



FINAL MEMORANDUM I-3-C

MIDDLE ROCKIES

RAPID ECOREGIONAL ASSESSMENT



Prepared for:



Department of Interior
Bureau of Land Management
Rapid Ecological Assessments

Prepared by:



With Assistance From:



Dr. Dennis Ojima
Dr. Jeff Hicke
Dr. Jesse Logan
Dr. Tania Schoennagel
Dr. Cameron Aldridge

Dr. Jim Graham
Dr. Michael Coughenour
Mr. Peter Lesica
Mr. Don Childress

October 26, 2011

This document was submitted for review and discussion to the Bureau of Land Management and does not reflect BLM policies or decisions.

TABLE OF CONTENTS

<u>SECTION</u>	<u>PAGE</u>
LIST OF TABLES	ii
LIST OF FIGURES.....	iii
LIST OF APPENDICES	iii
LIST OF ACRONYMS AND ABBREVIATIONS	iv
EXECUTIVE SUMMARY	ES-1
1.0 INTRODUCTION	1
1.1 RAPID ECOREGIONAL ASSESSMENT	1
1.2 ECOREGION	3
2.0 CONSERVATION ELEMENT MODELS	5
2.1 KEY CRITERIA FOR MODEL DEVELOPMENT	5
2.2 CONCEPTUAL ECOLOGICAL MODELS	7
2.2.1 System-Level Conceptual Models.....	8
2.2.2 Key Ecological Attributes and GIS Process Models	10
3.0 CHANGE AGENTS	13
3.1 PRIMARY CHANGE AGENTS	13
3.1.1 Wildfire	13
3.1.2 Climate Change	16
3.1.3 Vulnerability Assessment	20
3.1.4 Development	21
3.1.5 Invasive Species	23
3.1.6 Insect Outbreaks and Disease	28
4.0 CONSERVATION ELEMENTS	33
4.1 COARSE-FILTER CONSERVATION ELEMENTS.....	33
4.1.1 Coarse-Filter Conservation Element Distribution Data and Mapping	34
4.2 FINE-FILTER CONSERVATION ELEMENTS.....	34
4.2.1 Fine-Filter Distribution Data and Mapping.....	35
4.3 STATUS AND POTENTIAL FUTURE RISK ANALYSIS	35
4.4 CONSERVATION ELEMENT ASSESSMENT EXAMPLES	37
4.4.1 Five-Needle Pine Assemblage	37
4.4.2 Greater Sage-Grouse.....	44
4.4.3 Golden Eagle	52
4.5 ECOLOGICAL INTEGRITY ASSESSMENT	58
4.5.1 Ecological Integrity Assessment Framework.....	58
4.5.2 Application to Conservation Elements.....	65
5.0 RECOMMENDED MODELS, METHODS, AND TOOLS FOR THE RAPID ECOREGIONAL ASSESSMENT ANALYSIS	69

TABLE OF CONTENTS (Continued)

<u>SECTION</u>	<u>PAGE</u>
5.1 SCALE AND SCOPE	69
5.1.1 Spatial Scales	69
5.1.2 Time Horizons	69
5.2 STATISTICAL APPROACHES (E.G., MULTIVARIATE, LOGISTIC, OR GLM ANALYSES)	73
5.2.1 Introduction	73
5.2.2 Potential Statistical Analyses	74
5.3 DECISION-SUPPORT MODELS	75
5.3.1 Multi-Criteria Evaluation	75
5.3.2 Spatial Analytical Tools	75
6.0 REFERENCES	77

LIST OF TABLES

<u>NUMBER</u>	<u>PAGE</u>
Table 1.1-1. REA Phases and Tasks	1
Table 1.1-2. Middle Rockies Ecoregion Conservation Elements	1
Table 3.1-1. Change Agents Selected for the Middle Rockies	13
Table 3.1-2. Expanded Change Agents and Potential Effects Related to Habitat Loss and Disturbance	24
Table 4.1-1. Middle Rockies Coarse-Filter CEs	33
Table 4.2-1. Fine-Filter CEs for the Middle Rockies Ecoregion	34
Table 4.4-1. Preliminary Listing of Attributes, Indicators, and Metrics for the Five-Needle Pine Assemblage	41
Table 4.4-2. Data Needs and Availability for the Five-Needle Pine Assemblage	43
Table 4.4-3. Greater Sage-Grouse Ecological Attributes, Indicators, and Metrics	47
Table 4.4-4. Data Needs and Availability for the Greater Sage-Grouse	50
Table 4.4-5. Golden Eagle Attributes, Indicators, and Metrics	55
Table 4.4-6. Data Needs and Availability for the Golden Eagle	57
Table 4.5-1. Integration of Indicator Information on the Status of the Conservation Element	59
Table 4.5-2. Example of an Ecological Integrity Scorecard for a Hypothetical Wetland System	60
Table 4.5-3. Example of an Ecological Integrity Table for Wetland Ecosystems	63
Table 4.5-4. Metrics and Rating Criteria for the Rocky Mountain Lower Montane Riparian Woodland and Shrubland System	64
Table 4.5-5. Landscape Context Key Ecological Attribute Indicator Rating Calculation	64

LIST OF FIGURES

<u>NUMBER</u>		<u>PAGE</u>
Figure 1.2-1.	Extent of the Middle Rockies Ecoregion	3
Figure 2.2-1.	Example of Conceptual Ecological Models.....	8
Figure 2.2-2.	Example of System-Level Conceptual Model	9
Figure 2.2-3.	Example GIS Process Model.....	12
Figure 3.1-1.	Mean Fire-Free Interval Along a Temperature–Moisture Gradient (after Martin and Sapsis 1991).....	14
Figure 3.1-2.	Mountain Pine Beetle Conceptual Ecological Model	31
Figure 3.1-3.	Chronic Wasting Disease Among Free-Ranging Cervids by County, United States, April 2011	32
Figure 4.4-1.	Five-Needle Pine Ecological Process Model	38
Figure 4.4-2.	Five-Needle Pine System-Level Conceptual Model	39
Figure 4.4-3.	Greater Sage-Grouse Ecological Process Model	45
Figure 4.4-4.	Great Sage Grouse Assemblage System-Level Conceptual Model.....	46
Figure 4.4-5.	Golden Eagle Ecological Process Model.....	53
Figure 4.4-6.	Golden Eagle System-Level Conceptual Model	54
Figure 5.1-1.	Example Euclidean Distance Proximity Analysis on Feature Locations	71
Figure 5.1-2.	Example of Inverse Distance Weighting on Feature Locations	72

LIST OF APPENDICES

Appendix 1	Middle Rockies GAP Vegetation Systems
Appendix 2	Ecological Integrity Assessment

LIST OF ACRONYMS AND ABBREVIATIONS

ADS	Aerial Detection Surveys
AMT	Assessment Management Team
BLM	Bureau of Land Management
CA	change agent
CAPS	Crucial Areas Planning System
CE	conservation element
CWD	chronic wasting disease
EI	ecological integrity
EIAF	Ecological Integrity Assessment Framework
EMDS	Ecosystem Management Decision Support
EPA	Environmental protection Agency
ESA	Endangered Species Act
FCC	Federal Communications Commission
FLPMA	Federal Land Policy and Management Act
FMAR	forest mortality assessment report
FRCC	fire regime condition class
GAP	Gap Analysis Program
GCC	global climate change
GCM	Global Climate Model
GFDL	Geophysical Fluid Dynamic Laboratory
GIS	geographic information system
GNLCC	Great Northern Landscape Conservation Cooperative
HUC	Hydrologic Unit Code
IDW	inverse distance weighted
KEA	key ecological attributes
km	kilometer
km ²	square kilometers
LCC	Landscape Conservation Cooperative
LCCS	Land Cover Classification System
LCM	Landscape Condition Model
MCE	Multi-Criteria Evaluation
mi ²	square miles
MFISH	Montana Fisheries Information System
MPB	mountain pine beetle
MQ	management question
NCEP	National Centers for Environmental Protection
NS	NatureServe
NSCCVI	NatureServe Climate Change Vulnerability Index
NVCS	National Vegetation Classification System
PRISM	Parameter-elevation Regressions on Independent Slopes Model
REA	Rapid Ecoregional Assessment
RegCM	USGS Regional Climate Model
SAIC	Science Applications International Corporation
SLCLASS	succession classes
SGCN	Species of Greatest Conservation Need
SOW	statement of work
TNC	The Nature Conservancy

LIST OF ACRONYMS (Continued)

USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
VDDT	Vegetation Dynamics Development Tool
WLC	weighted linear combination
WPBR	white pine blister rust
WNV	West Nile virus

THIS PAGE INTENTIONALLY LEFT BLANK

EXECUTIVE SUMMARY

This memo summarizes the work completed as part of Phase I Task 3 of the Rapid Ecoregional Assessment (REA) for the Middle Rockies ecoregion. As stated in the Bureau of Land Management (BLM) Statement of Work (SOW), the objective of Task 3 is to identify, evaluate, and recommend various conceptual models, methods, and tools for addressing the management questions (MQs) identified during Task 1 of this Phase using the datasets that were discussed at Assessment Management Team (AMT) Workshop 2.

The identification of conceptual models, methods and tools that will answer the MQs requires an understanding of the ecological requirements of each of the Conservation Elements (CEs) and an understanding of which Change Agents (CAs) have the potential to affect the CE. In addition, due to recent emphasis on evaluating the potential impacts of climate change on western ecosystems new information on models and tools that could assist with answering MQs is being published on a weekly basis. The Great Northern Landscape Conservation Cooperative (GNLCC) funded studies on predicting climate change effects on aquatic ecosystems at the landscape scale and a study looking at habitat connectivity for the state of Washington and adjacent lands. This study included the development of geographic information system (GIS) tools to support manager's decision making process for conservation connectivity. In addition the GNLCC FY2011 funding priorities included: habitat connectivity, aquatic integration and climate. The state of Washington recently conducted a landscape level GIS study identifying and evaluating habitat connectivity and overall landscape integrity. Montana is currently using the same methodology and GIS tools used by Washington to investigate terrestrial integrity. After extensive research and discussion with these agencies, cooperatives and states, Science Applications International Corporation (SAIC) determined that the best approach is to be consistent with those entities and will attempt to use the same GIS based multi-criteria evaluation (MCE) methodology where it is available. It is important to note that many of these projects will not be complete in time for completion of this REA but it is also important that coordination of efforts occur so that Federal resources are not utilized to develop conflicting answers to the same MQs.

In order to answer the MQs, it is important to understand the ecological requirements of the species, assemblage or community being evaluated. This process started with the development of conceptual ecological models for each of the CEs. In this memo, we present examples of standardized conceptual ecological models for three of the CEs identified by the AMT at Workshop 1. Construction of these models began with a comprehensive literature review of CE ecological requirements and response of the CE to various CAs. Some of the conceptual ecological models included a variety of sub-models that illustrate the affect of different CAs on the CE. Once the models were completed by the various ecologists, they were sent out to various reviewers for a peer review process. Upon completion of the peer review these models were standardized into system models that are contained in Section 4.0 of this memo.

For the purposes of this memo, we refer to conceptual ecological models as those diagrammatic representations of resource values (as defined in the SOW glossary) that illustrate causal relationships between the CE and the CAs.

Examples of these models and the associated text are included in Section 4.0 of this memo. The purpose of the development of these models was to diagrammatically illustrate the ecological requirements of the CE and where possible identify direct, compounding and synergistic affects of the CAs. It is anticipated that these models will guide the development of the REA output products.

Upon completion of the conceptual ecological models, it was necessary to identify the key ecological attributes (KEAs) for each CE that can be spatially represented and ranked. For some species, the KEAs are well known from historical and recent research. For others, KEAs may still be in question depending on the geographic location of the CE on the landscape. However, the principles behind selection of the KEAs were developed after the protocols of Parrish et al. (2003) which were elaborated upon by Unnasch et al. (2008). The preliminary list of KEAs for the three example CEs are included as Tables 4.4-1, 4.4-3, and 4.4-5.

The next step was to review the datasets that were identified during Task 2 that could provide spatial data for each of the KEAs identified in the previous step. If datasets are incomplete or not available, the KEAs will require re-evaluation to determine if surrogate attributes can be utilized where data might be available. The datasets identified to represent the KEAs for each CE are contained in Tables 4.4-2, 4.4-4, and 4.4-6.

The final step of Task 3 was to develop the GIS process models. The GIS process models are diagrammatic illustrations of geospatial processes that the datasets will undergo to answer the MQs. The GIS process models could also be labeled as geospatial instructions or workflow processes that will be conducted to answer the MQs and show the geographic locations of “the best of the best”. For the purpose of keeping this memo short, the GIS process models were not included.

The GIS process models will not only function to generate datasets to depict the geographic location of information but will also have the utility of allowing BLM geospatial analysts to induce various scenarios on the landscape to complete “what if” scenarios. This theme has been the common thread throughout our REA process thus far. More specifically, although we recognize that everything we do as part of the REA process must be grounded in sound science, we also recognize that the tools, models and information developed must be easily understood and readily useable by BLM field personnel. If the information is not easily understood by field managers, it is not likely that the end results will be used at all. This common theme of clarity and usability will be carried forward into all future phases of the REA, as will continued coordination with state partners, LCCs, agencies or other entities.

If this process were to be repeated, we would suggest to completion of the system-level conceptual ecological models and identification of the KEAs before the dataset identification and evaluation task. Completion of Phase I in this order would focus the data identification task on the datasets necessary to represent the KEAs that will be used to geospatially represent the information necessary to answer the MQs. In addition, the identification of datasets that represent the KEAs will assist with determining the range of variability or scoring/ranking regionally significant resources across the ecoregion.

As part of this process, our geospatial analysts evaluated a variety of tools, methods and models. Much of this information is explained in Section 2.2 but also in Sections 5.1, 5.2 and 5.3. The implementation of GIS has allowed ecologists and field managers to manipulate data in ways that would have never been perceived as recent as twenty

years ago. Several proximity analysis tools including, Euclidian distance analysis, distance decay, and inverse distance weighting will be used combined with geoprocessing tools such as, buffer, intersect, overlay, merge and union used by geospatial analysts on a daily basis. It is inherent that assumptions will be required throughout this process as some of the identified data sources were never developed to be used to complete some of the analysis that are being proposed for today.

