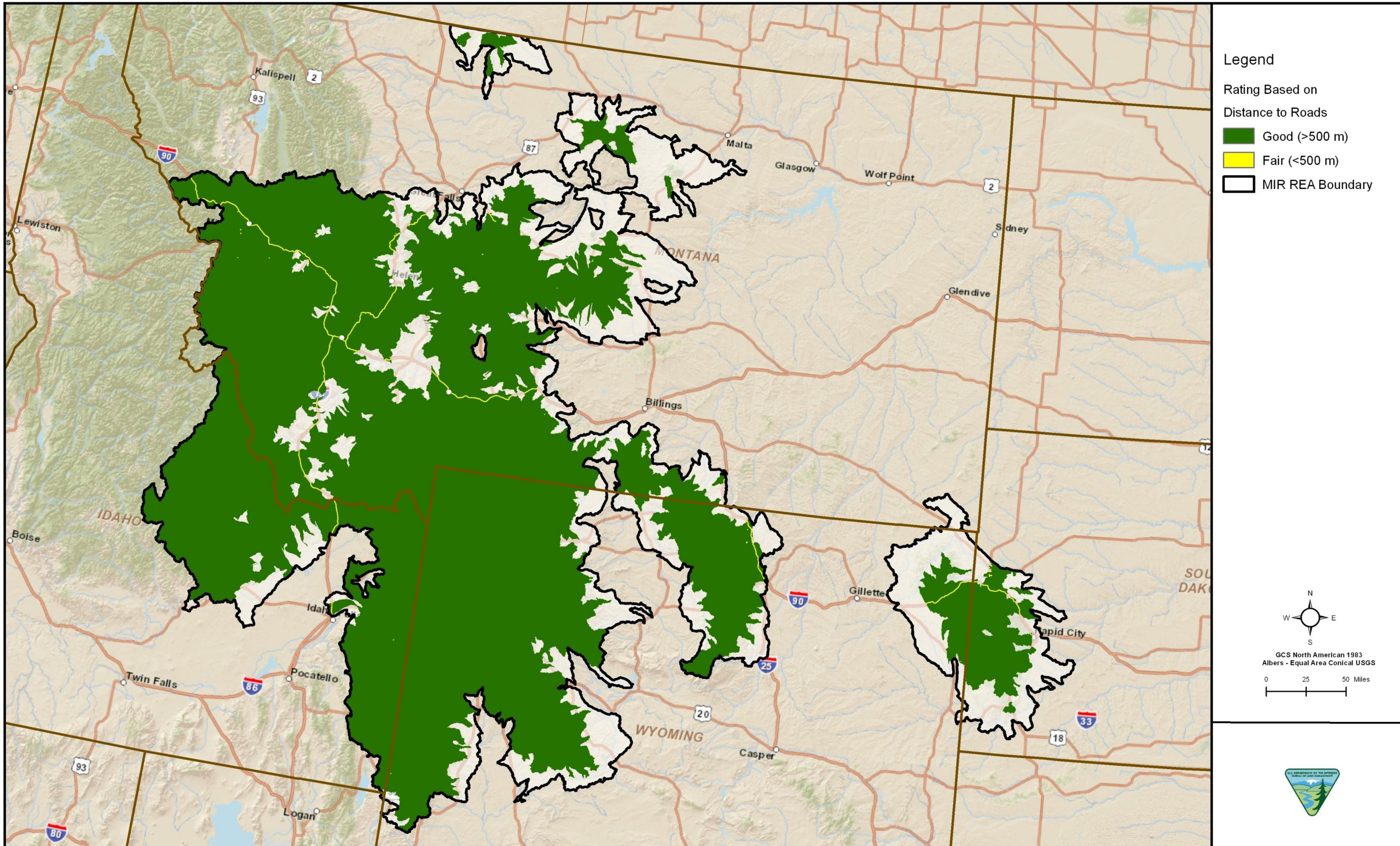

Figure E-6-24. Wolverine Distance to Roads

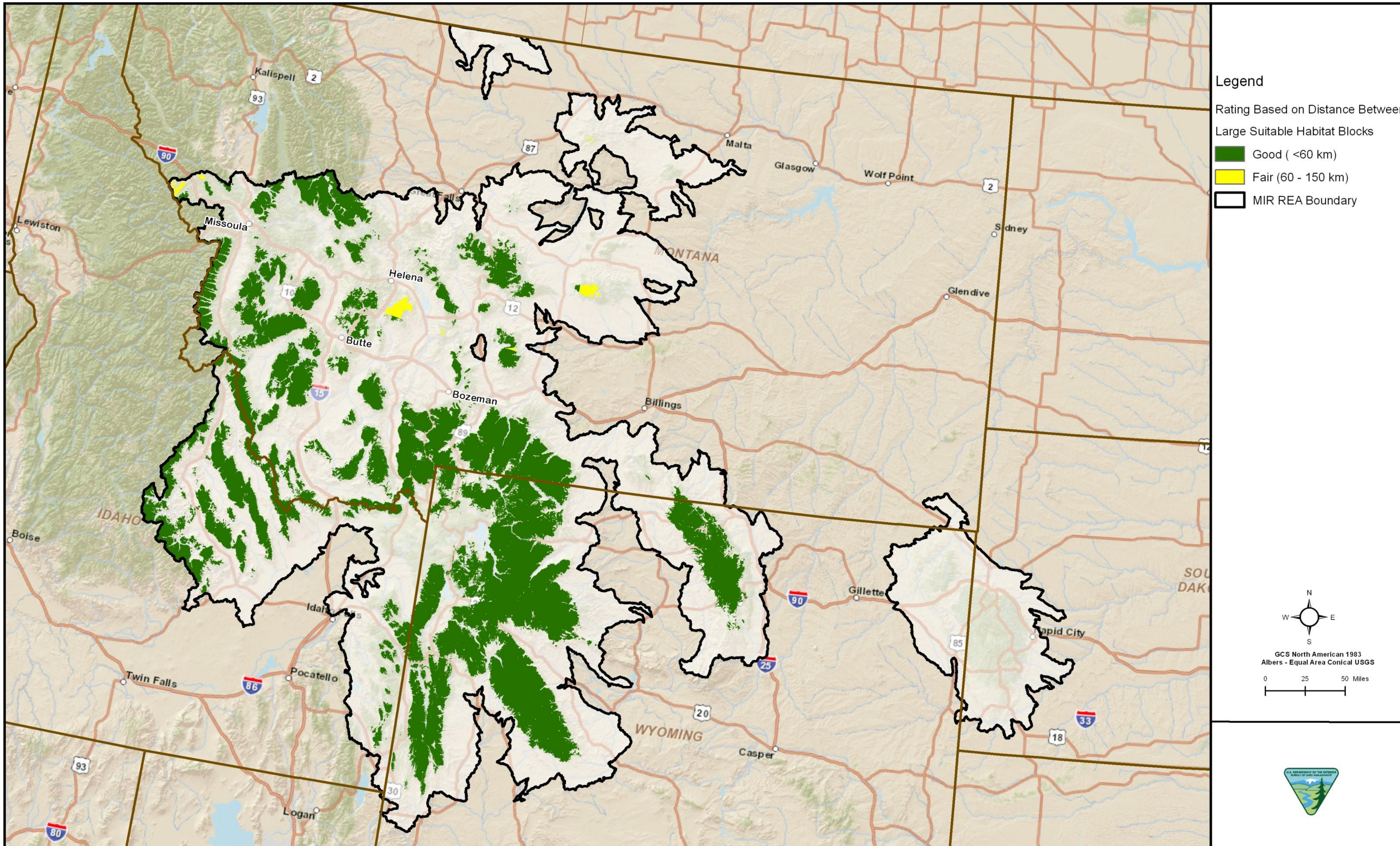

Figure E-6-25. Wolverine Distance Between Large Suitable Habitat Blocks

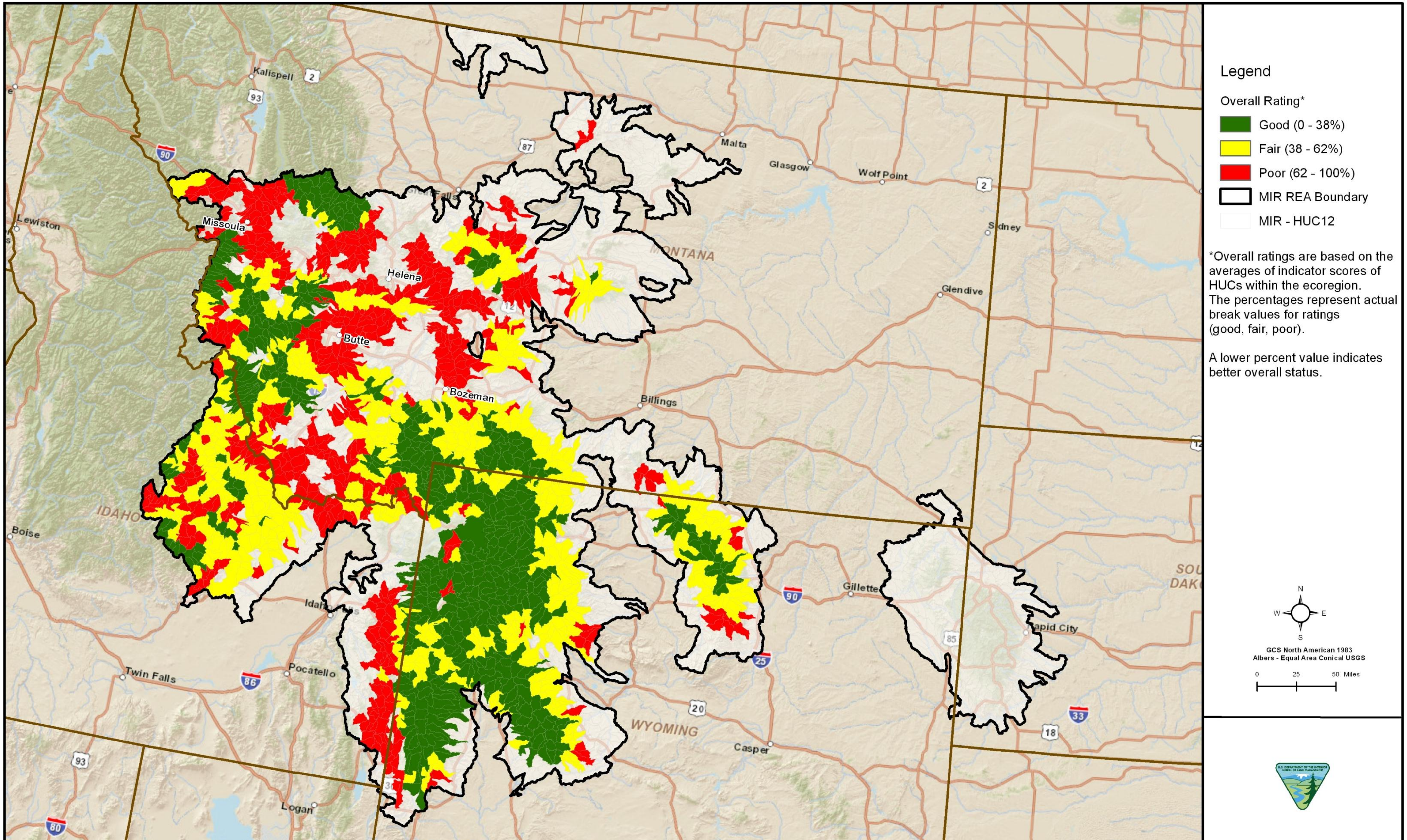

Figure E-6-26. Wolverine Current Status of Habitat

APPENDIX E-7

COLDWATER FISH ASSEMBLAGE CONSERVATION ELEMENT ANALYSIS FOR THE MIDDLE ROCKIES ECOREGION

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

<u>NUMBER</u>

THIS PAGE INTENTIONALLY LEFT BLANK

1.0 INTRODUCTION

The coldwater fish assemblage selected by the Assessment Management Team (AMT) includes spring/summer Chinook salmon (*Oncorhynchus tshawytscha*), summer steelhead *(Oncorhynchus mykiss)*, sockeye salmon (*Oncorhynchus nerka*), fluvial Arctic grayling (*Thymallus arcticus*), bull trout (*Salvelinus confluentus*), westslope cutthroat trout (*Oncorhynchus clarkii lewisi*), and Yellowstone cutthroat trout (*Oncorhynchus clarkii bouvieri*).

A variety of the management questions (MQs) apply to this assemblage. 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 those areas? In order to answer the MQs, ecological conceptual models were developed for the conservation element (CE) based on species habitat requirements and perceived change agent (CA) threats. The Rapid Ecoregional Assessment (REA) analysis presented here is based on the models, specific attributes defined as key parameters for evaluating CAs, and the availability of data.

THIS PAGE INTENTIONALLY LEFT BLANK

2.0 CONSERVATION ELEMENT DISCRIPTION

Many coldwater fish species in western aquatic ecosystems are declining. This assemblage is comprised of seven native coldwater fish species. Each species is briefly described below.

2.1 FLUVIAL ARCTIC GRAYLING

The fluvial Arctic grayling (*Thymallus arcticus*) is now extirpated from all areas of the ecoregion with the exception of a population in the Big Hole River watershed. A distinctive characteristic of this species is its large, sail-like dorsal fin. Grayling are spring spawners that broadcast eggs over gravel bottoms in moving streams; they are also generalists that eat a variety of aquatic invertebrates. In 2010, the U.S. Fish and Wildlife Service (USFWS) determined that listing this species as threatened or endangered was warranted, but the grayling was precluded by higher priority species.

2.2 BULL TROUT

Bull trout (*Salvelinus confluentus*) is a coldwater fish of pristine stream and lake habitats throughout the western United States. They require colder water temperatures than most salmonids and are usually found in cleaner substrate streams. Bull trout are threatened by habitat degradation and the construction of dams. This species is present in many drainages in Idaho and northwestern Montana, and they are listed by the USFWS as a threatened species.

2.3 SPRING/SUMMER CHINNOK SALMON

Chinook salmon (*Oncorhynchus tshawytscha*) is the largest of the Pacific salmon, can live up to 7 years, and can exceed 100 pounds. They are native to Idaho in the Snake River Basin and were introduced to the Fort Peck Reservoir in Montana in 1983 (Montana Fish, Wildlife, and Parks 2002)

2.4 SOCKEYE SALMOM

Sockeye salmon (*Oncorhynchus nerka*) is an anadromous species of salmon that average 2 - 6 pounds and average 16-26 inches in length. When these salmon move from saltwater to fresh water, the males develop a hump on their back and their jaws and teeth become hook-shaped. This is the third most abundant of the Pacific salmon species and is a keystone species in North American commercial fisheries. In Montana and Wyoming, the landlocked version of this species is referred to as the Kokanee salmon and is considered exotic and non-native. The Kokanee salmon is not part of this analysis.

2.5 SUMMER STEELHEAD TROUT

Steelhead trout (*Oncorhynchus mykiss*) is a native species of trout that are anadromous. This species is known only from the Snake River Basin in Idaho. They spawn in streams from mid-April to late June and use areas of gravel or cobble, depending on the size of fish. They primarily eat insects and zooplankton and are a common game species throughout the ecoregion.

2.6 WESTSLOPE CUTTHROAT TROUT

The westslope cutthroat trout (*Oncorhynchus clarkii lewisi*) is native to northern Idaho, western Montana, and the upper Missouri River, and is one of two native cutthroat species in the ecoregion. This species has not been recorded in Wyoming. Westslope cutthroat trout is known as an indicator species because it requires clear, cold water and secure, connected habitat safe from introduced predatory-type species. These trout feed on aquatic insects and zooplankton. Although this species is not protected, it is listed as a species of concern in Montana.

2.7 YELLOWSTONE CUTTHROAT TROUT

The Yellowstone cutthroat trout (*Oncorhynchus clarki bouvieri*) is a subspecies of the cutthroat trout and, as its name implies, is native to the Yellowstone River; today however, pure unhybridized populations are limited to some headwater streams and Yellowstone National Park (Montana FWP Field Guide 2012). This species is found in clear, cold streams, rivers, and lakes and feeds on aquatic insects and other fish. The primary threats to this species include non-native species, habitat degradation, and climate change (Gresswell, 2009). Although this species was reviewed for protection under the Endangered Species Act (ESA), the USFWS did not feel listing was warranted. This species is listed as a species of concern in Montana.

3.0 CONSERVATION ELEMENT DISTRIBUTION MODELING

In order to answer the MQs regarding the location and status of this assemblage across the ecoregion, a distribution layer was required for each of the focal species. Bull trout is present in many drainages in Idaho and northwestern Montana. The spring/summer Chinook salmon, sockeye salmon, and summer steelhead are present in the Snake River Basin in Idaho. The Yellowstone cutthroat trout has been recorded in Idaho, Montana, and Wyoming; however, the west slope cutthroat trout has only been recorded in Idaho and Montana. The fluvial life form of the Arctic grayling within the ecoregion is located only in the Bighole River drainage in western Montana.

Table E-7-1 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. Key data for the focal species include the locations of spawning and rearing areas, areas with potential for restoration of connectivity, and locations of barriers to fish passage such as dam locations. Geospatial data on the distribution of coldwater fish species in this assemblage were obtained from StreamNet and state agencies such as Montana's Fisheries Information System (MFISH).

Table E-7-1. Data Sources for Species Distribution Mapping for the Coldwater Fish Assemblage

Data Needs	Dataset Name	Source Agency	Type/Scale	Status	Use in REA
Spawning and Rearing Areas		ID, MT, WY State Fish and Game Agencies, Trout Unlimited		Require Data	No[1]
Important Angling Areas		ID, MT, WY State Fish and Game Agencies, Trout Unlimited		Require Data	No[1]
Areas with Potential for Restoration of Habitat or Habitat Connectivity	Fish Restoration Priority Watersheds	ID, MT, WY State Fish and Game Agencies		Require Data	No[1]
Current Distribution	StreamNet, MFISH	National Marine Fisheries Service (NMFS), USFWS, ID, MT State Natural Heritage Programs	Polyline	Acquired	Yes
	Yellowstone Trout for WY	WY State Fish and Game Agencies	Polyline	Require Data	Yes
Dams and Fish Ladders	National Inventory of Dams (NID)	United States Army Corps of Engineers (USACE)	Point	Pending NDA	Yes
	Fish Ladders	National Hydrography Dataset (NHD)	Point	Acquired	Yes
Critical Habitat	Critical Habitat • Bull Trout • Summer Steelhead	NMFS	Polygon	Acquired	Yes

[1] Data gap

StreamNet was used as the data source for distribution maps for the focal species based on recommendations from the AMT and state partners. Figures E-7-1 through E-7-5 show the distribution maps for focal species of this assemblage.

THIS PAGE INTENTIONALLY LEFT BLANK

4.0 CONCEPTUAL MODELS

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. CAs considered in this CE analysis include development, invasive species, climate change, and wildfire. However, not all of these could be mapped in the geospatial analysis.

4.1 ECOLOGICAL PROCESS MODEL

The ecological process model (Figure E-7-6) was developed to identify and link the key life cycle processes to specific ecological factors, or KEAs, that have the greatest potential to affect coldwater fish habitat throughout the ecoregion. Certain aspects of the distribution, habitat, and life history are shared by most of the coldwater fish species. They are all salmonids that require cold, clear streams, rivers, and lakes for spawning. Most excavate beds in stream channel gravels in which they deposit their eggs and most do not defend their young, which are opportunistic predators on available invertebrates. They exhibit multiple life history expressions, sometimes within the same species or populations, including anadromous, fluvial, and adfluvial life histories (Quinn 2005).

The key processes are identified in the model as green boxes. Following Unnasch et al. (2009), three broad headings or categories of ecological attributes (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-7-6) illustrates the interactions between the CAs and the primary habitat functions of this assemblage. With the exception of the period spent at sea by the anadromous species of this assemblage, the requirements of species within the Middle Rockies are sufficiently similar that a single system-level conceptual model was developed.

The most important CAs for this group of species are development, invasive fish species, and climate change; disease outbreaks and wildfire are also included in the model, as these CAs are growing concerns (Shepherd et al. 2003; May et al. 2007; Haak et al. 2010). However, not all of these could be mapped in the geospatial analysis.

4.2.1 Development

Past human development activities have adversely affected native coldwater fish species in many ways. Habitat loss has been a primary cause of depressed populations in Idaho (McIntyre and Rieman 1995). Logging, mining, urban/exurban development, road construction, and grazing have resulted in streambank erosion, sedimentation, adverse changes to channel configuration, and loss of riparian habitat, which provides shading and a source of insect prey for aquatic habitats (Spahr et al. 1991; Eaglin and Hubert 1993; Rieman and McIntyre 1993). Cattle trampling on native trout redds has raised concern that direct mortality from trampling may contribute to declines where the population is marginally stable without the additional impact of trampling (Peterson et al. 2010). In addition to increased sedimentation, water chemistry is degraded by contaminants and nutrients in runoff from adjacent developments, cropland, and grazing. Dams, improperly placed culverts, irrigation diversions, and other migration barriers have negatively affected individuals and habitat, and likely have interfered with metapopulation dynamics (McIntyre and Rieman 1995). As a result, populations have become increasingly fragmented. Surface and groundwater extraction for urban and exurban populations, agricultural irrigation, and industrial development adversely affect native coldwater fish populations. Much of the spawning habitat of Yellowstone cutthroat trout in tributaries of the upper Yellowstone River has been lost to irrigation withdrawals. Diversion of water for agriculture has exacerbated persistent drought conditions. Degradation of riparian vegetation on the Big Hole River and stream banks by cattle grazing, mass willow removal, and dewatering the river for agricultural uses have negatively impacted fish habitat (Byorth 1993).

4.2.2 Wildfire

Wildfire affects aquatic habitats and biota through water quality changes including sedimentation and debris flows. Climate change will increase the likelihood of wildfires in the presence of fuels and an ignition source in relation to the timing of snowmelt (Haak et al. 2010).

4.2.3 Climate Change

Reduced snowpack, water temperature changes, precipitation changes, and greater fluctuations in stream hydrographs will likely be significant stressors on native coldwater fish species that result from climate change (Rieman and Isaak 2010; Haak et al. 2010). Climate change is likely to eliminate some habitat directly through water quantity and temperature changes (Rieman and McIntyre 1993; Rieman et al. 2007) and indirectly through water quality changes. Water quantity issues associated with climate change include effects of persistent severe drought and impacts on recruitment due to sudden runoff events during hatching and emergence of larvae (Shepard and Oswald 1989; Haak et al. 2010). Conversely, extreme low flows during severe drought decrease survival of adults due to increased water temperatures, increased susceptibility to predation, and diminished habitat volume. During drought years, water temperatures have surpassed lethal limits for Arctic grayling (Lohr et al. 1996), and all salmonid species in the upper Big Hole River in Montana declined in abundance during a persistent drought (Byorth 1993). Haak et al. (2010) evaluated future risk due to four climate change effects (drought, summer temperature, winter flooding, and wildfire) for native coldwater fish in the ecoregion:

- For Yellowstone cutthroat trout, the greatest threats to currently occupied habitat is generally drought, followed by wildfire and winter flooding. Increasing summer temperature is a low risk for most populations.
- For westslope cutthroat trout in most basins, currently occupied habitat is at low risk for increasing summer temperatures and moderate risk for drought. Winter flooding and wildfire risk are more variable across basins, with 20 percent and 23 percent of sub-basins, respectively, rated at high risk.
- For fluvial arctic grayling in Montana, the USFWS has concluded that the Bighole River population is threatened by drought, habitat fragmentation and degradation, and encroachment by non-native trout (Peterson et al. 2005).

4.2.4 Invasive Species

The establishment of non-native fish in the waters occupied by native cutthroat trout populations; hybridization with other trout species such as rainbow trout and other native sub-species (i.e., Yellowstone cutthroat x westslope cutthroat); and competition with, and predation by, non-native fish species are among the primary threats to persistence of native populations. In Yellowstone River tributaries, downstream from Yellowstone National Park and in the upper Snake River basin, native cutthroat populations have been largely replaced by non-native trout and by hydrid cutthroat populations (Behnke 1992; Gresswell 1995). Lake trout have caused drastic declines in cutthroat populations through competition and/or predation on native juveniles (e.g., in Yellowstone Lake following the appearance of lake trout in 1994) (McIntyre 1996; Koel et al. 2005) and are the subject of management programs in affected waters. Analyses for the invasive species CA were not conducted for this CE because appropriate geospatial data were not available to portray this CA in a useful manner.

4.2.5 Disease Outbreak

All species of trout and salmon may become infected with the parasite responsible for whirling disease (*Myxobolus cerbralis*), an introduced disease agent first identified in the United States in 1956 and now present in Idaho (Idaho Fish and Game 2007) and Montana (since 1994), (Montana Fish, Wildlife and Parks 2011). The presence of the parasite does not always cause dramatic population losses, but it can be a serious problem in hatcheries and has had severe impacts on some wild trout populations in Montana's Madison River (Montana Fish, Wildlife and Parks 2011; Whirling Disease Initiative 2011). Although there have been some attempts to create maps of the whirling disease parasite's known distribution in the United States, these data are not consistent across all states or within the states of this ecoregion. The Big Sky Institute created a map of where the parasite has been detected by Hydrologic Unit Code (HUC) 8. However, this map has not been updated since 2009 (MT Water Center 2012).

The Infectious Hematopoietic Necrosis (IHN) virus affects salmonids, sturgeon, and a few other hosts, and has been identified in a northern Idaho hatchery (USGS 2011). The significance of disease as a CA for native coldwater fish is unknown at present, but it is included in the conceptual model due to the potential for spread of pathogens from hatchery facilities into habitats of wild salmonid populations. Analyses for the disease CA were not conducted for this CE because it was impractical to model at the ecoregional scale because appropriate geospatial data were not available.

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. 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-7-7. 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. Further information on the data gaps for these indicators is discussed in the respective CA analyses contained in Appendix C. Analysis for the development CAs, and future threats from development, wildfire, and climate change, are included for this CE.

THIS PAGE INTENTIONALLY LEFT BLANK

5.0 CHANGE AGENT ANALYSIS

A current status and future threat assessment for this assemblage was conducted for the Middle Rockies ecoregion using the 12-digit 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. Only the development CA was evaluated for current status. The CAs evaluated for future threats include development, wildfire, and climate change.

Since the scale of the analysis is at the HUC 12, a layer of 6th level HUCs was extracted for the ecoregion. A 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. 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.

5.1 CURRENT STATUS OF THE COLDWATER FISH ASSEMBLAGE

The current status of the coldwater fish assemblage was based on a table of ecological attributes, indicators, and metrics.

5.1.1 KEA Selection

Several KEAs were identified for evaluation of the current status for the CE in the ecoregion. Indicators are intended to be mappable conditions of the landscape that exist as specific datasets or that can be derived from existing datasets. Some attributes related to hydrology, water temperature, and population densities of introduced fish species were unsuited for geospatial analysis and they are therefore identified as data gaps and dropped from consideration for the REA. If possible, a surrogate better suited to geospatial analysis was used. Table E-7-2 identifies the attributes initially evaluated for use and whether they were excluded, modified, or retained based on specific rationale.

Table E-7-2. Key Ecological Attributes Excluded or Retained

Category	Attribute	Rationale
Size; Suitable habitat (spawning and rearing)	Uninterrupted stream segments	
Hydrologic processes	Magnitude and timing of flows (climate change)	Retained to assess climate change based on precipitation changes.
	Groundwater recharge; Presence/priority of aquifers in HUC	Excluded because data were not adequate.
	Surface water diversion	
	Winter flooding risk (climate change)	Retained to assess climate change on a CE-specific basis.
Condition; Water quality	Sedimentation (development)	Replaced by KEAs: Percent HUC in agricultural use and percent HUC in impervious cover.
	Contaminants	Retained; KEA identified as 303(d) listing.
Condition; Biotic	Presence of introduced fish species (brook trout, lake trout)	Excluded; impractical to model at the ecoregional scale based on introduced fish species density.
Stream Connectivity	Barriers to fish passage	Retained; KEA identified as number of dams in HUC.
Stream/floodplain/wetland Connectivity	Percent of HUC 12 in National Wetlands Inventory (NWI) (all polygons)	Excluded because the necessary data to rank HUC were missing.
	Percent of HUC 12 in NWI (natural polygons)	Excluded because the necessary data to rank HUC were missing.

Table E-7-3 identifies the remaining KEAs, indicators, and metrics used to evaluate development CA pathways affecting this CE across the ecoregion (as illustrated on Figure E-7-7). For each of the KEAs listed in Table E-7-3, a discussion of the indicator, metric, metric rank and value, data source(s), and references is provided. Several indicators for size, condition, and landscape context were used to assess the current status for the coldwater fish assemblage. 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. Some of the sources for indicators include Haak et al. (2010) for climate change indicators including wildfire risk, Stanley et al. (2010) for aquatic processes, and Stagliano (2007) for development-related indicators. The evaluation of the indicators and metrics used was carried out through the establishment of a CE rolling review team (RRT) comprised of Bureau of Land Management (BLM) fishery 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 for each KEA were equally weighted when evaluating the overall current status of the CE assemblage.

Table E-7-3. Cold Water Fish Assemblage Key Ecological Attributes, Indicators, and Metrics for Current Status Assessment for the Middle Rockies Ecoregion

Category	Key Ecological Attribute	Indicator / Unit of Measure	Metric			Data Source	Citation
			Poor = 3	Fair = 2	Good = 1		
Size	Habitat Size	Number of Dams in HUC	>=10	6 – 9	<=5	NID	Stagliano 2007
Condition	Habitat Quality	Percent of HUC in Gap Analysis Program (GAP) Status 1 or 2	<25%	25–60%	>60 %	PAD Version 1.2 April 2011	Stagliano 2007
	Water Quality	Percent of Riparian Corridor with Natural landcover	<25%	25-80 %	>80%	National Land Cover Dataset (NLCD) - 2006	U.S. Department of Argriculture (USDA) 2011
		Number of oil/gas wells	>20	10-20	0 – 9	BLM Oil and Gas Wells	Stagliano 2007
		Percent of streams that are 303(d)- listed	>=10%	1-9%	0%	NHD Plus Streams U.S. Environmental Protection Agency (USEPA) 303(d) list	USDA 2011
		Number of Mines	>3	1 - 3	0	U.S. Geological Survey (USGS) Mineral Resources Data System (MRDS)	Data Quantiles
		Number of TRI sites	>1	1	0	USEPA Envirofacts Data- TRI class	Data Quantiles

Table E-7-3. Cold Water Fish Assemblage Key Ecological Attributes, Indicators, and Metrics for Current Status Assessment for the Middle Rockies Ecoregion (Continued)

Category	Key Ecological Attribute	Indicator / Unit of Measure	Metric			Data Source	Citation
			Poor = 3	Fair = 2	Good = 1		
Context	Landscape Structure	Percent of streams/ shorelines within 40-m of road	>2.5%	1 - 2.5%	<1%	NHD Plus Streams, Water bodies, Area Topographically Integrated Geographic Encoding and Referencing (TIGER) Roads 2010 - All Roads	Stagliano 2007
		Percent of HUC in agricultural use (cropland)	>60%	30 - 60%	<30%	NLCD - 2006	Allan 2004
		Percent of riparian corridor in agricultural use (cropland)	>6%	3 - 6%	<3%	NLCD - 2006	Stagliano 2007
		Percent of HUC impervious	>10%	6 - 10%	<6%	NLCD - 2006	Allan 2004 Table 1 from Appendix E page 142 of Annis et al. 2010. Wang et al. 2008
		Percent of riparian corridor in impervious	>10%	5 - 10 %	<5%	NLCD - 2006	Wang et al. 2008 Joubert and Loomis 2005
		Population in HUC 12 per square kilometer (km^2)	>300	100-300	<100	Landscan 2000 Global Population Database	Wang et al. 2008

In instances where data were quantified within a riparian corridor, both stream and shoreline features were buffered. For instance, buffering National Hydrography Dataset (NHD) stream centerlines did not accurately represent riparian areas for wide rivers or reservoirs and would only encompass water. To overcome this problem, a “shoreline” layer for the wide river channels and impoundments was created using NHD waterbodies and NHD Area polygons. A 40-meter (m) buffer inland from these shorelines was used to capture the riparian area. The GIS riparian layer resulting from the shoreline processing was then combined with buffers for standard stream center lines to create a single riparian area layer to use for riparian assessments.

5.1.1.1 Dams and Surface Water Diversions

Dams and surface water diversions have been documented to change hydrologic flows through a watershed and disrupt normal geomorphic processes downstream, and they are usually point sources of stocked non-native species. Although counting the number of dams or diversions may not be completely representative of the impact of these features, it does provide a basis for comparing stream alteration between watersheds. The number of dams in an HUC could also be indicative of introduced species colonization points (Stagliano 2007).

Data on dams and surface water diversions in the ecoregion was obtained from the U.S. Army Corps of Engineers (USACE) National Inventory of Dams (NID) (USACE 2010). The inventory consists of data for approximately 45,000 dams, which were gathered from extensive record searches; some feature extraction from aerial imagery. In most cases, dams within the NID are regulated (construction permit, inspection, and/or enforcement) by federal or state agencies that have basic information on the dams within their jurisdiction (USACE 2010). Figure E-7-8 shows the location of dams within the ecoregion.

The number of dams and non-dam diversions that intersected streams in the 6th level HUC watershed within the ecoregion were summed and then assigned a relative rank if good, fair, or poor, as noted in Table E-7-3. The scoring system used for this indicator was adopted from Stagliano (2007). If there are 5 or less dams per HUC, then the HUC was ranked as good and received a metric score of 1. If the number of dams was between 6 and 9 per HUC, then a rating of fair with a metric score of 2 was assigned. If the number of dams and non-dam diversions was 10 or greater, then a rating of poor with a metric score of 3 was assigned.

5.1.1.2 Percent of HUC 12 in Status 1 or 2

The indicator used to assess habitat condition is the proportion of stream located within a public or privately protected land area; it is assumed that the higher the proportion of stream in protected areas, the higher the quality.

This analysis used data from the Protected Areas Database of the United States (PAD-US), which is a GIS database hosted by the Gap Analysis Program (GAP) that illustrates and describes public land ownership and management and conservation lands nationally, including voluntarily provided privately protected areas. PAD-US identifies land that is managed through various measures for the preservation of biological diversity and other natural, recreational, and cultural uses. The PAD-US version 1.2 includes various protected areas such as the National Park Service (NPS) boundaries, Department of Defense (DOD) boundaries in cooperation with DOD Partners in Flight, Marine Protected Areas, the BLM National Landscape Conservation System (NLCS) authoritative boundaries, and the NLCS National Trails and Wild and Scenic Rivers. The PAD-US provides a spatial dataset of public and private lands and waters secured by a conservation situation that includes an explicit level of security from future conversion and current incompatible uses (USGS 2012). All lands identified in the PAD-US are assigned GAP conservation status codes to indicate the level of protection provided to each parcel based on management intent for long-term biodiversity conservation. GAP codes of 1 and 2 are lands managed for permanent biodiversity protection, 3 designates multiple-use lands that may support extractive uses, and 4 indicates no known mandate for permanent protection (USGS 2012). Figure E-7-9 shows the areas defined as GAP 1 and 2 lands.

For the analysis of habitat quality, an estimate of the percentage of the HUC in GAP 1 or 2 protected areas was determined. The scoring system used for these indicators was adopted from Stagliano (2007) and is presented in Table E-7-3.

5.1.1.3 Percent of Riparian Corridor with Natural Landcover

This KEA addresses habitat condition. The presence of native vegetation that is vigorous, healthy, and diverse in age, structure, cover, and composition is indicative of a watershed that is functioning properly throughout the stream corridor or along wetlands and water bodies (USDA 2011). Various studies have documented that intact riparian areas help to minimize the impact of agriculture and other disturbance to aquatic communities (Wenger 1999).

For this analysis, a riparian vegetation cover data layer was created using the most recent version (2006) of the National Land Cover Database (NLCD). The NLCD provides Landsat-based, 30-m resolution spatial reference and descriptive data for characteristics of the land surface, such as thematic class (e.g., urban, agriculture, and forest), percent impervious surface, and percent tree canopy cover. NLCD products are created by the Multi-Resolution Land Characteristics (MRLC) Consortium, a partnership of federal agencies led by the U.S. Geological Survey (USGS) (Homer et. al. 2012).

For each 6th level HUC, the data from the NLCD was used to estimate the percentage of stream miles containing riparian areas; a relative rank of good, fair, or poor, as noted in Table E-7-3, was then assigned. The percentages used to rank this attribute were based on the U.S. Department of Argriculture (USDA) Riparian/Wetland Vegetation Condition Rating Rule Set (USDA 2011). Figure E-7-10 presents the percentage of HUC riparian corridor with natural landcover.

5.1.1.4 Number of Oil and Gas Wells

The number of oil and gas wells was used by Stagliano (2007) as an indicator of condition based on the assumption that the presence and number of oil and gas wells in a particular location would impact water quality due to operational activities associated with well development, as well as potential spills. Potential impacts to BLM resources from exploration and production (E&P) operations may include soil, air and water contamination, habitat fragmentation, deforestation, and erosion.

The BLM compiles a large amount of statistical information relating to oil and gas leasing on federal lands. Data for this indicator were prepared by BLM from a compilation of oil and gas well data from various state government agencies that oversee the administration of these data in their respective states. These data were used to create an oil and gas well data layer which was overlain on the HUC watershed layer (Figure E-7-11).

The number of oil and gas wells located within the HUC was calculated and then assigned a relative rank of good, fair, or poor, as noted in Table E-7-3. The scoring system used for this indicator was adopted from Stagliano (2007).

5.1.1.5 303(d) Listing

This KEA represents the water quality of a stream based on its status as defined by Section 303(d) of the Clean Water Act (CWA). Waterbodies with 303(d) listing are considered impaired based on national water quality standards. Surface waters can be added to the 303(d) list for two reasons: 1) when water quality standards are not being met or, 2) designated uses are not being achieved. Although a 303(d) listing does not mean that the species associated with this assemblage would not be present, this listing is an indication of habitat condition.

Stream data were obtained from the USGS NHD and water quality data were obtained from the U.S. Environmental Protection Agency (USEPA) Water Quality Standards Database (WQSDB). NHD-Plus is an integrated suite of application-ready geospatial data products, incorporating features of the NHD, the National Elevation Dataset (NED), and the National Watershed Boundary Dataset (WBD). NHD-Plus includes a stream network based on the medium resolution NHD (1:100,000 scale), elevation-derived catchments, feature naming, and value-added attributes that can produce cumulative drainage areas and land cover, temperature, and precipitation distributions.

USEPA's WQSDB contains information reported by the states to USEPA about the conditions in their surface waters, and is comprised of information on the attainment of water quality standards. The WQSDB provides information regarding the water bodies listed by the state as impaired under Section 303(d). As part of a state's water quality standards, designated uses (drinking water supply, recreational use, and fish protection) provide a regulatory goal for the water body and define the level of protection assigned to it (USEPA 2012).

For this analysis, the stream name and the spatial representation were extracted from NHD as a data layer; the 303(d) list data were joined to the NHD layer to map the impeded streams (Figure E-7-12). The percentage of streams in the 5th level HUC watershed within the ecoregion that were included on the 303(d) list were calculated, and then a relative rank of good, fair, or poor (as noted in Table E-7-3) was assigned. If zero percent of the stream miles or lake area were 303(d)-listed, then a ranking of good with a metric score of 1 was assigned. If less than 10 percent of the stream miles or lake area were 303(d)-listed, then a rating of fair with a metric score of 2 was assigned. If more than 10 percent of the stream miles or lake area were 303(d)-listed, then a rating of poor with a metric score of 3 was assigned. The percentages used to rank this attribute were based on the USDA Water Quality Condition Ranking Rule Set (USDA 2011).

5.1.1.6 Number of Mines

Surface water bodies and groundwater supply can be adversely affected by mining. Some of the impacts can include drainage of usable water from shallow aquifers, lowering of water levels in adjacent areas, poor-quality water flow to nearby streams, and increased runoff of poor-quality water and erosion from spoil piles.

Data on the locations of mines in the ecoregion was extracted from the USGS's Mineral Resources Data System (MRDS). The MRDS is a database that includes information on the metallic and nonmetallic mineral resources in the United States and the world. Included are deposit name, location, commodity, deposit description, geologic characteristics, production, reserves, resources, and references (USGS 2005).

For this analysis, locations of the mines within the ecoregion were extracted from MRDS as a data layer (Figure E-7-13). The total number of mines in each HUC watershed was summed and then a relative rank of good, fair, or poor, as noted in Table E-7-3, was assigned. The percentages used to rank this attribute were based on quantiles of the dataset (MoRAP 2012).

5.1.1.7 Number of Toxic Release Inventory Sites

Toxic chemicals are typically generated inland and are carried by air and/or fresh water to surface water bodies where they tend to accumulate in sediments. At high enough levels, chemicals can have an immediate effect on stream biota, or the effects may be chronic, eliminating the more sensitive species and disrupting ecosystem balance over time. This ecoregion has also been impacted by historical mining activities, which have resulted in toxic releases that have impacted water, soil, and the environment.

Data on the location of toxic releases was extracted from the USEPA's Envirofacts database. This database includes information from the USEPA's Toxic Release Inventory (TRI), which contains data on disposal or other releases of toxic chemicals from U.S. facilities. Data are submitted annually by U.S. facilities that meet TRI reporting criteria. Through the USEPA's Geospatial Data Download Service, the USEPA Geospatial Data File containing facility and site information from USEPA's TRI system can be downloaded. The file is Internet accessible from the Envirofacts Website (www.epa.gov/enviro), and the data may be downloaded in Extensible Markup Language (XML), Environmental Systems Research Institute (ESRI) Shapefile, or ESRI relational feature class format.

For this analysis, locations of the TRI sites within the ecoregion were extracted from Environfacts database as a data layer (Figure E-7-14). The total number of TRI sites in each HUC watershed was summed and then a relative rank of good, fair, or poor (as noted in Table E-7-3) was assigned. If no TRI sites were located in the HUC (0 percent), then the HUC was ranked as good and received a metric score of 1. If the number of TRI sites was 1, then a rating of fair with a metric score of 2 was assigned. If the number of TRI sites was 2 or greater, then a rating of poor with a metric score of 3 was assigned. The percentages used to rank this attribute were based on quantiles of the dataset (MoRAP 2012).

5.1.1.8 Percent of Stream/Shoreline from Roadways

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 the habitat of this assemblage. 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. Streams in close proximity to roads are also more likely to be affected than those at a greater distance (Stagliano 2007).

Stream data were obtained from the NHD (as discussed in Section 5.1.1.5) for each HUC area within the ecoregion and overlain with the roadway data layer. 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 percent of streams/shorelines within the HUC that were located within 40 m of a roadway was calculated, and then each HUC was assigned a relative rank of good, fair, or poor based on percentage as noted in Table E-7-3 and presented on Figure E-7-15. The scoring system used for this indicator was adopted from Stagliano (2007) based on the concept that if the percentage of stream miles within 40 m of a road are generally low, roads would not be a major source of disturbance in the study area.

5.1.1.9 Agricultural Use

Agricultural land use degrades streams by increasing nonpoint inputs of pollutants, impacting riparian and stream channel habitat, and altering flows. Negative impacts to aquatic life have been documented when approximately 30 to 60 percent of the land area is in agricultural use (Sheeder and Evans 2004). Where agriculture or other anthropogenic activity extends to the stream margin and natural riparian forest is removed, streams are usually warmer during summer, receive fewer energy inputs as leaf litter, and primary production usually increases (Quinn 2000).

For this analysis, two KEAs were evaluated; percent of agriculture land use within HUC as a whole and percent of riparian corridor within agricultural land use area. The land use data layers were created using the NLCD. Agricultural land use areas are defined by the NLCD as areas characterized by herbaceous vegetation that has been planted or is intensively managed for the production of food, feed, or fiber, or is maintained in developed settings for specific purposes. Herbaceous vegetation accounts for 75 to 100 percent of the cover. Data extracted included land uses of cultivated crops and pasture/hay. The riparian corridor area data were extracted from the NLCD using the open water, woody wetlands, and emergent herbaceous wetlands criteria. Figure E-7-16 illustrates the landcover types used for this layer.

Data from the NLCD were used to estimate the percentage of agricultural land use within the HUC as well as the percentage of riparian corridor (stream miles) with adjacent agricultural land use. A relative rank of good, fair, or poor (as noted in Table E-7-3) was assigned based on the percentage calculated for each KEA. For the percentage of HUC in agriculture land use, if less than 30 percent of the HUC was agricultural land use, then the HUC was ranked as good and received a metric score of 1. If the percentage was between 30 and 60 percent, then a rating of fair with a metric score of 2 was assigned. If the percentage was greater than 60 percent, then a rating of poor with a metric score of 3 was assigned. The percentages used to rank this attribute were based on citations from Allen (2004).

Likewise, if the percentage of riparian corridor adjacent to agricultural land was less than 3 percent, between 3 and 6 percent, or greater than 6 percent, then ratings of good, fair, or poor were assigned, respectively. The metrics used to score the percent of riparian corridor in agricultural use were adopted from Stagliano (2007).

5.1.1.10 Impervious Cover

Areas of land covered by concrete, asphalt, buildings, or even severely compacted areas of soil are impervious to rain water. Various studies from around the country show that stream ecosystems and water quality degrade as impervious surfaces increase. Significant impairment to streams often occurs when more than 10 percent of the land within a watershed is covered with impervious surfaces. When these levels exceed 25 percent, most watersheds experience severe ecosystem and water quality impairment (New Jersey Water Supply Authority 2002).

For this analysis, two KEAs were evaluated; percent of impervious cover within HUC as a whole and percent of impervious cover within the riparian corridor. The land use data layers were created using the NLCD. Data extracted from the NLCD included land use categories of developed and barren. The riparian corridor area data were extracted from the NLCD using the open water, woody wetlands, and emergent herbaceous wetlands criteria. Figure E-7-16 shows the landcover designations.

Data from the NLCD was used to estimate the percentage of impervious cover within the HUC as well as the percentage of impervious cover within the riparian corridor (stream miles). A relative rank of good, fair, or poor (as noted in Table E-7-3) was assigned based on the percentage calculated for each KEA. For the percentage of HUC in impervious cover, if less than 6 percent of the HUC was developed or barren, then the HUC was ranked as good and received a metric score of 1. If the percentage was between 6 and 10 percent, then a rating of fair with a metric score of 2 was assigned. If the percentage was greater than 10 percent, then a rating of poor with a metric score of 3 was assigned. The percentages used to rank this attribute were based on Allen (2004), Wang et al. (2008), and Annis et al. (2010).

Likewise, if the percentage of impervious cover adjacent to the riparian corridor was less than 3 percent, between 3 and 6 percent, or greater than 6 percent, then ratings of good, fair, or poor were assigned, respectively. The metrics used to score the percentage of impervious cover adjacent to the riparian corridor were based on Wang et al. (2008) and Joubert and Loomis (2005).

5.1.1.11 Population

Human population growth is an indicator of landscape context and is used as a surrogate indictor for the potential impacts associated with development and urbanization that would impact stream quality.

Population data were extracted for the ecoregion using the Oak Ridge National Laboratory's LandScan 2010 Global Population Dataset. The LandScan global population distribution modeling process uses sub-national-level census counts for each country and primary geospatial input or ancillary datasets, including land cover, roads, slope, urban areas, village locations, and high-resolution imagery analysis, all of which are key indicators of population distribution. Within each country, the population distribution model calculates a "likelihood" coefficient for each cell and applies the coefficients to the census counts, which are employed as control totals for appropriate areas. The total population for that area is then allocated to each cell proportionally to the calculated population coefficient. The resultant population count is an ambient or average day/night population count as people per cell (Oak Ridge National Laboratory 2010).

Data from the LandScan was used to estimate the average population within the HUC. A relative rank of good, fair, or poor (as noted in Table E-7-3) was assigned based on the average population calculated by LandScan. An average population of less than 100 people was ranked as good and received a metric score of 1. Populations between 100 and 300 people received a rating of fair with a metric score of 2. Average populations of greater than 300 were given a rating of poor with a metric score of 3. The values used to rank this attribute are based on Wang et al. (2008). Figure E-7-17 shows the population rank results within the ecoregion.

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 coldwater fish habitat for each HUC across the ecoregion. A method of aggregating scores was used to summarize overall threats for each HUC unit with regard to habitat quality. Based on each KEA rating of good, fair, or poor, an HUC quality rank score was subsequently assigned to the KEA. Once the ranks for each individual KEA were assigned, a simple additive method was used to combine the ranks into an overall score for each HUC. The resulting additive scores from the individual KEAs ranged from 23 to 45, with larger numbers indicating lower threats or better ecological conditions. These cumulative scores were then placed into categories of good, fair, or poor.

Although the good, fair, or poor ratings could be attributed any number of ways, a quantile classification method in ArcMap was used to place an HUC into each category. This approach was taken, in part, because meaningful ecological thresholds for the additive scores are not known and because the resulting ratings provide a relative measure of aquatic ecological integrity of the stream resources within the Middle Rockies ecoregion. Thus, the resulting ratings are relative to the study area and should be interpreted as a gradient from poor to good (MoRAP 2012).

The overall ratings were developed as a relative measure of aquatic ecological intactness across a large geographic area. In addition, this assessment was intended to be repeated in a quick manner. As such, there are several limitations to the current status assessment. The first is that the resulting additive index and associated ranks are very much a factor of the data that was available consistently over the study area. No consideration was given to the impacts of development residing upstream of a given HUC; therefore, the entire contributing area is not generally considered. Because the final rankings are based on additive scores, it is also possible that one single indicator could significantly diminish the habitat status at any given location. HUCs with a single, pervasive condition will invariably score high, giving the false indication that the current status is good. Specific weights to the individual threat analysis indicators were also not incorporated into the overall rating. Part of the difficulty in assigning weighting factors lies in determining how much/many of a given threat has the same ecological response as another threat (e.g., how many mines does it take to have a similar ecological impact as 25 percent cropland in a watershed?).

With consideration of these limitations, this assessment can be used to provide a means to establish baseline conditions for this CE in the Middle Rockies ecoregion and can be used to characterize the potential trends in the coming years (MoRAP 2012).

A summary of the current status ratings based on the CE distribution is provided in Table E-7-4. 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 miles per HUC that were rated as good, fair, or poor. The results of the current status assessment indicate that approximately 28 percent of the 6th level HUC watersheds that intersect the cold water fish assemblage distribution received an overall good rating. Seventy-one (71) percent of the projected habitat for this assemblage received a fair or poor rating.

Table E-7-4. Current Status Ratings for the Cold Water Fish Assemblage

Overall Rating by 6th Level HUC	Total Square Miles[a]	Percentage of Total Square Miles[a, b]
Good	14,177	27.9
Fair	16,972	33.6
Poor	19,571	38.5

[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

Future threats associated with wildfire and climate change were assessed using KEAs as presented in Table E-7-5. Future threats were also qualitatively evaluated for climate change for long-term change (50-year; 2050 to 2069).

Table E-7-5. Coldwater Fish Assemblage Key Ecological Attributes, Indicators, and Metrics for Future Threat Assessment for the Middle Rockies Ecoregion

Category	Key Ecological Attribute	Indicator / Unit of Measure	Metric: Poor = 3	Metric: Fair = 2	Metric: Good = 1	Data Source	Citation
Condition	Wildfire Threat	Wildfire threat	All other fuels[1]	Grass & mesic shrublands[1]	Non-fuels[1]	Digital Elevation Model (DEM):Elev LANDFIRE: Fire fuel (Anderson 1982)	Haak et al. 2010
	Climate Change; Hydrologic Processes	Winter Flooding threat	High-Risk [2]: Snow to transient or snow to rain dominant.	Moderate-Risk [2]: transient to rain dominant.	Low-Risk[2]: Remains snow dominant or remains rain dominant or low winter precipitation.	Parameter-elevation Regressions on Independent Slopes Model (PRISM) temperature and precipitation data (Daly et al. 2008)	Haak et al. 2010
		Summer Temperature threat	Fish species-specific. Ranks determined by species temperature thresholds.[3]			PRISM temperature (Daly et al. 2008)	Haak et al. 2010

[1] See Table E-7-6
[2] Average computed by HUC to develop ranks for high, moderate, and low risk.
[3] See Table E-7-7

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.

5.2.1 Wildfire Threat

Future threats associated with wildfire was assessed using methods similar to those used by Haak et al. (2010); this included utilizing elevation zones and Anderson Fire Behavior Fuel Models (Anderson 1982) to compute fire risk scores for each HUC 12. Haak et al. (2010) generally assumed "that wildfire is a function of climate, fuels, and ignition and that changing climate conditions in the western United States will continue to increase the likelihood of wildfires in the presence of fuels and an ignition source".

A Digital Elevation Model (DEM) was used to define a future fire risk elevation zone between 1,680 and 2,690 m. Haak et al. (2010) cite work by Westerling et al. (2006) that indicates areas in the Rocky Mountain region within this elevation zone have recently been prone to earlier snowmelt and more wildfires. Elevations outside of this zone were not considered for wildfire risk.

Within the fire risk zone, Anderson Fire Behavior Fuel Model (Anderson 1982) data from the LANDFIRE 2008 refresh (http://www.landfire.gov/NationalProductDescriptions1.php) were used to define risk types. As noted in Table E-7-5, non-fuel types (urban, snow/ice, agriculture, water, or barren) were assigned a score of zero. Grasslands and mesic shrublands were considered low-risk and assigned a score of 1 (fire behavior fuel model types 1-7). All other fuel types (fire behavior fuel model types 8-13) were considered high-risk and assigned a score of 3. Using a 5-square kilometers (km^2) roving window, an average fire risk score was calculated for each 30-m grid cell. This grid was then used to compute an average risk for each HUC 12 (MoRAP 2012). Figure E-7-19 shows the future wildfire threat score based on HUC.

In comparing the species distribution maps developed for each of the focal species (Figures E-7-1 and E-7-5) with the future wildfire layer, wildfire poses little potential future threat to coldwater fish habitat.

5.2.2 Climate Change

In addition to the overall climate change assessment conducted for the ecoregion (presented in Appendix C-5), select hydrologic processes were also evaluated for this CE within the context of potential threat from climate change. Using methods described by Haak et al. (2010), hydrologic process indicators assessed include winter flooding threat and summer temperature threat (Table E-7-5). A KEA for drought threat using the Palmer Drought Severity Index was not conducted because there is a time scale built into the index and it is therefore not suitable for the determination of longer-term hydrologic drought such as those that impact stream flow, reservoirs, and aquifers (NOAA 2003).

5.2.2.1 Winter Flooding Threat

The threat of winter flooding due to changing climate was assessed in a general manner, following Haak et al. (2010), by utilizing a combination of precipitation and temperature data to identify watersheds with changing precipitation regimes (rain dominant, snow dominant, and transient).

Parameter-elevation Regressions on Independent Slopes Model (PRISM) data for precipitation (Daly et al. 2008) was used to calculate the 1970-2000 average winter precipitation (November-March) for each HUC 12. Following Haak et al. (2010), we put the data into 10 categories using natural breaks. HUCs falling into the lowest category were classified as "low winter precipitation" and not processed further. All other HUCs were retained for further assessment. The average January – March temperature for each HUC was computed and then increased by 3 degrees Celsius (°C) to account for climate change. The current temperature and future scenario temperature fields were then assigned precipitation regimes as follows: < -1°C = snow, -1°C to 1°C = transient, >1°C = rain. Precipitation regime change was computed by comparing the two data fields, and a risk was then assigned (Table E-7-6). Watershed precipitation regimes that changed from snow to transient or snow to rain were assigned high-risk, regimes that changed from transient to rain were assigned moderate risk, and regimes that had low precipitation or did not change were assigned low-risk. Good, fair, or poor ratings were applied to each HUC 12 based on the risk (Figure E-7-20).

Table E-7-6. Winter Flooding Risk Assessment

Precipitation Regime Change	Risk Assigned
Low precipitation	Low risk
Remains snow	Low risk
Remains rain	Low risk
Transient to rain	Moderate risk
Snow to rain	High risk
Snow to transient	High risk

In comparing the species distribution maps developed for each of the focal species (Figures E-7-1 and E-7-5) with the future precipitation layer (Figure E-7-20), five of the seven species (bull trout, Chinook salmon, sockeye salmon, steelhead trout, and westslope cutthroat trout) scored poorly, indicating that their habitat is at a higher risk of potential future threat due to winter flooding.

5.2.2.2 Summer Temperature Threat

Coldwater fish species are very sensitive to water temperature changes. For this indicator, each fish species was independently assessed; therefore, this indicator was not included in the final overall ratings for each HUC but is intended to be a species-specific modifier. In order to assess the threat from changes to summer temperature, temperature thresholds of suitable, marginal, and unsuitable were determined based on mean July air temperature for each of the focal species (July is often the hottest month in the Rocky Mountains). This was accomplished by buffering the stream segments that represent each species distribution (Figures E-7-1 through E-7-5) by 30 m and then using these buffers to extract an average 1970-2000 July air temperature for each stream segment using PRISM data (2004). These ranges were standardized by attributing the 1:100,000 scale NHD+ stream lines for each species. This alleviated problems of overlapping lines and inconsistent resolutions so that all species could be assessed consistently.

To determine temperature suitability thresholds for each species, the mean, maximum, and standard deviation temperature was calculated. The mean temperature plus one standard deviation was classed as suitable (good); the break at suitable to the maximum temperature was classed as marginal (fair); and anything greater than the maximum was classed as unsuitable (poor) (Table E-7-7). Next, we computed the average July temperature for the species distribution within each HUC 12. Using methods described in Haak et al. (2010), the mean July temperature was increased by 3°C and then the good, fair, or poor suitability classes were applied to each HUC 12.

Table E-7-7. Temperature Thresholds Used For Summer Temperature Change Threat Key Ecological Attribute

Species	Suitable Temperature Range (°C)	Marginal Temperature Range (°C)	Unsuitable Temperature Range (°C)
Arctic grayling	<=19.2	19.2-21.6	>21.6
Bull trout	<=18.2	18.2-20.1	>20.1
Chinook salmon	<=20.7	20.7-21.9	>21.9
Sockeye salmon	<=20.5	20.5-20.6	>20.6
Steelhead trout	<=20.0	20.0-20.6	>20.6
Westslope cutthroat trout	<=17.7	17.7-20.6	>20.6
Yellowstone cutthroat trout	<=18.2	18.2-22.5	>22.5

Figures E-7-21 through E-7-27 present the future summer temperature change threat by HUC for each of the seven focal species. Of these seven species, four (bull trout, Chinook salmon, sockeye salmon, and Arctic grayling), scored poor or fair, indicating that their habitat is at a higher risk of potential future summer temperature change threat.

THIS PAGE INTENTIONALLY LEFT BLANK

6.0 MANAGEMENT QUESTIONS

The relevant MQs for the coldwater fish assemblage include those defined as part of the Aquatic/Riparian Biotic Resources category. The overall MQ was: Where are the important regionally significant aquatic/riparian biotic 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 maps developed for each focal species. 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 THE CURRENT LOCATIONS OF REGIONALLY SIGNIFICANT AQUATIC/RIPARIAN HABITATS, INCLUDING RIVERS, STREAMS, LAKES, PONDS, WETLANDS, SPRINGS, AND RESERVOIRS?

For the coldwater fish assemblage, the species distribution maps provided in Figures E-7-1 through E-7-5 define occupied areas that are already considered regionally significant aquatic habitat. Among these areas, an enhanced definition of the significance of the areas can be determined by using the overall current status figure (Figure E-7-18) based on relative threats.

6.2 WHERE ARE RIPARIAN OR AQUATIC AREAS CURRENTLY AT RISK OF FRAGMENTATION IMPOUNDMENT, DIVERSION, AND LOWERED WATER TABLES DUE TO DEVELOPMENT, MINERAL EXTRACTION, AND AGRICULTURAL AND RESIDENTIAL DEVELOPMENT?

The current status layer provided on Figure E-7-18 can be used to identify the general ecoregional areas with HUCs illustrated in red, indicating habitat conditions that are currently at risk due to development activities.

6.3 WHAT IS THE CURRENT FLOW REGIME (HYDROGRAPH) OF REGIONALLY SIGNIFICANT STREAM OR RIVER HABITATS OR DURATION AND EXTENT OF SURFACE WATER IN REGIONALLY SIGNIFICANT POND AND LAKE HABITATS?

Information on flow regimes of particular streams or lakes can be accessed from the USGS based on the desired stream reach or area where the species is found, as indicated on Figures E-7-1 through E-7-5.

6.4 HOW HAVE DOMINANT SPECIES CHANGED OVER TIME?

This REA focused on potential impacts associated with CAs on these keystone species on an ecoregional basis. This MQ is relevant to a stream-reach or lake-specific evaluation of the fish community without regard to potential CAs.

6.5 WHERE ARE EXOTIC SPECIES AN EXISTING AND POTENTIAL PROBLEM?

This MQ is not able to be answered based on the lack of a comprehensive dataset for fish within the ecoregion. Instead, BLM may want to focus future evaluations or actions in those areas defined as good quality habitat (Figure E-7-18).

6.6 WHERE ARE DEGRADED AQUATIC SYSTEMS (WATER QUALITY) AND WHAT ARE THE SOURCES OF THE DEGREDATION (SALINE DISCHARGES, PETROCHEMICAL DISCHARGES, LEACHING OF TOXIC MINERAL SALTS, EUTROPHICATION DUE TO CONCENTRATED NUTRIENT RUNOFF, OTHER)?

Several surrogate indicators were used to assess water quality conditions, including use of the 303(d)-listed streams (Figure E-7-12), the location and number of oil and gas wells (Figure E-7-11), locations of mines (Figure E-7-13), and the areas of land under agricultural use (Figure E-7-16). The overall current status layer provided on Figure E-7-18 can be used to identify areas with current landscape uses that may contribute to degraded aquatic systems.

6.7 WHERE WILL REGIONALLY SIGNIFICANT AQUATIC HABITATS POTENTIALLY EXPERIENCE THE GREATEST EFFECTS OF CLIMATE CHANGE (DURATION AND MAGNITUDE OF FLOW, DURATION AND EXTENT OF SURFACE WATER PRESENCE, IF APPLICABLE)?

Climate change was evaluated for the coldwater fish assemblage based on winter precipitation changes (Figure E-7-20) and summer temperature changes (Figures E-7-21 through E-7-27). The analyses conducted indicate that of the seven focal species, five (bull trout, Chinook salmon, sockeye salmon, and Arctic grayling) had poor temperature change scores (for both winter and summer), indicating that their habitat is at a higher risk of potential future threat as a result of climate change.

6.8 WHERE ARE THE MOST SPECIES LOSSES LIKELY TO OCCUR DUE TO TEMPERATURE INCREASES OR WATER REDUCTIONS?

Climate change was evaluated for the each of the focal species based on summer temperature changes (Figures E-7-21 through E-7-27). The analyses that were conducted indicate that of the seven focal species, four species (bull trout, Chinook salmon, sockeye salmon, and summer steelhead trout) had poor or fair temperature change scores, indicating that their habitats are at a higher risk of potential future threat.

6.9 WHAT/WHERE IS THE POTENTIAL FOR FUTURE CHANGE IN DOMINANT SPECIES COMPOSITION OF REGIONALLY SPECIFIC AQUATIC HABITATS?

This REA focused on potential impacts associated with the assemblage as a whole, not on a community-level approach.

6.10 WHAT AREAS HAVE POTENTIAL FOR REGIONALLY SIGNIFICANT AQUATIC HABITAT RESTORATION (BASED ON AVAILABLE GEOSPATIAL DATA)?

Figure E-7-18, combined with the species distribution maps provided in Figures E-7-1 through E-7-5 can be used to identify areas in which aquatic habitat restoration activities for the assemblage may be important.

6.11 WHERE ARE AQUATIC HABITAT STRONGHOLDS FOR SENSITIVE SPECIES THAT ARE INTACT AND PROVIDE THE BEST OPPORTUNITY FOR PROTECTION, RESTORATION, AND ENHANCEMENT?

Figure E-7-18, combined with the species distribution maps provided in Figures E-7-1 through E-7-5, can be used to identify areas in which the occurrence of species in a particular stream reach and habitat quality is high. The REA did not consider population size as an attribute of "stronghold" because data were not inadequate across the ecoregion to be used in this manner.

6.12 WHERE ARE SENSITIVE AQUATIC SPECIES AT RISK FROM STREAM CONNECTIVITY OR FROM INTERBREEDING WITH CLOSELY RELATED NON-NATIVE OR EXOTIC SPECIES?

Unfortunately, comprehensive ecoregion-wide data on non-native or exotic species were not available; therefore, a definitive answer to this MQ could not be provided. This MQ may be more suitable for a step-down analysis. One example of this is the lake trout depredation on cutthroat trout in the Yellowstone Area of this ecoregion. This depredation is well documented in this part of the ecoregion. However, these types of data across the ecoregion were not available.

THIS PAGE INTENTIONALLY LEFT BLANK

7.0 REFERENCES

Allen, J.D., 2004. Landscapes and Riverscapes: The Influence of Land Use on River Ecosystems. *Annual Review of Ecology and Systematics*, 35, 257-284.

Anderson, H.E. 1982. Aids to Determining Fuel Models for Estimating Fire Behavior: U.S. Forest Service General Technical Report INT-122, 22p.

Annis, G.M., S. P. Sowa, D. D. Diamond, M. D. Combes, K. E. Doisy, A. J. Garringer, and P. Hanberry. 2010. Developing Synoptic Human Threat Indices for Assessing the Ecological Integrity of Freshwater Ecosystems in EPA Region 7. Final report, submitted to Environmental Protection Agency. 192 pp.

Behnke, R.J. 1992. Trout of western North America. American Fisheries Society Monograph 6.

Byorth, P.A. 1993. Big Hole River Arctic grayling recovery projects: Annual monitoring report 1992. Submitted to Fluvial Arctic Grayling Workgroup. Montana Department of fish, Wildlife, and Parks, Bozeman, MT.

Daly, C., Halbleib, M., Smith, J.I., Gibson, W.P., Doggett, M.K., Taylor, G.H., Curtis, J., and Pasteris, P.A., 2008, Physiographically-sensitive mapping of temperature and precipitation across the conterminous United States: International Journal of Climatology, v. 28, p. 2031–2064, doi:10.1002/joc.1688, accessed July 28, 2009, at http://www.prism.oregonstate.edu/pub/prism /docs/intjclim08-physiographic_mapping-daly.pdf.

Eaglin, G.S. and W.A. Hubert. 1993. Effects of logging and roads on substrate and trout in streams of the Medicine Bow National Forest, Wyoming. North American Journal of Fisheries Management 13(4):844-846.

Federal Register. 1991. Endangered and threatened species: endangered status for Snake River sockeye salmon-910379-1256.91. Department of Commerce, National Oceanic and Atmospheric Administration.

Gresswell, R.E. 1995. Yellowstone cutthroat trout. RM_GTR 256., pp. 36-54. Accessed online at http://www.fs.fed.us/rm/pubs_rm/rm_gtr256/rm_gtr256_036_054.pdf.

Gresswell, R.E. (2009). Yellowstone Cutthroat Trout (Oncorhynchus clarkii bouvieri): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. June 30. Available: http://www.fs.fed.us/r2/projects/scp/assessments/yellowstonecutthroattrout.pd

Haak, A.L., J.E. Williams, D. Isaak, A. Todd, C.C. Muhlfeld, J.L. Kershner, R.E. Gresswell, S.W. Hostetler, and H.M. Neville. 2010. The potential influence of changing climate on the persistence of salmonids of the inland west. U.S. Geological survey Open-File Report 2020-1236. 74 pp.

Hickman, T. and R.F. Raleigh. 1982. Habitat suitability models: cutthroat trout. USDI Fish and Wildlife Service, Washington, D.C. FWS/OBS-82/10.5. vi+38 pp.

Homer, C.H., Fry, J.A., and Barnes C.A., 2012, The National Land Cover Database, U.S. Geological Survey Fact Sheet 2012-3020, 4 p.

Idaho Fish and Game. 2007. Management Plan for conservation of Yellowstone cutthroat trout in Idaho. http://fishandgame.idaho.gov/fish/programs/ ontana one.pdf.

Joubert, Lorraine and George Loomis. 2005. Chepachet Village Pollution Risk Indicators (Report Appendix B). Chepachet Village Decentralized Wastewater Demonstration Project. University of Rhode Island. http://www.uri.edu/ce/wq/NEMO/Publications/PDFs/WW.AppB4.%20Indicators andRatingChep.pdf.

Koel, T. M., P. E. Bigelow, P. D. Doepke, B. D. Ertel, and D. L. Mahony. 2005b. Nonnative lake trout result in Yellowstone cutthroat trout decline and impacts to bears and anglers. *Fisheries* 30(11):10‑19.

LANDFIRE 1.1.0. Vegetation Condition Class layer. U.S. Department of the Interior, Geological Survey. [Online]. Available: http://landfire.cr.usgs.gov/viewer/ [2012, May].

Lohr, S.C., P.A. Byorth, C.M. Kaya, and W.P. Dwyer. 1996. High-temperature tolerances of fluvial arctic grayling and comparisons with summer river temperatures of the Big Hole river, Montana. Transactions of the American fisheries Society 125(6):933-939.

May, B.E. 1996 Yellowstone cutthroat trout, Oncohynchus clarki bouvier. Pages 11-35 in D.A. Duff (editor), Conservation assessment for inland cutthroat trout :distribution, status and habitat management implications. USDA Forest Service, Intermountain Region, Ogden, UT. Viii+120 pp.

McIntyre, J.D. 1996. Review and assessment of possibilities for protecting the cutthroat trout of Yellowstone Lake from introduced lake trout. In J.D. Varley and P. Schullery, eds. The Yellowstone Lake crisis: confronting a lake trout invasion. National Park Service report. Yellowstone National Park, Wyoming.

McIntyre, J.D. and Rieman, B.E. 1995. Westslope cutthroat trout. RM_GTR 256. Accessed online at http://www.fs.fed.us/rm/pubs_rm/rm_gtr256/rm_gtr256_001_015.pdf.