The other focus of this effort has been to identify KEAs and associated datasets that can be quantified, ranked or scored to determine relative range of variability's for the purposes of determining regional significance or assessing a summary or ecological integrity (EI) status. The BLM and United States Geological Survey (USGS) issued the Final Index of EI clarification-bullets document. This document provided a very generic set of bullet-point guidelines for the development of an index to EI. Our evaluation of various approaches to assessing summary status or EI is contained in Section 4.5. Our approach to EI is summarized in Appendix 2.

THIS PAGE INTENTIONALLY LEFT BLANK

1.0 INTRODUCTION

1.1 RAPID ECOREGIONAL ASSESSMENT

REA is the BLM's first step toward a broader initiative to systematically develop and incorporate landscape-scale information into the evaluation and eventual management of public land resources. The spatial extent of an REA encompasses an ecoregion to more fully understand ecological conditions and trends; natural and human influences; and opportunities for resource conservation, restoration, and development. REAs also identify important resource values and patterns of environmental change that may not be evident when evaluating smaller, local land areas. REAs describe and map areas of high ecological value and then assess the potential of these values to be affected by environmental CAs.

The REA process is organized into phases with specific tasks in each phase (Table 1.1-1). Phase I includes all of the tasks that are required prior to conducting the REA: refinement of MQs, and selection of CEs and CAs. Task 2 of Phase I includes the identification and evaluation of potential data to be used for the Middle Rockies REA and task 3 includes the identification, evaluation and recommendation of models, methods, and tools that will be used to help answer and address the MQs identified in the first task of this phase. The final task of this phase is to complete a work plan that will identify how the REA will be completed. Phase II includes: analysis of the data relative to the identified CAs and CEs, documentation of the results, and culminates in the REA document which will guide BLM and other land managers in developing and prioritizing planning and management strategies.

Table 1.1-1. REA Phases and Tasks

Phase	Task #	Product
I. Pre-assessment	1	Refine MQs, CEs, and CAs. Provide conceptual ecoregion models.
	2	Identify and recommend datasets for analysis
	3	Identify and recommend analytical models and tools
	4	Prepare REA work plan
II. Assessment	1	Synthesize datasets
	2	Conduct analyses and generate findings
	3	Prepare REA report, maps, and supporting documents

Bold indicates current phase

The CEs to be evaluated in Phase II are listed in Table 1.1-2.

Table 1.1-2. Middle Rockies Ecoregion Conservation Elements

Conservation Element (CE)	Species Included (if assemblage)
Big Game Assemblage	Elk, mule deer, bighorn sheep and pronghorn.
Coldwater Fish Assemblage	Spring/summer Chinook salmon, summer steelhead, sockeye salmon, fluvial Arctic grayling, bull trout, westslope cutthroat trout, and Yellowstone cutthroat trout.

Table 1.1-2. Middle Rockies Ecoregion Conservation Elements (Continued)

Conservation Element (CE)	Species Included (if assemblage)
Five-Needle Pine Assemblage	Whitebark pine and limber pine.
Forest Carnivore Assemblage	American marten, wolverine, and Canada lynx.
Golden Eagle	
Grizzly Bear	
Greater Sage-Grouse	
Evergreen Forest Woodland	Rocky Mountain Lodgepole Pine Forest, Rocky Mountain Subalpine Spruce-Fir Forest and Woodland (Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland and Rocky Mountain Subalpine Spruce-Fir Forest and Woodland), Middle Rocky Mountain Montane Douglas-fir Forest and Woodland, Northwestern Great Plains – Black Hills Ponderosa Pine Woodland and Savanna, Other
Deciduous Forest and Woodland	Aspen (Rocky Mountain Aspen Forest and Woodland), Other
Riparian	Riparian
Shrubland	Inter-Mountain Basins Sagebrush (Inter-Mountain Basins Montane Sagebrush Steppe, Inter-Mountain Basins Big Sagebrush Steppe, Inter-Mountain Basins Big Sagebrush Shrubland, and Wyoming Basins Dwarf Sagebrush Shrubland and Steppe), Other
Grasslands	Northwestern Great Plains Mixedgrass Prairie, Northern Rocky Mountain Lower Montane, Foothill and Valley Grassland, Other

This memorandum summarizes efforts completed for Phase I Task 3 (Table 1.1-1). Integral to completion of this task was the development of examples of conceptual ecological models for some CEs identified as part of Task 1. The conceptual ecological models relate each CE to other CEs, other resources, and CAs within the ecoregion. It is anticipated that these models will help to guide the development of output products. Once the conceptual ecological models were developed, the next step was to develop GIS process models. It is important to note that a variety of assumptions are required in the development of the models and to the extent practicable, these assumptions will be based on the literature relevant to the various assemblages, communities or CEs. In addition, the categorization or scoring of data will sometimes be based on best professional judgment and expert knowledge. SAIC will work closely with the AMT to document the assumptions and decisions that are based on expert knowledge or best professional judgment. Coordination of the development of spatial data is a common theme that the SAIC Team will continue to focus on through the REA process. We recognize and appreciate the fact that BLM state partners and others have developed or are in the process of developing spatial data similar to what will be developed from the REA. Further, as directed by the AMT, we will continue to coordinate with BLM partners on the development of new datasets and the use of existing datasets so that the MQs can be answered in a manner consistent with the state partners and the REA process.

1.2 ECOREGION

The Middle Rockies ecoregion includes portions of western Montana and Wyoming, eastern Idaho, and several small, non-contiguous areas in central Montana, northeastern Wyoming, and western South Dakota (Figure 1.2-1). The spatial boundary for this REA will include this ecoregion (Middle Rockies Level III Ecoregion – 6.2.10), as defined by the Commission for Environmental Cooperation (2006), plus a buffer consisting of those 5th level Hydrologic Unit Code (HUC) watersheds that overlap the ecoregion boundary. The purpose of the buffer is to help ensure a seamless boundary between mapped layers generated for REAs in neighboring regions, and to avoid problems associated with “edge effects” during GIS analyses. With the buffer area, the extent of the Middle Rockies REA will be approximately 105,000 square miles (mi²) (271,949 square kilometers [km²]).

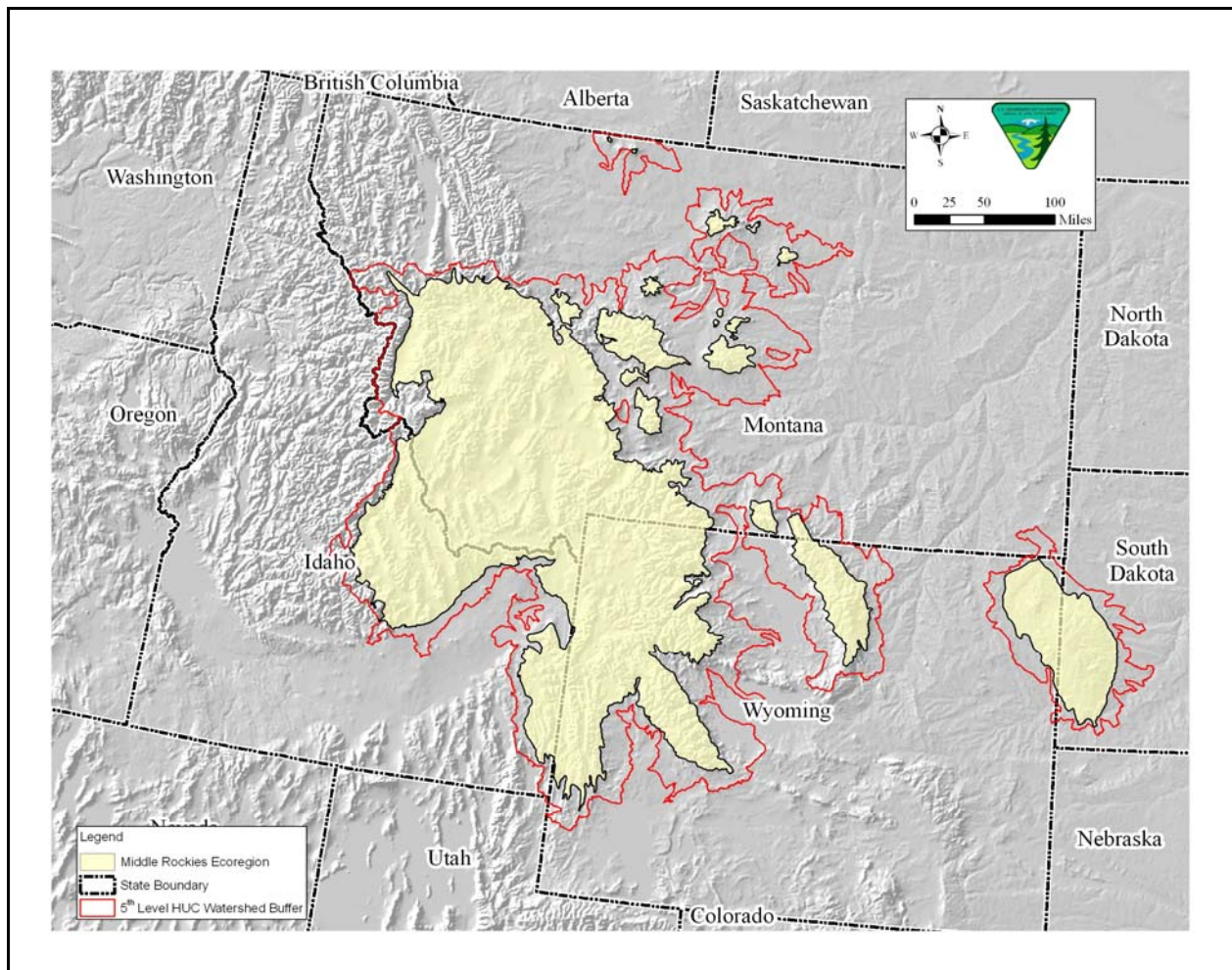


Figure 1.2-1. Extent of the Middle Rockies Ecoregion

THIS PAGE INTENTIONALLY LEFT BLANK

2.0 CONSERVATION ELEMENT MODELS

This section presents concepts related to the hierarchical structure of our approach to modeling CEs that will assist with the development of answers to the MQs. Our first objective was to develop a comprehensive organization that specifies the logic, sequence and tools used in the REA. In developing our organizational strategy, the SAIC team took guidance from the BLM's recent "Lessons Learned Report: Ecoregional Assessment Processes" (Braake and McCaffrey 2010). This effort offers important principles for BLM and partners in the REA process to develop an improved and more consistent approach to ecoregional assessments. An important recommendation in developing REAs is that they be "approached systematically, with the understanding that initial assessments will be periodically updated to include new science and the adaptive management results" (Braake and McCaffrey 2010). Thus the SAIC team developed a systematic hierarchical approach, which incorporates sufficient flexibility to accommodate additional data and insights as new information becomes available.

SAIC recognizes that there is heterogeneity in the quantity, reliability (*sensu* Romesburg 1981, Murphy and Noon 1992) and degree of uncertainty associated with individual data sets. Our first priority was to develop models that are grounded in sound science and capture and address the complex dynamics of the system across time and space to the most detailed level of current knowledge. However, we are also aware of the limitations of such high-resolution models (e.g., data gaps, hypothetical relationships, uncertainty regarding the expected effects or pathways).

As an additional priority, we focused on synthesizing existing information and producing models that incorporate relevant available information, but were not controlled by data gaps, hypotheses or uncertainty. While models developed at this scale are designed to reduce the reliance on "imperfect" knowledge and uncertainty, they also offer the opportunity to be adaptive and relevant for management decisions at the landscape scale. Future updates of these models must include refined or new scientific information and could involve the introduction of additional components. The models developed as part of this task will guide the development of output products and analysis of landscape-scale conditions. As a first step to model development, a variety of criteria were developed. These criteria are listed below.

2.1 KEY CRITERIA FOR MODEL DEVELOPMENT

The SAIC team, AMT members and workshop participants jointly developed a set of guiding principles that inform the utility of conceptual models in the REA process. In designing the conceptual models, the SAIC team considered the following criteria:

- Does it help to answer management questions?

Our conceptual models were specifically constructed to help answer the relevant MQs and to provide meaningful metrics for assessing EI at the landscape-scale. MQs ensure that agency and stakeholder mandates, missions and values are respected and that the manager's and the scientist's concerns are integrated into a clear framework. MQs provide an important filtering device when deciding what information is relevant and appropriate. The SAIC team examined the applicable MQs for each CE and scored each model for its contribution to resolving relevant MQs.

- Does it use reliable and available existing data?

The Federal Land Policy and Management Act of 1976 (FLPMA) directs BLM to use science in its decision-making process. SAIC relied on an extensive review of the current scientific literature, in concert with the professional inputs from workshop participants, SAIC ecologists, and the scientific reviewers. For the REA process, SAIC geospatial analysts are performing a comprehensive standard data evaluation, identifying gaps within the data and documenting the associated weaknesses of the individual datasets. Each dataset is compared and documented for quality and usability against the 11 BLM criteria identified from the 2008 DOI Data Quality Management Guide. All data will be reviewed in a GIS to determine the geographic extent, coverage and scale of the data relative to the ecoregion extent. Spatial accuracy and extent of coverage are then determined through the use of two specific established GIS datasets. In addition to observable spatial accuracy, attribute tables were evaluated to determine if attribute information is relevant for that particular dataset. Finally each dataset that was acquired throughout this process was examined to determine the quality of the associated metadata.

- Is it easy to understand?

Because conceptual models are designed to communicate complex issues, we felt they needed to be clear and easy to understand. We employed a consistent notation and diagrammatical layout to all models, to ensure that they convey the essential information quickly and requiring a minimal of specialized knowledge or familiarity with the particular system. We also provide extensive narrative to document the scientific basis for each conceptual model.

- Does it meet constraints on time and costs of implementation?

REAs are intended as relatively short (12-18 month) processes that are updated frequently (e.g., every 5 years) to maximize flexibility. In most cases, the narrow project horizon does not facilitate extensive data mining efforts (e.g., combining data from multiple sources) or collection of new information. Cost of implementation was another important factor when developing conceptual models, especially where uncertainty about ecosystems could result in very costly restoration actions. We maintained a strict focus on restoration potential based on the degree of departure from historic conditions in our assessments, to ensure that restoration options could be appropriately prioritized.