Missouri Resource Assessment Partnership (MoRAP). 2012. *Coldwater Fish Assemblage Threat Analysis in the Middle Rockies Ecoregion, Methods Report.* School of Natural Resources, University of Missouri, Columbia, Missouri. May.

Montana Fish, Wildlife and Parks. 2002. Fort Peck Reservior Fisheries Management Plan 2002 – 2012.. Prepared by Montana Fish, Wildlife and Parks, Region 6. Available at http://fwp.mt.gov/fwpDoc.html?id=7288 .

Montana Fish, Wildlife and Parks. 2011. Whirling Disease website. http://fwp.mt.gov/fishing/guide/ANS/parasites_pathogens.html#whirlingdisease.

Montana FWP Field Guide 2012 - Yellowstone Cutthroat Trout — Oncorhynchus clarkii bouvieri. Montana Field Guide. Montana Natural Heritage Program and Montana Fish, Wildlife and Parks. Retrieved on October 8, 2012, from http://FieldGuide.mt.gov/detail_AFCHA02087.aspx

Montana Water Center. 2012. http://whirlingdisease.montana.edu/images/distribution%20maps/sm_gif/Nationwide_webview.jpg.

National Ocenaic and Atmospheric Administration (NOAA) 2003. North American Drought: A Paleo Perspective; Palmer Drought Severity Index (PDSI). November 12. Accessed on August 7, 2012 from http://www.ncdc.noaa.gov/paleo/drought/drght_pdsi.html.

New Jersey Water Supply Authority. 2002. Raritan Basin; Portrait of a Watershed. Raritan Basin Watershed Management Project, New Jersey Water Supply Authority. August. Available at http://www.raritanbasin.org/Alliance/Documents/Summary_Report.pdf

Oak Ridge National Laboratory (ORNL). 2010. *LandScan Documentation*. United States Department of Energy. Available at http://www.ornl.gov/sci/landscan/ Accessed on June 26, 2012.

Peterson, D.P., B.E. Rieman, M.K. Young, and J. Brammer. 2010. *Modeling predicts that redd trampling by cattle may contribute to population declines of native trout.* Ecological Applications 20(4):954-966.

Peterson, D., C. Young-Dubovsky, B. Snyder and M. Williams. 2005. Draft Programmatic EA for Candidate Conservation Agreement with Assurances and Associated Permit for fluvial Arctic grayling in the upper Big Hole River, Montana

PRISM (2004) PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu, created 4 Feb 2004.

Quinn, J.M. 2000: Effects of pastoral development. Pp. 208–229 in Collier, K.; Winterbourn, M. (Eds): New Zealand stream invertebrates: ecology and implications for management. Caxton, Christchurch, NZ.

Quinn, T.P. 2005. The behavior and ecology of Pacific salmon and trout. University of Washington Press: Seattle, WA.

Rieman, B.E. and J.D. McIntyre. 1993. Demographic and habitat requirements for conservation of bull trout. USDA Forest Service. Intermountain Research Station, Gen. Tech. Report INT-302.38pp.

Rieman, B.E., D.J. Isaak, JS. Adams, D. Horan, D. Nagel, C. Luce, and D. Myers. 2007. Anticipated climate warming effects on bull trout habitats and populations across the Interior Columbia river basin. Transactions of the American Fisheries Society 136:1552-1565.

Rieman, B.E., D.J. Isaak. 2010. Climate change, aquatic ecosystems, and fishes in the rocky Mountain West: implications and alternatives for management. Gen. Tech. Rep. RMRS-GTR-250. USDA Forest Service, Rocky Mountain Research Station. Fort Collins, CO. 46 pp.

Sheeder, S. and B. Evans, 2004. Estimating nutrient and sediment threshold criteria for biological impairment in Pennsylvania watersheds. J. Amer. Water Resources Assoc., 40(4):881-888.

Shepard, B. B., and R. A. Oswald. 1989. Timing, location, and population characteristics of spawning Montana Arctic grayling (*Thymallus arcticus montanus* [Milner]) in the Big Hole River drainage, 1988. Montana Department of Fish, Wildlife, and Parks, Bozeman.

Shepherd, B.B., B.E. May, and W. Urie. 2003. Status of the Westslope cutthroat trout (*Oncorhynchus clarki lewisi*) in the United States:2002. Westslope Cutthroat Interagency Conservation Team. https://research.idfg.idaho.gov/Fisheries Research Reports/Mgt901-101Shepard200 Status of Westslope Cutthroat Trout in the US.pdf.

Spahr, R., L. Armstrong, D. Atwood, and M. Rath. 1991. Threatened, endangered and sensitive species of the Intermountain Region. U.S. Forest Service. Ogden, UT.

Stagliano, David, M. 2007. Freshwater Conservation Measures for the Northern Great Plains Steppe Ecoregion of Montana. Report to The Nature Conservancy, Ecoregional Measures Team and The Montana Field Office. Montana Natural Heritage Program, Helena, Montana 36 pp. plus appendices.

Stanley, E.H., S.M. Powers, and N.R. Lottig. 2010. The evolving legacy of disturbance in stream ecology: concepts, contributions, and coming challenges. Journal of the North American Benthological Society 29(1):65-83.

Thurow, R.F., C.E. Corsi, and V.K. Moore. 1988. Status, ecology, and management of Yellowstone cutthroat trout in Upper Snake River Drainage, Idaho. American fisheries Society Symposium 4:25-36.

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.

U.S. Army Corps of Engineers (USACE) 2010. National Inventory of Dams. Available at http://geo.usace.army.mil/pgis/f?p=397:1:0::NO:::/

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.

U.S. Department of Agriculture (USDA) Forest Service. 2011. Watershed Condition Classification Technical Guide. Washington D.C.: U.S. Department of Agriculture, Forest Service, Watershed, Fish, Wildlife, Air, and Rare Plants Program.

United States Geological Survey (USGS) 2005, Mineral Resources Data System: U.S. Geological Survey, Reston, Virginia. http://tin.er.usgs.gov/mrds/

USGS 2012. PAD-US The National Inventory of Protected Areas. Available at http://gapanalysis.usgs.gov/padus/files/2012/10/usgs-gap-fact-sheet-padus-Sept2012.pdf. September.

Varley, J.D. and R.E. Gresswell. 1988. Ecology, status and management of the Yellowstone cutthroat trout. American Fisheries Society Symposium 4:13-24.

Wang, L., T. Brandon, P. Seelbach, A. Cooper,, D. Allen, R. Clark Jr., M. Wiley. 2008. Landscape Based Identification of Human Disturbance Gradients and Reference Conditions for Michigan Streams. Environmental Monitoring and Assessment, 141, 1-17.

Waples, R.S., O.W. Johnson, and R.P. Jones. 1991. Status review for Snake River sockeye salmon. NOAA Technical Memorandum NMFS-F/NWC 195. Northwest Fisheries Science Center.

Wenger, Seth. 1999. A review of the scientific literature on riparian buffer width, extent and vegetation. Institute of Ecology, University of Georgia.

Westerling, A.L., Hidalgo, H.G., Cayan, D.R., and Swetnam, T.W. 2006. Warming and Earlier Spring Increase – western U.S. Forest Wildfire Activity: Science, v. 310, p. 940-943.

Whirling Disease Initiative. 2011. Accessed online at http://whirlingdisease.montana.edu/default.asp.

Yellowstone Cutthroat Trout — Oncorhynchus clarkii bouvieri. Montana Field Guide. Montana Natural Heritage Program and Montana Fish, Wildlife and Parks. Retrieved on August 6, 2012, from http://FieldGuide.mt.gov/detail_AFCHA02087.aspx.

APPENDIX E-7

FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

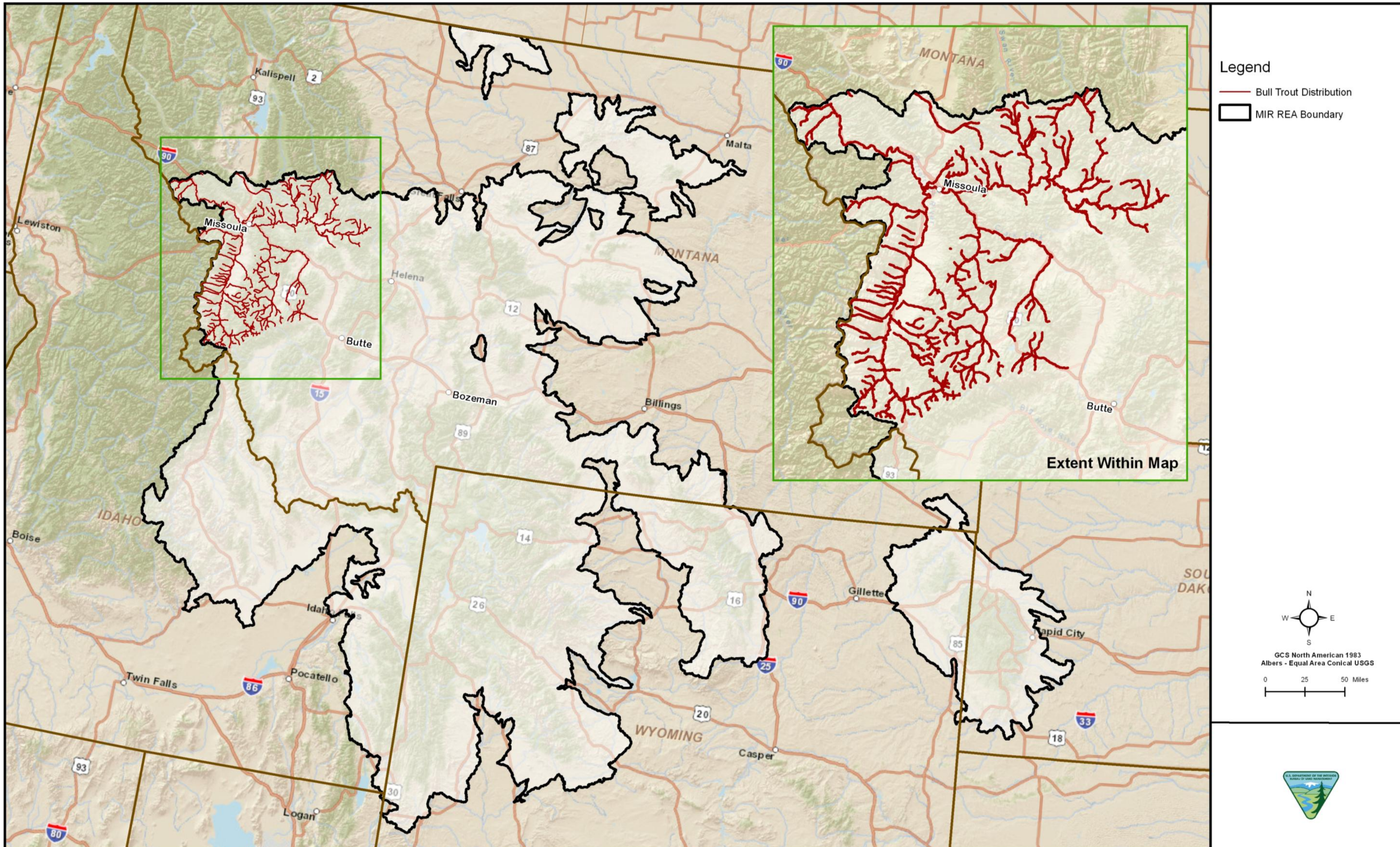

Figure E-7-1. Distribution of the Bull Trout in the Middle Rockies Ecoregion

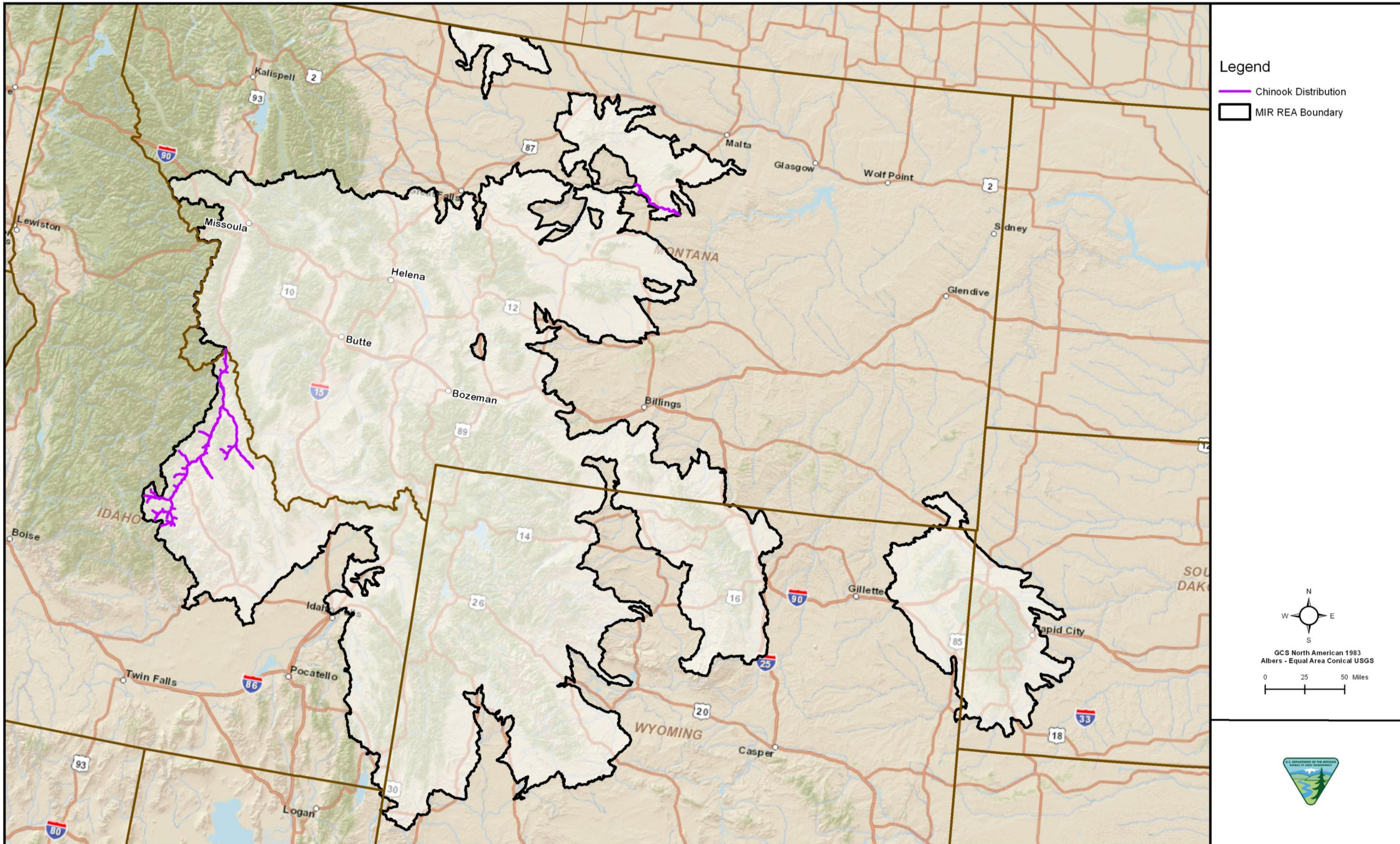

Figure E-7-2. Distribution of the Spring/Summer Chinook Salmon in the Middle Rockies Ecoregion

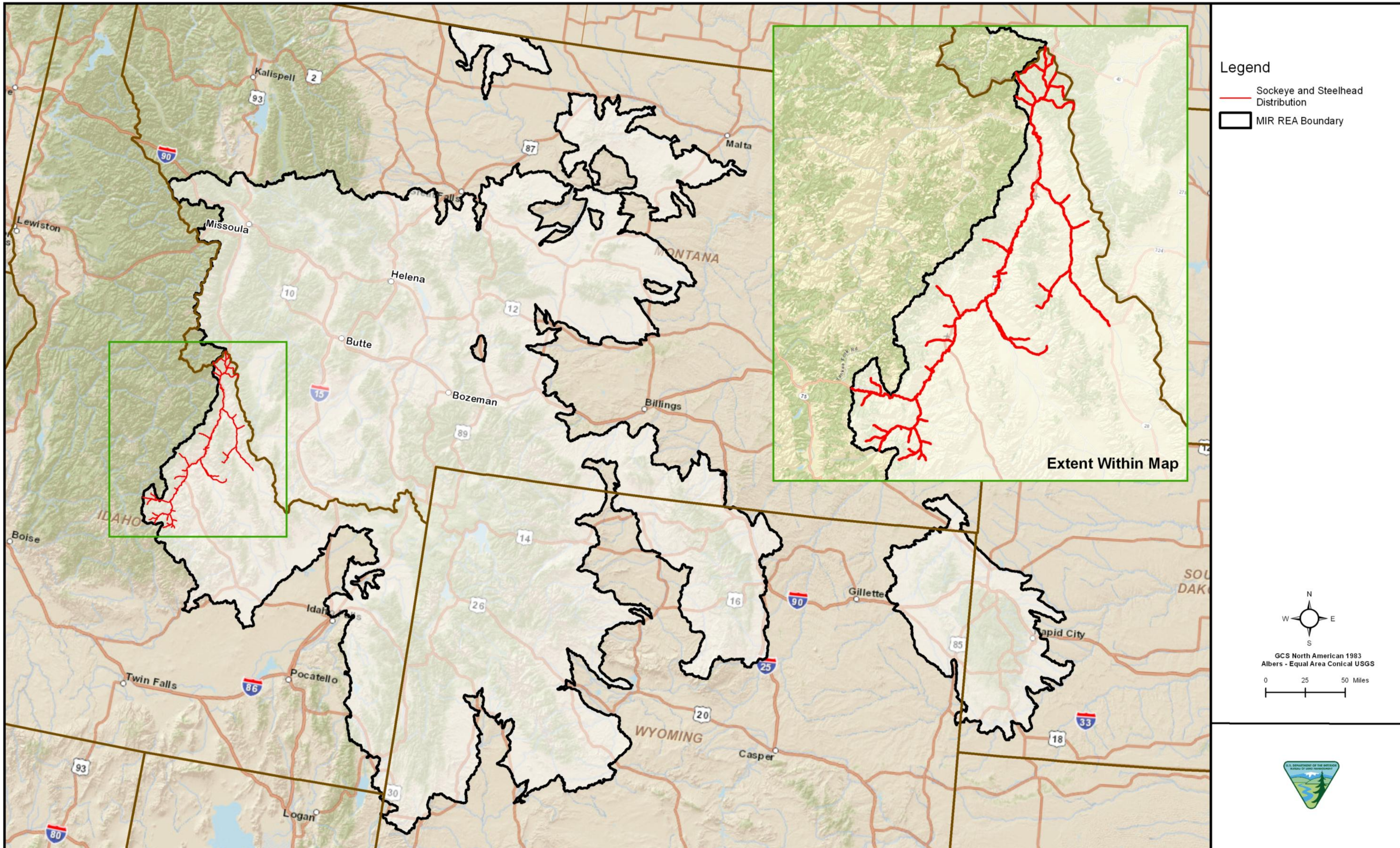

Figure E-7-3. Distribution of the Sockeye Salmon and Summer Steelhead in the Middle Rockies Ecoregion

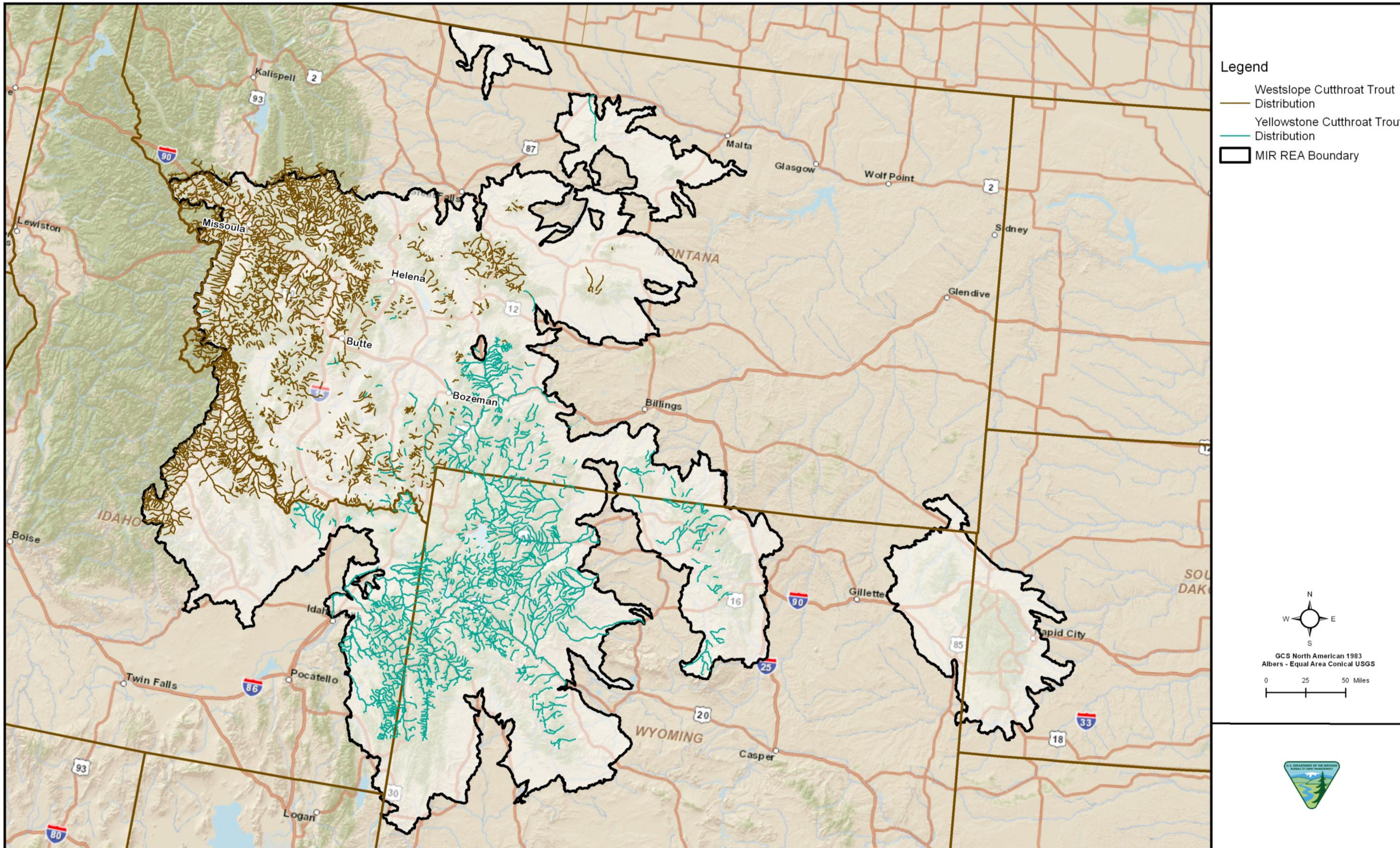

Figure E-7-4. Distribution of the Westslope Cutthroat Trout and Yellowstone Cutthroat Trout in the Middle Rockies Ecoregion

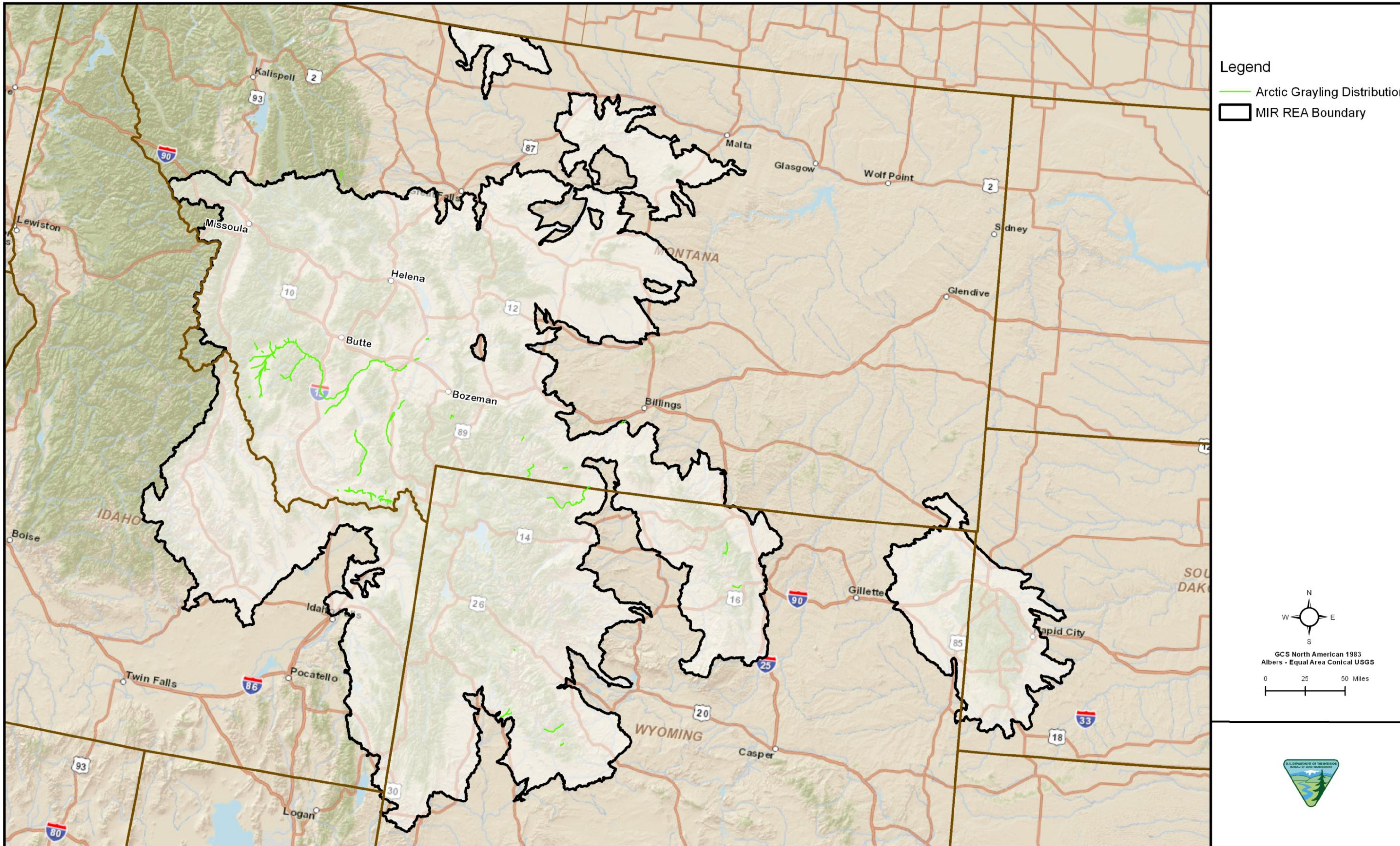

Figure E-7-5. Distribution of the Arctic Grayling in the Middle Rockies Ecoregion

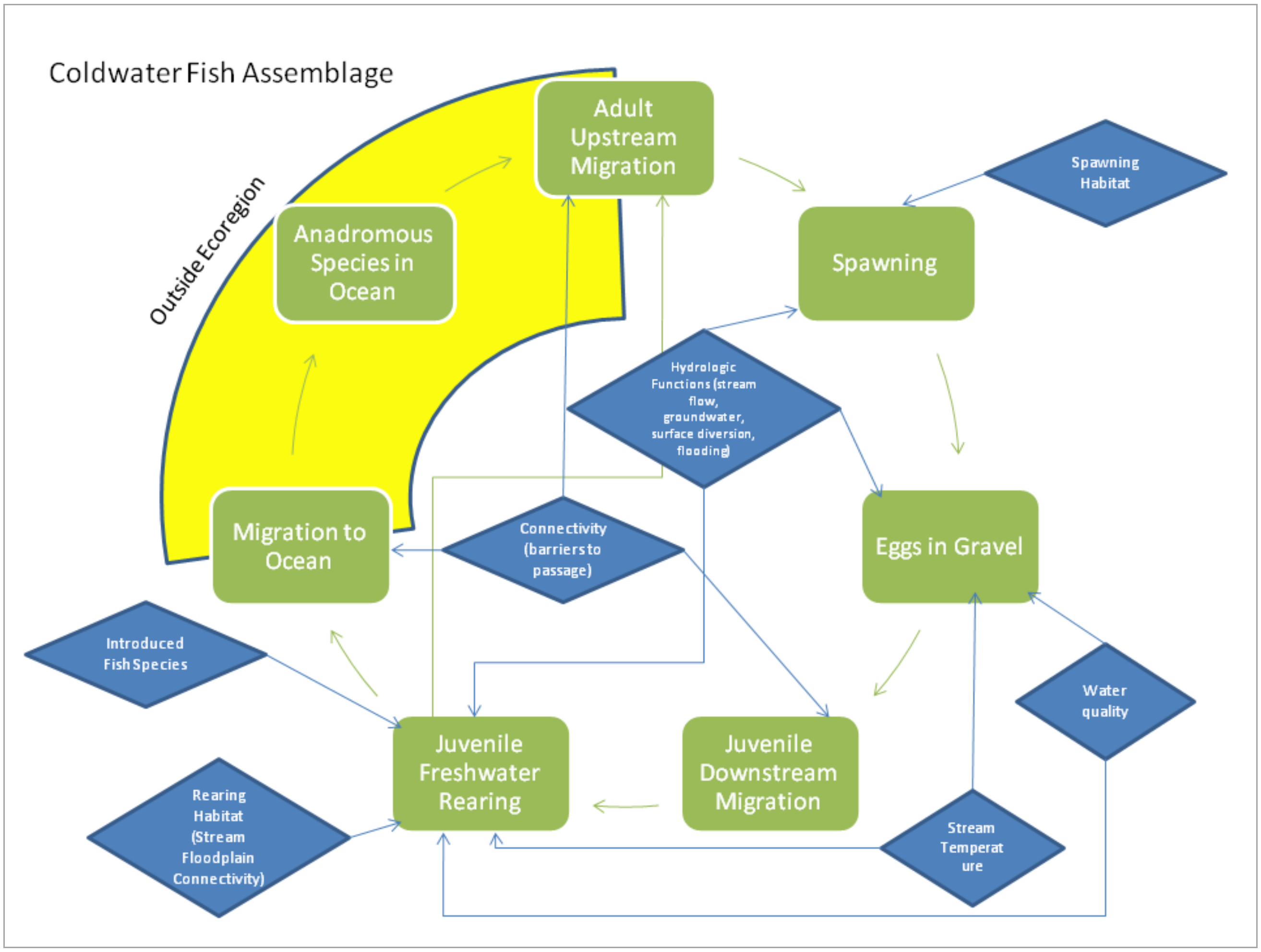

Figure E-7-6. Ecological Process Model for the Coldwater Fish Assemblage

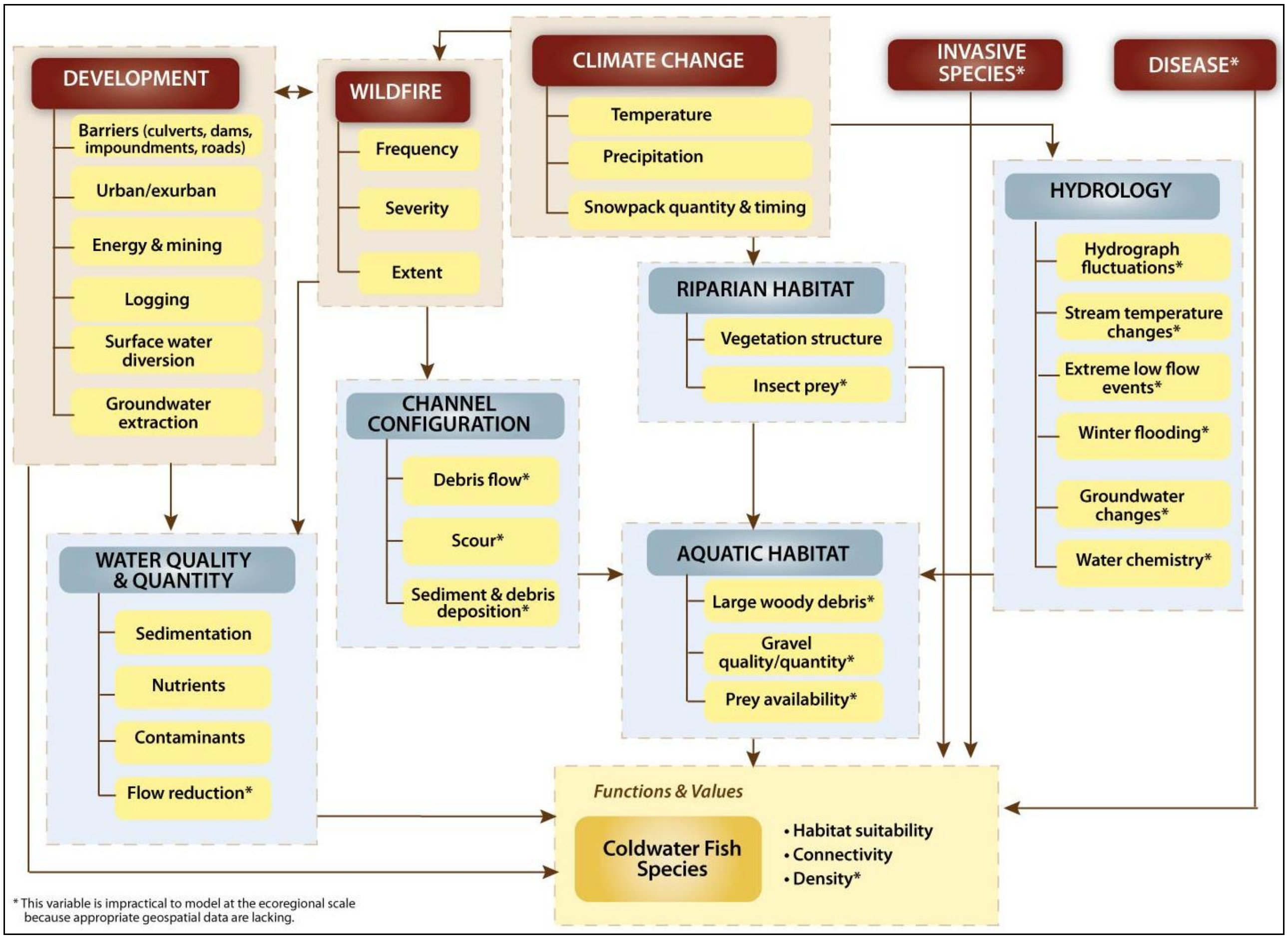

Figure E-7-7. System-Level Conceptual Model for the Coldwater Fish Assemblage

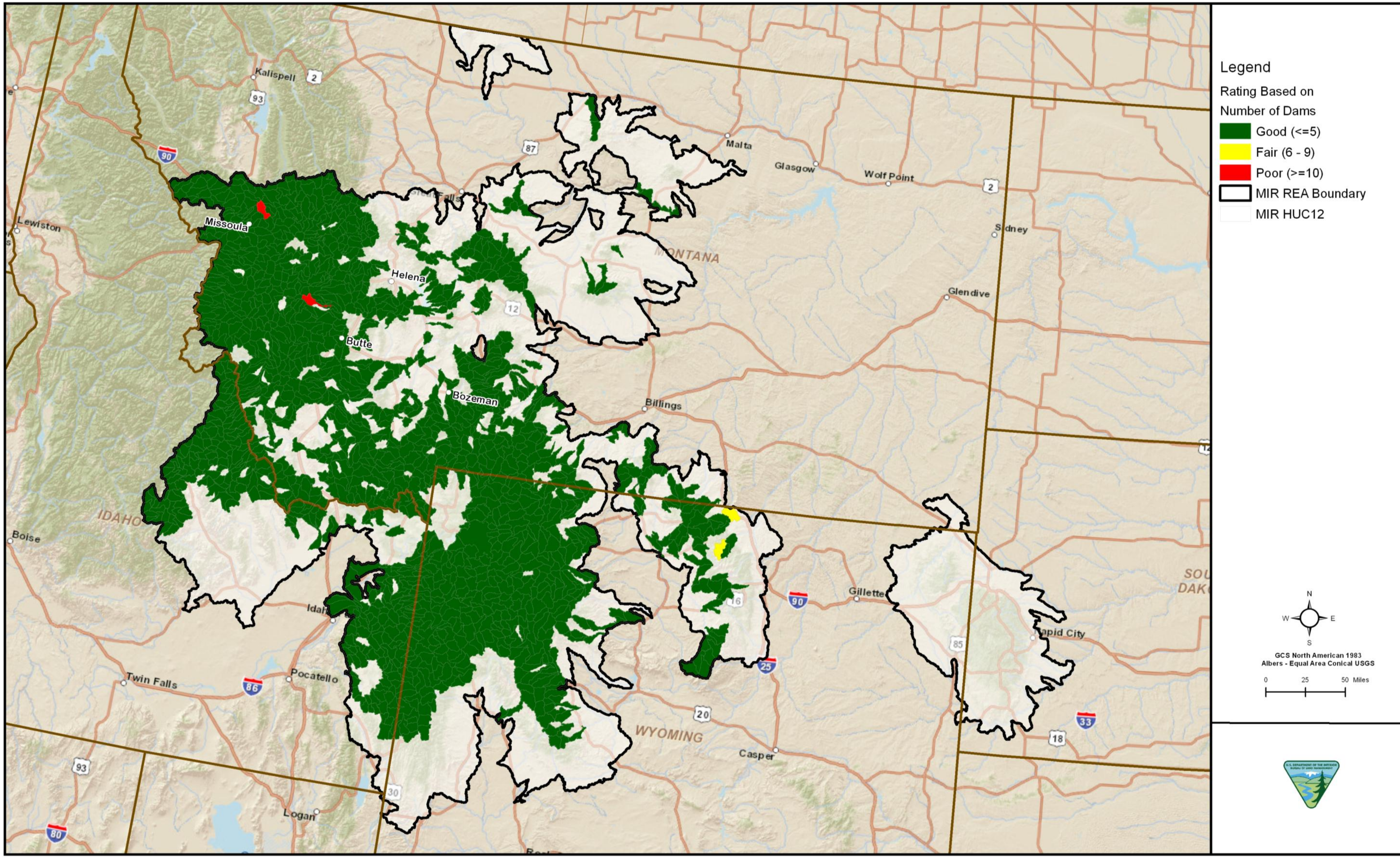

Figure E-7-8. Location of Dams

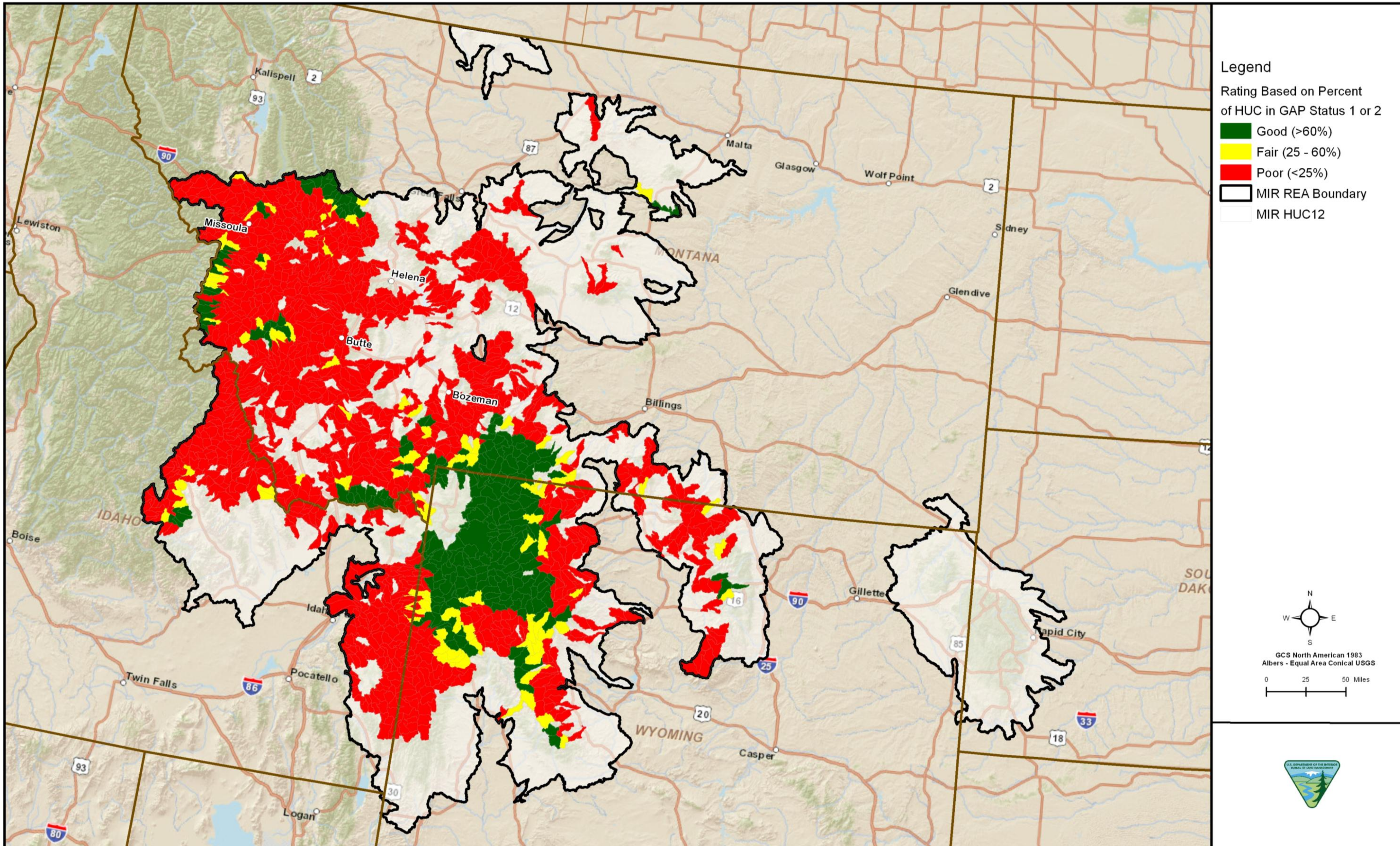

Figure E-7-9. Percentage of HUC in GAP 1 or 2 Lands

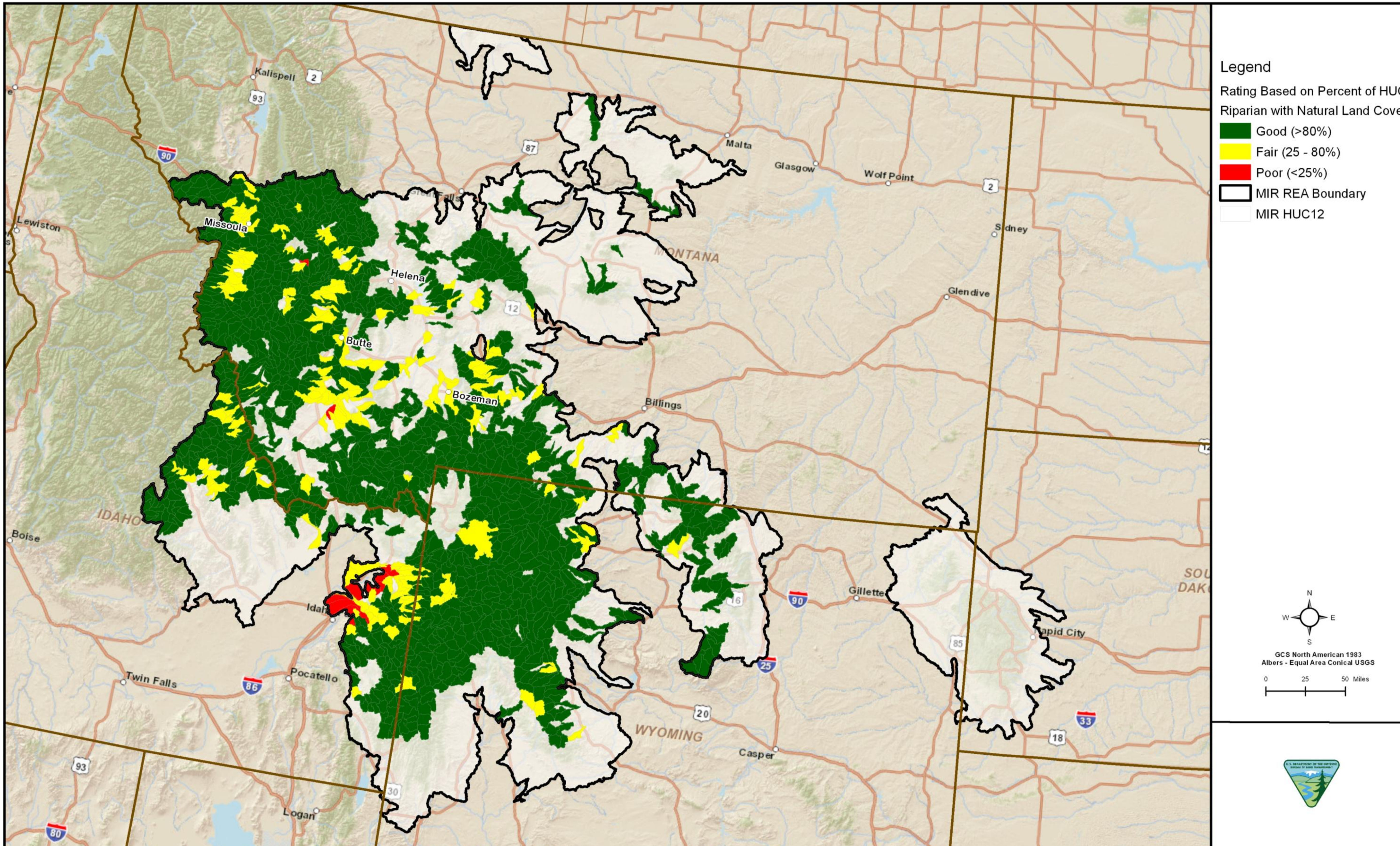

Figure E-7-10. Percent of Riparian Corridor with Natural Landcover

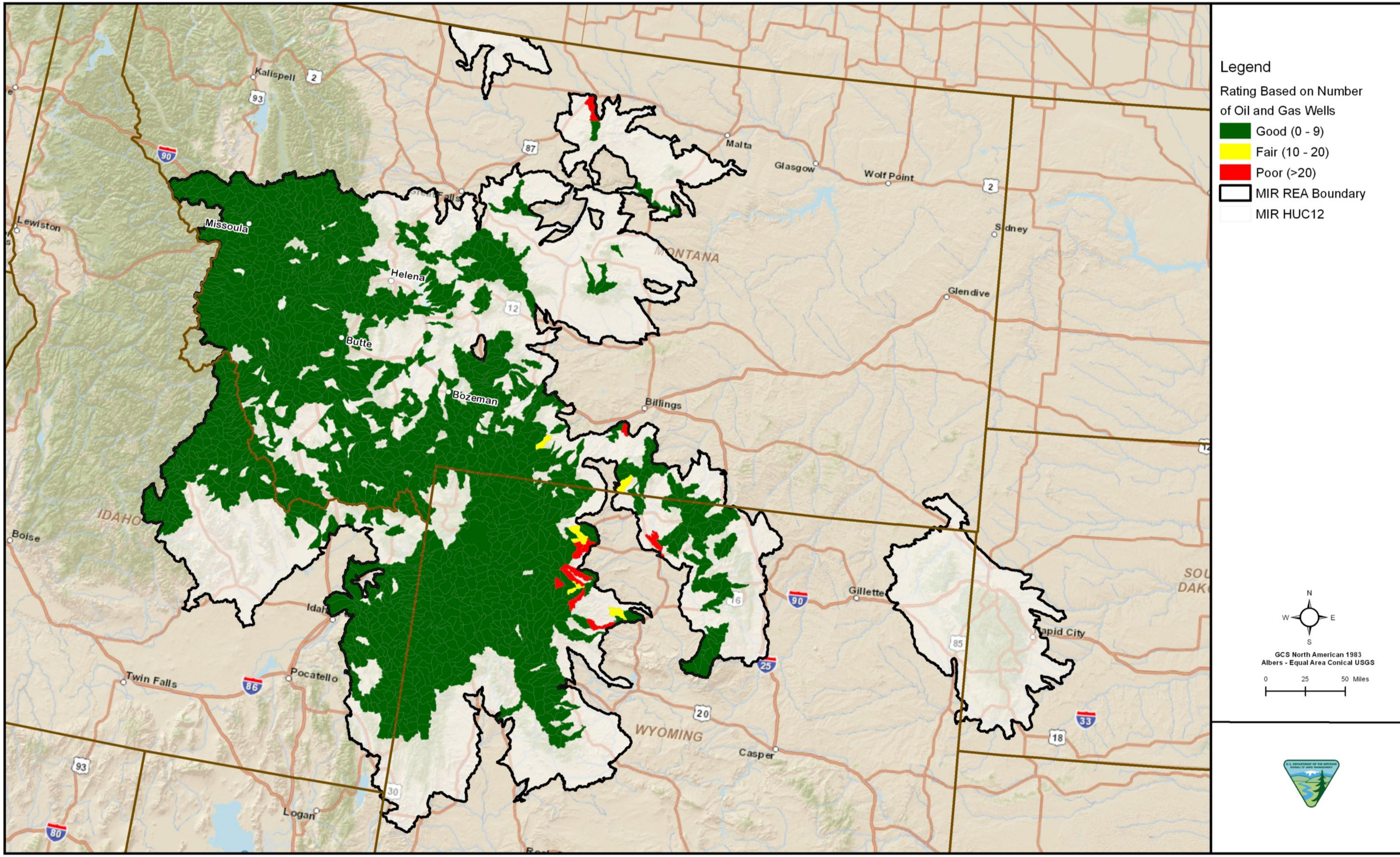

Figure E-7-11. Locations of Oil and Gas Wells

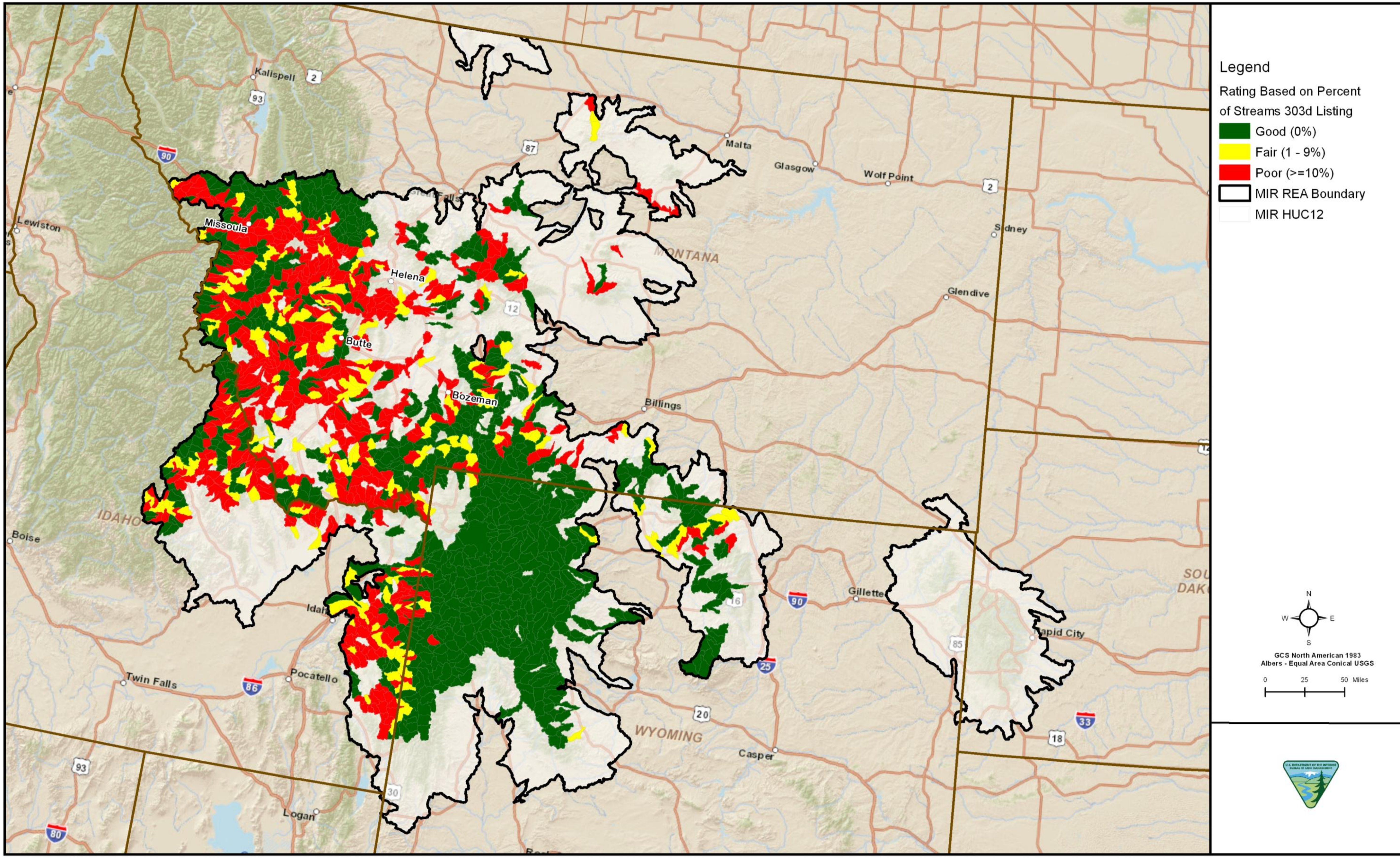

Figure E-7-12. Locations of 303(d)-Listed Streams

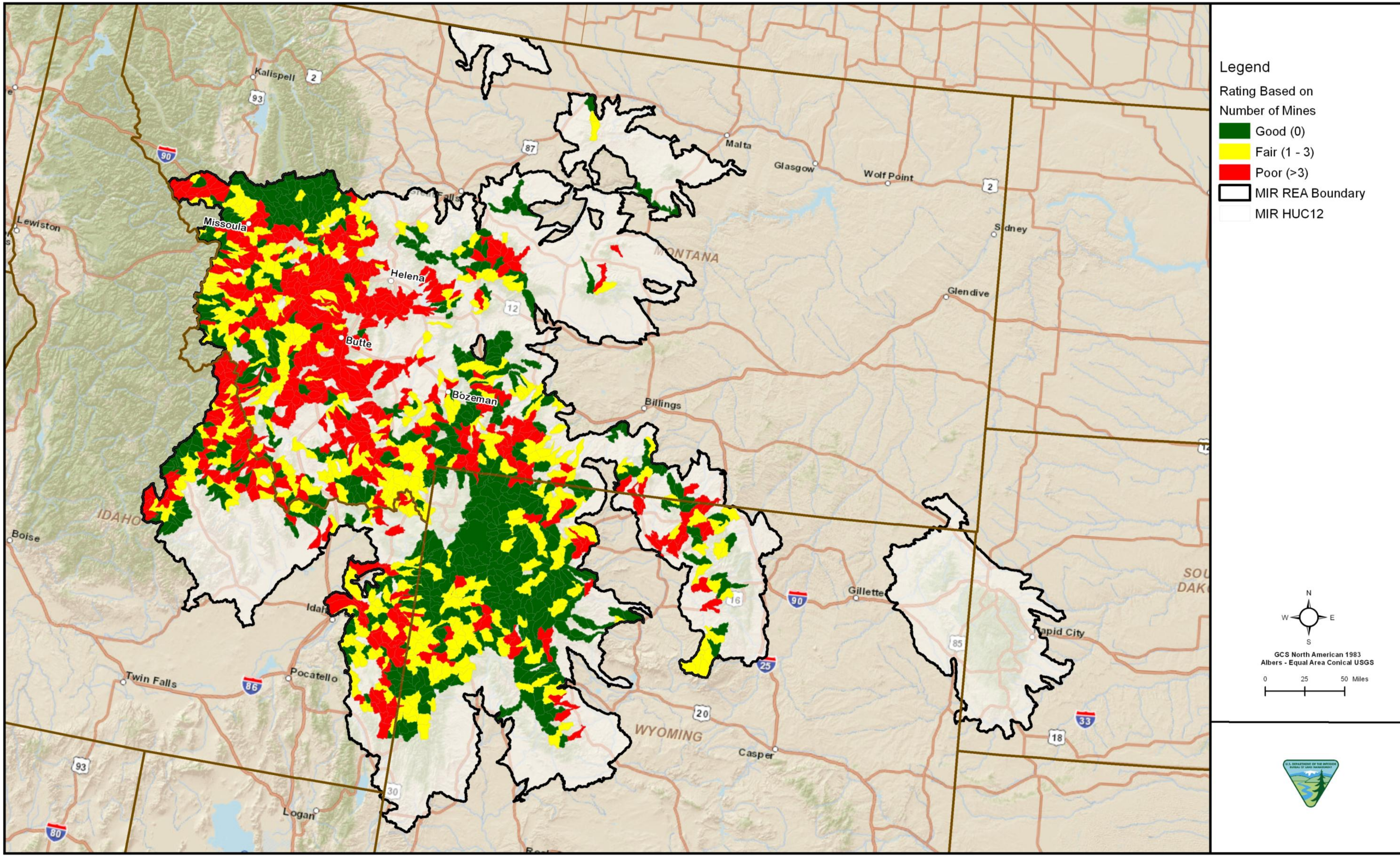

Figure E-7-13. Number of Mines

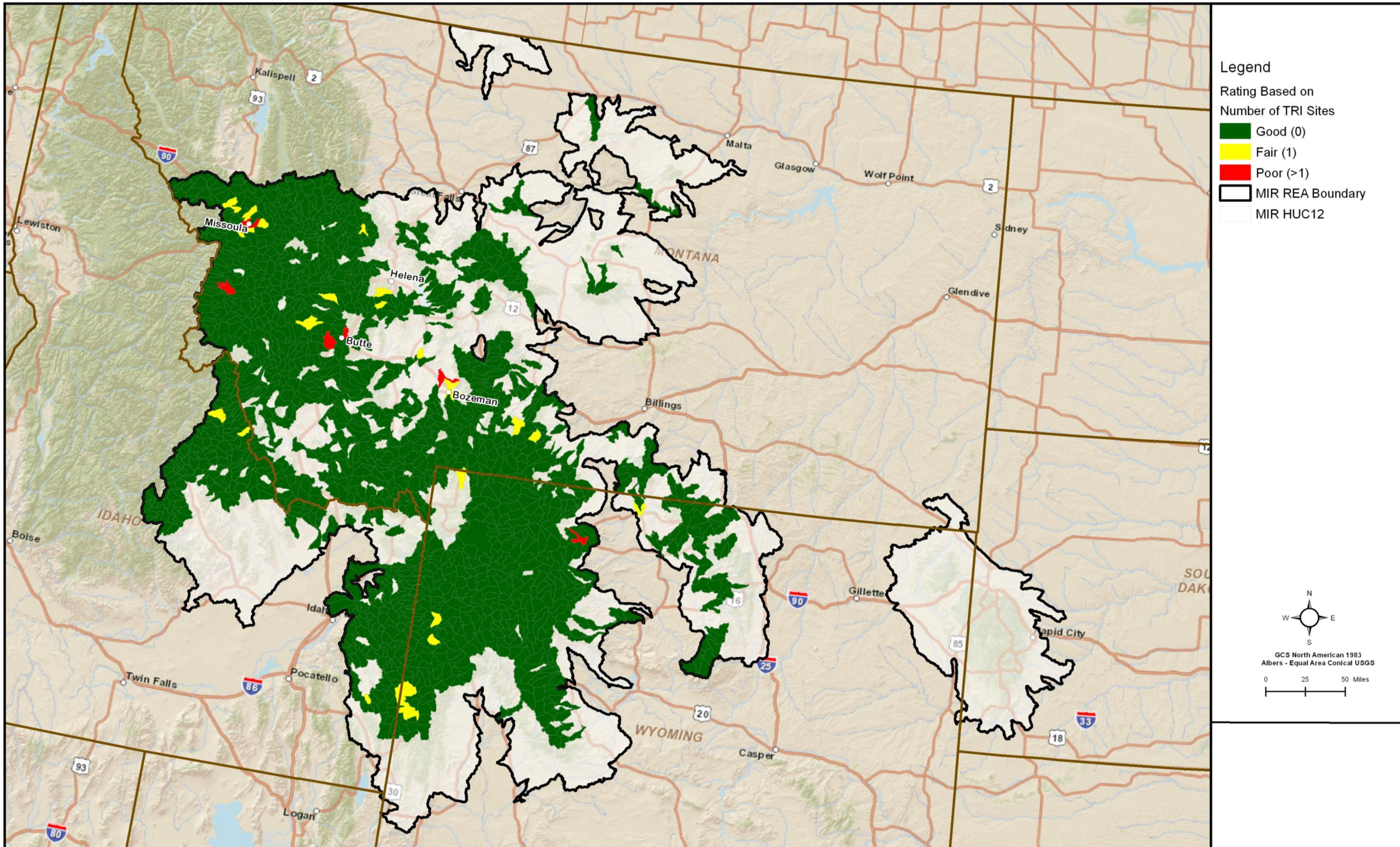

Figure E-7-14. Location of Toxic Release Inventory Sites

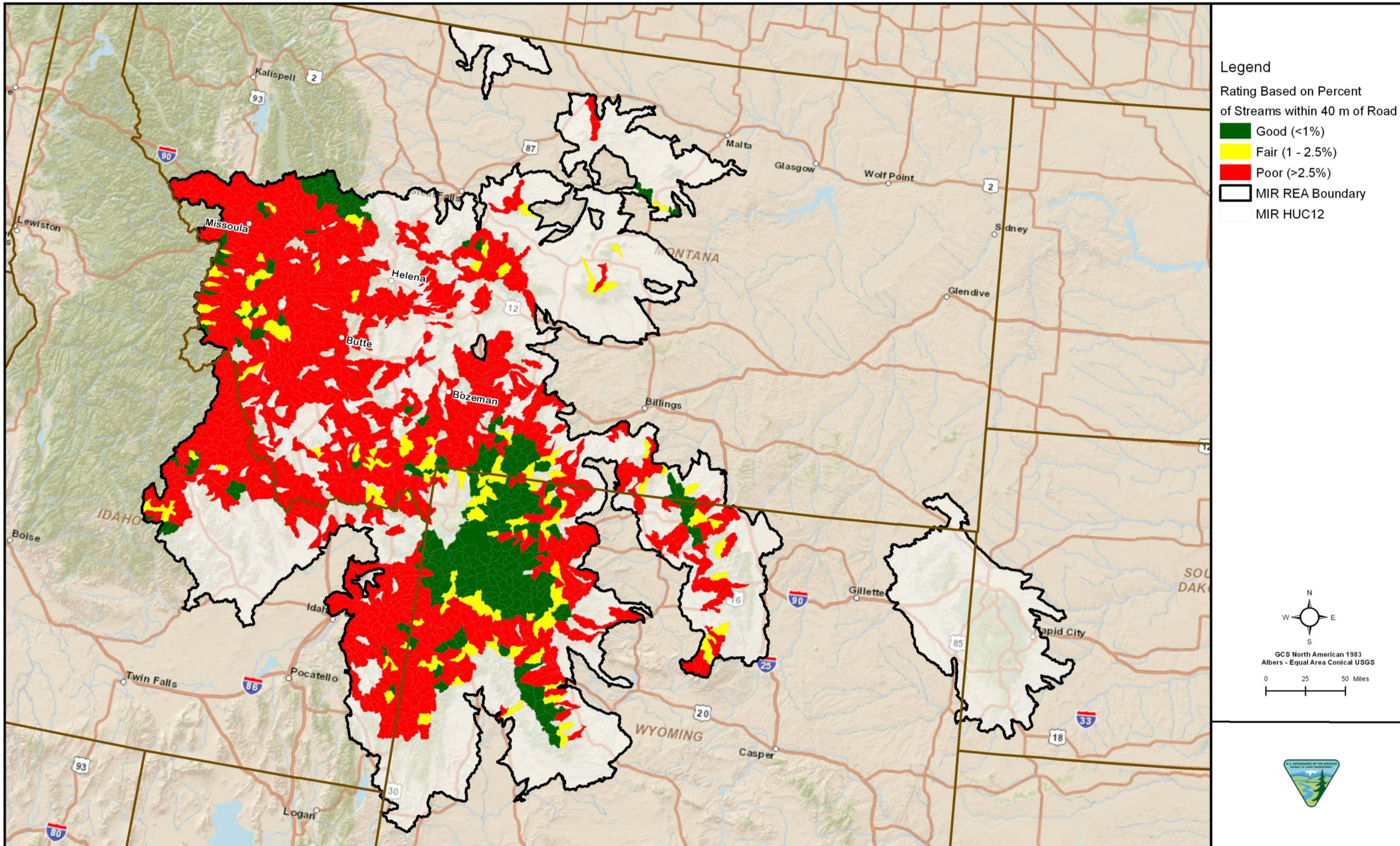

Figure E-7-15. Percentage of Streams/Shoreline within 40 meters of Roadway

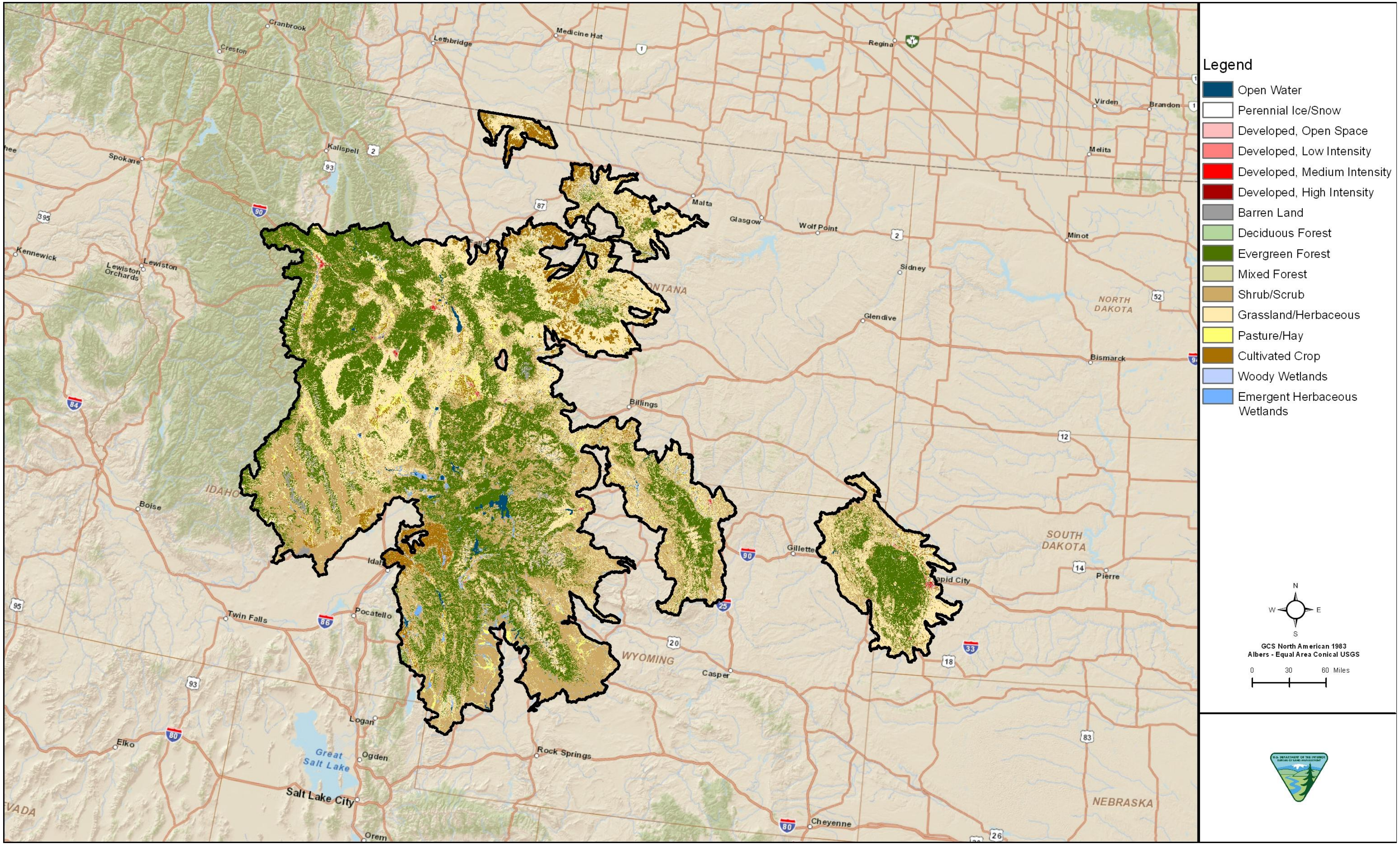

Figure E-7-16. Land Use Designations for Agricultural and Impervious Cover

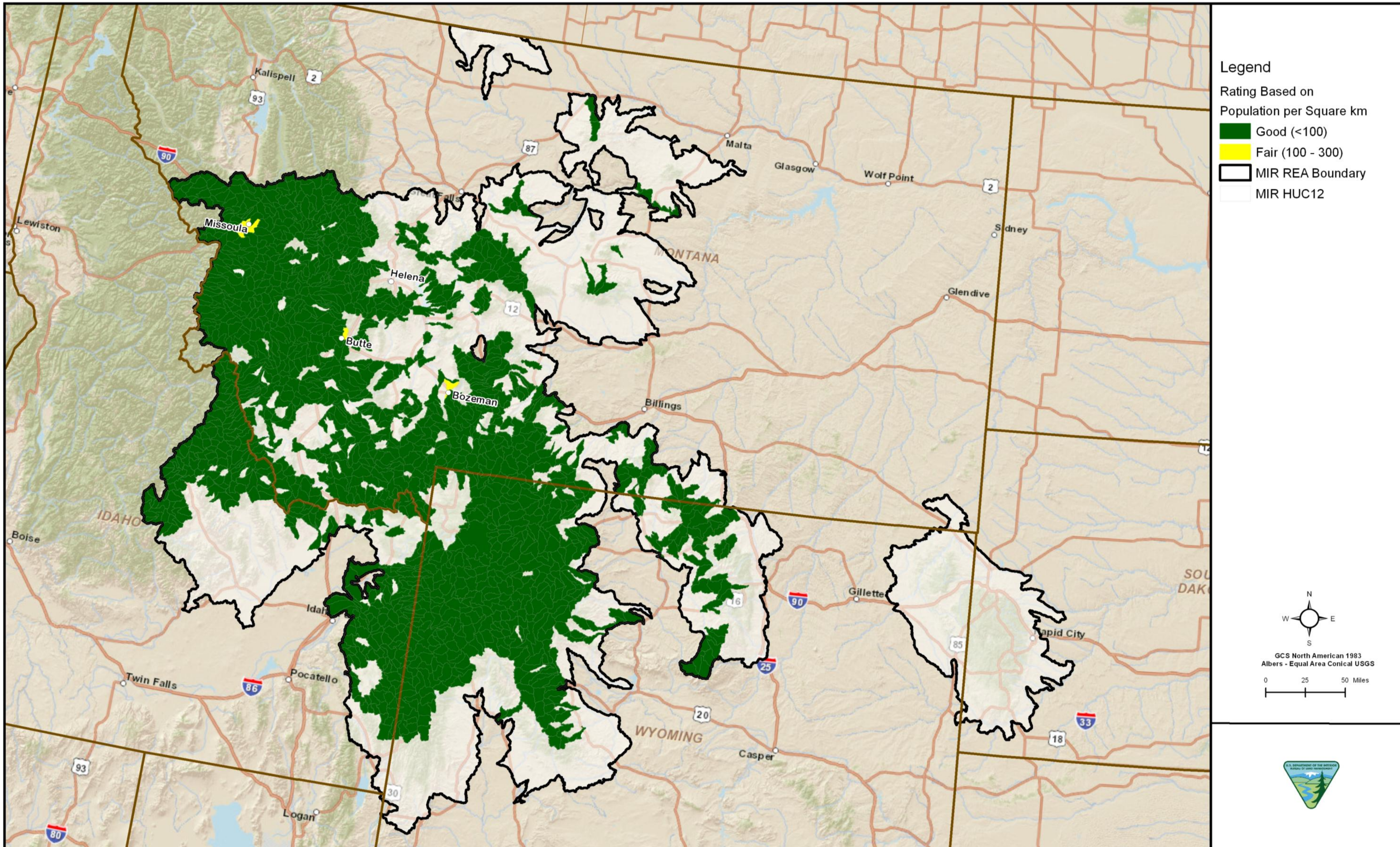

Figure E-7-17. Population Rank Results per HUC