- Is it applicable and useful for BLM managers?

Although REAs are top-down efforts for developing ecoregional directions, scientific models do not make decisions. Our models and analysis results will supply important information on which decisions can be made, but we agree with the Lessons-Learned document (Braake and McCaffrey 2010) that “science should not tell the manager what to do”. Throughout this effort, SAIC is conscientious about providing informative products that are easily accessible and communicated to a wide array of audiences and which are highly relevant to management decisions at the appropriate scales.

2.2 CONCEPTUAL ECOLOGICAL MODELS

A conceptual ecological model can be thought of as a map of concepts and their relationships. Conceptual models help to organize the existing knowledge and assumptions about a particular system, and thus aid in defining the scope and scale of the analysis. They are generally constructed as diagrams with shapes that represent the main components (concepts) of the system, and arrows that identify flows of material and information. They provide linkages of stressors to ecological endpoints, and are associated with text describing the key elements of the models.

In order to answer the MQs identified during Task 1, it is important to understand the ecological requirements of the CE being evaluated. Construction of the original set of conceptual ecological models began with an exhaustive literature review of CE ecological requirements and the CAs that have the potential to affect the CE. In addition, if models for CEs have been previously developed by state partners, agencies or other entities, this information was evaluated as part of this initial step. Some of the original models included sub-models which illustrate the interaction of multiple CAs on the CE. An example of two of these models is contained in Figure 2.2-1.

The main function of the conceptual ecological models in the REA process is as tools to discern what attributes will be important to map and to guide and direct the in-depth analysis of management options and their ecological implications across the landscape. Maintaining the context of specific MQs and future scenarios is crucial. Furthermore, conceptual ecological models may also be used to: a) explore indirect pathways for ecological effects; b) identify sensitive linkages which may be critical to assessing EI; c) identify and characterize existing uncertainties; and d) identify important data gaps. It is important to note that the conceptual ecological models are not designed to show ranges of variability or uncertainty for species, communities or ecosystems.

Conceptual ecological models require few resources but can be critical in defining essential questions (Pavao-Zuckerman 2000). This facilitates an honest assessment of limitations and provides a direction for future improvements. They furthermore provide a useful basis for discussion among scientists, stakeholders and managers. By graphically formalizing complex issues and dynamics, conceptual models are an ideal method to communicate across traditional discipline boundaries (Allen and Hoekstra 1992) which can enhance broad acceptance of methodology and results of ecoregional assessments.

The examples of the system-level conceptual ecological models presented in this memorandum are essentially “stressor” models, which depict the effects that environmental stress (i.e., CAs) imposes on key ecosystem components (CEs). The SAIC team adopted the hierarchical approach of nested conceptual models ranging from an ecosystem-wide, comprehensive view of ecological processes to a detailed depiction of how geospatial information is processed to derive EI values for landscape elements. Our approach logically progresses from models that describe components and relationships at the ecoregion level (See Memo 1) to models specific to individual CEs, and finally, to a specific sequence of geoprocessing steps which will provide the input (metrics) for determining regional significance or completion of the EI or summary assessment (Figure 2.2-1).

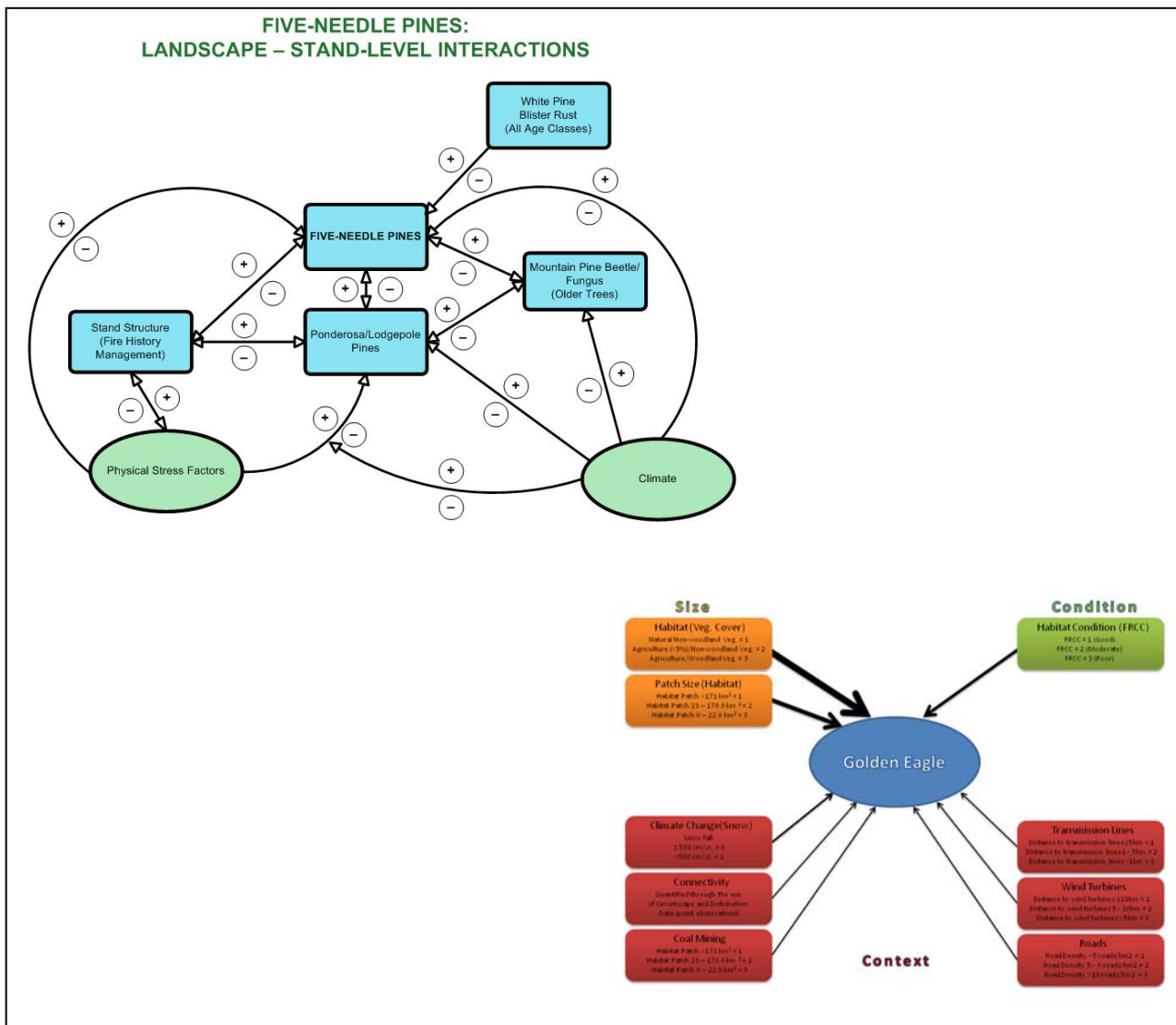


Figure 2.2-1. Example of Conceptual Ecological Models

This hierarchy is influenced by a) the best available science and ecological understanding of species life history, CAs and ecological system dynamics, b), the MQs developed and refined under Phase 1, Task 2, and c) the availability and applicability of geospatial data. Within this hierarchical structure, we designed the conceptual ecological models and GIS process models. Both of which are discussed in the following sections.

2.2.1 System-Level Conceptual Models

Based on the conceptual ecological models, system-level conceptual models ("system models") were developed to depict key interrelationships between structural ecosystem components (e.g., vegetation communities), system drivers (e.g. CAs) and various CEs (Figure 2.2-2).

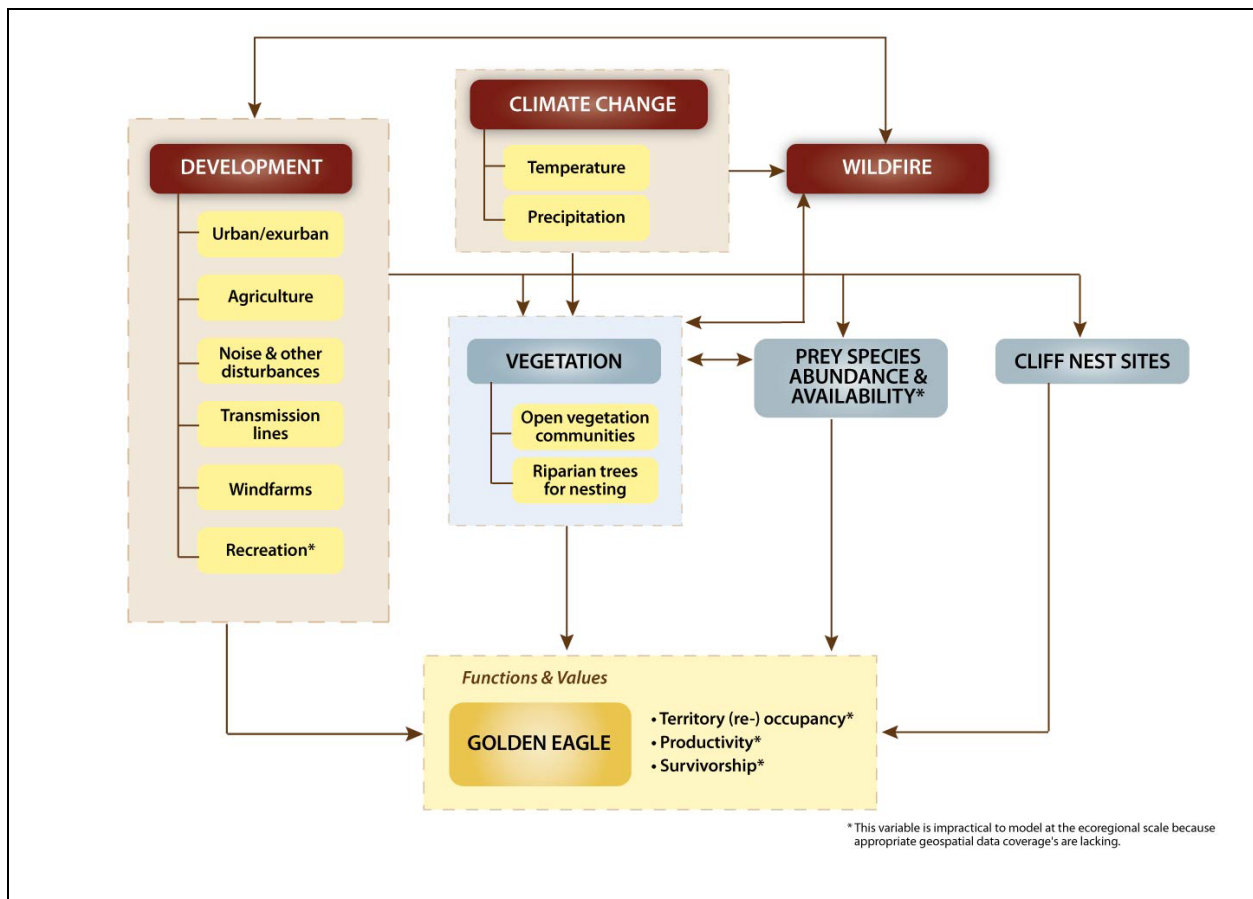


Figure 2.2-2. Example of System-Level Conceptual Model

System models are designed to contain a great variety of detail, specify potential effects and describe assumptions, and as such, provide the ecological framework for lower level models and analysis. The goal of these models is to qualitatively document essential processes and causal relationships that form the dynamics of communities at the landscape scale. In these models, arrows represent causal relationships or assumptions about a CA, while boxes represent ecosystem components and their attributes (Figure 2.2-2). Mapping important ecological relationships in this way provides the context and scope for assessing EI (Karr 1991, Gentile et al. 2001). Following Gentile et al. (2001) we present system models as first approximations which are constructed to capture the current scientific understanding based on a variety of inputs, ranging from replicated, peer reviewed scientific reports, to local expert knowledge. As new information is acquired or as other scientists add new insights, these system models must be continually updated to represent the best available science.

System models were designed to incorporate available and ecologically relevant information, regardless of whether this information could inform the final EI analysis or be presented in a map format or not.

System models may contain sub-models or nested structures to reflect the dynamics within a given ecosystem component. For example, vegetation communities may respond differently to fire, depending on their seral stage and past fire history. Semiarid vegetation dynamics are well document and often involve multiple pathways to change (Westoby et al. 1989). Therefore, the SAIC team incorporated nested structures wherever appropriate. Other nested structures may exist in the form of ecological

feedback loops (e.g., predator prey relationships, source-sink dynamics, epizootic diseases and disease vectors, or where biological and physical interactions occurred at different spatial or functional scales).

2.2.2 Key Ecological Attributes and GIS Process Models

Upon completion of the system models, it was important to identify the KEAs for each CE that can be spatially represented and ranked. For some species, the KEAs are well known from historical and recent research. For others, KEAs may still be in question depending on the geographic location of the CE on the landscape. The principles behind selection of the KEAs that were developed after Parrish et al. (2003) and elaborated upon by Unnasch et al. (2008): “KEAs of a resource include:

- Critical or dominant characteristics of the resource, such as specific characteristics of (a) demographic or taxonomic composition; (b) functional composition; (c) spatial structure; (d) range or extent; and
- Critical biological and ecological processes and characteristics of the environment that: (a) limit the regional or local spatial distribution of the resource; (b) exert pivotal causal influence on other characteristics; (c) drive temporal variation in the resource’s structure, composition, and distribution; (d) contribute significantly to the ability of the resource to resist change in the face of environmental disturbances or to recover following a disturbance; or (e) determine the sensitivity of the resource to human impacts.”

KEAs and their measurable indicators are listed in tables that accompany each of the example conceptual models in Section 2.0. Applications of attributes and indicators in EI assessments are described in greater detail in Section 4.0, but in this section, we describe their use in formulating data inputs into GIS process models. Unnasch et al. (2008) recommended that three factors be considered when selecting attributes:

- “**Size** refers to attributes related to the numerical size and/or geographic extent of the focal ecological resource” (CE in this REA). An example would be the area within which a particular ecological system occurs.
- “**Condition** refers to attributes related to biological composition, reproduction and health, and succession; critical ecological processes affecting biological structure, composition and interactions; and physical environmental features within the geographic scope of the focal ecological resource. Examples include species composition and variation, patch and succession dynamics in ecological systems, and ...disturbance regimes...”.
- “**Landscape Context** refers to both the spatial structure (spatial patterning and connectivity) of the landscape...and to critical processes and environmental features that affect the focal ecological resource from beyond its immediate geographic scope. Examples of the former include attributes of fragmentation, patchiness, and proximity or connectivity among habitats. Examples of the latter include... regional or larger-scale disturbances.”

Indicators are specific characteristics of the KEAs that can be individually measured, combined into a multi-metric index, or expressed as a frequency Unnasch et al. (2008). Indicators are:

- Easily measured in a reliable, repeatable, and accurate fashion.

- Unambiguously associated with ecological attributes.
- Sensitive to CAs or other stressors at relevant spatial and temporal scales.
- Comprehensive and complementary.
- Scientifically defensible and interpretable in common language.

Indicators in this REA will be developed primarily based on remotely sensed information, some of which has been previously field-calibrated. The CE KEA table also suggests appropriate metrics for each indicator and the type of rating scale that would be used for each indicator (e.g., presence/absence, or ranking within an appropriate range of variability for the attribute in question). Indicators will be the subject of geospatial modeling applications depicted in the GIS process models for each CE described in Section 2.0. Thus, the information in the KEA tables links conceptual modeling of the effects of CAs on CEs with the data manipulation steps depicted in the GIS process models. The attributes tables also provide the rating scales required for developing EI scorecards as described in Section 4.0.

The GIS process models were created by examining the system models and extracting key attributes that can be spatially represented. The GIS process models (Figure 2.2-3) outline the series of data transformations, intermediate outputs, and final analysis products. The blue ovals on the far left represent data sources such as the BLM linear features layer. The yellow squares represent data selected from the larger dataset (if a selection is required) such as selecting out types of roads from the BLM linear features layer dataset. The white boxes are GIS spatial operations that will be administered to the appropriate layers. These are usually union (overlay all data into one layer) or intersects (overlay all data only keeping data where common overlaps exists between the datasets). Green ovals represent intermediate datasets that will be used later to generate the final layers. An example of this would be development layers that are combined (unioned) together to form one intermediate layer representing areas influenced by development. The orange ovals are final output products. In some instances where Maxent modeling is implemented it can be used as a final output. It can also be an input layer to another final layer, such as a layer showing areas susceptible to change based on CAs and climate scenarios.

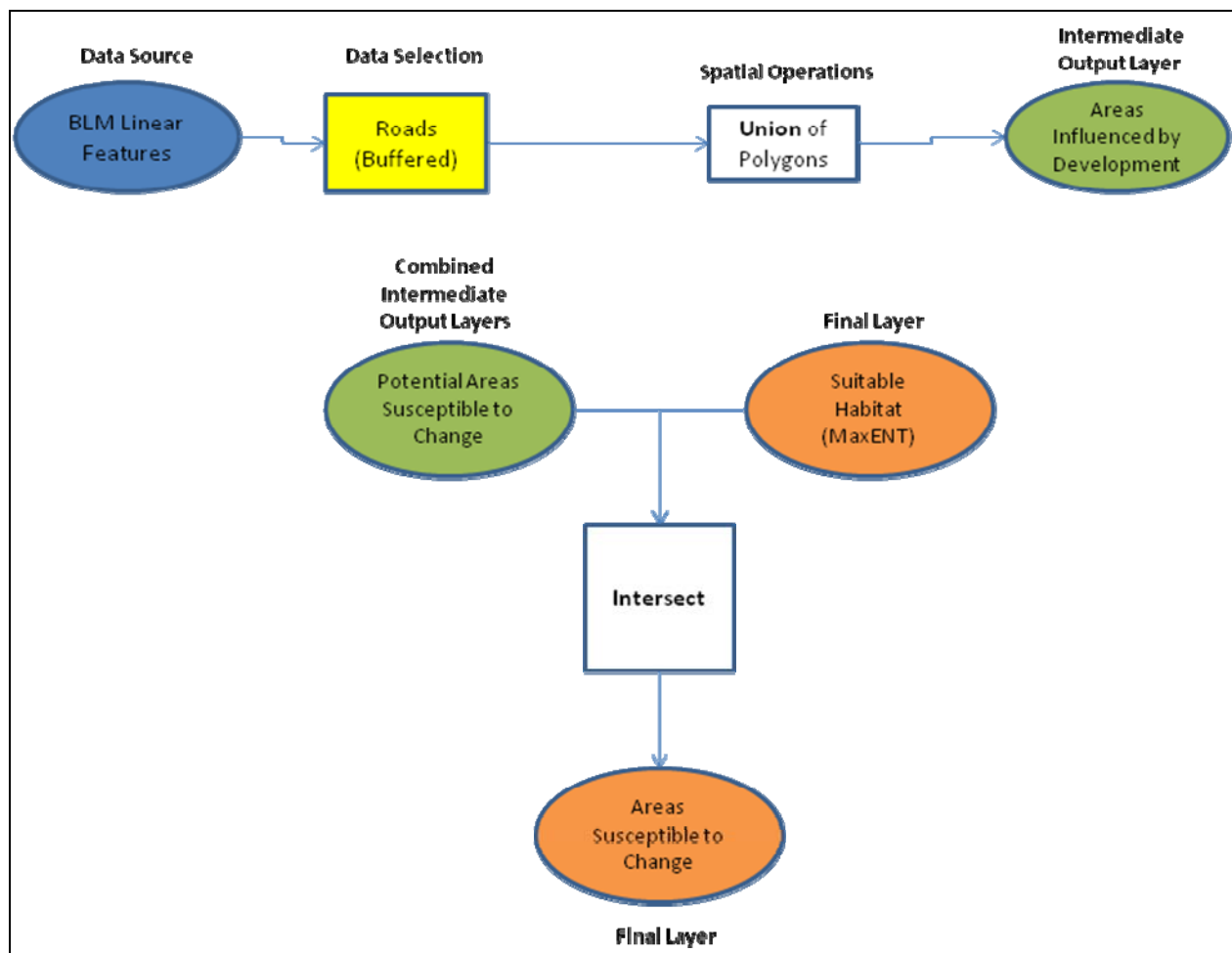


Figure 2.2-3. Example GIS Process Model

3.0 CHANGE AGENTS

3.1 PRIMARY CHANGE AGENTS

The initial CAs for this ecoregion were outlined by the AMT in the SOW. The REA process focuses on regionally significant CAs that operate and impact on large scales, not on a site-by-site basis. For the purpose of this analysis, CAs were divided into five categories (fire; invasive species; insect/diseases; climate; and development) (Table 3.1-1). Several of these categories were subsequently divided into subcategories, as shown below.

Table 3.1-1. Change Agents Selected for the Middle Rockies

Change Agents
Fire
Development
Urban and Exurban
Agricultural
Hydrological
Invasive Species
Terrestrial
Aquatic
Climate Change
Insect Outbreaks and Diseases

3.1.1 Wildfire

The Middle Rockies Ecoregion is highly diverse and encompasses large contrasts in latitude, elevation, climate, and fire ecology. This section provides some background on the ecology of fire, its importance to the disturbance regimes of landscapes and vegetation communities of the Middle Rockies ecoregion, and a description of how fire regimes are represented in the REA to develop vulnerability assessments and evaluate landscapes.

Fire is a key ecological process in western ecosystems (Baker 2009, Pyne 1992). Fire influences virtually all other ecosystem processes (Agee 1993, Dale et al. 2001), such as landscape patterns and species diversity (Swetnam and Betancourt 1997, Haire and McGarigal 2009), nutrient cycling, hydrology and erosion (Agee 1993), air quality (Sampson et al. 2000), plant ecology (Miller 2000) and the maintenance of wildlife habitats and biodiversity (Noss and Cooperrider 1994). Fire is strongly influenced by weather and climate, but also may in return affect climate feedbacks (Houghton and Hackler 2000, Westerling et al. 2006). Climate change and fire interactions include increased area burned (Flannigan et al. 2005), variability and frequency of extreme fire weather (Flannigan and Wotton 2001) and length of fire seasons (Wotton and Flannigan 1993). Insects and plant diseases often contribute to the occurrence and severity of fire by increasing fuels.

3.1.1.1 Historical Disturbance Regimes

Historic disturbance have shaped vegetation structure, species composition and spatial distribution across the landscape. In many western ecosystems, fire intervals depend on the type of vegetation (Martin and Sapsis 1991, Figure 3.1-1) with fire intervals being shortest in ponderosa pine forests and longest in spruce-fir forests and deserts. A natural fire regime describes the role fire would play across a landscape in the absence of modern human mechanical intervention, but including the influence of aboriginal burning (Agee 1993, Brown 1995).

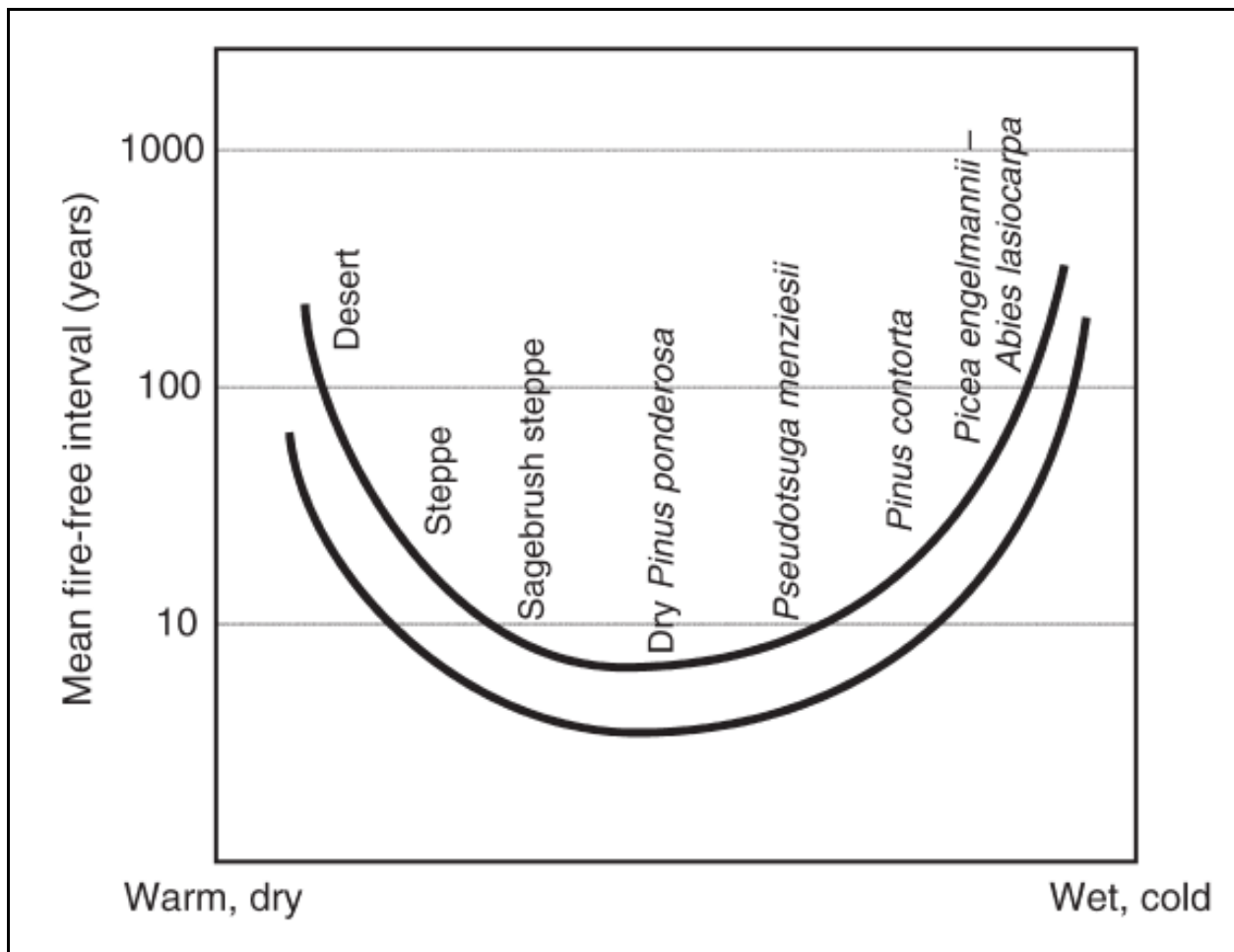


Figure 3.1-1. Mean Fire-Free Interval Along a Temperature–Moisture Gradient (after Martin and Sapsis 1991)

In grassland and shrub communities, short fire return intervals tend to favor dominance by grass species and often remove the majority of woody vegetation. In those communities longer fire return intervals allow shrub and woody vegetation to increase and become dominant or co-dominant with grass species. Due to the high frequency of fires, short interval fire regimes typically cause communities in a non-equilibrium state (i.e., fire maintained seral disclimax) and maintain a multi-age structure and spatial patchiness of vegetation conditions.

Forest communities in the Middle Rockies ecoregion characterized by long fire intervals are the subalpine forests (Engelmann spruce, subalpine fir, whitebark pine) and montane seral forests (lodgepole pine, aspen) where intervals between fires typically

range from 100 to 300 years. Sagebrush communities are generally thought of as being fire-tolerant, however, there is considerable debate among scientists on historic fire regimes in sagebrush communities. Especially xeric sagebrush environments, such as Wyoming big sagebrush (*A. tridentata* ssp. *wyomingensis*) communities may have historically had long fire intervals. Baker (2006) suggests that fire rotation in low sagebrush (*A. arbuscula*) may be a minimum of 325-450 years, 100-240 years in Wyoming big sagebrush and 70-200 years or more in mountain big sagebrush (*A. tridentata* ssp. *vaseyana*).