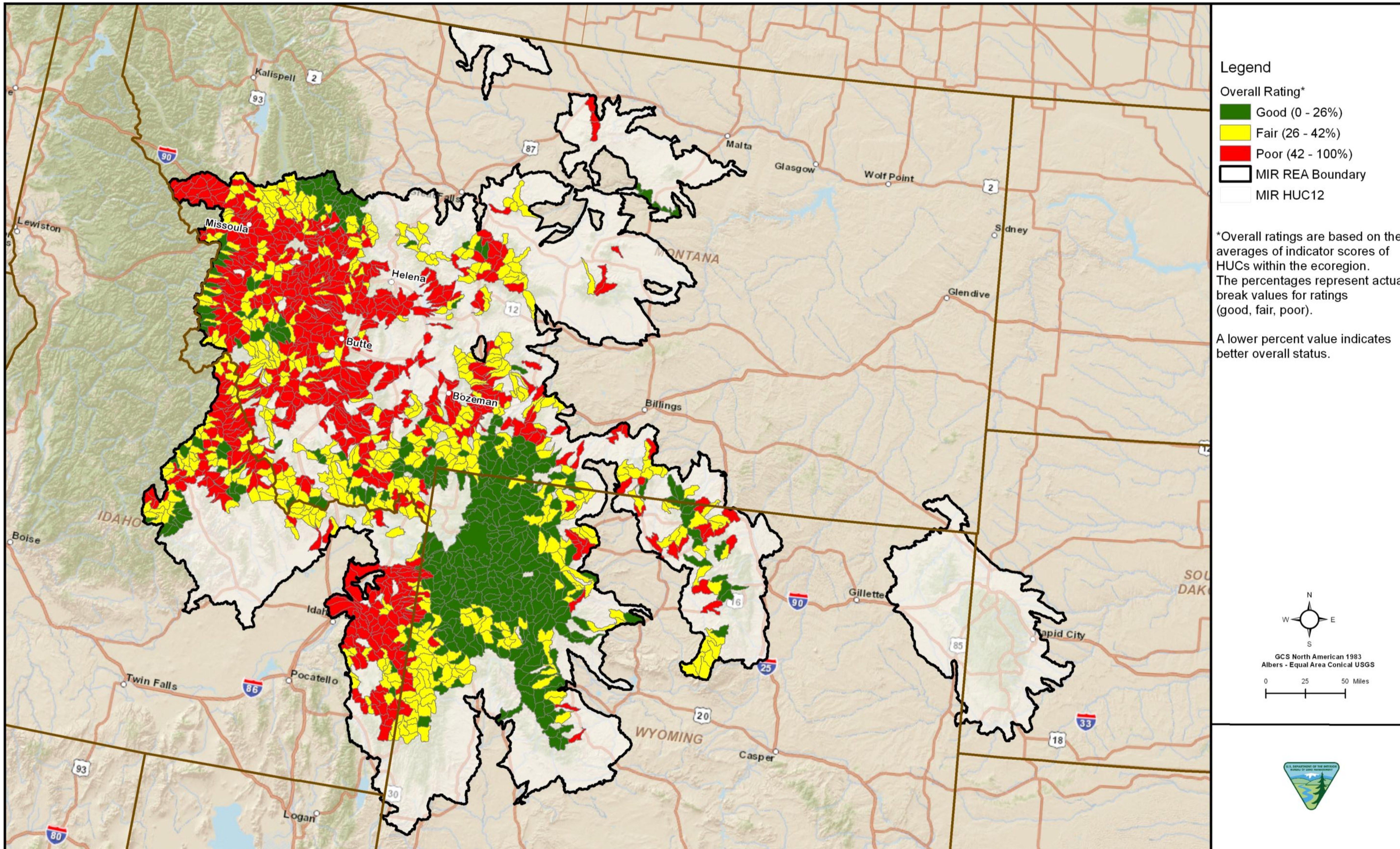

Figure E-7-18. Overall Current Habitat Status for the Coldwater Fish Assemblage

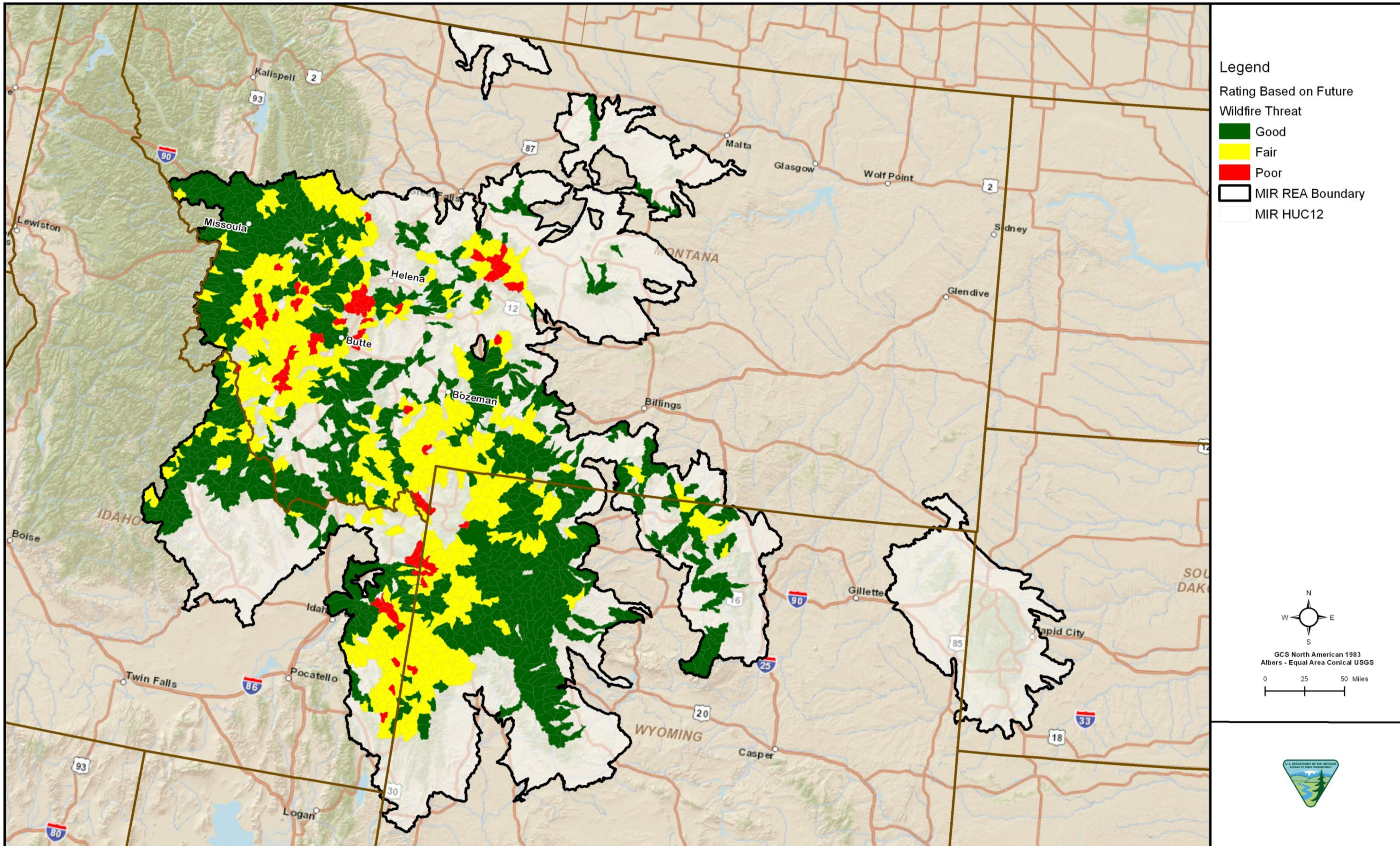

Figure E-7-19. Future Wildfire Threat by HUC for Coldwater Fish Assemblage within the Middle Rockies Ecoregion

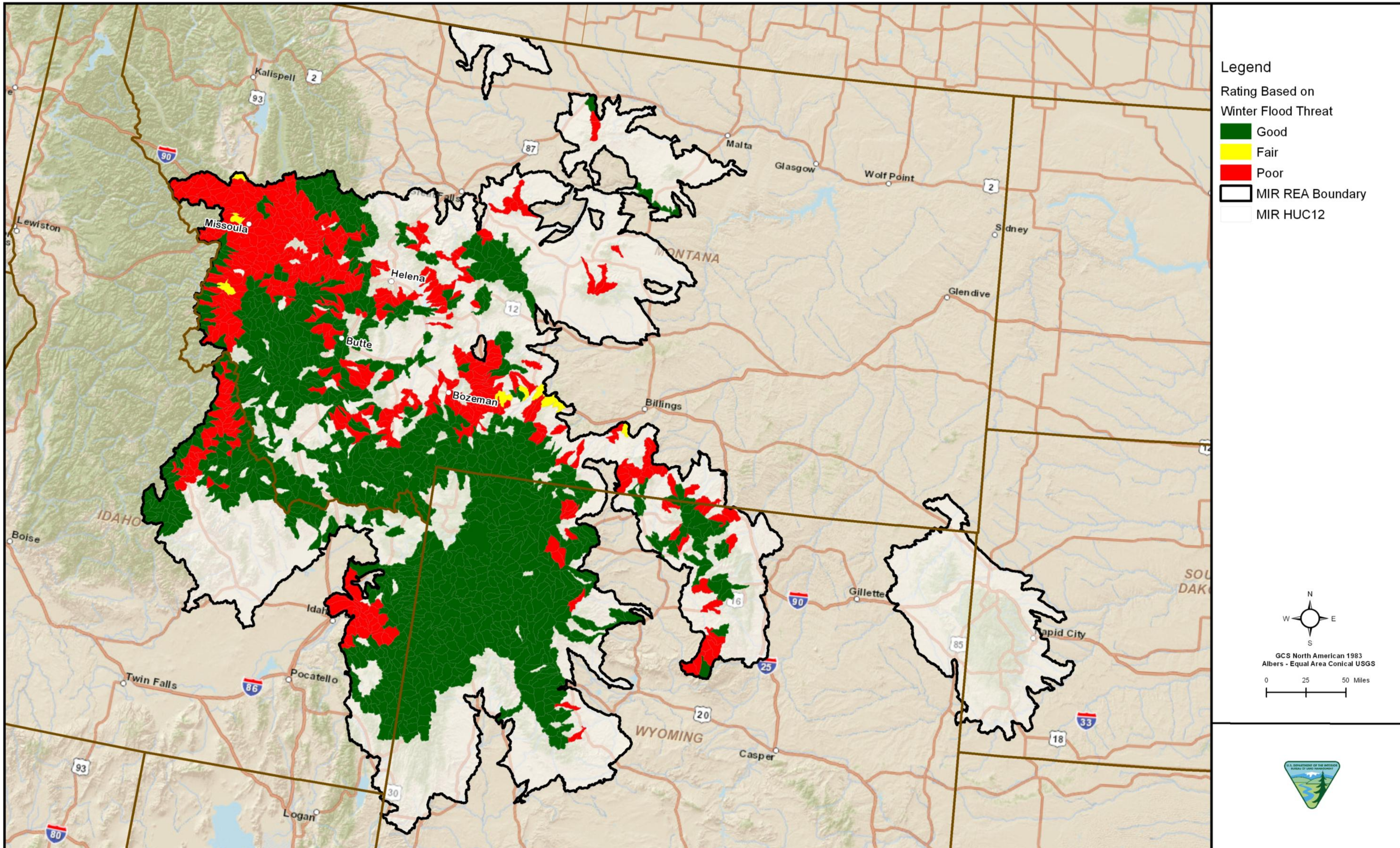

Figure E-7-20. Winter Flood Risk by HUC for Coldwater Fish Assemblage within the Middle Rockies Ecoregion

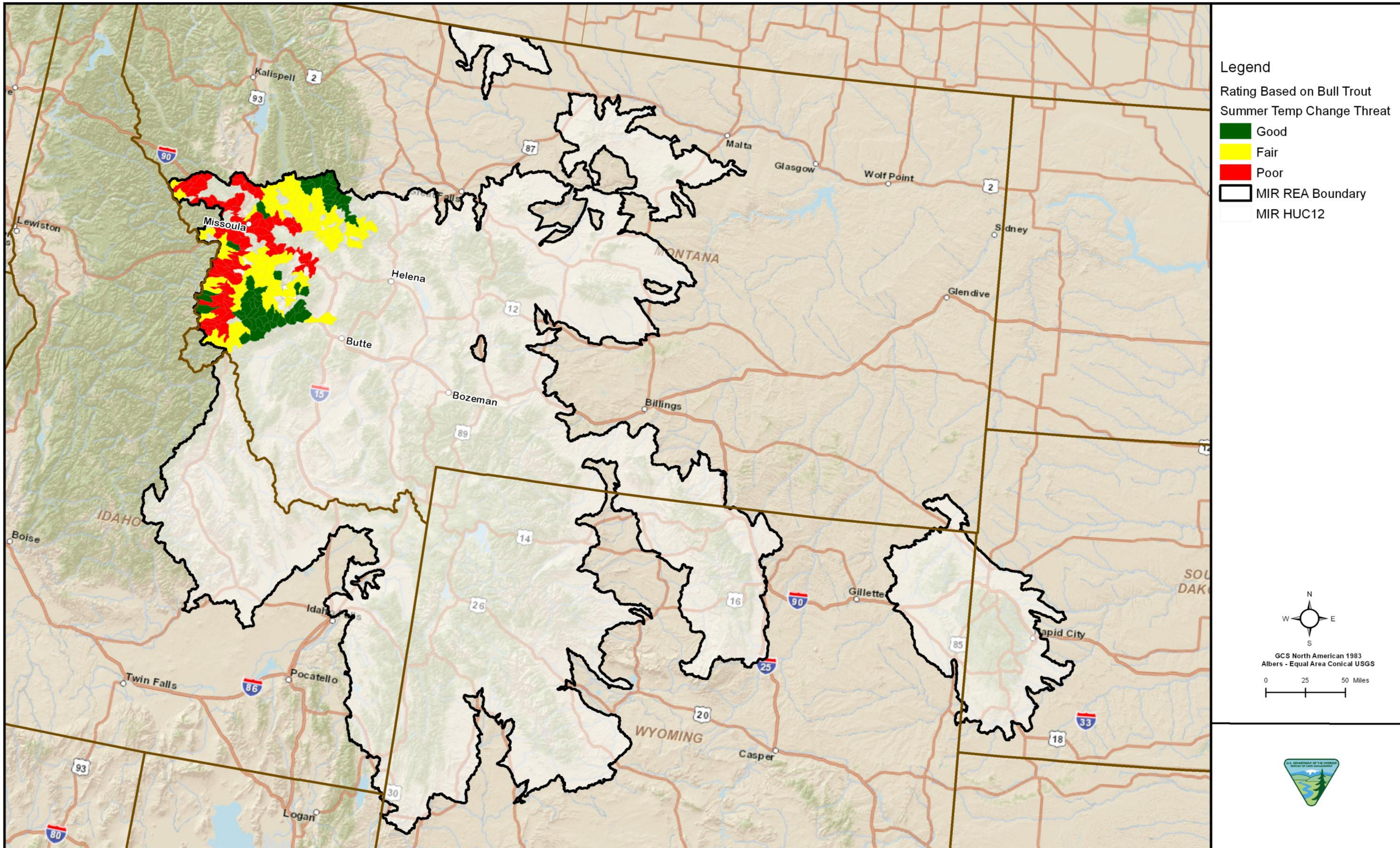

Figure E-7-21. Future Temperature Change Threat by HUC for Bull Trout within the Middle Rockies Ecoregion

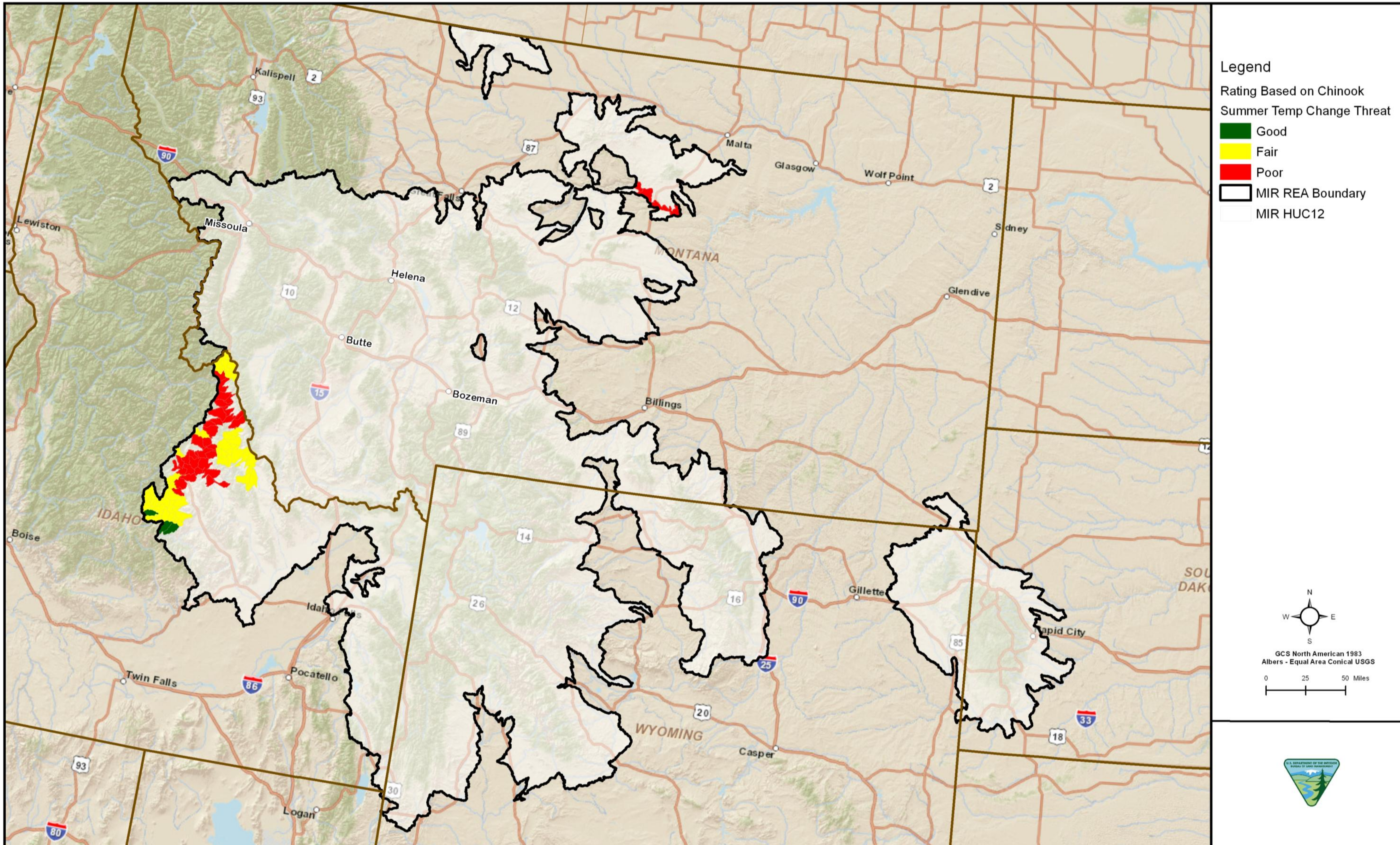

Figure E-7-22. Future Temperature Change Threat by HUC for Spring/Summer Chinook Salmon in the Middle Rockies Ecoregion

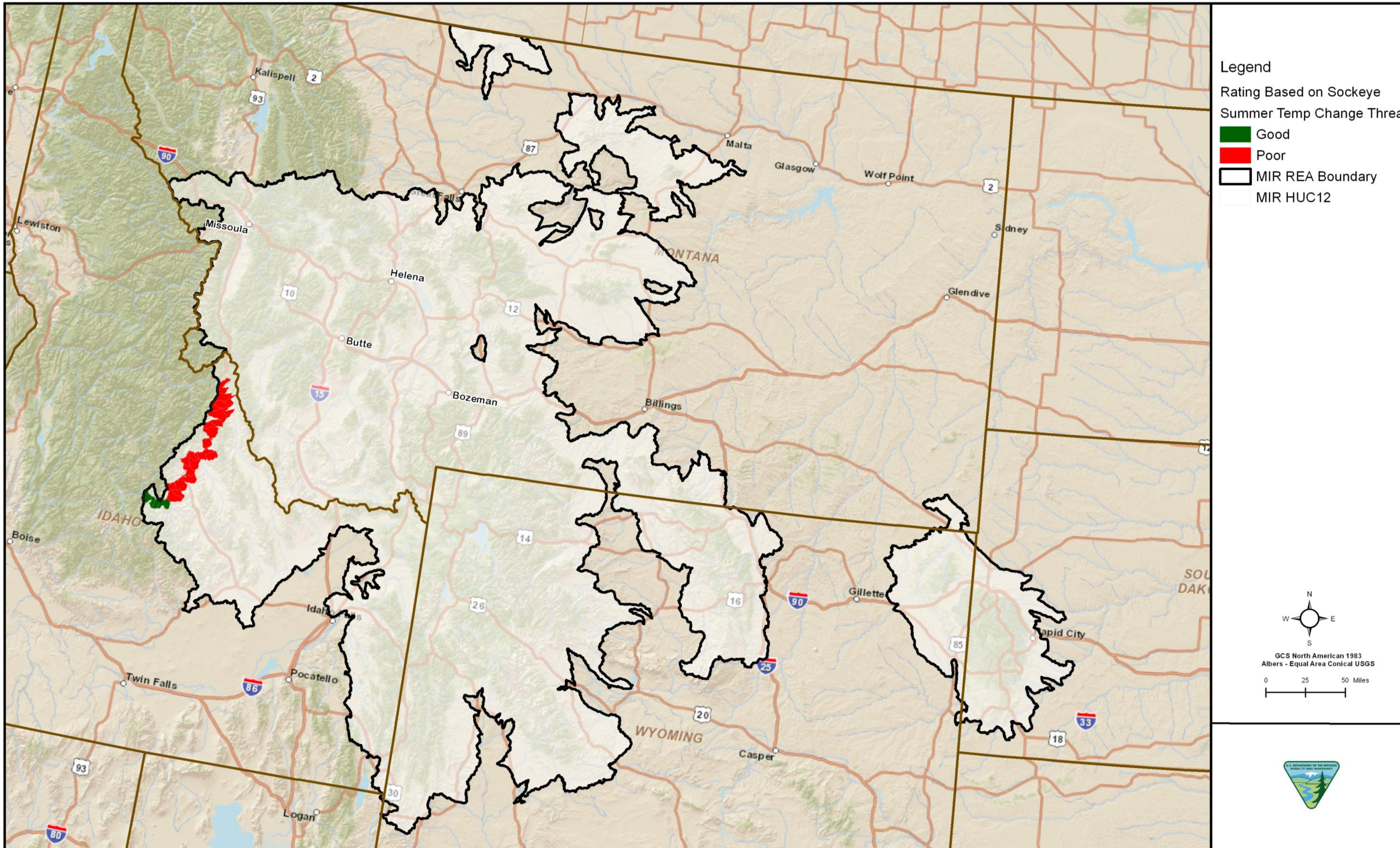

Figure E-7-23. Future Temperature Change Threat by HUC for Sockeye Salmon in the Middle Rockies Ecoregion

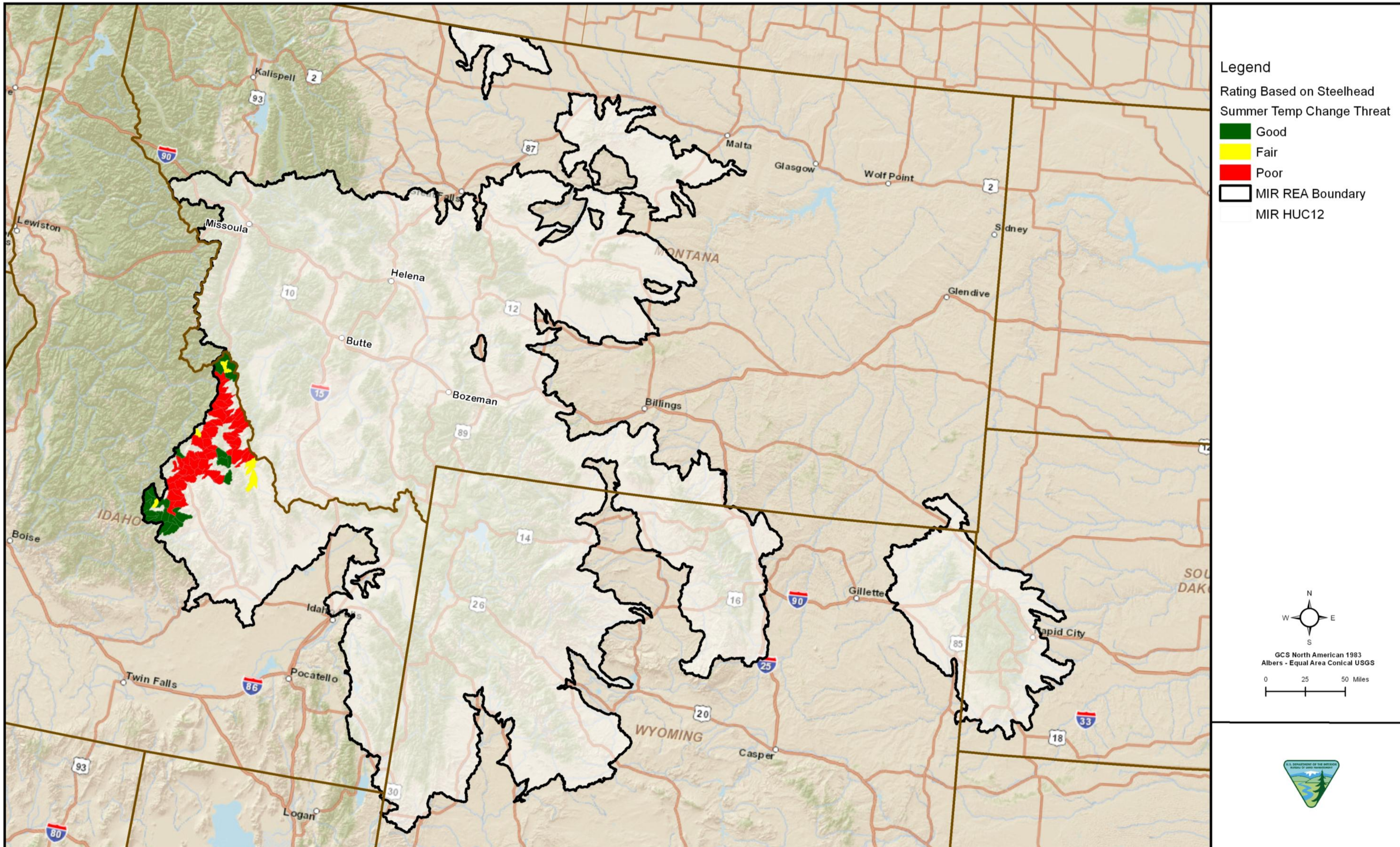

Figure E-7-24. Future Temperature Change Threat by HUC for Summer Steelhead in the Middle Rockies Ecoregion

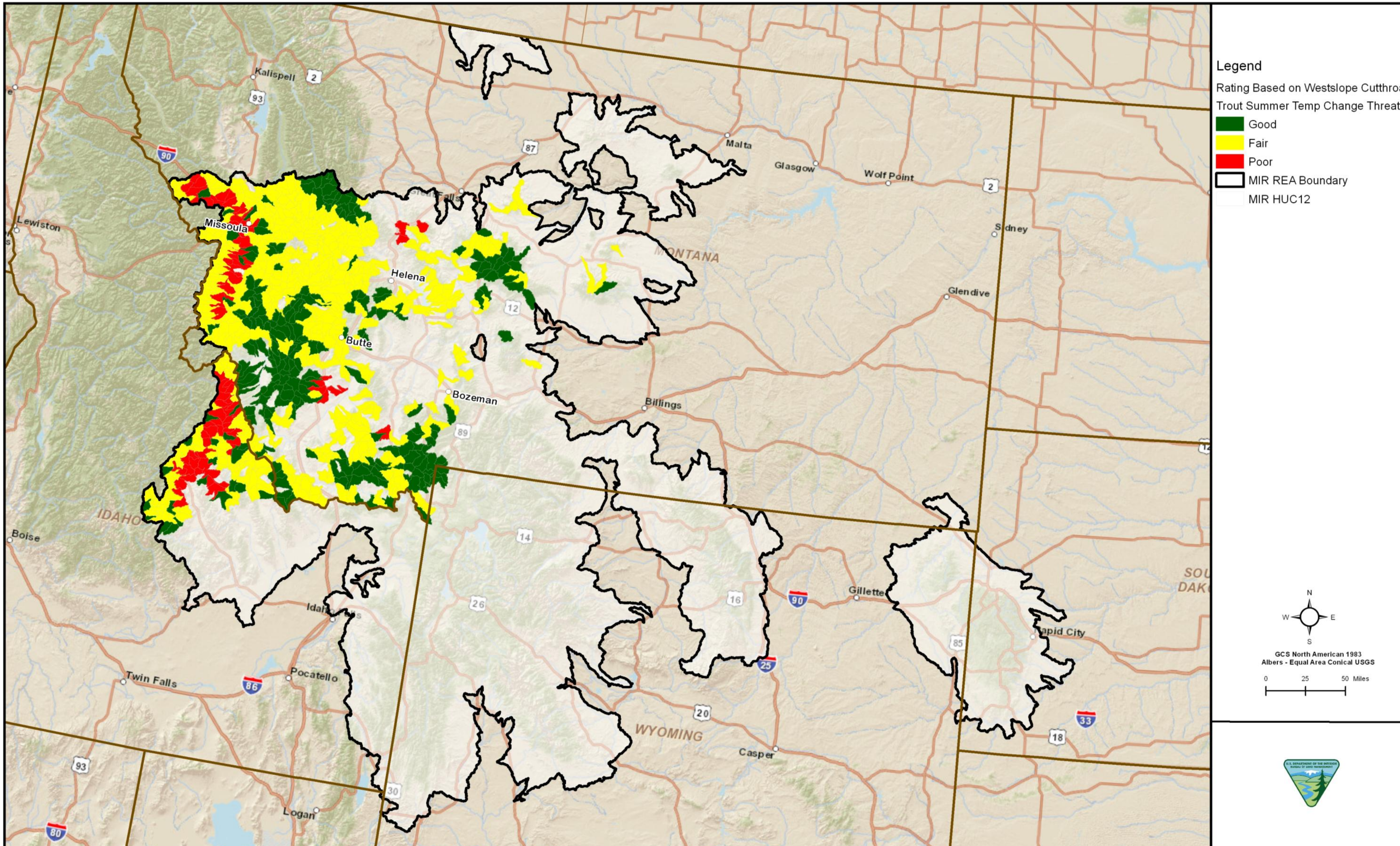

Figure E-7-25. Future Temperature Change Threat by HUC for Westslope Cutthroat Trout in the Middle Rockies Ecoregion