The relationship between fire regimes, landscape mosaics, and stand structural diversity is fairly well studied. In general, short fire-free intervals and low-severity fire regimes are associated with relatively small fires, creating small-grained landscape mosaics of patchy or multi-cohort communities with substantial vertical and horizontal structural diversity (e.g., low-elevation ponderosa pine). In contrast, long fire-free intervals and high-severity fire regimes are associated with relatively large fires, which may create even-aged conditions over large patches. Based on coarse-scale definitions for historical fire regimes developed by Hardy et al. (2001) and Schmidt et al. (2002) five natural fire regimes are classified based on average number of years between fires (fire frequency) combined with the severity (amount of replacement) of the fire on the dominant overstory vegetation (Barrett et al. 2010).

3.1.1.2 Human Impacts on Fire Regimes

For the Middle Rockies, the primary influence has been the suppression of fire for nearly 100 years. This 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 (structure, species composition, nutrient cycles, decomposition rates, evapotranspiration, soil temperatures, productivity and water-holding capacity, litter and duff layers, herbaceous forage for ungulates and wildlife cover), and landscape level ecosystem attributes (proportion of early seral stages), landscape homogeneity, patch diversity, patch size, contagion, insect and disease outbreaks, higher carbon emissions, and increase in drought.

3.1.1.3 Conditions Influencing Wildfire Events

3.1.1.3.1 Fire Weather

Most fires are ignited by lightning strikes during the summer months, with a peak occurrence in the second half of August (Bartlein et al. 2003). Lightning strikes are a major source of ignition of wildfires throughout the ecoregion. The number of days with lightning flashes ranges from 20-40 per year (Reap 1986), and dry lightning storms are more likely to ignite fires than those accompanied by extensive precipitation. Precipitation levels, temperature, relative humidity and wind speed are the primary factors influencing wildfire risk. Increased temperatures due to climate change could increase fire risk, which could compound existing fire risks (IPCC 2007). Climate change could also promote the rapid increase of diseases and pests that attack tree species (Shugart et al. 2003) and could result in greater fuel loads.

3.1.1.3.2 Fuels

Fuels are combustible materials comprised of both living and dead vegetation. Fuel types vary in their flammability and in the height of flames they promote. Wildland fuels

can also be described using vertical separation as ground, surface, ladder and aerial fuels. The LANDFIRE fuel loads data describe the composition and characteristics of both surface and canopy fuels.

3.1.1.3.3 Topography

Topography influences wildfire behavior largely by affecting fuel moisture (solar exposure) and air / oxygen movement. On slopes, warm air rises along the slope causing a draft which will cause wildfires to usually burn up-slope. The steeper the slope, the more rapidly the fire will burn up-slope (and more intensely). Steepness of the slope also results in more preheating of fuel in front of the fire and faster igniting of the fuel. Topography is explicitly modeled within LANDFIRE.

3.1.1.4 Fire Regime Condition Class

A fire regime condition class (FRCC, Barrett et al. 2010) characterizes the degree of departure from the historical fire regime, mostly due to human intervention in natural fire regimes. This departure results in changes to one (or more) of the following ecological components: (a) vegetation characteristics (species composition, structural stages, stand age, canopy closure, and mosaic pattern) and (b) fuel composition, (c) fire frequency, severity, and pattern and (d) other associated disturbances (e.g. insect and disease mortality, grazing, and drought). Low departure is considered to be within the natural (historical) range of variability, while moderate and high departures are outside of that range. Characteristic vegetation and fuel conditions are considered to be those that occurred within the natural (historical) fire regime. Uncharacteristic conditions include invasive weeds, insects, diseases, selectively harvested forest composition and structure, or repeated annual grazing (Barrett et al. 2010).

Because LANDFIRE characterizes conditions with respect to departure from “simulated” historical reference conditions, the resulting succession classes (SCLASS), FRCC and departure (DEP) are dependent on the accuracy of the modeled results. It is important to recognize that the LANDFIRE maps were designed to support fire and landscape management planning, but were not designed to develop detailed species-driven EI assessments. LANDFIRE generally does not explicitly describe uncharacteristic vegetation conditions and may not be appropriate at the finer scale required to model fire effects on individual CEs, which may be sensitive to vegetation condition, especially where non-equilibrium conditions prevail. Furthermore, LANDFIRE provides coarse-scale reference condition for vegetation communities through its Biophysical Settings module. However, it is important to note that there is still considerable scientific debate over historic fire regimes (see Baker 2009).

3.1.2 Climate Change

3.1.2.1 Climate Model Output

The goal for the REA is to have an understanding of how predicted changes in climate may affect MQs region-wide and for managers to be able to determine how some characteristic of the climate at a particular location contributes to determining appropriate management actions and whether a CE can exist there now and in the future. It is understood that there will be a number of other episodic events other than climate that contribute to the current or future distribution of CEs. Therefore, a method of assessing the small number of important characteristics of current and future climate

at that location is necessary to relate that information to other ecological factors that control the distribution of the species or community (Fagre et al. 2009, Littell et al. 2010). In most cases, it is not known how or even if the various climatic characteristics and ecological characteristics at a specific site are important to the distribution of the CE so what is required are tools to help managers make a first educated guess that is understood to be only approximate and will hopefully be refined in the future with additional data.

Models, whether physical, statistical, mathematical, computer simulations, or various combinations of those different model types are designed, constructed, and intelligently used to help answer “what if” questions where the desired objective is inaccessible because it is distant in time and/or space or because there are a large number of objects that have some desired expected characteristic (mean, median, etc) with a desired range of variation around the expected characteristic. Individual models produce outputs that can either be a single value (deterministic: i.e. you give it one set of inputs and when run it, you always get the same result), a range of values (probabilistic: i.e. you give it exactly the same inputs each time you run it but the model may produce different results each time). Probabilistic models are designed to generate variable output, or some form of unpredictable output (extreme or chaotic events: i.e. you give the model one set of inputs, run it, and get very different results each time). Combinations of the various types of models as sub-models of a larger model or combining them as a chain of models can also significantly affect the result.

Two classes of predictive climate models are required for the REA: coarse-scale spatial resolution Global Climate Model (GCM) output converted into fine-scale spatial resolution for temperature or precipitation using the Parameter-elevation Regressions on Independent Slopes Model (PRISM), and; coarse-scale spatial resolution GCM output converted into medium-scale spatial resolution for a number of climatic variables using the USGS Regional Climate Model (RegCM) for the region of the REA.

While the ultimate spatial scale for the REA is HUC12 for landscape units and HUC10 for determining summary status of the CEs, it is important to understand the scale conversion process from coarse to medium and fine spatial scales. It is also important to understand the distinction between current climate models such as PRISM and the National Centers for Environmental Protection (NCEP). Current climate models such as PRISM and NCEP take historical data from a large number of weather stations and use a variety of methods to extrapolate across the landscape to make predictions about the climate at a particular point on the ground based on the selected set of historical weather years. Future climate models, GCMs (commonly referred to as global climate change models and formerly known as global circulation models) use heat balance simulations (incoming energy from the sun - loss of energy to space = energy remaining on the earth) to make predictions about how much of the sun’s energy will remain on the earth and where it will be distributed. The use of these data as tools for assessing CE vulnerability is described in Section 5.3.

3.1.2.2 *Current Climate Models*

PRISM uses historical data from weather stations and follows a coordinated set of rules, decisions, and calculations that are typically used by climatologists to create a climate map. Using a weighted linear regression for each station it interpolates the data across the landscape using the grid square size set in the analysis. The weight is the sum of the weights specified for distance, elevation, cluster, vertical layer, topographic facet,

coastal proximity, and effective terrain (Daly and Johnson 2008). During the winter temperature inversions are common in mountainous terrain in the western US due to down-slope cold air drainage with valleys and canyons being colder than mid-slope areas (Wyoming's Bighorn Valley for example) and elevation thresholds for the lapse rate function can be set to compensate for this phenomenon (Daly and Johnson 2008, Daly et al. 2008, 2009). PRISM's spatial resolution is approximately 3x4 km but 800 m x 800 m data has been made available for the REA. Currently only monthly and annual minimum, maximum, and mean temperature, monthly and annual mean diurnal temperature range, and monthly and annual mean total precipitation are available outputs from PRISM. The NCEP model predicts and extrapolates a range of climatic variables but at a medium spatial scale resolution of 32 x 32 km resolution and its data are generally downscaled (discussed later) for incorporation into regional climate models (RCMs).

3.1.2.3 *Future Climate Models*

There are approximately 50 GCMs that are well documented but three are required for use in the REA (ECAMS5, GMA2, and Geophysical Fluid Dynamic Laboratory [GFDL] CM2.0). All GCMs divide the earth into four compartments: atmosphere, terrestrial, sea ice, and oceans but differ in how complex they simulate those four compartments (e.g. the atmosphere can be 6,000 to 15,000 grid squares in extent on the earth's surface and 12 to 56 layers deep), how sensitive they are to the drivers of climate, and how sensitive they are to anthropogenic changes (Ray 2008, Mote and Salathé Jr. 2010, Ray et al. 2010). While any level of anthropogenic changes could be simulated in the models, most models have been run for three CO₂ emission scenarios over a 100 year time period (B1=low CO₂ emissions, A1B=medium CO₂ emissions, and A2=high CO₂ emissions which is also known as "business as usual") so that they can be compared against those standards. The REA requires the use of the A2 scenario. Regardless of the emission scenario, the output of the models is similar until the mid-century evaluation point required for the REA when they begin to diverge (Ray 2008, Mote and Salathé Jr. 2010, Ray et al. 2010). After mid-century the differences in climate predictions arise partially due to different CO₂ emissions levels but most of the differences are due to differences in the models themselves (Ray 2008, Mote and Salathé Jr. 2010, Ray et al. 2010). Unless there is a particular need to use a single model, the next choice is how many models to run, how to select which models to run, and how to use the model output from multiple models (statistical or ensemble techniques) and there are no hard and fast rules (Mote and Salathé Jr. 2010). For the REA there is the option of using the individual results or a simple average of results of the three GCMs as incorporated into PRISM and RegCM, which is described below.

GCMs provide useful predictions of temperature changes (at a particular altitude above the influences of the earth's surface) but not very useful predictions in precipitation changes (because of interactions with the earth's surface) so GCM temperature predictions are used in more spatially localized models (downscaled - which is discussed later). The output of the GCMs produces averages and variability that mimic, in a general way, large-scale climatic events such as the El Nino/La Nina pattern. The temporal resolution of GCMs is generally three-month seasons and their spatial resolution is approximately a 120x120 km grid square (Ray et al. 2010).

RegCM was developed by the National Center for Atmospheric Research (NCAR) in the late 1980s (Elguindi et al. 2010). RegCM is characterized as a dynamic downscaled

regional climate model. It is dynamic because it is composed of a number of mathematical equations representing physical factors that act on climate near the surface of the earth where local effects such as mountain ranges can exert influence on climate. This explicit influence of surface topography and other factors is in contrast to GCMs that use similar equations but look at broad-scale atmospheric and oceanic circulation patterns at an altitude that is generally above the influence of surface features such as mountain ranges.

In addition to the CO₂ scenario there are a number of other conditions and parameters that must be set in RegCM, PRISM (Daly and Johnson 1998), and NCEP (Messinger et al. 2006; Saha et al. 2010) and those choices will have a significant effect on model output. Perhaps the most important parameter is the land surface and vegetation classification or Common Land Model that uses any of 25 USGS vegetation categories which do not necessarily correspond in classification or extent to the vegetation CEs. The result of the model's vegetation requirement is that the model may not accurately depict changes in the species true habitat.

3.1.2.4 *Downscaling and Bias Correction*

Because GCMs are designed to model dynamics in the atmosphere at altitudes above the effects of features like mountain ranges on a scale of 160x160 km they aren't informative for fine-scale use, because they are designed to be heat balance simulations for the entire planet. The process of extrapolating (disaggregating) GCM output to a grid of fine-scale squares on the earth's surface is called downscaling and there are two general methods: a) dynamic downscaling, which is designed within a RCM, or; b) statically downscaling, which applies the GCM predicted temperature change within the 160x160 km region of the atmosphere directly above the finer scale grid square to the PRISM model output (i.e., in its simplest form statistical downscaling determines that if the PRISM model indicates the temperature should be 52 degrees F and the GCM output predicts a +2 degrees Fahrenheit change [anomaly] at mid-century then the predicted temperature under that GCM and scenario is 54 degrees Fahrenheit).

RegCM is considered to be dynamically downscaled because it generalizes the averaged output from ensembles made up of various combinations available GCMs, and uses that data in a climate model with a spatial resolution or grid size that is used for its simulations that is much finer (15x15 km) than that of GCMs (160x160 km). The GCM dynamics as well as the local dynamics in the RCM are both retained. The REA will use the USGS RegCM 15 x 15 km (RegCM) dynamic downscaled data (provided by Steve Hostetler) that is bias corrected (see below) using either PRISM 15 x 15 km data or to NCEP (Messinger et al. 2006) simulation data (S. Hostetler pers. com.).

Statistical downscaling can be done in many ways but the most common are: a) simply add the GCM predicted temperature change to the PRISM output ("simple delta" method), and; b) a more complex mathematical function that spatially adjusts the GCM output before adding it to PRISM (transient delta) (Wood et al. 2004; Mauer 2007, Anonymous 2010, Mote and Salathé Jr. 2010, Ray et al. 2010). The simple delta method is in widespread use by various agencies within the project areas but assumes, among other things, that the frequency and magnitude of extreme weather events in the future are the same relative to future weather as they are now. The transient delta method introduces some of the future variability into the result.

The accuracy of a climate model's forecasts, known as a model's skill, is tested by hindcasting or running the model with data from a known historic period (PRISM or NCEP) and comparing the results against observed data for that time period. All climate models, regional or general, deviate in some systematic fashion from the observed data and that deviance is defined as the model's bias and that bias is generally removed from the model results before the data are downscaled (Ray et al. 2008). The GCM analyses for the western U.S. typically have a temperature bias of about +2 degrees Fahrenheit in the winter and -3 degrees Fahrenheit in the summer. This inaccuracy is removed from the model output through a process called "bias correction". Bias removal does not necessarily make future predictions more accurate, because it is based on the dynamics of observed data for the baseline period after being run through simulations using the GCM or RCM. This creates a historical period that is modeled and is consistent with observed climate but assumes that the frequency and magnitude of extreme weather events in the future are the same as they are now.