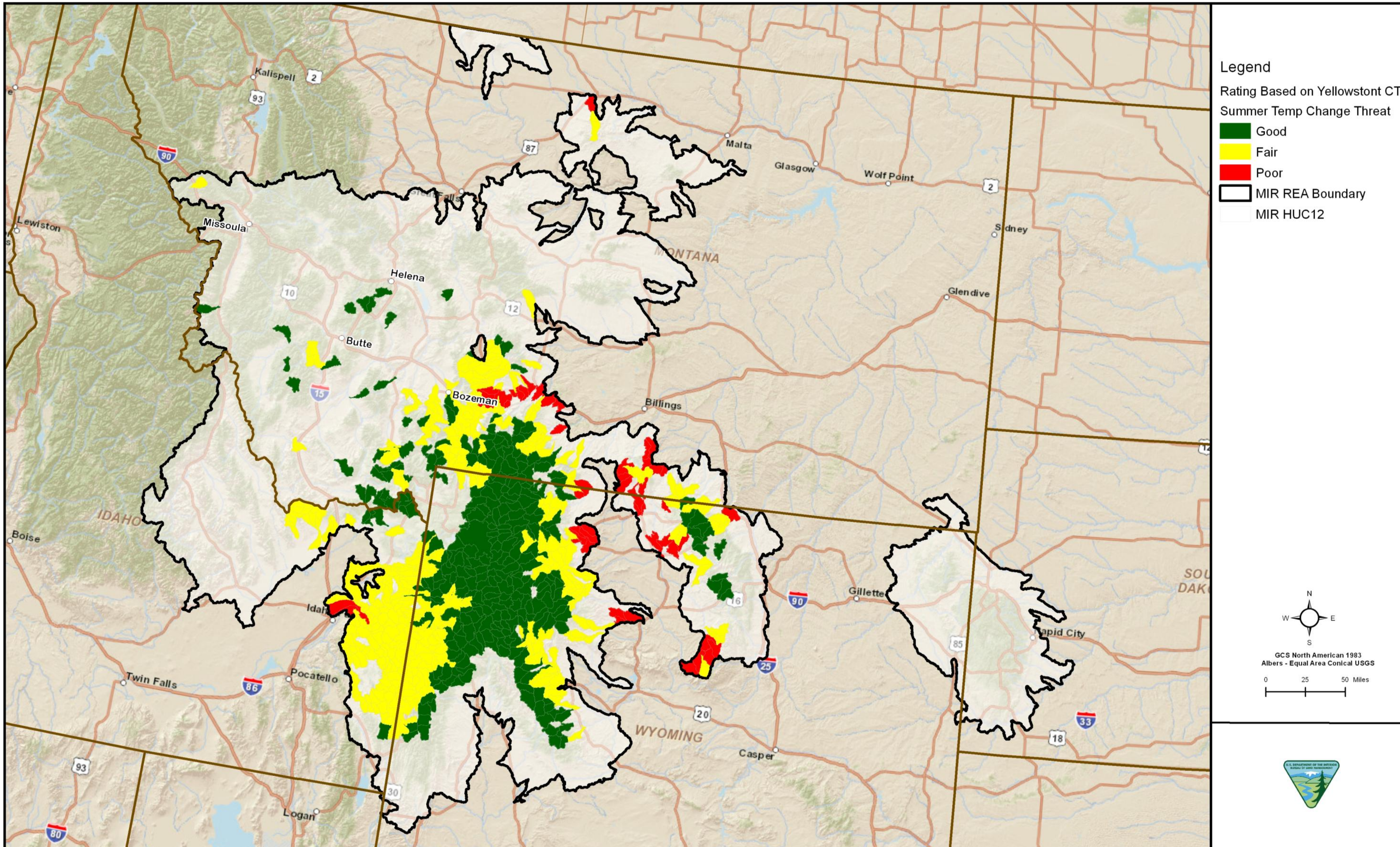

Figure E-7-26. Future Temperature Change Threat by HUC for Yellowstone Cutthroat Trout in the Middle Rockies Ecoregion

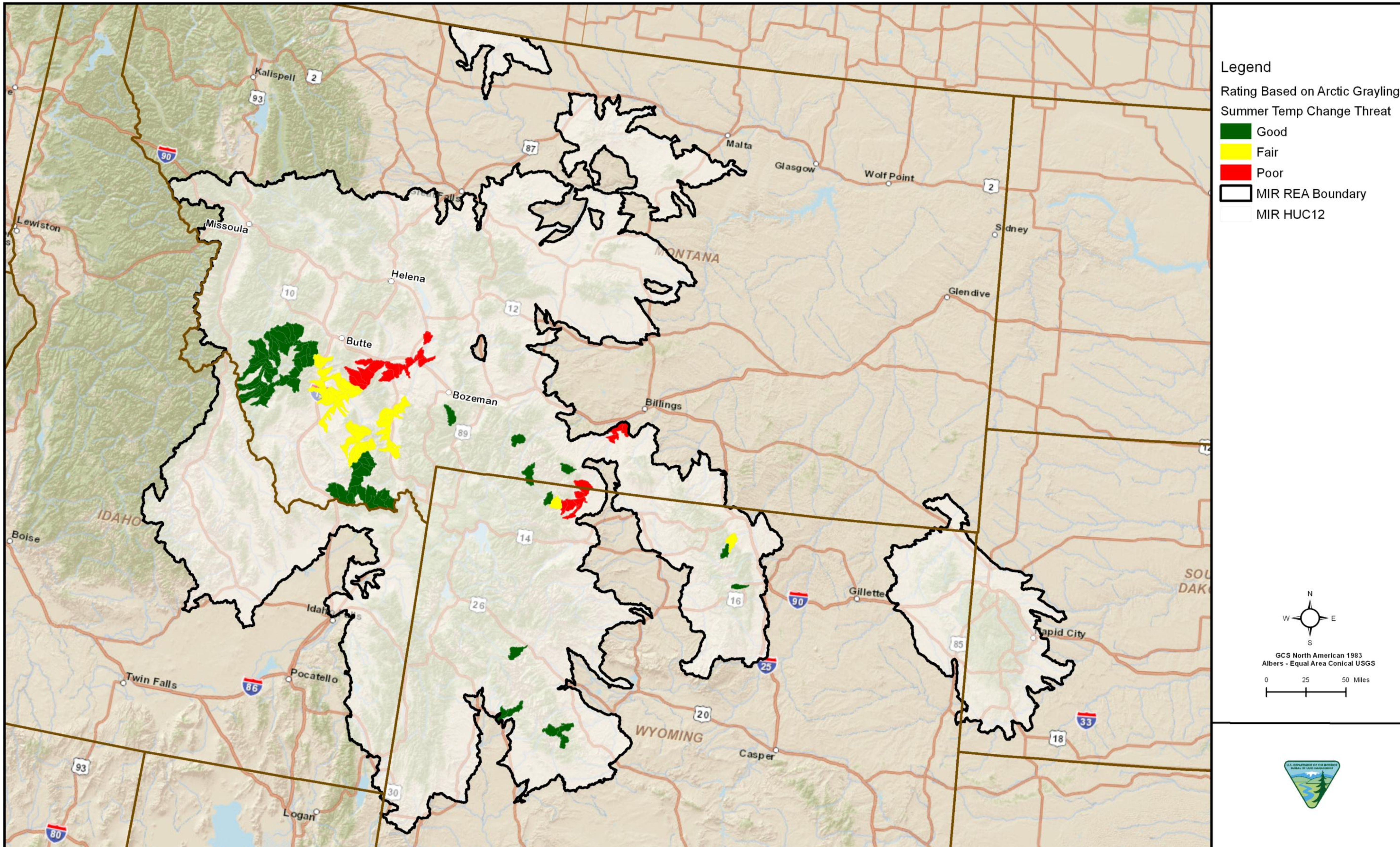

Figure E-7-27. Future Temperature Change Threat by HUC for Arctic Grayling in the Middle Rockies Ecoregion

APPENDIX E-8

FIVE-NEEDLE PINE CONSERVATION ELEMENT ANALYSIS FOR THE MIDDLE ROCKIES ECOREGION

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

The five-needle pine assemblage conservation element (CE) includes a number of species, but for purposes of this Rapid Ecoregional Assessment (REA), two species (whitebark pine [*Pinus albicaulis*] and limber pine [*Pinus flexilis*]) were identified by the Assessment Management Team (AMT) as the focal species for this assemblage. Their distributions have been affected by insect outbreak and disease, altered fire regimes, succession, climate change, and clearing to reduce encroachment on grasslands. The whitebark pine has been determined by the U.S. Fish and Wildlife Service (USFWS) to be warranted but precluded from listing, with a listing priority number of 2, the highest a species can be without being listed.

A variety of the management questions (MQs) apply to this assemblage. 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 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. CAs considered in this analysis include climate change, wildfire, and insect outbreak and disease.

THIS PAGE INTENTIONALLY LEFT BLANK

2.0 CONSERVATION ELEMENT DESCRIPTION

In the Rocky Mountains, whitebark pine ranges from central Wyoming northward into Canada; limber pine co-occurs with whitebark pine in this area of the United States and also ranges through Colorado and even further south depending on the taxonomic treatment (Schoettle 2004a,b; Schoettle and Sniezko 2007; Tomback and Achuff 2010).

At the upper tree line, these species occur in four vegetation types: 1) productive, closed-canopy forests in lower elevation mesic areas that are successional to fir, spruce, and hemlock; 2) lower timberline exposed sites consisting of elfin forests, groves, or tree islands; 3) krummholtz formations at the subalpine tree line, and 4) lower subalpine sites where they remain a component of a seral vegetation type (Keane 2000). These vegetation types are a product of biological interactions and physical drivers.

Little is known about the ecology of the lower tree line limber pine woodland (Means 2010). There appears to be a large difference in the maximum age of trees in upper tree line stands (1,500 years) and lower tree line stands (300 years) (Schuester et al. 1994, Means 2010). These lower tree line woodlands have been historically treated as a non-desirable invader of rangeland and have been eliminated from areas where it does not occur on rocky outcrops (Means 2010). It is unclear what the baseline conditions were for this woodland, but, as it occurs on a constantly shifting ecotone, treating it as a static successional stage is inappropriate (Means 2010).

THIS PAGE INTENTIONALLY LEFT BLANK

3.0 CONSERVATION ELEMENT DISTRIBUTION MAPPING

3.1 DATA IDENTIFICATION

A variety of existing data layers were identified to be used for the five-needle pine distribution mapping. They include geospatial data from land cover data sources (such as Gap Analysis Program [GAP], Regional Gap Analysis Program [ReGAP], and Landscape Fire and Resource Management Planning Tools Project [LANDFIRE]) created from satellite imagery and predictive modeling. Also identified were other existing distribution data from U.S. Forest Service (USFS) projects including Aerial Detection Surveys (ADS), Whitebark and Limber Pine Information System (WLIS), and Forest Health Technology Enterprise Team (FHTET). Additional data were obtained from the Boise, Idaho, Bureau of Land Management (BLM). In addition to existing, readily-available land cover data, Science Applications International Corporation (SAIC) has worked with members of the AMT to obtain expert knowledge data. The five-needle pine distribution datasets are further described in Table E-8-1.

Table E-8-1. Data Sources for Conservation Element Distribution Mapping

Data Needs	Dataset Name	Source Agency	Type/Scale	Status	Use in REA
Distribution	Healthy Stands	USFS	Polygon	Data Gap	No
	Declining Stands	USFS	Polygon	Data Gap	No
	Deceased Stands	USFS	Polygon	Data Gap	No
	Protected Stands	USFS	Polygon	Data Gap	No
	Unprotected Stands	USFS	Polygon	Data Gap	No
Predicted Distribution	GAP Vegetation	ReGAP/GAP	Raster	Data Gap	No
	LANDFIRE	LANDFIRE	Raster	Data Gap	Yes

3.2 DISTRIBUTION MAPPING METHODS

Acquiring geospatial data for five-needle pine distribution that covered the entire ecoregion at an appropriate scale was challenging. For other vegetation analysis, ReGAP/GAP; however, whitebark pine and limber pine are not well classified in the updated ReGAP and GAP landcover datasets. The LANDFIRE Refresh 2008 data existing vegetation (EVT) has a whitebark pine and limber Pine classification. Based on rolling review team (RRT) recommendations, the LANDFIRE data were compared to the digital representation of the “Atlas of United States Trees” by Elbert L. Little, Jr. to ensure that the LANDFIRE data were within the natural range of the five-needle pine. Ultimately, LANDFIRE data were used to map five-needle pine distribution, as presented on Figure E-8-3.

THIS PAGE INTENTIONALLY LEFT BLANK

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-8-1) was developed to identify and link the key life cycle processes to specific ecological factors, or KEAs, that have the greatest potential to affect the assemblage throughout the ecoregion.

The key processes are identified in the model as green boxes. Following Unnasch et al. (2009), three broad headings or categories of ecological attributes (EAs) (size, condition and landscape 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 landscape 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 to represent this category.

4.2 SYSTEM-LEVEL MODEL

The system-level conceptual model (Figure E-8-2) illustrates the interactions between the CAs and the primary habitat functions of this assemblage. The primary CAs are identified across the top in red. Change in wildfire regimes, climate change, and insect outbreaks and disease are the most important CAs.

4.2.1 Wildfire

Five-needle pines are characterized by long fire intervals in which intervals between fires typically range from 100 to 300 years. Low-to-moderate intensity fires can help reduce fuel and competing vegetation of the five-needle pine. However, when fuel loads increase these stands can burn large areas of five-needle pine habitat. In addition, stand replacing fires make the potential for natural reseeding difficult. Altered fire regimes in five-needle pine stands could result in uncharacteristic, severe, stand-replacing wildfires.

The primary CA influence in this ecoregion has been the suppression of fire for nearly 100 years. The removal of fire from the fire-dominated ecosystems of the Rocky Mountains has caused cascading effects (Keane et al. 2002) that have affected stand-level attributes (e.g., structure, species composition, nutrient cycles, decomposition rates, litter and duff layers, herbaceous forage for ungulates and wildlife cover, etc.) and landscape-level ecosystem attributes (e.g., proportion of early seral stages, patch diversity, patch size, insect and disease outbreaks). Fire is strongly influenced by weather and climate, but also may in return affect climate feedbacks (Houghton and Hackler 2000; Westerling et al. 2006).

4.2.2 Insect Outbreaks and Disease

Two primary organisms that impact the five-needle pine assemblage are the mountain pine beetle (MPB) (*Dendroctonus ponderosae)* and white pine blister rust (WPBR) (*Cronartium ribicola*). MPB is a native insect that occurs in endemic and epidemic populations capable of producing small-scale forest mortality. Historically, MPB were generally controlled by weather. At low infestation levels, MPB attacks can be overcome by tree defenses, such as sap production, but trees that are stressed by drought or other insects and pathogens are more vulnerable. Under endemic conditions, individual trees are killed, resulting in patchy mortality throughout the stand (Samman and Logan 2000). During outbreaks, 80 percent or more of trees in even-aged pine stands can be killed over a 5 to 7-year period.

MPB infestations are restricted by climatic conditions unfavorable for brood development. Temperature determines the rate of development of the various life stages of MPB and, hence, the timing of the various life stages. There is an evolutionary tradeoff between early emergence to maximize the period for egg-laying, and later emergence to avoid mortality due to cold spring or early summer temperatures. Additionally, because attacks by MPB on its primary hosts (lodgepole pine and ponderosa pine), are only successful if there is a coordinated mass attack on individual trees, synchronous maturation of the adult beetles is also critical to MPB success. This synchronization is controlled by the higher temperature threshold requirement of the fourth larval stage (instar) (Bentz et al. 2007). Both timing and synchrony are critical and are controlled directly by the temperature of MPB habitat, which is the phloem of the host tree (Logan and Powell 2001; Powell and Logan 2005; Powell and Bentz 2009). MPB life cycle synchrony is optimal when the cycle is completed in a single year (univoltine), as is the typical case at lower elevations; MPB life cycle is less optimal when cooler temperatures slow the cycle to one to two years per generation (fractional voltinism), as is common in mid-elevation forests; the life cycle is even less optimal at the coolest high elevation whitebark pine forests, where the life cycle requires at least two years to complete (semivoltism) (Logan and Powell 2001; Logan and Powell 2009).

WPBR is a fungal disease that occurs on white pines in Eurasia, where it is native, and in North America where it was introduced in contaminated imported black currant and white pine nursery stock on both the east and west coasts (Geils et al. 2010). North American white pine species (including white bark and limber pines) (Tomback and Achuff 2010) are very susceptible to the disease, although a small number of trees in each stand have some degree of resistance (Kearns and Jacobi 2007; King et al. 2010; Larson and Kipfmueller 2010). WPBR kills trees of all ages and size classes by girdling branches and trunks, and it greatly reduces cone and seed production of infected trees. Silvacultural control methods can be used under some limited settings, but the main management emphasis is on developing and maintaining a tree breeding program that preserves the resistance genes and produces seed for restoring stands devastated by WPBR (Burns et al. 2008; Schwandt et al. 2010; Zeglen et al. 2010). Because WPBR is still undergoing a southward range expansion in the western United States and has not completely invaded all stands within its current range (Burns et al. 2008; Geils et al. 2010), and because other factors such as mountain bark beetle, fire suppression, and global climate change also affect the same stands, it has proven very difficult to separate how the various factors interact. However, the overall prognosis for white pine species such as whitebark pine and limber pine is for large reductions in the extent of their ranges and stand densities (Tomback and Achuff 2010). These effects will occur across a vast landscape and will result in biological and ecosystem-level impacts that will vary with the characteristics of each site.

4.2.3 Climate Change

Climate change is one of the greatest potential threats affecting five-needle pine forests. Global climate change is predicted to drive the upper tree line forests such as the five-needle pine forest assemblage to higher elevations.

Climate change also has indirect effects on five-needle pines from insect outbreaks and disease. MPB occurs in endemic and epidemic proportions depending on stand structure, host susceptibility, climate, and environmental interactions. There is some uncertainty given the shortness of historical records of outbreaks, but generally MPB occurs endemically at low population densities, primarily in low-elevation, primary-host, lodgepole-ponderosa pine forests; less so in mid-elevation, non-host, spruce-fir forests; and only infrequently in high-elevation, rare-host, whitebark-limber pine forests. Historically, eruptive outbreaks have occurred infrequently in all three forest/woodland types in response to short-term climatic variation. This pattern appears to be changing to more protracted outbreaks and an increasing frequency (and even novel impacts) in high elevation whitebark pine forests and woodlands in response to global climate change-driven temperature changes (Logan et al. 2010; Raffa et al. 2008). Neither limber pine nor whitebark pine have significant defenses against MPB (Raffa et al. 2008), so the complex ecological relationships among the species are reduced to temperature controls on MPB and dispersal distance from lodgepole-ponderosa pine forests (Logan et al. 2010; Logan and Powell 2009). Given the rapid colonization by MPB in areas previously unsuitable, it appears climate change will allow the MPB to further expand its range.

5.0 CHANGE AGENT ANALYSIS

A threat assessment was conducted on the five-needle pine for the Middle Rockies ecoregion with native 30-meter (m) raster data 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. For each analysis, a series of intermediate data layers were created based on the KEA indicators that are scored according to a designated metric and then ranked (good, fair, or poor). If necessary, data from multiple source datasets were combined.

Since the scale of the reporting unit is at the Hydrologic Unit Code (HUC) 12, a layer of 6th level HUCs 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. The intermediate CA layers were then combined together to form a single layer outlining the current status or future threat status for each HUC.

Although numerous preliminary KEAs and indicators that may affect this species were initially identified in the early phases of the REA (as illustrated on Figure E-8-2) not all were included in this analysis because either the attribute or indicator was not suitable for a landscape-level analysis or because data are not available to support the analysis. The specific indicators that could not be modeled are identified with an asterisk on Figure E-8-2. Further information on the data gaps for these indicators is discussed in the respective CA analyses contained in Appendix C.

Table E-8-2. Key Ecological Attributes Retained or Excluded

Category	Key Ecological Attribute		Explanation
1. Size	Size of Patches		This analysis was completed and included as a KEA used in the current status assessment.
2. Condition	a.	Vegetation Condition Class (VCC)	Retained to show the vegetation and fire regime departure in the ecoregion. Also used in conjunction with lodgepole pine for future fire risk.
	b.	Invasive Species	Dropped due to insufficient data.
	c.	Insect Outbreak	Retained to show current outbreak of major insect threats in the ecoregion and future risk of outbreaks.
3. Structure	a.	Fragmentation/ Connectivity	Retained to show the fragmentation throughout the ecoregion. Same analysis could be used to determine potential for connectivity.

5.1 CURRENT STATUS

Table E-8-3 identifies the KEAs, indicators, and metrics that were used to evaluate the CAs and pathways affecting this CE across the ecoregion. The five-needle pine process analysis is designed to create a series of intermediate layers that are primarily based on the wildfire and insect and disease outbreak CAs. The analysis is based on the geospatial data available.

Table E-8-3. Key Ecological Attribute Table for the Five-Needle Pine Assemblage

Category	Ecological Attribute	Indicator/Unit of Measure	Metric			Data Source	Citation	Weight
			Poor = 3	Fair = 2	Good = 1			
Size	Patch Size	Size of patches (Acres)	<321	322-5,551	5,552-90,554	LANDFIRE	RRT guidance	0.33
Landscape Structure	Structure	VCC	VCC 3	VCC 2	VCC 1	LANDFIRE	RRT guidance	0.33
Landscape Condition	Insect outbreak	MPB Infestation on five-needle pine	>70.5%	26-70.5%	0-26%	ADS	RRT guidance	0.33

Analysis Unit = 30-m pixel
Reporting Unit = 6th level HUC

5.1.1 KEA Data Analysis for Current Status

For each of the KEAs listed in Table E-8-3, 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 threat status for the five-needle pine (Table E-8-3). This table was limited to size and landscape context based on spatially-available attributes and key factors affecting five-needle pine in the 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 five-needle pine RRT comprised of BLM foresters. 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 Patch Size

The LANDFIRE Refresh 2008 data EVT was used for mapping the five-needle pine assemblage. The Whitebark Pine and Limber Pine Society of American Forests classifications were queried out from the LANDFIRE EVT 2008 data.

Patch size for the five-needle pine was determined by finding acres of contiguous 30-m raster cells. After reviewing the patch size analysis, it appears an artifact of satellite imagery is to have a high number of isolated pixels and to overestimate large numbers of contiguous pixels. This results in large variations of values and made it difficult to score size based on appropriate sizes of five-needle pine on the landscape. After much discussion with the RRT, it was decided to allow the data to dictate the scoring.

There are several ways to classify the data for scoring. The Jenk’s Natural Breaks Method was used for this analysis. However, due to the issues with the variation in the size of patches, the Geometric Interval Classification was used. Geometric intervals are used to delineate classes based on groupings inherent in the data. The Geometric Interval Classification attempts to balance the changes in the middle values and the extreme values.

Figure E-8-4 is a graphical representation of patch size for the five-needle pine. Red displays low scoring patches, while green shows higher scoring patches.

5.1.1.2 Vegetation Condition Class

For landscape structure, the LANDFIRE Vegetation Condition Class (VCC) data were used to show changes in vegetation and fuels from their historical condition. For the Middle Rockies, a group of subject matter experts (SMEs) went through an exercise to illustrate fire regime (frequency and severity) departure. The historic biophysical setting (BpS) was attributed with a current fire severity and frequency, and then compared with the reference (historic) fire frequency and severity for each type. From these data, we were able to develop a fire frequency departure map, a fire severity departure map, and then a composite map (which took the highest of either departure). This modified composite layer was used as the best indicator for potential threat to the five-needle pine from an uncharacteristic fire.

The VCC layer was extracted to the five-needle pine layer. The data were already categorical, so VCC departure 1 was good, VCC departure 2 was fair, and VCC departure 3 was poor. The five-needle pine VCC layer is displayed on Figure E-8-5.

5.1.1.3 MPB Infestation

The MPB and WPBR CAs pose the greatest threat to the five-needle pine. The USFS ADS polygon data from 1994-2010 were used to map the MPB presence in the five-needle pine. The MPB vector layer was converted to raster so it could be overlayed on the five-needle pine 30-m raster data. Statistics were run to determine the amount of infestation within the five-needle pine patches. The higher the percent infestation calculated from the analysis, the worse the score. The three classes of good, fair, and poor were determined using natural breaks (Table E-8-3). Figure E-8-6 shows the MPB infestation scores. Red displays patches with higher MPB infestation, while green shows lower infestation.

The ADS has a classification for WPBR; however, after reviewing the data, the RRT determined the data were greatly underestimating the presence of WPBR. For WPBR, SAIC plotted data from the WLIS. WLIS is a database of summary data of plots established for whitebark and limber pines in the United States and Canada, assembled from researchers, surveyors, and literature sources. In addition, data from FIA plots with whitebark or limber pine are included. Since the WLIS data are point data, they could not be used to predict what the percent infestation is on a patch of five-needle pine. Though the WLIS data were not conducive to the current status GIS analysis approach, they were used to map current presence of WPBR. Figure E-8-7 displays data from WLIS with WPBR data from ADS, which was converted to a point data layer to represent current presence of WPBR. It was not used in the current status analysis, but was used in the future threat analysis.

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 five-needle pine habitat for each HUC across this ecoregion. A method of aggregating scores was used to summarize overall threats with regard to five-needle pine habitat quality. Individual threats can identify areas of potential risk to five-needle pine populations, but aggregated scores can provide important information with relation to areas where five-needle pine might encounter multiple threats.

In order to create a combined score for each HUC unit based on varying levels of importance for each KEA, it is necessary to aggregate the data through a weighting process. The weighted sum tool was used to combine each analysis input map to create an overall Current Status Map (Figure E-8-8). Equal weights were used when summing the threats for the five-needle pine.

The resulting output gives each five-needle pine pixel a score based on current status. Figure E-8-8 displays these results; red indicates areas of poor status, while green indicates areas rated at better current status based on the measured attributes.

The overall threat score for each 6th level HUC was assigned a current habitat quality rating of good, fair, or poor based on the natural breaks method. Statistics were run on the results from Figure E-8-9 to determine the average overall score. The overall result was then scored based on natural breaks. A higher overall threat score would result in a rating of poor for the HUC, indicating that there are existing threats to the habitat based on the KEA metrics.

It should be noted that when displaying results at the 6th level HUC watershed, a few isolated 30-m pixels will determine the score for that watershed (thus potentially scoring a watershed as poor or good). However, this may be misrepresentative due to the lack of pixels classified as that vegetation type (e.g., there are only a few pixels in the Black Hills forest classified as five-needle pine that are driving the scores for several watersheds). In addition, SMEs indicated the only five-needle pine distribution in the Black Hills is on Harney Peak in South Dakota.

The results of the current status analysis based on the 6th level HUC for the ecoregion are presented on Figure E-8-9. The overall current status results show relatively good scores in the southern and southeastern portions of the ecoregion. Five-needle pine forests in areas such as the Bighorn Mountains, the Wind River Range, and Greater Yellowstone National Park scored well for current status. However, areas in the central and north-central portions of the ecoregion, such as Helena and Deerlodge National

Forests, scored poor for current status. It appears the overall scoring of the five-needle pine status is heavily dependent on the current MPB infestation in the ecoregion.

One issue with geospatial analysis across a large ecoregion that is irregular in shape like the Middle Rockies is the potential impacts on the outputs. For example, the Big Horns are somewhat isolated from the rest of the ecoregion, thus having an impact on results. There is significant MPB infestation in the Big Horns. However, when compared to the entire Middle Rockies ecoregion it does not score as poorly as other areas. This can be an artifact of large scale analysis, and may need to be addressed in future REAs.

Scores for VCC (Figure E-8-5) indicate the five-needle pine have undergone partial vegetation departure, with areas in the northwest scoring predominately fair. MPB infestation ratings were poor for five-needle pine in the north-central areas of the Middle Rockies in near Helena. Five-needle pine forests more centrally located such as the Greater Yellowstone National Park, and the Teton and Gallatin National Forests also scored poor for current MPB infestation. Though the WPBR presence data (Figure E-8-7) was not included in the current status analysis, it does indicate a heavy presence throughout the Middle Rockies.

A summary of the current status ratings based on the CE distribution is provided in Table E-8-4. 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 miles per HUC that were rated as good, fair, or poor. The results of the current status assessment indicate that the majority (approximately 42.6 percent) of the 6^{th} level HUC watersheds that intersect the five-needle pine assemblage distribution received an overall good rating. However, a larger percentage of the total land area is still considered below acceptable conditions, with approximately 57.4 percent of the HUC watershed rated as fair or poor.

Table E-8-4. Summary of Current Status Ratings for the Five-Needle Pine Assemblage

Overall Rating by 6^{th} Level HUC	Total Square Miles[a]	Percentage of Total Square Miles[a, b]
Good	37,774	42.6
Fair	27,967	31.6
Poor	22,852	25.8

[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

Future threat analysis was conducted for development, insect outbreak and disease, and climate change. Climate change was modeled based on a 15-kilometer (km) grid created for regional analysis. This analysis included a comparison of current climate patterns to future modeled climate patterns and resulted in the delta (change) output figures. Further details regarding the climate change analysis are provided in Appendix C-5.

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.

5.2.1 Conservation Element-Specific Future Threats Analysis for Development, Wildfire, and Insect Outbreak and Disease

5.2.1.1 KEA Data Analysis for Future Threat Status

As with the current status analysis, the main CAs likely to impact the five-needle pine are the MPB, WPBR, and fire. Table E-8-4 identifies the KEAs, indicators, and metrics that were used to evaluate the future threat CAs and pathways affecting this CE across the ecoregion (as illustrated on Figure E-8-2). The five-needle pine analysis is designed to create a series of intermediate layers that are primarily based on the geospatial data available on the future projections for the CAs impacting this CE (Table E-8-5). Future KEAs were determined primarily by the availability of data relevant to the future status of the five-needle pine.

There are no future models available for future insect outbreak/disease or wildfire risks. Therefore, existing data were used based on several assumptions. For example, it is assumed that the closer a five-needle pine stand is to an existing outbreak, the more likely it will be infested in the future. The future threat analysis also investigated risk of further fragmentation, as the five-needle pine stands have become increasingly fragmented due to MPB and WPBR infestations. Further fragmentation could lead to increased decline due to inbreeding and the ability of the Clark's nutcracker to disperse seeds.

Table E-8-5. Five-Needle Pine Future Threat Attributes, Indicators, and Metrics for the Middle Rockies Ecoregion

Category	Ecological Attribute	Indicator / Unit of Measure	Metric			Data Source	Citation	Weight
			Poor = 3	Fair = 2	Good = 1			
Landscape Structure	Fire	Fire (spatial-temporal patterns of proximity of lodgepole/mixed conifer stands based on VCC classes 2 and 3 and proximity	<1 mile	1-2 miles	>2 miles	LANDFIRE	RRT guidance	0.25
	Fragmentation	Neighborhood analysis	0-38%	38-70%	70-100%	LANDFIRE	RRT guidance (scoring based on natural breaks)	0.25
Landscape Condition	Insect outbreak	Proximity to MPB infestation	<2 miles	2-5 miles	>5 miles	ADS	RRT guidance	0.25
	Disease	Proximity to WPBR presence	<300 m	300 m -2 miles	>2 miles	WLIS	RRT guidance	0.25

5.2.1.2 VCC and Proximity

The future fire risk of the proximity of five-needle pine to the lodgepole-mixed conifer stands based on VCC classes 2 and 3 were analyzed. This was based on the assumption that five-needle pine forests in close proximity to lodgepole-mixed conifer stands are more likely to have large, severe fires and are at a higher risk in the future.

ReGAP data were used to query the Rocky Mountain lodgepole pine forest and Rocky Mountain poor-site lodgepole pine level 3 classifications. These data were then added together using map algebra to determine where the VCC classes 2 and 3 intersected with the lodgepole pine. A Euclidean distance proximity analysis was run from the resulting layer to determine the distance from that layer to five-needle pine. The proximity analysis was then extracted to the five-needle pine layer and scored based on Table E-8-4. Scores were then determined by the RRT. Figure E-8-10 displays the model for future fire risk to lodgepole pine in this ecoregion.

5.2.1.3 Proximity to MPB and Proximity to WPBR

A Euclidean distance proximity analysis was run from the USFS ADS data from 1994-2010 polygon data based on the assumption that the five-needle pine stands in close proximity to MPB infestations are at risk in the future. As stated previously, the WLIS point data were used with the WPBR ADS data to map WPBR presence. Though these data were not used in the current status analysis, they were used in the future threat analysis. To determine future threat on five-needle pine from WPBR, the Euclidean distance proximity analysis was used. The same assumption was made for the WPBR (e.g., if a five-needle pine forest was near a known presence of WPBR, it was at risk in the future). The proximity analysis was extracted to the five-needle pine forests and then scored based on Table E-8-4. Scores were then determined by the RRT. Figure E-8-11 shows the MPB proximity scores; Figure E-8-12 shows the WPBR proximity scores. Red displays patches with higher MPB infestation, while green shows lower infestation.

5.2.1.4 Fragmentation

A forest fragmentation index was created by doing a neighborhood analysis on the five-needle pine layer. To look at the potential for future fragmentation, the Integrated Climate and Land-Use Scenarios (ICLUS) 2030 Urban/Exurban modeled data were extracted from the five-needle pine distribution layer.

The analysis looks at each pixel classified as five-needle pine and its neighbors. A 10x10 neighborhood was used for this analysis. There is no literature specific to the moving window size for this type of analysis. Several other moving window sizes were considered, but the 10x10 window seemed most appropriate to the RRT. The forest fragmentation index is based on the number of five-needle pine pixels surrounding each other. The lower the number, the higher the fragmentation index, which assumes a higher potential for fragmentation.

Figure E-8-13 displays the model for the fragmentation index of five-needle pine in this ecoregion.

5.2.2 Future Threats Overall Score

The future overall score was compiled using the methods described in Section 5.1.2. Figure E-8-15 displays the overall combined score for future threats to five-needle pine and Figure E-8-15 displays the overall combined score by 12-digit HUC. Equal weights were used when summing the threats for the five-needle pine. The resulting output gives each five-needle pine forest 30-m pixel a score based on future threat. Figure E-8-14 displays these results; red indicates areas of higher threats, while green indicates areas of lower threats based on the measured attributes. The results of the future threat analysis based on the 6th level HUC for the ecoregion are presented on Figure E-8-15. Due to the likelihood of future insect and disease outbreak and the fire departure of adjacent forests, the five-needle pine forests scored poorly in much of the Middle Rockies ecoregion.

Most of the ecoregion scored poorly for future fire because of the proximity of lodgepole/mixed conifer stands based on VCC classes 2 and 3. The potential for future MPB infestation (Figure E-8-11) indicates further infestation of five-needle pine forests throughout the Middle Rockies. Based on recent insect outbreaks and the predicted increase in temperatures, it is likely that the trend of severe bark beetle outbreaks will continue to occur given susceptible stand conditions. However outbreaks are periodical (with intervals between epidemics from 70-100 years) (Perkins and Roberts 2003) and depend on climate and stand conditions.

The WPBR proximity analysis (Figure E-8-12) scores much of the five-needle pine as good or fair for future infestation. However based on current presence, coupled with the MPB infestation this can be assumed a continued thereat in the future to the five-needle pine forests. As stated previously in section

5.1.2, the scores for the Big Horns appear to be impacted due to size and shape of the Middle Rockies ecoregion. SMEs indicate the Big Horns are heavily impacted by MPB and WPBR; however the overall future threats score may not be illustrating the severity of the insect and disease infestation.

5.2.3 Development Change Agent

The ecoregion-wide future threat analysis was conducted as presented in Appendix C-1. For this broad assessment, development was limited to potential energy development and climate change, as this CE appears to be at low risk from the threats from modeled urban growth based on the modeled growth for the ecoregion (Figure C-1-8) and potential agricultural development in forested areas

5.2.3.1 Oil Production Potential

This future analysis characterized potential oil production areas rather than oil well locations (Figure C-1-4). These larger oil production extents were 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 five-needle pine forests.

The five-needle pine forests in this ecoregion appear to be at low risk from potential oil production. The majority of potential oil production is limited to lower elevation areas in northern Wyoming. There is one area in north-central Montana that is at moderate risk from potential oil production development; however, from an ecoregional scale it does not appear that future oil development will negatively affect five-needle pine.

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 reserves within the Middle Rockies. 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.

5.2.3.2 Natural Gas Production Potential

This future analysis characterized potential gas production areas rather than actual gas well locations (Figure C-1-3). These larger gas production extents could be used to qualitatively assess the potential effect of future gas production activities. Although these areas are 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 five-needle pine.

The five-needle pine in this ecoregion appear to be at low risk from potential gas production. The majority of potential gas production is in lower elevation areas in northern Wyoming where potential is limited. There is one area in north-central Montana that is at moderate risk from potential natural gas development; however, from an ecoregional scale it does not appear that future natural gas development will negatively affect five-needle pine.

5.2.3.3 Future Potential for Solar Development

This future potential analysis characterized the future potential for solar development based on the solar potential maps developed by National Renewable Energy Laboratory (NREL). Although these maps are very crude, the highest potential for solar development is shown to occur primarily outside of the five-needle pine distribution area.