3.1.3 Vulnerability Assessment

Determining how vulnerable the CEs are to global climate change will prove challenging on many levels. Fundamentally, while climate change is modeled as a deterministic process based on model parameters with some inherent variability, as the various climatic characteristics change across the landscape at different rates a series of novel climates will occur that have no modern analogs so it will be difficult to determine how species CEs will respond (Williams and Jackson 2007). This means that attempts to use static concepts such as forest types, disturbance return intervals, historic ranges of variability that are included in models such as LANDFIRE will become increasingly problematic in a dynamically changing climate that defies categorization (Mote and Salathé Jr. 2010). Even larger changes may become apparent as thresholds are crossed that cause immediate and irreversible changes to ecosystems (Fagre et al. 2009). Additionally, climate models only provide data on how the climatic physical process will change and they cannot incorporate a wide range of biological interactions that are known to be important in determining the distribution of species and ecosystems (Littell et al. 2010).

The climate change vulnerability assessment approach is divided into an exposure assessment and a sensitivity assessment. Exposure is a CE's range location with respect to areas of greatest climate change, while sensitivity is the species' biologic and ecologic ability to survive or adapt to climate change. Vulnerability also has a strong regional context and a subtle human value context of species versus ecosystem functioning. Compared to vegetation modeling, vulnerability assessment is less quantitative but also has less uncertainty. It does not predict whether or where values may expand or contract. Instead, it shows qualitatively the risk of change.

For species and species assemblage CEs, climate change vulnerability assessments will use only the NatureServe Climate Change Vulnerability Index (NSCCVI) to assess the potential effects of climate change on species CEs. The NSCCVI process uses a range of attributes of the species that when assessed with the forecasted climatic change determines a species' vulnerability. Species scored as extremely, highly, or moderately vulnerable will be mapped as an overlay over the climate change scenario maps corresponding to the main climatic drivers (temperature and or wetness when the vulnerability thresholds are met) and the spatial characteristics that contribute to exceeding any documented vulnerability threshold. The range distribution of each

species meeting the vulnerability threshold will be classified according to the vulnerability values under the climate scenarios and also compared to natural and anthropogenic factors to determine their relative contributions to its vulnerability. Other climatic drivers or indices such as precipitation, evaporation, evapotranspiration, or snow water equivalent may be used to address MQs depending on discussions with the AMT.

The NSCCVI anticipates using data from an ensemble of Global Climate Models (GCMs) that are statistically downscaled and bias corrected and appended to USDA PRISM data at either 3 x 4 km or 400 x 400 m resolution (Young et al. 2010). However, the SOW states that the REAs should use the USGS RegCM 15 x 15 km (RegCM) dynamic downscaled data (provided by Steve Hostetler) that is appended to either PRISM 15 x 15 km data or to NCEP (Messinger et al. 2006) simulation data (S. Hostetler pers. com.). For purposes of this REA, it is assumed that bias correction has been done for both PRISM and NCEP data by the USGS and that spatial resolution of the models which the RegCM data are appended to is 15 x 15 km to match the spatial resolution of RegCM.

For non-species CEs, climate change vulnerability assessments will be divided into an exposure assessment and a sensitivity assessment. Exposure is a CE's range location with respect to areas of greatest climate change, while sensitivity is the species' ability to survive or adapt to climate change. The risk of change results of these assessments will be shown qualitatively as map overlays using the appropriate climatic data.

A very significant complication in applying the vulnerability analysis to the REA region is the lack of a dataset that provides a continuous coverage of the distributions of each species across the ecoregion at an equivalent spatial resolution. One method to both analyze the vulnerabilities of the various species with respect to climate and to produce maps of the distributions of the species that meet the vulnerability thresholds will be to model each species distribution data set independently for each GIS coverage and to produce a composite map of the various coverages. The result of these non-equivalent GIS coverages is that the vulnerability analysis must be qualitative. Examples of what the analysis might look like are contained in a variety of recent reports (see Ashton et al. 2010, McWethy et al. 2010).

3.1.4 Development

The objective of assessing effects of development-related CAs is to identify areas in which CEs are currently affected by CAs and areas in which CEs are at risk from CAs in the future.

3.1.4.1 Refinement of Development Change Agents

Memo I-1-C (Section 5.2.2) identified and described some broad categories of the development CA. We refined and expanded the listing of development categories based on results of our literature review of the effects of CAs on CEs and relevant available datasets. Our interim findings dataset availability were presented in Memo I-2-C (Section 2.2.3.2), but this effort continues through the present task. The listing below summarizes the data categories related to human development as a CA that we depict in models for fine-filter CEs (see individual CE models in Section 4.0 for detailed discussions of CA effects). As described in detail in the example CE sections, these are the CAs that we propose to use in the REA, with the provision that some additional

datasets may be acquired or developed in the future for use in the REA while others may be dropped from consideration if better datasets are obtained. Some human activities including livestock grazing and logging are agents of change in native ecological systems in this ecoregion, but are not included in the REA as described in Memo I-1-C.

- **Urban, Exurban, and Industrial Development**
 - o Urban/industrial development
 - o Exurban development (commuter communities and vacation homes in areas bordered by natural ecosystems)
 - o Infrastructure (roads, utility corridors, and railroads)
 - o Energy exploration and development (extractive and renewable), mineral extraction
- **Agricultural Land Use**
 - o Conversion of native ecological systems to pasture, cropland, and orchards.
 - o Extraction of water for irrigation or mining—effects on surface and groundwater flows
 - o Nutrient and herbicide contamination of aquatic systems
- **Hydrological Alterations (Dams, Diversions, Water Table Drawdown, Industrial Uses)**
 - o Altered hydrograph (stream flow, depth, timing, curtail flood events)
 - o Barriers to fish and wildlife passage
 - o Reduced wetland and riparian habitat
 - o Channelization, levee construction leading to loss of habitat complexity and services for aquatic biota.

3.1.4.2 Change Agent Effect Pathways

In general, human development CAs affect CEs by changing the total habitat area and the suitability of available habitat for the CEs. We grouped the effects of development-related CAs into several broad pathways because some effects are directly related to conversion of land cover types (requiring analysis of the footprint of the CA), whereas other habitat effects are indirect and are related to proximity or intensity of an adjacent human development activity (requiring other analytical tools suited to measurement of intensity, interspersed, distance, or density). Other effect pathways are related to behavioral responses or risk of mortality of a CE, which would require analytical tools such as inverse distance weighting, which considers distance, intensity or severity. The listing is not intended to be comprehensive but indicates some of the ways in which inputs will be grouped in the analysis of change effects. In general, the effects of development can be grouped as follows:

- **Habitat Loss.** The effect pathways are relatively direct and result from land conversion from native ecosystems to human-dominated ecosystems. Conversion of native ecosystems to agriculture, urban, exurban, or industrial systems reduces the available habitat for CEs. In cases where CE species are

able to occupy human-dominated ecological systems (such as pastures and croplands), habitat suitability is usually reduced relative to native ecosystems.

- **Habitat Degradation.** Degradation of habitats is related to proximity or adjacency to the offsite human development footprint and/or development-related activities. Indirect effects of human development and human activities on CEs include loss of habitat suitability due to changes in water availability and quality, changes in availability or access to shelter, prey or forage resources; barriers to movement, and reduced in suitability of habitat patches, among others. Pathways for habitat degradation often involve changes in ecological processes and increased variability in natural disturbance regimes, for example, water withdrawal can lead to greater variability in seasonal hydrograph and result in degradation or loss of wetlands, and loss of connectivity, spawning and rearing habitat for fish species. Indirect effects of human land use and activities can include increased spread of invasive species, predators, competitors, parasites, and disease organisms.
- **Population Effects (Behavioral Disturbance and Direct Mortality).** Effects pathways include disruption of wildlife movement due to behavioral avoidance, disruption of reproductive cycles, increased risk of predation, accidental mortality due to collisions with vehicles, transmission infrastructure, electrocution, poaching, and mortality resulting from adverse management actions (e.g., management of grizzly bear/human interactions). In stream barriers such as dams and impoundments, surface water diversions, alterations in channel configuration, and flow regimes affect the ability of fishes to migrate from spawning and rearing habitat, leading to population isolation, loss of genetic variability, and increased vulnerability to stochastic events.

Table 3.1-2 is a generic listing of the expanded list of CAs, some of their potential pathways for affecting CEs, a listing of other CAs which may interact with development to exacerbate the effects, and a listing of some of the CEs that would be affected by development. The concepts outlined in this table are explored in greater detail in the example CE descriptions in Section 5.0, which also provide lists of datasets that are proposed for the analysis, and GIS process models.

3.1.5 Invasive Species

The assessment of the effects of the invasive species CA will identify areas where they currently conflict with areas of high ecological value and where the frequency and severity of the effects will change in the future. Invasive species data for all areas of this ecoregion is generally not available. Although some aquatic invasive species data is available, data related to terrestrial invasives is generally not available. Because terrestrial invasive data is generally not available, roads may be used as a surrogate for this CA.

3.1.5.1 Change Agent Effect Pathways

In general, invasive species CAs affect CEs by reducing the extent and quality of habitat or by affecting the CEs directly through predation or interbreeding. In most case there are complex and synergistic relationships between the invasive species CAs and other CAs such as disturbance, fire, and global warming. We have found very little data that extensively and accurately maps the invasive species CA and in many cases, this REA

Table 3.1-2. Expanded Change Agents and Potential Effects Related to Habitat Loss and Disturbance

Change Agent Category	Change Agent	Effect Pathways	Interactions with other CAs	Affected CEs
Urban development Exurban residential Industrial development	Dwellings, commercial and industrial facilities and associated land clearing)	Habitat loss: Land cover conversion from native ecological systems to human-dominated ecological systems Habitat degradation: Fragmentation of suitable habitats, spread of invasive species, increased ignition sources, contaminant, nutrient, and sediment runoff into aquatic systems. Behavioral/avoidance effects on wildlife species due to increased human access into native ecosystems Population effects on wildlife species due to increased risk of mortality, disruption of reproductive cycles	Transportation and transmission line/corridors Fire Invasive species	Many coarse-filter CEs: Increasingly foothills and lower montane ecological systems Many fine-filter CEs
Transportation	Roads, railroads	Habitat loss: Land cover conversion from native ecological systems to transportation corridors. Habitat degradation: Fragmentation of suitable habitats, spread of invasive plant seed vectors, increased ignition sources, contaminant and sediment runoff into aquatic systems, increased mass wasting, channelized or constrained stream flow. Behavioral/avoidance effects on wildlife species due to increased human access into native ecosystems for fire suppression, energy site access, and recreation. Population effects: Increased risk of mortality for wildlife species	Urbanization (growth-induced expansion of transportation infrastructure)	Greater Sage-Grouse Big game Golden Eagle Coldwater fish assemblage

Table 3.1-2. Expanded Change Agents and Potential Effects Related to Habitat Loss and Disturbance (Continued)

Change Agent Category	Change Agent	Effect Pathways	Interactions with other CAs	Affected CEs
Transmission lines/corridors	Electric transmission; water, gas pipelines and associated land clearing	Habitat loss: Land cover conversion from native ecological systems to transmission corridors. Habitat degradation: Habitat fragmentation, increased human access into native ecosystems for infrastructure construction and maintenance. Population effects: Increased risk of mortality for wildlife species: collision, electrocution, and increased predation	Urbanization (growth-induced expansion of infrastructure)	Golden Eagle Greater Sage-Grouse
Energy development	Existing and leased oil and gas extraction sites and facilities Existing and leased renewable energy sites and facilities (wind, solar, geothermal)	Habitat loss: Land cover conversion from native ecological systems to transmission corridors. Habitat degradation: Habitat fragmentation and loss of connectivity, increased human access into native ecosystems for energy development, corridors for invasive species, ignition sources, groundwater extraction, discharge of pollutants into aquatic systems. Population effects: Increased risk of mortality for wildlife species due to collisions with infrastructure, behavioral/avoidance due to increased human access into native ecosystems, disruption of reproductive cycles.	Transportation Transmission lines/corridors	Many coarse-filter CEs and fine-filter CEs (pronghorn, mule deer, Greater Sage-Grouse, Golden Eagle)

Table 3.1-2. Expanded Change Agents and Potential Effects Related to Habitat Loss and Disturbance (Continued)

Change Agent Category	Change Agent	Effect Pathways	Interactions with other CAs	Affected CEs
Mineral extraction	Buildings, other structures, and associated land clearing	Habitat loss: Land cover conversion from native ecological systems to human-dominated ecological systems Habitat degradation: Fragmentation of suitable habitats spread of invasive species, increased ignition sources, contaminant, nutrient, and sediment runoff into aquatic systems. Population effects: Increased risk of mortality for wildlife species, behavioral/avoidance due to increased human access into native ecosystems, disruption of reproductive cycles.	Transportation	Many coarse-filter CEs and fine-filter CEs
Hydrologic alterations	Groundwater extraction, wells(municipal and industrial uses) Surface water diversion (municipal and industrial uses) Flood control, dams and reservoirs, weirs, channelization, levees	Habitat loss and degradation: Loss of wetlands and riparian ecological systems extent and suitability due to reduced water table and surface water flows. Habitat degradation for aquatic biota due to hydrograph (flow and depth) changes resulting from impoundments and channelization. Population effects: Barriers to migration for aquatic biota, genetic isolation	Agriculture, Urban/industrial development Energy development (water withdrawals and discharge of pollutants) Mineral Extraction (water withdrawals and discharge of pollutants) Fire regime (decreased fuel moisture) Climate change	Many coarse-filter CEs and fine-filter CEs

Table 3.1-2. Expanded Change Agents and Potential Effects Related to Habitat Loss and Disturbance (Continued)

Change Agent Category	Change Agent	Effect Pathways	Interactions with other CAs	Affected CEs
Agriculture	Cropland, pastures, orchards Surface water diversion (irrigation withdrawals) Water quality effects	Habitat loss: Land cover conversion from native ecological systems to agricultural systems Habitat degradation: Runoff conveying nutrient, sediment and contaminant loads	Invasive species	Many coarse-filter CEs Fine-filter CEs: Greater Sage-Grouse and coldwater fish

will have to rely on characteristics of the CEs to accurately model current invasive species management issues. Much of the GIS data available for this CA was limited to countywide scale data or single point observations. The USGS and state agencies were able to provide some data, and that information will be attributed to the models when appropriate and available.

- **Habitat Loss.** The direct effects of invasive species on habitat are often difficult to separate from indirect effects with the exception of measurable changes in the fire regime a prime example of which is the conversion of sagebrush to annual grassland through an increased frequency of fire regimes. One more subtle form of habitat loss is the conversion of riparian cottonwood gallery forest to a system dominated by Russian olive through beaver preference for cottonwood and a lack of seedling recruitment due to altered riparian flows, the tolerance of Russian olive to a shaded understory, and the dense canopy of Russian olive that forms soon after the cottonwood trees die. This would also lead to the loss of large nest trees. At this time, it is not known if these areas will be able to be represented on a map.
- **Habitat Degradation.** Degradation can occur through canopy structural changes that are less than complete conversion. The increased canopy density Russian olive canopies as well as the increased width of the invaded riparian woodland due to Russian olive's tolerance of upland areas are examples of this effect.
- **Hybridization.** The loss of genetic distinctiveness through hybridization of native fish with introduced fish is a serious concern as is increased predation on native species. Introduced salmonids such as lake trout and brook trout in particular have had a serious impact on native coldwater salmonids including cutthroat trout and bull trout in this ecoregion.

3.1.6 Insect Outbreaks and Disease

The mountain pine beetle (MPB) (*Dendroctonus ponderosae*) CA is one of over 1,400 species of bark beetles distributed in over 90 genera. Their habitat is the nutrient and sugar carrying phloem tissue immediately under the bark of host trees where the beetles excavate galleries, introduce pathogenic fungi and bacteria, and lay their eggs (Raffa et al. 2008). When the larvae hatch they continue to feed on the phloem and construct galleries that end in a pupal chamber from which brood adults will emerge. Less than one percent of the bark beetle species experience population outbreaks and only a few of those species, concentrated in three genera, generally kill their tree host species. Even within those few tree-killing species, population densities generally remain in a low endemic state so only a few trees are killed within stands. When infrequent eruptive outbreaks occur, a large percentage of larger trees within stands are killed. Historically, outbreaks tended to build and then subside rapidly due to complex interactions between: MPB biology; host tree vulnerability which is a function of biology, stand age structure, stand structural heterogeneity, and stand connectivity; MPB predators and competitors, and; climate/weather (primarily temperature) (Raffa et al. 2008). MPB is endemic in lodgepole-ponderosa pine forests and occasionally temperature driven eruptive outbreaks occur in those forests and in upper treeline five-needle pine forests and woodland (1930s, 1970s, 1980-current). Little information is available regarding the effects of MPB on lower treeline limber pine woodland.

3.1.6.1 Management Questions

MPB interacts with other CAs such as fire regime, white pine blister rust (WPBR) and global climate change (GCC) in complex ways that overlap with other MQs that are more fully illustrated in the Five-Needle Pine Assemblage MQs. The following MQs are directly related to MPB:

- 5h) Which insects and diseases might pose a significant future problem?
- 5i) Where will state and federal high valued resource areas be affected through changes in intensity and range of insects and disease?
- 5j) What has the change been in frequency and severity of outbreaks (in the last 50 years) and where have they occurred?
- 5k) How and where are frequency and severity of outbreaks expected to change in response to climate change and other CAs such as change in fire frequency?
- 5l) Where are the major tree stands that have been substantially impacted by insects?
- 5m) Based on climate change models what areas could be susceptible to insect infestation or disease in the future?
- 5o) Where are the stands of major tree species that have not been impacted by insects or diseases?

3.1.6.1.1 Ecological Considerations for the Mountain Pine Beetle

The conceptual model for MPB is based on what is known about its biology and how it interacts with the species of the Five-Needle Pine Assemblage. Because of its complex interactions with other CAs its ecological and ecosystem-level interactions are shown in the Five-Needle Pine Assemblage models.

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. This elevational separation is not absolute and lodgepole-whitebark pine mixed forests are also common (Logan and Powell 2001). Little information is available regarding its effects on lower treeline limber pine woodland. Historically, eruptive outbreaks have occurred infrequently all three forest/woodland types in response to short term climatic variation but this pattern appears to be changing to more protracted outbreaks and an increasing frequency and novel impacts in high elevation whitebark pine forests and woodlands in response to GCC driven temperature changes (Logan et al. 2010, Raffa et al. 2010). Lower treeline limber pine woodlands are an exception to this pattern as the frequency of outbreaks at lower elevations is expected to decrease with GCC driven temperature changes (Littell et al. 2010).

The altitudinal or orographic driven historical reduced frequency of MPB outbreaks on whitebark pine has been explained through the use of models that incorporate temperature controls on MPB larval spring or early summer survivorship and MPB adult population size and the distribution of living host trees (Powell and Bentz 2009, Bentz et al. 2010, Logan and Powell 2009). In low elevation lodgepole-ponderosa pine forests the critical factors that are correlated with a high risk of a MPB eruptive outbreak are a dense population of adult MPB and host susceptibility. Temperature determines the rate of development of the various life stages of MPB and hence the timing of the various life

stages and 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 are only successful if there is a coordinated mass attack on individual trees, synchronous maturation of the adult beetles is also critical to its success. This synchronization is controlled by the higher temperature threshold requirement of the fourth larval stage (instar) (Benz et al. 2008). So both timing and synchrony are critical and controlled directly by the temperature of its habitat which is the phloem of the host tree (Logan and Powell 2001, Powell and Logan 2005, Powell and Benz 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, less optimal when cooler temperatures slow the cycle to one to two years per generation (fractional voltinism) as is common in mid-elevation forests, and even less optimal at the coolest high elevation whitebark pine forests where the life cycle requires at least two years to complete (semivoltinism) (Logan and Powell 2001, Logan and Powell 2009).

Host tree vulnerability in low elevation primary-host lodgepole-ponderosa pine forests is a function of biology as these pine species have evolved pitch and toxic chemical defense mechanisms, tree stress level which can reduce the defensive response (water, nutrient, root infections, etc.), the density of host trees, and a homogeneous age structure dominated by larger trees that are more preferable hosts to MPB. 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).

High elevation whitebark pine forests and woodlands have historically been infrequently impacted by eruptive outbreaks (1930s and 1970s) only when winter temperatures were warm enough to allow all life stages to overwinter and when there is sufficient summer thermal energy to maintain univoltine life cycles (Logan et al. 2010, Logan and Powell 2009). Temperature forcing due to GCC has likely changed this historic pattern (Logan and Powell 2009, Logan et al. 2010) and, while initially creating less optimal temperatures, when the temperature increases beyond approximately 2°C a threshold is reached where univoltine life cycles become stable in high elevation whitebark pine forests and woodlands (Logan et al. 2001, Logan and Powell 2009).

Management actions to reduce the impact of MPB on five-needle pines are very limited and may include:

1. Protection of five-needle pine in areas that are more resistant to climate change and integrate the protection with the WPBR resistance breeding program described under that CA.
2. Maintain a heterogeneous structure in the forests and woodlands.

3.1.6.1.2 Mountain Pine Beetle System-Level Conceptual Model

The MPB model shown in Figure 3.1-2 has been simplified from the multiple models presented in Raffa et al. (2008) to focus on the specific conditions under which MPB will impact the Five-Needle Pine Assemblage both at lower treeline and at upper treeline. It assumes that there are no dispersal limitations for MPB that host populations are not substantially limiting, that climate is generally within the normal range of variation until a series of years with abnormally warm temperatures or global climate drives

temperatures past a threshold, and that stand structure (size class, species identity, etc.) are not limiting. Feedback from the affected forest and woodland types, such as resistance in the lodgepole-limber pine forest are also not shown. The indirect effect of lodgepole pine in a mixed lodgepole-whitebark pine forest is shown. Required input data layers for the current distribution of the Five-Needle Pine Assemblage and MPB outbreaks can be found in Section 4.0, Table 4.1-2.

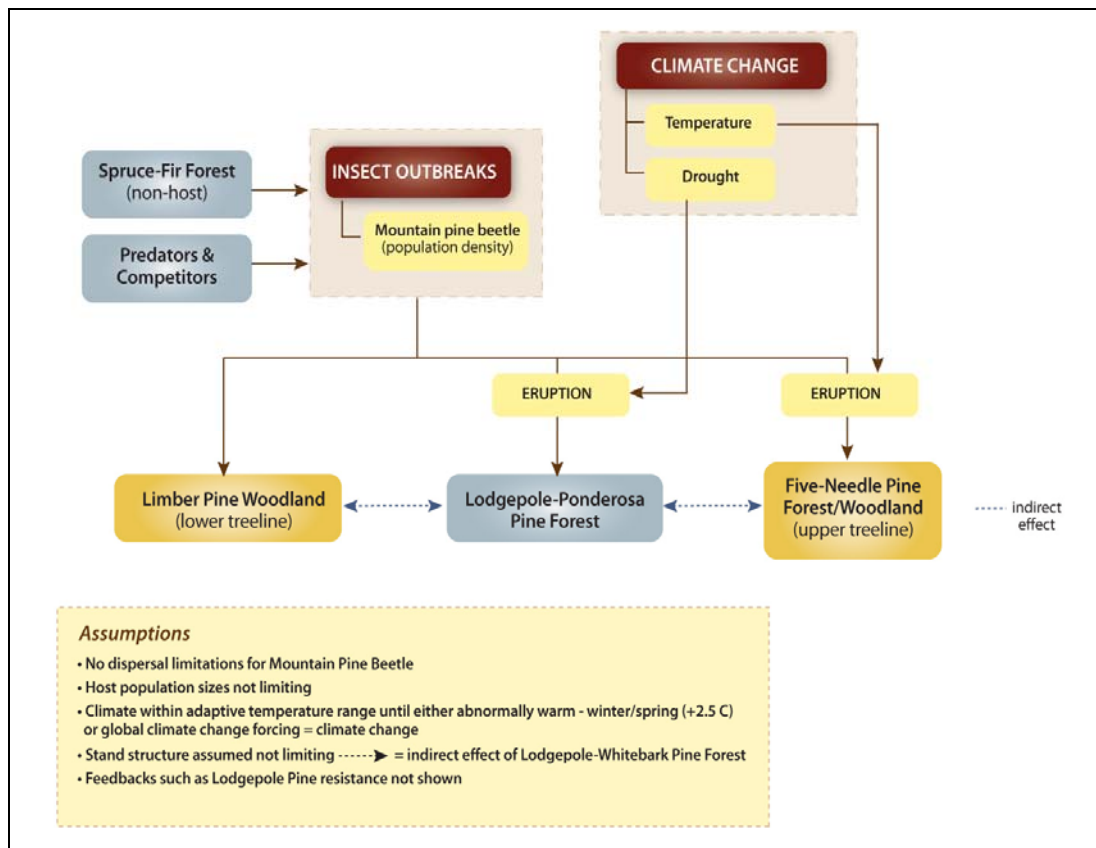


Figure 3.1-2. Mountain Pine Beetle Conceptual Ecological Model

3.1.6.2 Disease

Although it is recognized that disease plays an important role in the ecology of the Middle Rockies ecoregion, adequate data might not be available to illustrate the real impact of disease on the ecoregion. If data is not available, it will be noted as such, and appropriate assumptions will be made for this CA.

3.1.6.2.1 West Nile Virus

First observed in New York in 1999, the West Nile virus (WNV) has rapidly spread west across North America, reaching the west coast in 2004 (Centers for Disease Control and Prevention 2011). Most affected by this virus were American crow (*Corvus brachyrhynchos*) populations (Caffrey et al. 2005). Naugle et al. (2004) reported the first WNV case in Greater Sage-Grouse (GSG) in northeast Wyoming, resulting in a 25 percent decline in survival of four populations (Naugle et al. 2004). Walker (2007) showed that Greater Sage-Grouse chick and adult survival was significantly lower due to WNV and resulted declining male and female lek attendance. A highly efficient vector of WNV in North America is the mosquito (*Culex tarsalis*, Hayes et al., 2005; Turell et

al., 2005), which is thought to increase due to water development and well ponds associated with oil and gas exploration.

3.1.6.2.2 *Chronic Wasting Disease*

Chronic wasting disease (CWD) is a prion disease that affects North American cervids. The known natural hosts of CWD are mule deer, white-tailed deer, elk, and moose. CWD was first identified as a fatal wasting syndrome in captive mule deer in Colorado in the late 1960s and in the wild in 1981. By the mid-1990s, CWD had been diagnosed among free-ranging deer and elk in a contiguous area in northeastern Colorado and southeastern Wyoming, where the disease is now endemic. In recent years, CWD has been found in areas outside of this disease-endemic zone, including areas east of the Mississippi River. The geographic range of diseased animals currently includes 15 U.S. states and two Canadian provinces and is likely to continue to grow (Figure 3-1.3). Surveillance studies of hunter-harvested animals indicate the overall prevalence of the disease in northeastern Colorado and southeastern Wyoming from 1996 to 1999 was estimated to be approximately five percent in mule deer, two percent in white-tailed deer, and less than one percent in elk.