5.2.3.4 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 future wind turbine locations were based on the location of documented wind speeds suitable for turbines.

Data characterized by the NREL was used to create a potential future wind turbine area 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. Wind power classes were characterized as good, fair, or poor for direct comparison to the current wind condition (Figure C-1-7).

Higher elevations within this ecoregion are more susceptible to the threats related to future wind turbines due to the higher wind speed levels at these elevations. The mapped areas most susceptible to future wind turbines do intersect with much of the five-needle pine distribution. However, wind energy development does not appear to be a probable threat to forests because developers would more likely site wind farms on open lands where clearing would not be required. In addition there is little literature to support that wind turbines will pose a major risk to the future of the five-needle pine.

5.2.3.5 Overall Development CA Future Threats

A fossil fuel energy output 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-1-2). Most of the five-needle pine in the Middle Rockies ecoregion are at low risk from fossil fuels production.

A renewable energy output layer was created to address the MQs associated with future renewable energy production. This layer was created by averaging the NREL wind speed data layer with the NREL solar energy data layer (Figure C-1-6). This output layer provides equal weighting to potential wind and solar energy production 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.

Because of the intricacies involved in the assessment of renewable energy production with regard to five-needle pine, a limited approach must be taken in this analysis. The majority of the five-needle pine in this ecoregion are considered to be at low risk from potential renewable energy production.

5.2.3.6 Climate Change Future Threats

It remains difficult to draw conclusions from the climate change 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.

Figure C-5-8 shows an increase in temperatures predicted to 2060. Increases in the Mean Annual Temperature in the Middle Rockies ecoregion are predicted to range from 1.9-2.4 degrees Celsius (°C).

Increasing temperatures due to climate change allow more time for the MPB to complete its life cycle, which allows populations to grow more quickly than in the past (Bentz et al. 2007). The temperature data output indicate that the high elevation southern ranges could experience the greatest increases in temperature. The precipitation data indicate that there could be decreased snow water equivalent (SWE) in these same ranges; this would result in less soil moisture during the growing season, resulting in increased tree water stress and increased susceptibility to MPB outbreaks. Based on the current trends of increased outbreaks associated with increased temperatures, it is assumed there will be a higher population of MPB in five-needle pine forests, likely increasing mortality.

Figure C-5-1 (in Appendix C-5) shows the model for predicted precipitation change to 2060 across the Middle Rockies ecoregion. Changes throughout the ecoregion range from an increase to 99 mm in some areas to a decrease to 75 mm in other areas. This minimal change, coupled with predicted increases in temperatures and altered fire regimes, could result in more frequent and severe fires.

THIS PAGE INTENTIONALLY LEFT BLANK

6.0 MANAGEMENT QUESTIONS

The relevant MQs for the five-needle pine assemblage include those defined as part of the Terrestrial Biotic Resources 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 five-needle pine distribution model. Several examples of how the REA can be used to answer MQs (as noted in Appendix A) are provided below; these examples demonstrate the functionality of the REA and provide an opportunity to discuss data gaps that were identified during this REA.

6.1 WHICH SPECIES GROUPS SHOULD BE USED AS SURROGATES?

To adequately map the potential distribution of the five-needle pine, the LANDFIRE Refresh 2008 classifications for whitebark pine and limber pine were used (see Figure E-8-3).

6.2 WHERE WILL CURRENT CONSERVATION ELEMENT VEGETATION TYPES BE AT GREATEST RISK FROM CHANGE AGENTS?

The full range of figures and analyses for the five-needle pine can be used to answer this complex MQ. The models created throughout this process were created to directly address the affects of CAs on five-needle pine forests. All of the CAs were addressed spatially and are described in detail in this section, and all of the CAs were spatially attributed to the distribution of the five-needle pine. The figures in section 5 represent threats by the 30-m analysis unit, while figure E-8-15 represents the sum of all the threats at the 12-digit HUC reporting unit.

6.3 WHICH AREAS HAVE POTENTIAL FOR RESTORING CONSERVATION ELEMENT SPECIES HABITAT OR HABITAT CONNECTIVITY FOR CONSERVATION ELEMENT SPECIES, CURRENTLY AND IN THE FUTURE?

The fragmentation index (figure E-8-13) represents the potential for further fragmented five-needle pine forests. It can also be used to show areas where future restoration may be the most beneficial. The fragmentation index shows areas where restoration could potentially connect larger stands together.

6.4 WHERE WILL CONSERVATION ELEMENTS BE AT RISK FROM ALTERED FIRE REGIMES? WHERE ARE AREAS WITH POTENTIAL TO SHOW FUTURE INCREASES OR DECREASES IN WILDFIRE FREQUENCY OR INTENSITY?

Figure E-8-5 represents the VCC for the five-needle pine. This figure represents changes in vegetation and fuels from their historical condition. For the Middle Rockies a group of SMEs went through an exercise to illustrate fire regime (frequency and severity) departure. The historic BpS was attributed with a current fire severity and frequency, and then compared with the reference (historic) fire frequency and severity for each type. From these data, we were able to develop a fire frequency departure map, a fire severity departure map, and then a composite map (which took the highest of either departure). This modified composite layer was used as the best indicator for potential threat to five-needle pine forests from an uncharacteristic fire.

6.5 WHICH INSECTS AND DISEASES MIGHT POSE A SIGNIFICANT FUTURE PROBLEM?

The MPB and the WPBR are the greatest threats to future of the five-needle pine forests. Figures E-8-11 and E-8-12 display five-needle pine forests in close proximity to current MPB and WPBR infestations.

The assumption is that the five-needle pine stands in close proximity to MPB and WPBR infestations are at risk in the future. Red displays patches with higher MPB infestations; while green shows lower infestations.

6.6 WHERE WILL STATE AND FEDERAL HIGH-VALUED RESOURCE AREAS BE AFFECTED THROUGH CHANGES IN INTESITY AND RANGE OF INSECTS AND DISEASE?

Based on the analysis results of Figures E-8-11 and E-8-12, five-needle pine forests on USFS and BLM lands in the north-central portion of the ecoregion have the potential to be significantly affected through insect outbreaks and disease. Also five-needle pine forests in Yellowstone National Park and forests adjacent to the park appear to be at risk due to MPB and WPBR.

6.7 HOW AND WHERE ARE FREQUENCY AND SEVERITY OF OUTBREAKS EXPECTED TO CHANGE IN RESPONSE TO CLIMATE CHANGE AND OTHER CHANGE AGENTS SUCH AS CHANGE IN FIRE FREQUENCY?

Based on predicted increases in temperatures (based on the climate change analysis discussed in Appendix C-5), it is likely that the trend of severe MPB outbreaks will continue to occur. The climate change analysis predicts an increase across the entire ecoregion; however the analysis predicts a somewhat gradual gradient of higher temperatures from north to south.

6.8 WHERE ARE THE STANDS OF MAJOR TREE SPECIES THAT HAVE NOT BEEN IMPACTED BY INSECTS OR DISEASES?

Figure E-8-6 displays current infestation of the MPB on five-needle pine stands. Areas in green are stands that have been less impacted by MPB. Figure E-8-7 displays the presence of WPBR from both the WLIS and ADS data.

7.0 REFERENCES

Bentz, B. J., and G. Schen---Langenheim. 2007. The mountain pine beetle and whitebark pine waltz: has the music changed? pp. 43---50. In Proceedings of whitebark pine: A pacific coast perspective. U.S. Department of Agriculture Forest Service. R6---NR---FHP---2007---01.

Bower, A.D. and S.N. Aitken. 2007. Mating system and inbreeding depression in whitebark pine (*Pinus albicaulis* Engelm.). Tree Genetics and Genomics 3:379-388.

Burns, Kelly S.; Schoettle, Anna W.; Jacobi, William R.; Mahalovich, Mary F. 2008. Options for the management of white pine blister rust in the Rocky Mountain Region. Gen. Tech. Rep. RMRS-GTR-206. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 26 p.

Geils, BW., Hummer, K.E., Hunt, R.S. 2010. White pines, Ribes, and blister rust: a review and synthesis. Forest Pathology (3/4): 147-185.

Houghton, R.A., and J.L. Hackler. 2000. Changes in terrestrial carbon storage in the United States. I: The roles of agriculture and forestry. Global Ecology and Biogeography 9: 125-144. doi: 10.1046/j.1365-2699.2000.00166.x

Keane, R.E., S.F. Arno, and C. Stewart. 2000. Ecosystem-based management in the whitebark pine zone. In: Smith, H.Y. (ed.) 2000. The Bitterroot Ecosystem Management Research Project -- what we have learned: symposium proceedings; 1999 May 18-20; Missoula, MT. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Proceedings RMRS-P-17 Pages 36-41

Keane, R., Ryan, K., Veblen, T., Allen, C., Logan, J. and Hawkes, B. 2002. Cascading effects of fire exclusion in Rocky Mountain ecosystems : a literature review. USDA Forest Service, Rocky Mountain Research Station, General Technical Report RMRS-GTR-91, 24 pp.

Kearns, H.S.J.; Jacobi, W.R. 2007. The distribution and incidence of white pine blister rust in central and southeastern Wyoming and northern Colorado. Can. J. For. Res. 37: 462-472.

Keane, R.E. and R.A. Parsons. 2007. Restoring whitebark pine forests of the northern Rocky Mountains. Rocky Mountain Research Station, USFS Research Note RMRS-RN-32.

King, J.N.; David, A.; Noshad, D.; Smith, J., 2010: A review of genetic approaches to the management of blister rust in white pines. For. Pathol. 40, 292–313.

Larson, E.R., Kipfmueller, K.F., 2010. Patterns in whitebark pine regeneration and their relationships to biophysical site characteristics in southwest Montana, central Idaho, and Oregon, USA. Can. J. For. Res. 40, 476–487.

Logan, J.A. and Powell, J.A. 2001. Ghost forests, global warming, and the mountain pine beetle (Coleoptera: Scolytidae). American Entomologist: 47: 160-172.

Logan, J. A., and J. A. Powell. 2009. Ecological consequences of forest-insect disturbance altered by climate change. Pages 98–109 in F. H. Wagner, editor. Climate warming in western North America. University of Utah Press, Salt Lake City, Utah, USA.

Logan, J.A., MacFarland, W.W., and Willcox, L. 2010. Whitebark pine vulnerability to climatedriven mountain pine beetle disturbance in the Greater Yellowstone Ecosystem. Ecological Applications 20: 895–902.

Means, R.E. 2010. Synthesis of lower treeline limber pine (*Pinus flexilis*) woodland knowledge, research needs, and management considerations. Oral presentation with forthcoming proceedings. High-

Five Symposium: the future of high-elevation five-needle white pines in western North America. June 28-30. Missoula, MT.

Perkins, D.L.; Roberts, D.W. 2003. Predictive models of whitebark pine mortality from mountain pine beetle. Forest Ecology and Management 174: 495–510.

Powell, J.A., and B.J. Bentz. 2009. Connecting phenological predictions with population growth rates for mountain pine beetle, an outbreak insect. Landscape Ecology. 24:657-672.

Powell, J.A., and J.A. Logan. 2005. Insect seasonality: circle map analysis of temperature-driven life cycles. Theoretical Population Biology 67:161–179.

Raffa, K. F., B. H. Aukema, B. J. Bentz, A. L. Carroll, J. A. Hicke, M. G. Turner, and W. H. Romme. 2008. Cross-scale drivers of natural disturbances prone to anthropogenic amplification: the dynamics of bark beetle eruptions. BioScience 58:501–517.

Samman, S. and J. Logan (2000). Assessment and response to bark beetle outbreaks in the Rocky Mountain area, USDA Forest Service. RMRS-GTR-62.

Schoettle, A.W. 2004a. Ecological roles of five-needle pine in Colorado: potential consequences of their loss. In: Sniezko, R.; Samman, S.; Schlarbaum, S.; Kriebel, H., eds. Breeding and genetic resources of five-needle pines: growth adaptability and pest resistance. 2001 July 24-25; Medford, OR. IUFRO Working Party 2.02.15. Proc. RMRS-P-32. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 124-135.

Schoettle, A.W. 2004b. Developing proactive management options to sustain bristlecone and limber pine ecosystems in the presence of a non-native pathogen. In: Shepperd, W.D.; Eskew, L.G., eds. Silviculture in special places: proceedings of the 2003 National Silviculture Workshop, RMRS-P-34. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 146-155. Available: http://www.fs.fed.us/rm/ pubs/rmrs_p034/rmrs_p034_146_155.pdf [2007, Sept. 5].

Schoettle, A.W. and R.A. Sniezko. 2007. Proactive intervention to sustain high-elevation pine ecosystems threatened by white pine blister rust. Journal of Forestry Research 12:327-336.

Schuster, W.S., J.B. Minton, D.K. Yamaguchi, and C.A. Woodhouse. 1994. A comparison of limber pine (*Pinus flexilis*) ages at lower and upper treeline sites east of the continental divide in Colorado. American Midland Naturalist 133:101-111.

Schwandt, J.W.; Lockman, I.B.; Kliejunas, J.T.; Mulir, J.A., 2010: Current health issues and management strategies for white pines in the western United States and Canada. For. Pathol. 40, 226–250.

Tomback, D.F. and P. Achuff. 2010. Blister rust western forest biodiversity: ecology, values and outlook for white pines. Forest Pathology 40:186-225.

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.

Westerling, A.L., H.G. Hidalgo, and T.W. Swetnam. 2006. Warming and earlier spring increase western US forest wildfire activity. Science 313: 940-943. doi: 10.1126/science.1128834

Zeglen, S.; Pronos, J.; Merler, H., 2010: Silvicultural management of white pines in western North America. For. Pathol. 40, 347–368.

APPENDIX E-8

FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

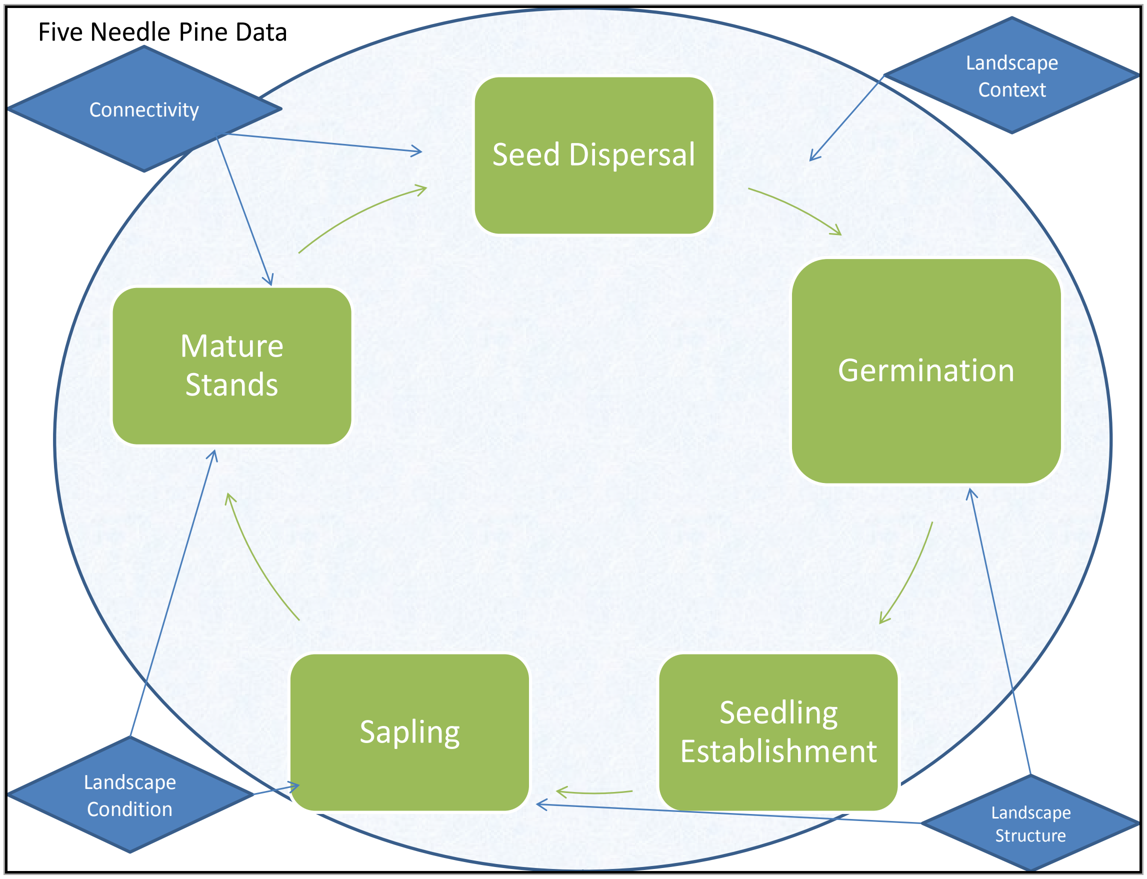

Figure E-8-1. Ecological Conceptual Model

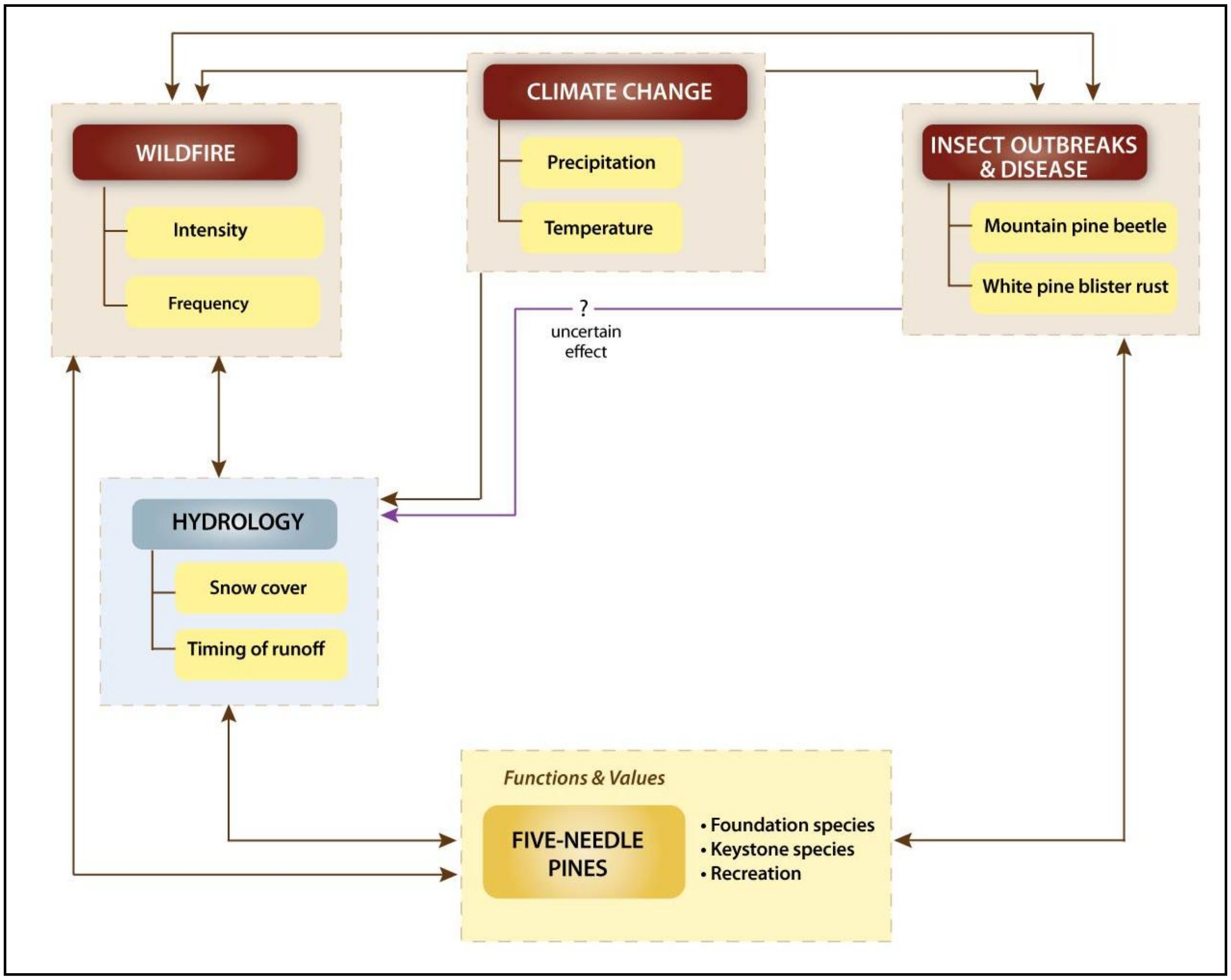

Figure E-8-2. System Level Model

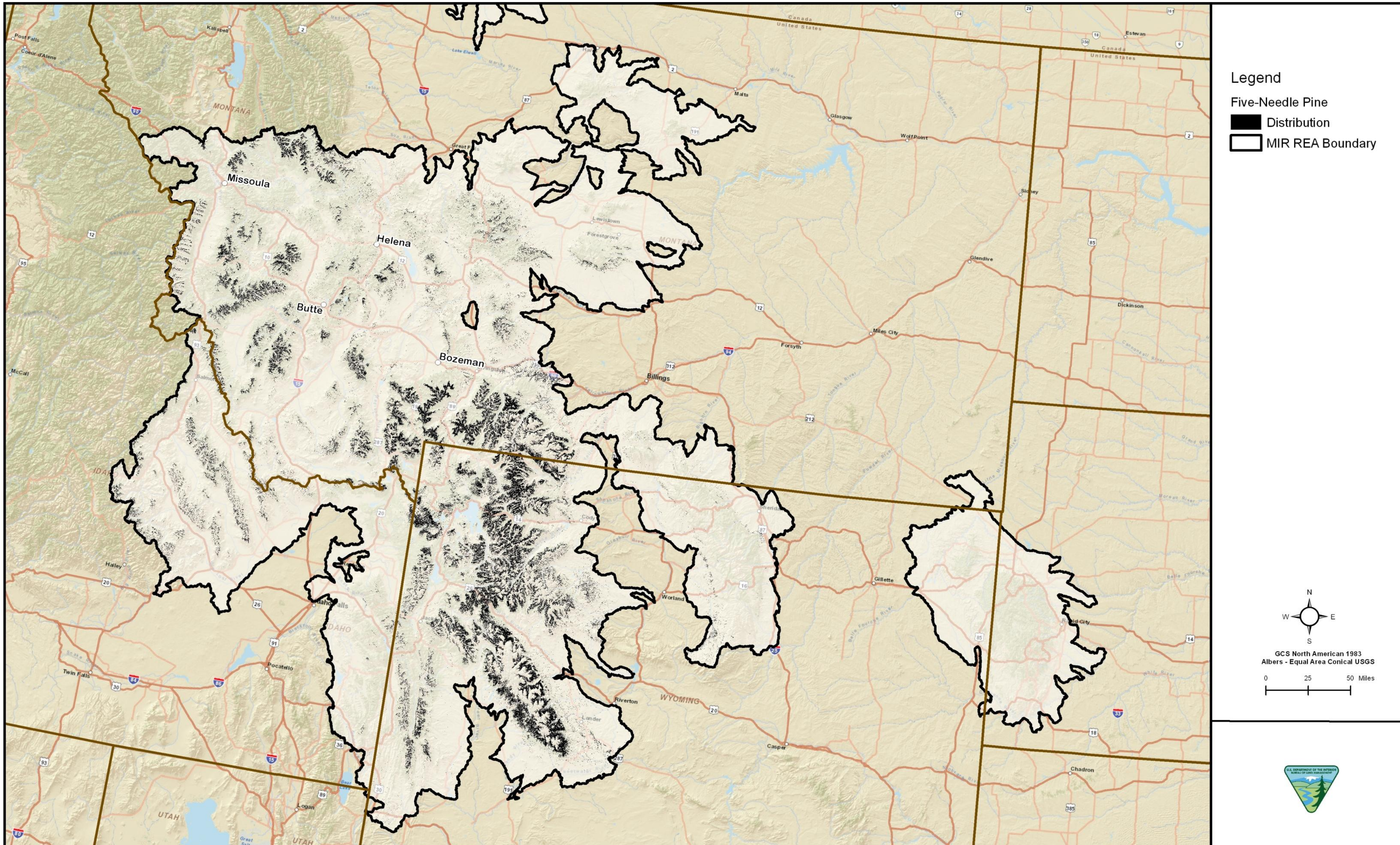

Figure E-8-3. Five-Needle Pine Distribution

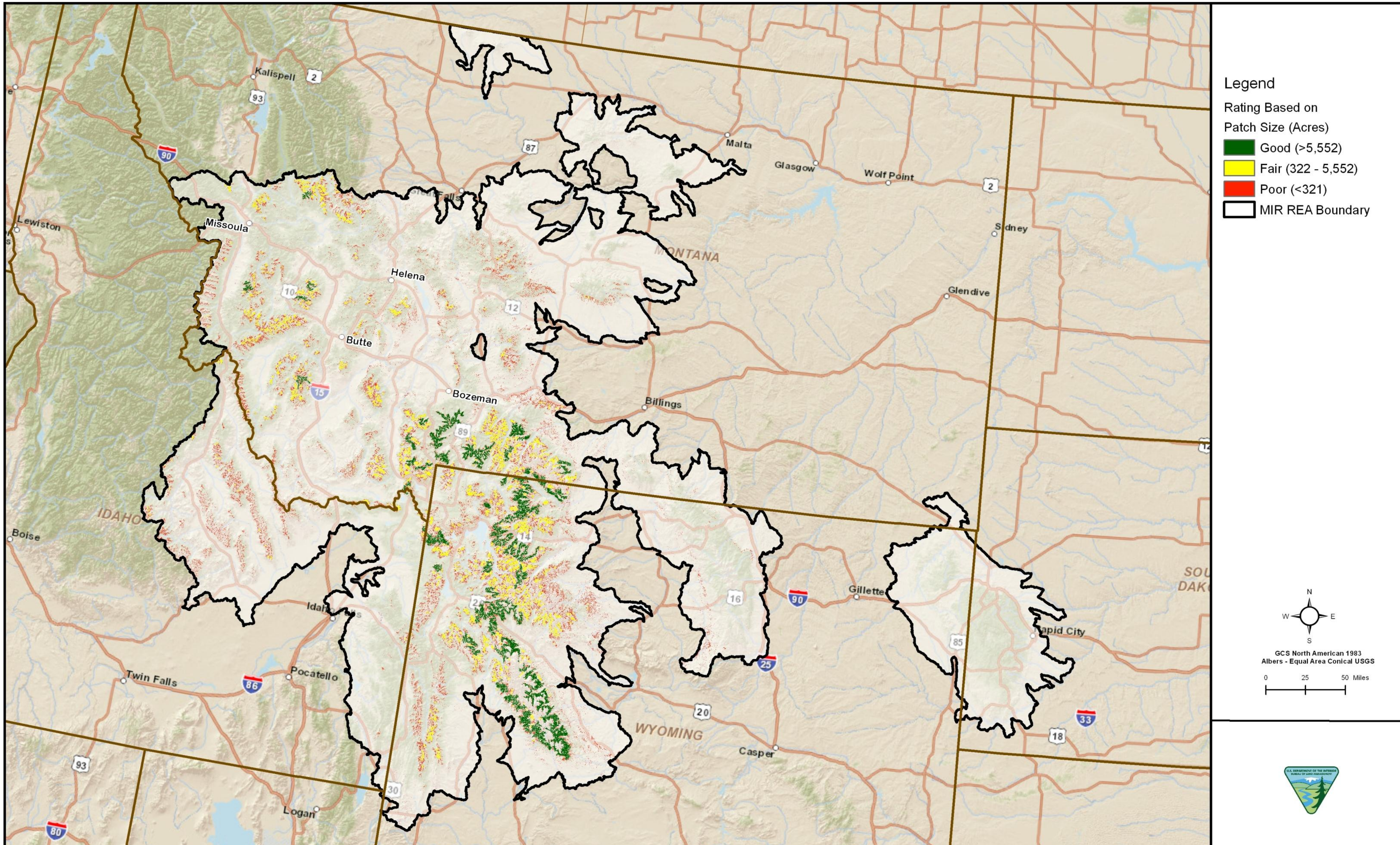

Figure E-8-4. Five-Needle Pine Patch Size

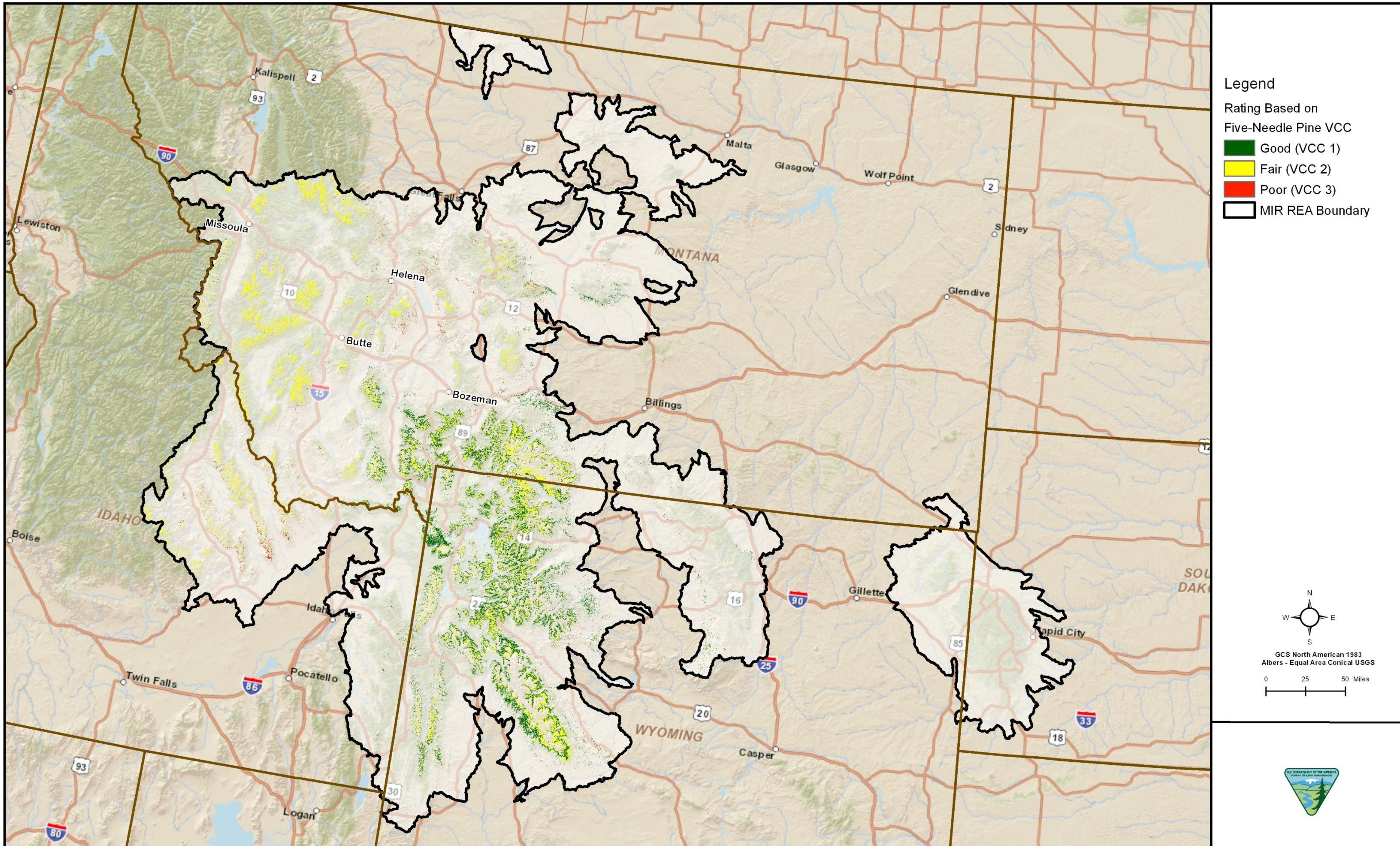

Figure E-8-5. Five-Needle Pine Vegetation Condition Class

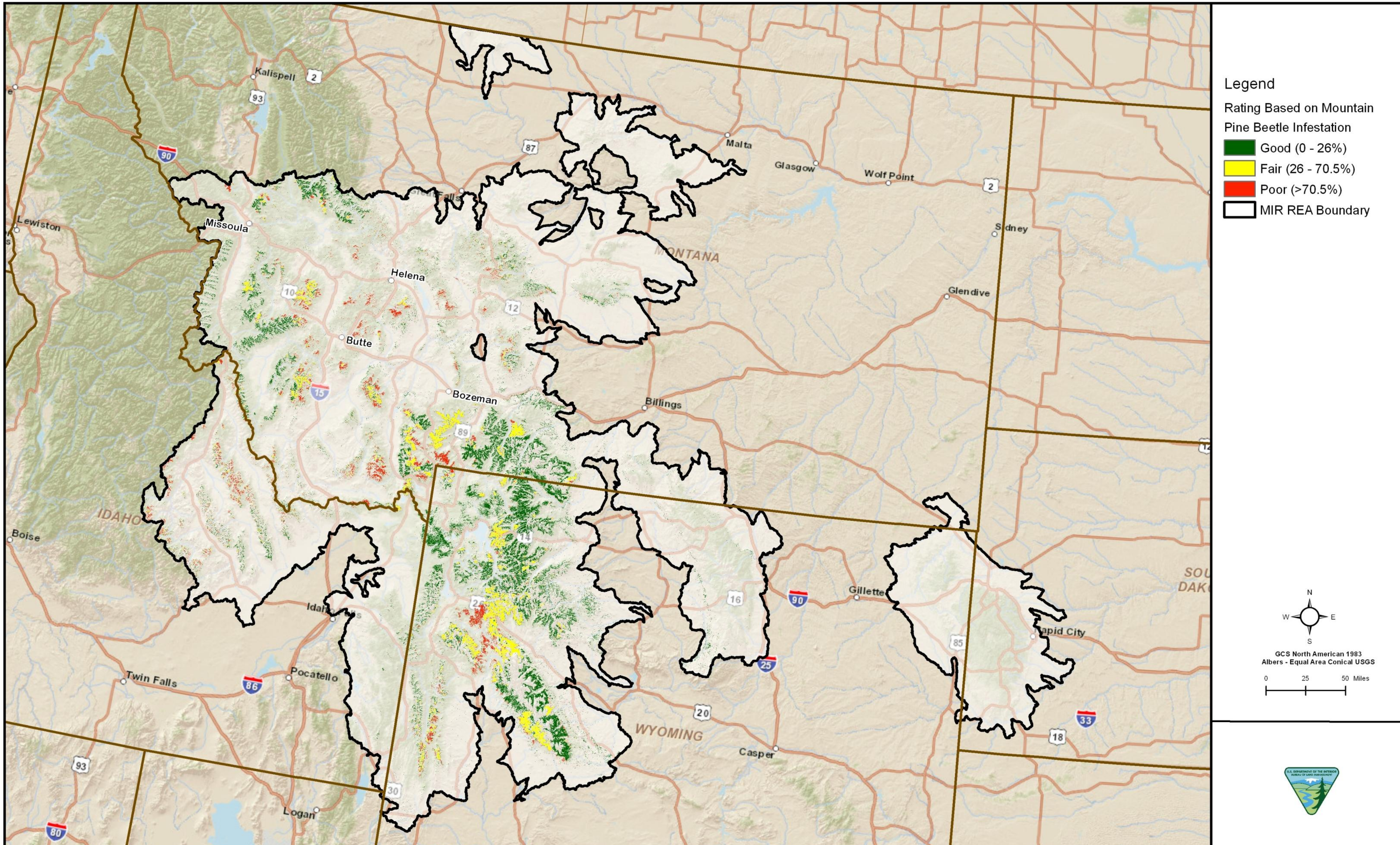

Figure E-8-6. Five-Needle Pine Mountain Pine Beetle Infestation

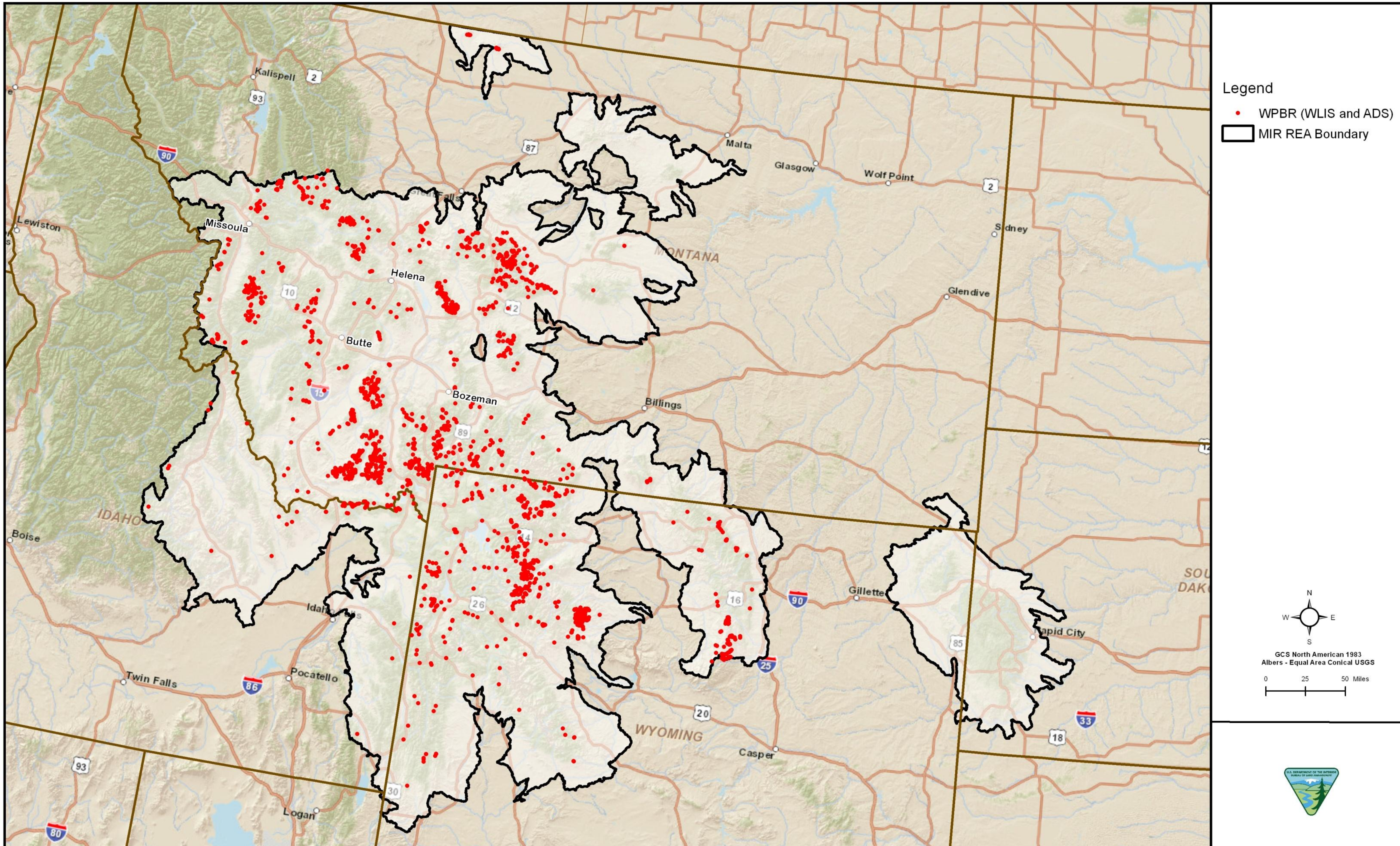

Figure E-8-7. White Pine Blister Rust Presence

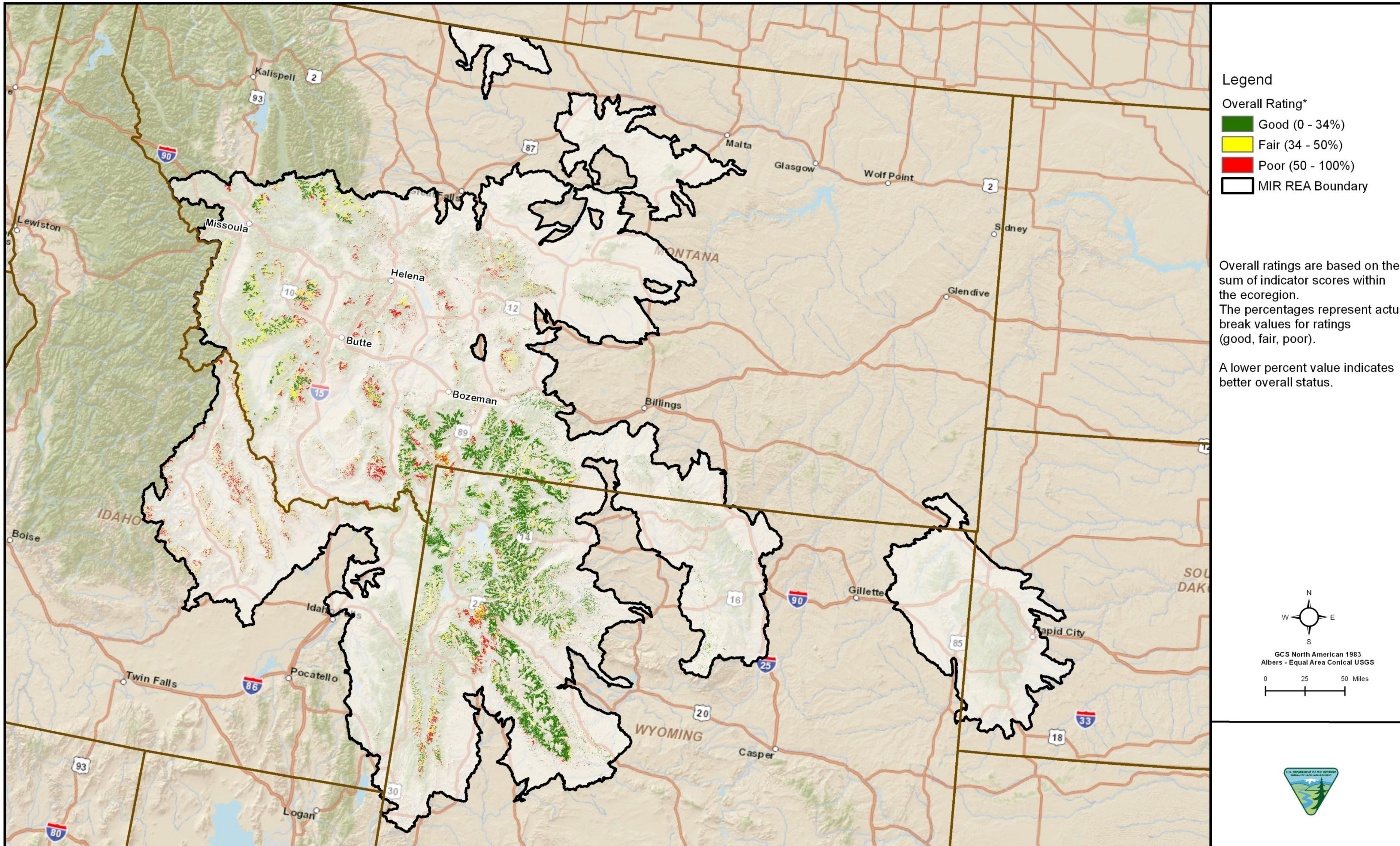

Figure E-8-8. Five-Needle Pine Current Status Map

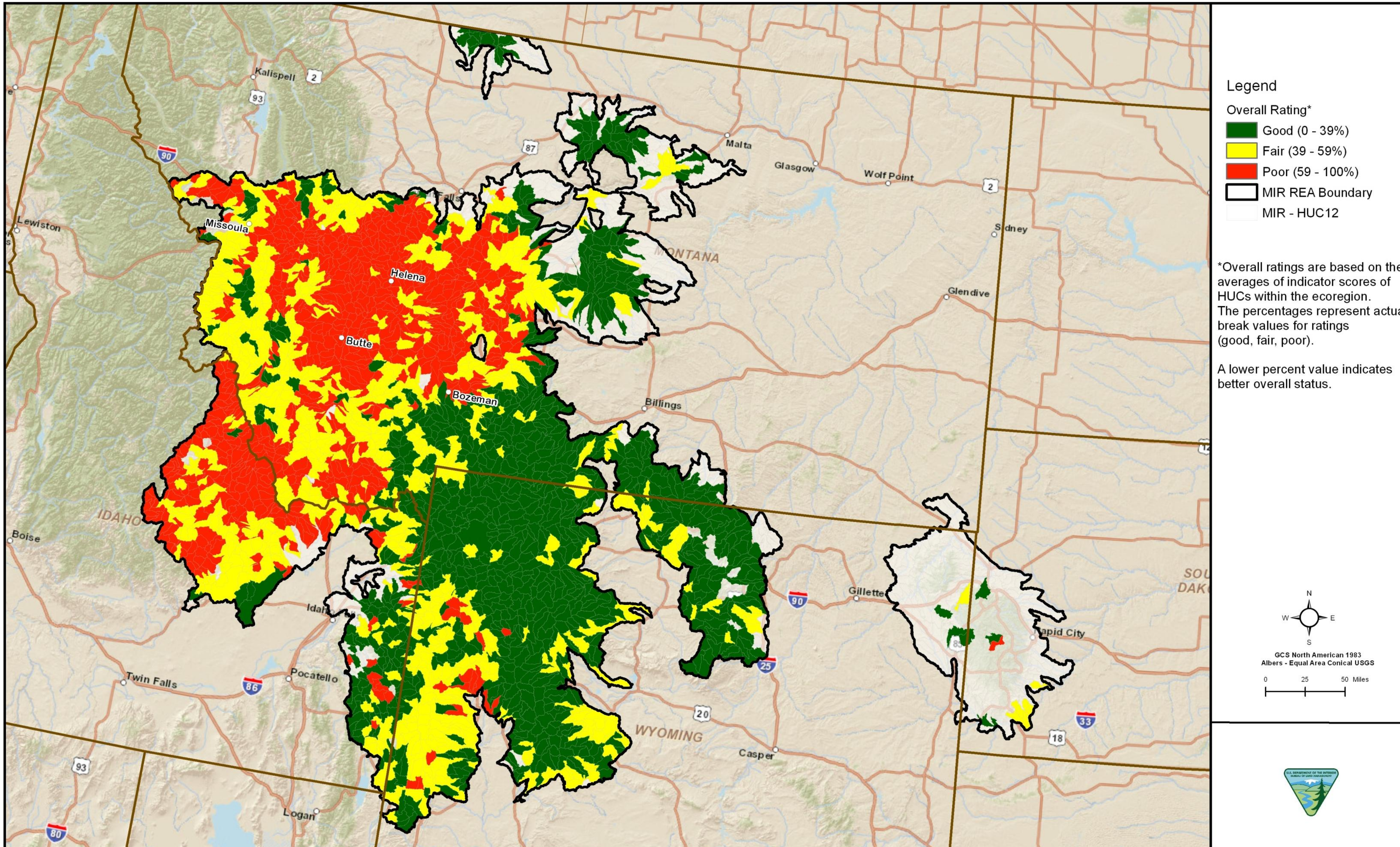

Figure E-8-9. Five-Needle Pine Current Status by 6th Level Hydrologic Unit Code

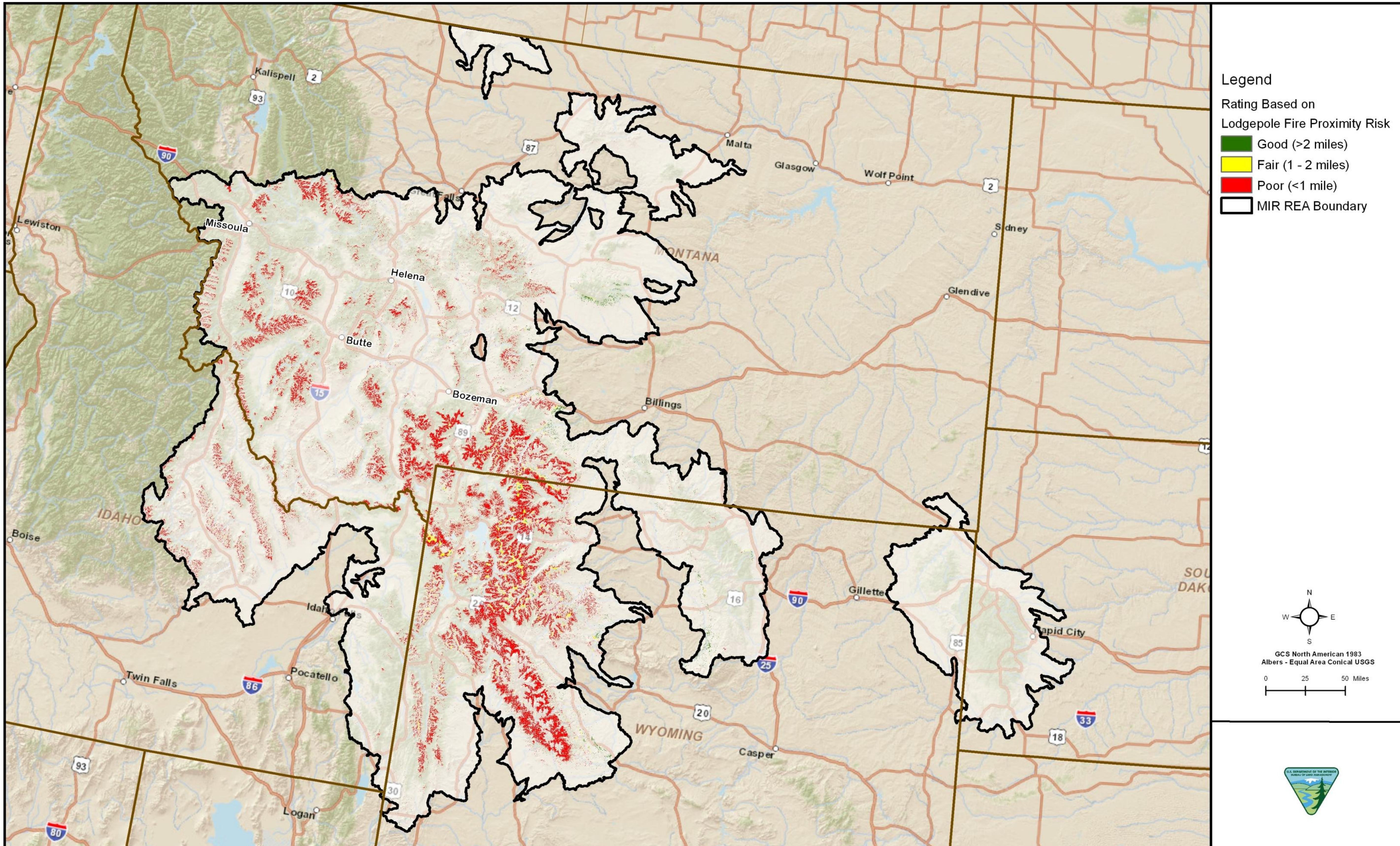

Figure E-8-10. Five-Needle Pine Future Severe Fire Risk

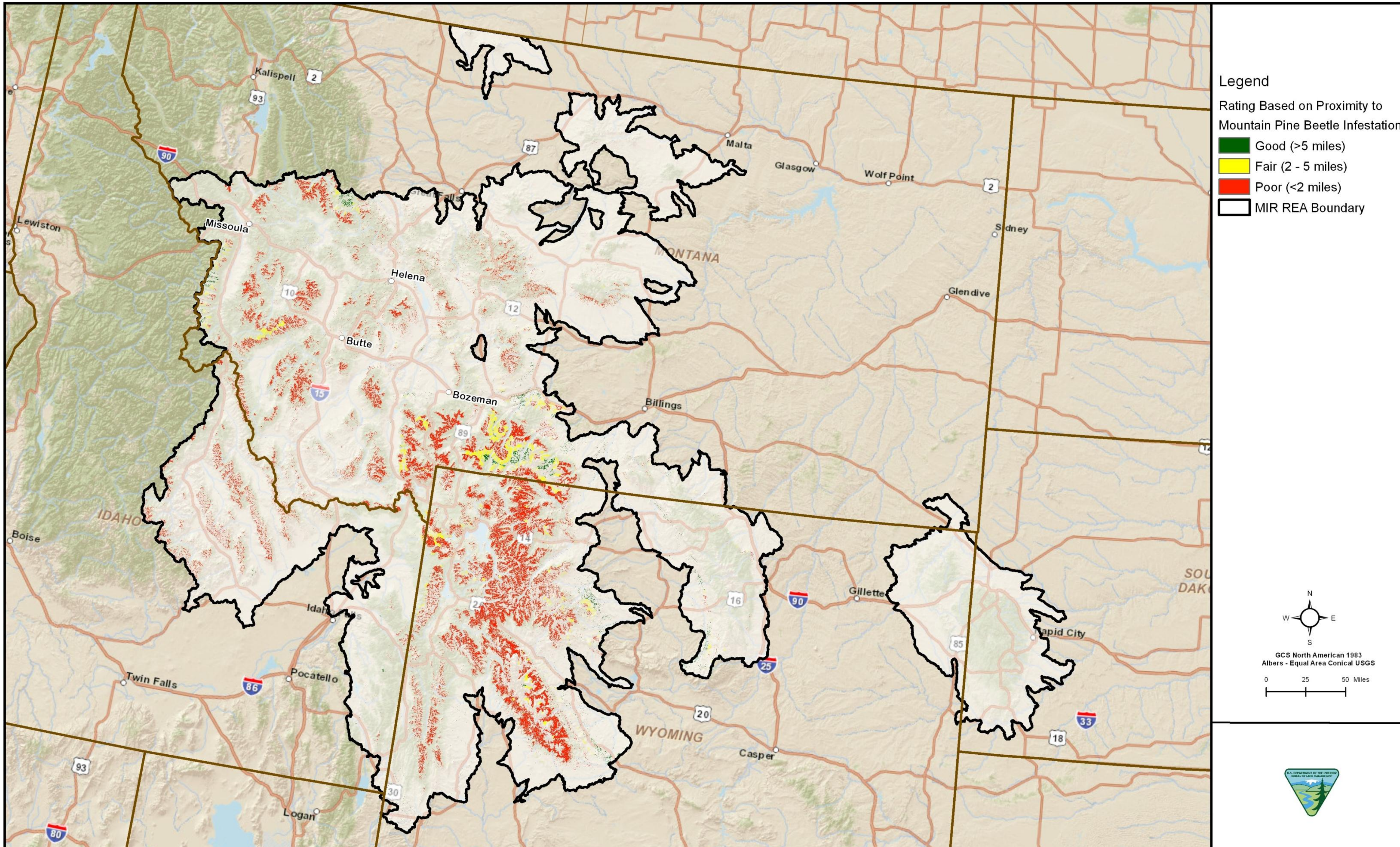

Figure E-8-11. Five-Needle Pine Mountain Pine Beetle Proximity Analysis

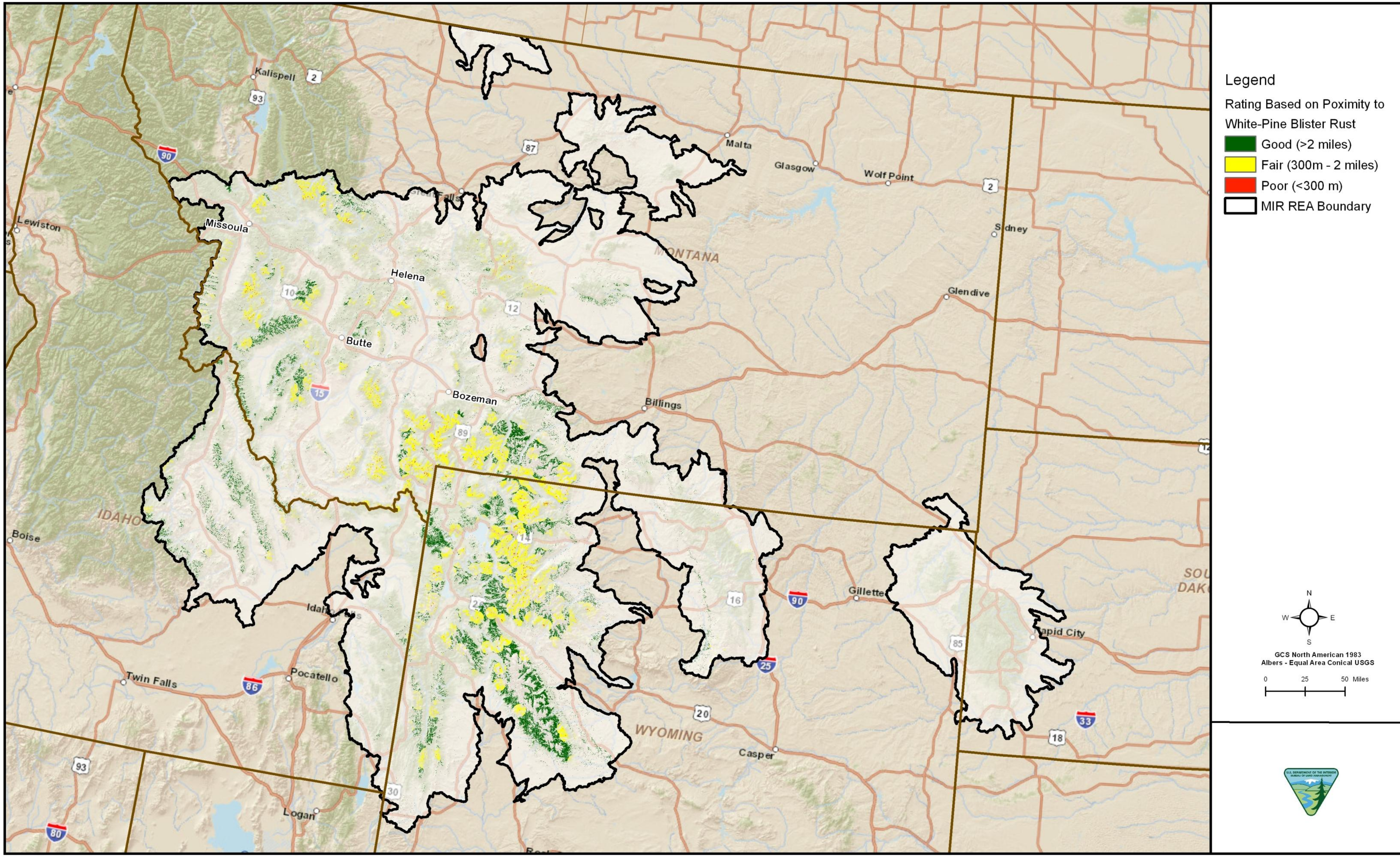

Figure E-8-12. Five-Needle Pine White Pine Blister Rust Proximity Analysis

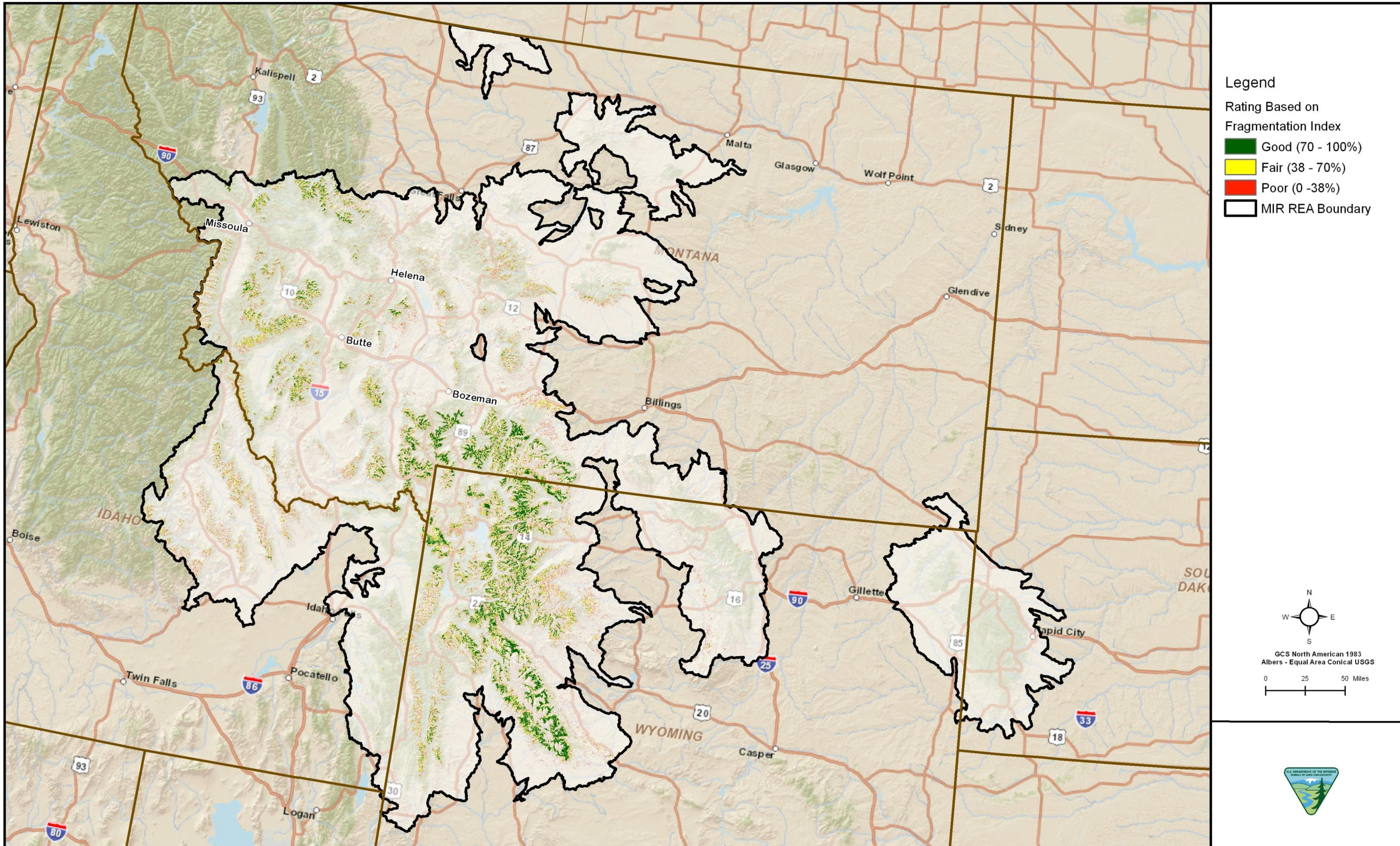

Figure E-8-13. Five-Needle Pine Fragmentation Index

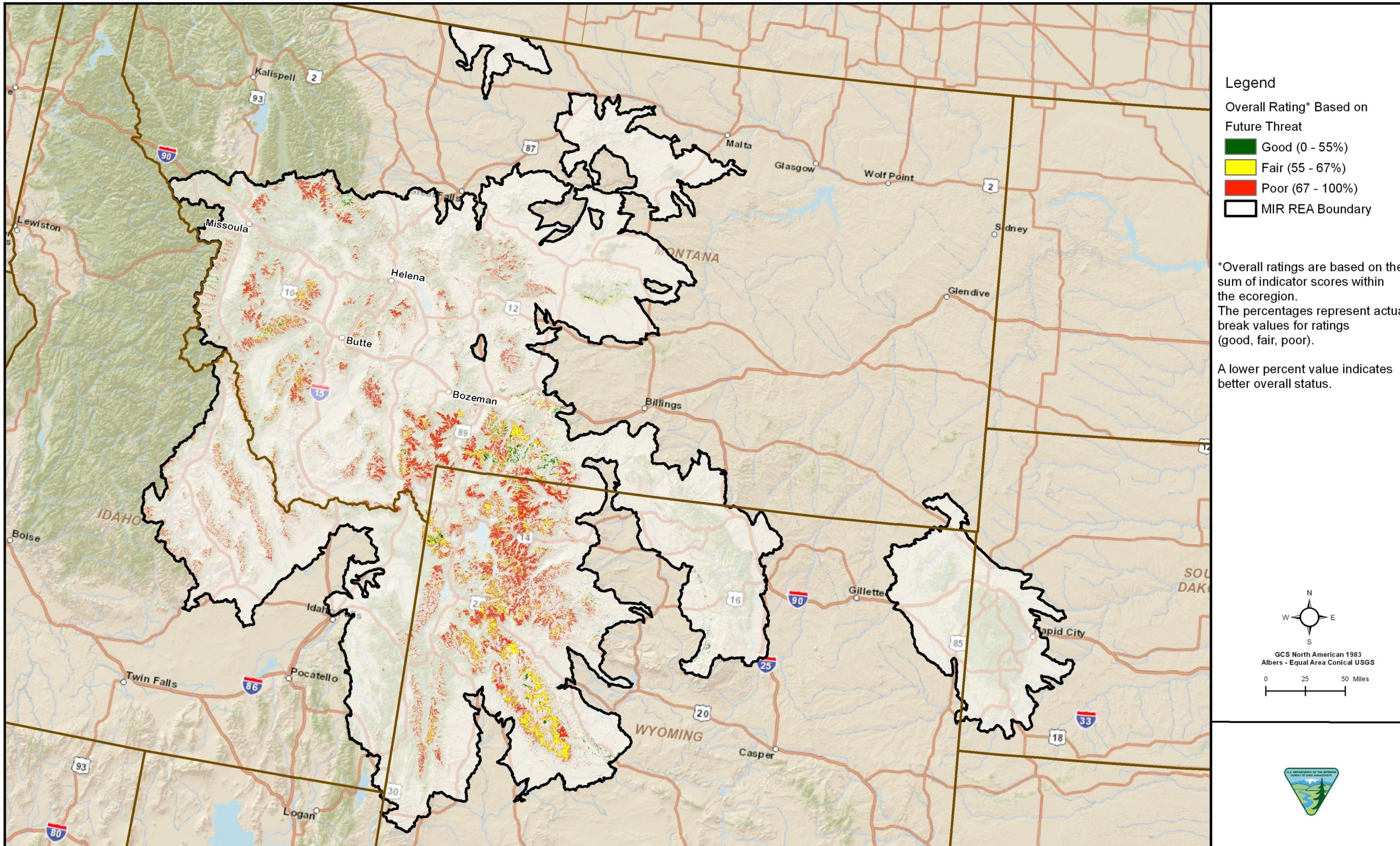

Figure E-8-14. Five-Needle Pine Future Threat

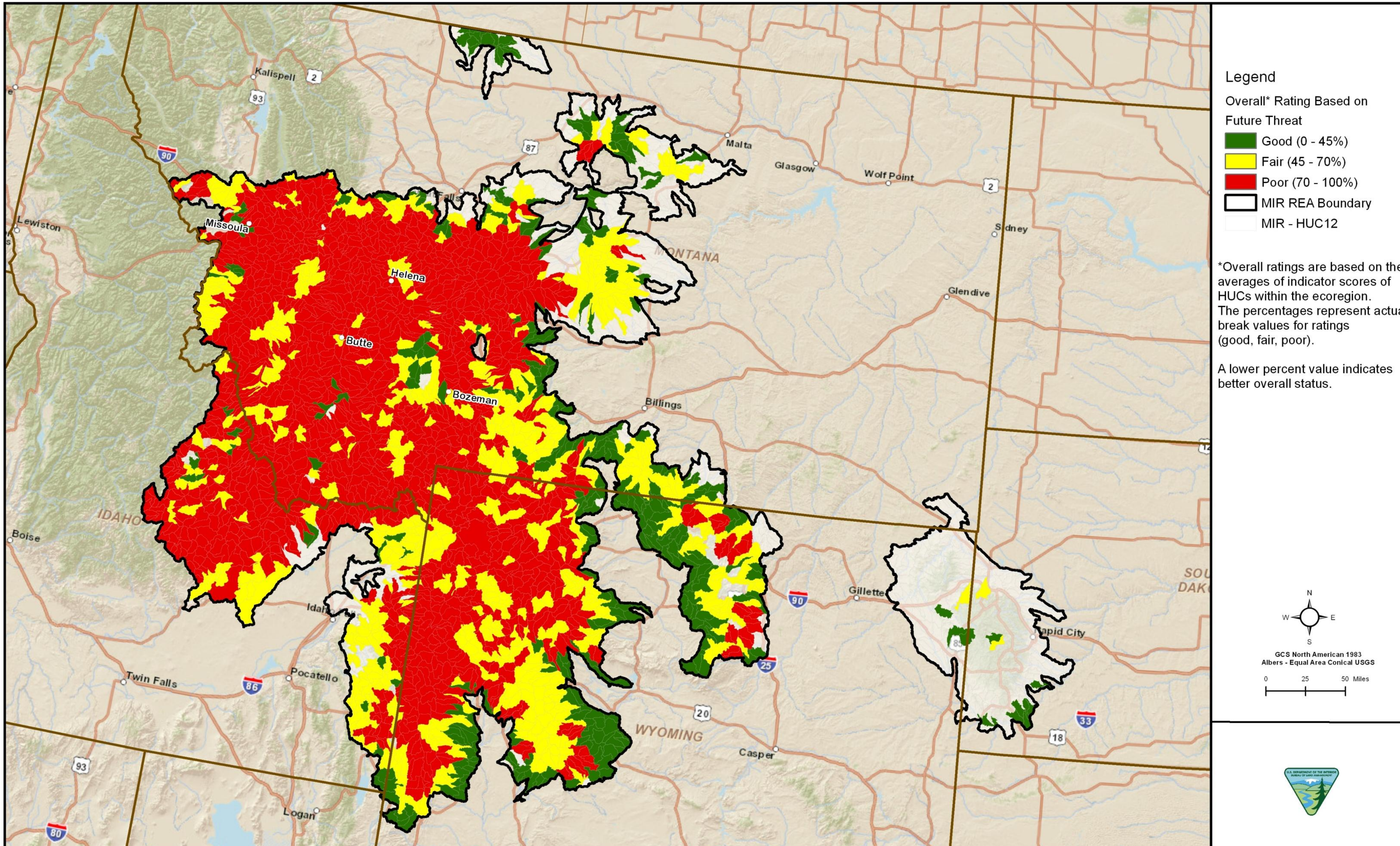

Figure E-8-15. Five-Needle Pine Future Threats by 6th Level Hydrologic Unit Code