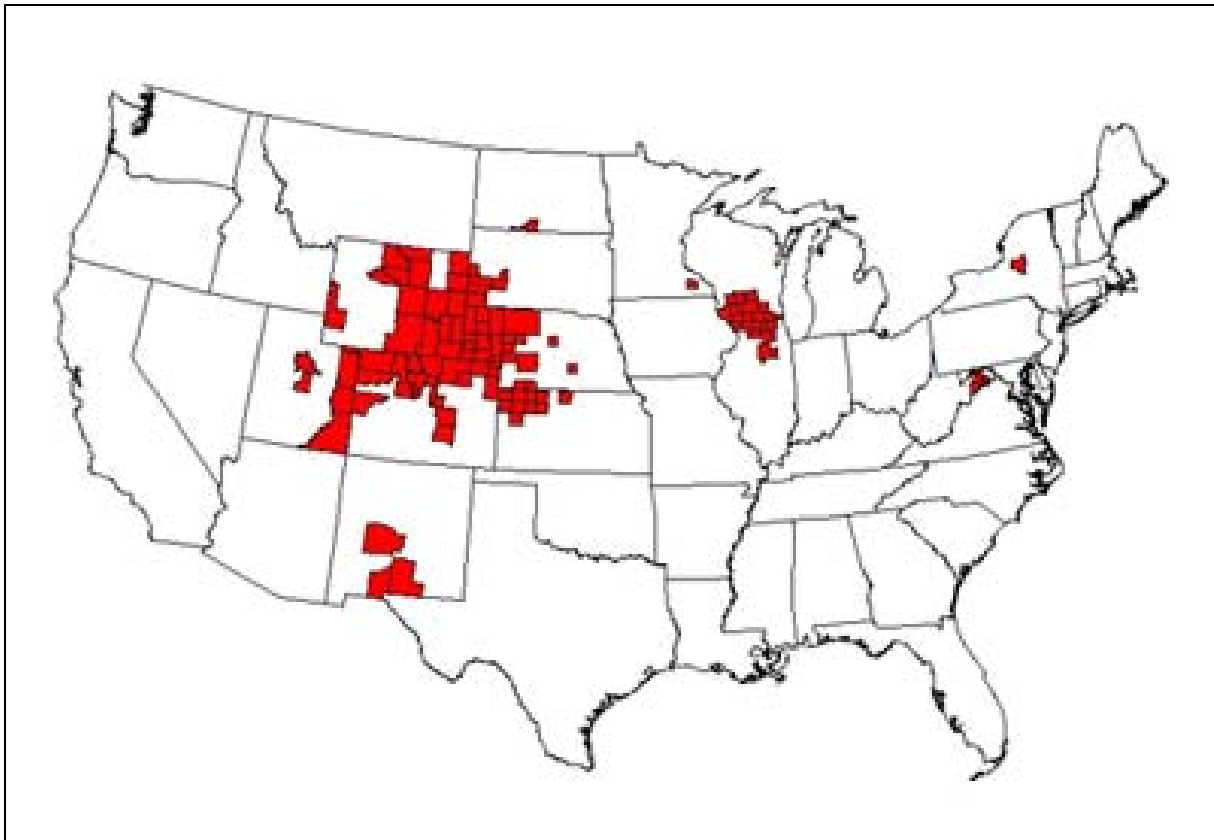


Figure 3.1-3. Chronic Wasting Disease Among Free-Ranging Cervids by County, United States, April 2011

4.0 CONSERVATION ELEMENTS

As recommended in the SOW, the coarse-filter/fine-filter approach was used to ensure that the suite of CEs adequately represented the ecoregion's resources of conservation concern. This approach focused on ecosystem representation, complemented by a limited subset of focal species assemblages and individual species. The objective of this dual approach was to include the ecosystems and ecological functions (coarse-filter) that are required to evaluate biotic integrity, while also providing for biodiversity and species of concern (fine-filter).

4.1 COARSE-FILTER CONSERVATION ELEMENTS

The intent of the coarse-filter CE selection is to include all of the major ecosystem types that occur within the assessment area, and should represent all of the predominant natural ecosystem functions and services in the ecoregion. The desired outcome of coarse-filter selection is to provide coverage for the vast majority of species that occur in the ecoregion.

At AMT Workshop 4, all of the GAP Level 3 vegetation systems in this ecoregion were evaluated and discussed. This discussion focused on which Level 3 systems are most representative of the ecoregion and which ones the AMT felt would be most important to evaluate in Phase II. Table 4.1-1 lists the coarse-filter CEs that will be evaluated during the analysis phase.

Table 4.1-1. Middle Rockies Coarse-Filter CEs

Division Name	Middle Rockies Level 3 Coarse Filters
Terrestrial Systems	
Evergreen Forest Woodland	Rocky Mountain Lodgepole Pine Forest
	Rocky Mountain Subalpine Spruce-Fir Forest and Woodland (Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland and Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland)
	Middle Rocky Mountain Montane Douglas-fir Forest and Woodland
	Northwestern Great Plains - Black Hills Ponderosa Pine Woodland and Savanna
	Other
Deciduous Forest and Woodland	Aspen (Rocky Mountain Aspen Forest and Woodland)
	Others
Riparian	Riparian
Shrubland	Inter-Mountain Basins Montane Sagebrush Steppe
	Other
Grasslands	Northwestern Great Plains Mixedgrass Prairie
	Northern Rocky Mountain Lower Montane, Foothill and Valley Grassland
	Other

4.1.1 Coarse-Filter Conservation Element Distribution Data and Mapping

This analysis will focus on answering MQ related to: 1) Where are they; 2) What is their current status and; 3) What is happening to them? In order to answer the “where are they” question distribution has to be mapped before the status questions can be answered.

To map distribution of the coarse-filter CEs in the Middle Rockies ecoregion SAIC will use a mosaic of GAP data sources, including two of the National GAP landcover regions, the Northwest and North Central. The source data for the Northwest region was the Northwest ReGAP dataset that improved upon the original Northwest GAP analysis. The Gap Analysis Program (GAP) was developed to help answer questions about species biodiversity and species habitat (USGS 2010). Its overall goal was to assist resource managers in decision making where there is a lack of information about the full range of species on the landscape.

Because some of the Level 3 systems comprise small percentages of the Middle Rockies ecoregion that could not be analyzed at the landscape level, the AMT decided to combine those small percentage systems with other Level 3 systems. For example, the Inter-Mountain Sagebrush system will include the following Level 3 systems: Inter-Mountain Basins Big Sagebrush Steppe, Inter-Mountain Basins Montane Sagebrush Steppe, Wyoming Basins Dwarf Sagebrush Shrubland and Steppe, and Inter-Mountain Basins Big Sagebrush Shrubland (Table 4.1-1).

To create the current distribution of the coarse-filter CEs SAIC will extract each level 3 system that is associated with the division as listed in Table 4.1-1.

4.2 FINE-FILTER CONSERVATION ELEMENTS

The fine filter focuses on species and species assemblages that include rare species and landscape/keystone species that may not be identified sufficiently in a coarse-filter analysis. Table 4.2-1 lists the fine-filter CEs that will be evaluated in the analysis phase of the REA.

Table 4.2-1. Fine-Filter CEs for the Middle Rockies Ecoregion

Conservation Element	Notes
Grizzly bear	Montana Consistently Occupied Habitat Layer
Forest Carnivore Assemblage (C. Lynx, Wolverine, Marten)	WCS and USFS Modeled Data Layers
Greater Sage-Grouse	BLM Currently Occupied Habitat and Breeding Bird Density Layers will be used
Big game Crucial Winter Range & Parturition Areas (Mule Deer, Elk, Rocky Mountain bighorn sheep)	WAWFA and Rocky Mountain Elk Foundation data will be used
Pronghorn (migration corridors)	Expert knowledge will be used to identify corridors
Native Cold Water Aquatic assemblage (Cutthroat Trout, summer steelhead, bull trout, sockeye, Chinook, fluvial Arctic grayling)	Combination of data from the following sources will be used: StreamNET, MFish and Wyoming Game and Fish Department
Five-Needle Pine Assemblage (Whitebark Pine, Limber Pine)	GAP, ReGAP and LANDFIRE data will be used along with USFS and other data

Table 4.2-1. Fine-Filter CEs for the Middle Rockies Ecoregion (Continued)

Conservation Element	Notes
Golden Eagle	Distribution will be modeled using Maxent supplemented with information from known migration corridors and expert knowledge
Marten	Distribution will be modeled using Maxent supplemented with information from expert knowledge

4.2.1 Fine-Filter Distribution Data and Mapping

Table 4.2-1 lists the fine-filter CEs and the source of the data that will be used as distribution in the analysis phase. For most of the fine-filter CE distribution mapping SAIC will use either existing data or existing distribution models provided by state or federal agencies, such as Montana, RMEF and WAFWA. The fine-filter CEs; marten and Golden Eagle do not have existing distribution models for the entire ecoregion. For these species SAIC will use point occurrence data to develop Maxent distribution models and supplement that information with expert knowledge. Since the Greater Sage-Grouse is such a highly studied species, the AMT advised SAIC to use the BLM currently occupied habitat and breeding bird density layers. Big game species (bighorn sheep, elk, pronghorn and mule deer) will rely on expert knowledge and any up to date Western Association of Fish and Wildlife Agencies (WAFWA) or Rocky Mountain Elk Foundation (RMEF) data layers. Data from the USFWS recovery and occupied habitat layer will be used for Grizzly bear habitat analysis. For distribution of coldwater fish species, SAIC will rely on information from StreamNET and Montana Fisheries Information System (MFISH) for suitable habitat. Cutthroat trout (Yellowstone) occur in Wyoming which doesn't participate in StreamNet so Wyoming Game and Fish Department data will be used.

The Maxent model combines species occurrence data with input overlay layers to determine a probability of suitability. The species occurrence data will naturally contain some uncertainty in the accuracy of the positions. This can be due to how the data is collected (GPS vs. approximation on map) and where it is collected (field survey vs. road kill). Montana Fish Wildlife and Parks is currently developing a guidance document that will help define a common approach for defining the spatial uncertainty of the occurrence points to be used in the model. They are also creating a common approach for Maxent modeling with regards to cell size and input layers used within each model.

4.3 STATUS AND POTENTIAL FUTURE RISK ANALYSIS

In order to answer the question regarding current status and potential for future risk, the SOW required the development of standardized conceptual ecological models for all of the CEs. As mentioned previously, the purpose of the models is to illustrate KEAs of the CE and how they could potentially interact with the CAs. On July 1, 2011 SAIC provided the BLM subject matter experts with updated narrative, models and KEA tables in the form of "CE Packages." After further discussion it was decided that due to the complexity of the topic a "rolling review" process will be used for the remainder of the REA process. The "rolling review" process will allow subject matter experts (SMEs) from BLM to work with SAIC in finalizing the conceptual models and KEA tables. The intent of the process is, as data sources and distribution maps are developed, they will be

provided to the SMEs for review to help determine what can actually be analyzed geospatially at the landscape scale. To achieve this objective the “rolling reviews” should answer the following six questions:

- 1) How do we get to distribution?
- 2) What are the key processes?
 - a. What can be measured
 - b. What cannot be measured
- 3) What is the analysis unit?
- 4) Why these indicators?
- 5) How do the indicators interact?
- 6) How do we sum up to get at quality?

Section 4.4 provides examples of the three preliminary fine-filter CE packages. The examples are: five-needle pine, Greater-Sage Grouse, and the Golden Eagle. These examples provide the conceptual models and attempt to illustrate the ecological requirements and how they may be affected by the CAs in the ecoregion. Also included are the KEAs and narrative describing why the attributes were chosen.

Section 4.5 introduces SAIC’s approach to Ecological Integrity (EI). The approach will attempt to use the coarse-filter/fine-filter approach similar to the other CEs. However, EI is different in the aspect that integrity in this example is not based on MQs, but the integrity of the ecosystem regardless of the importance to managers. This process will start with the identification of native or natural areas throughout the Middle Rockies. For the first step of the EI analysis, SAIC will follow the Montana and Washington methodologies to create geospatial data displaying relative “naturalness or native areas” of the current vegetation. The next step will be to follow the Faber-Langendoen et al (2009), process for a Level 1 remote assessment using key ecological attributes to evaluate those areas. The AMT and SAIC determined that EI would be assessed using both aquatic and terrestrial fine-filter CEs and combined aquatic/terrestrial ecosystems at the 5th Level watershed. Appendix 2 further describes and illustrates the EI approach.

As stated above the CMs and KEAs examples are preliminary and will change as we go through the “rolling review” process. It is anticipated that some attributes, indicators and metrics will be changed or dropped as we get further into the geospatial data generation. As with any analysis at this scale several types of GIS data will be used. Geospatial data will include vector in form of point, polyline and polygon data layers. Raster data will also be used and the resolution for this may range from 30m to 15k. Thus, some of the analysis and how the indicators will be reported are a “work in progress.” Many of our KEAs have indicators with absolute size or patch size. How this will be reported is still in question. For example, a patch may score high due to size and connectivity. However, it may intersect several 6th level watersheds, which could mean not every watershed intersected by the patch will be scored equally. SAIC will investigate different ways of handling these situations; by potentially looking at what percent is in the watershed or zonal statistics when scoring a watershed. SAIC may recommend the reporting unit be maintained in its native form instead of rolling up to the watershed level. It is anticipated that topics such as this will be presented to the SMEs in the “rolling review” process.

4.4 CONSERVATION ELEMENT ASSESSMENT EXAMPLES

4.4.1 Five-Needle Pine Assemblage

A variety of the MQs identified in Phase I Task 1 apply to this assemblage. Many of the MQs can be summarized into two primary questions: 1) where are the important areas (extent, configuration, connectivity, etc.) for this assemblage? and 2) what is the status of the assemblage in those areas? The intent of the process described below is to answer the MQs applicable to this assemblage.

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

Whitebark pine and the limber pine have been identified by the AMT as focal species for this assemblage. Their distributions have been affected by a variety of factors including WPBR, MPB, altered fire regimes, and, for low-elevation tree line limber pine, clearing to reduce encroachment on grasslands.

This assemblage will be evaluated under the following set of assumptions:

1. The modeling for this assemblage will focus on broad landscape factors and not on small-scale local habitat features that may be important at the county level but not important at the broad ecoregional level.
2. Not every acre of five-needle pine habitat will be identified through this analysis.
3. The emphasis will be on large intact blocks of habitat and how they are connected or how far apart they are from one another and their juxtaposition on the landscape.

4.4.1.1 Management Questions Relative to the Five-Needle Pine Assemblage

A variety of the MQs identified in Phase I Task 1 apply to this assemblage. Many of the MQs can be summarized into two primary questions: 1) where are the important areas (extent, configuration, connectivity, etc.) for this assemblage? and 2) what is the status of the assemblage in those areas? The intent of the process described below is to answer the MQs applicable to this assemblage.

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

Whitebark pine and the limber pine have been identified by the AMT as focal species for this assemblage. Their distributions have been affected by a variety of factors including WPBR, MPB, altered fire regimes, and, for low-elevation tree line limber pine, clearing to reduce encroachment on grasslands.

4.4.1.2 Five-Needle Pine Assemblage Distribution Mapping

In order to answer the MQs regarding the location and status of the Five-Needle Pine Assemblage across the Middle Rockies ecoregion, a variety of existing data layers will be used. Geospatial data has been obtained from land cover data such as GAP, ReGAP and LANDFIRE created from satellite imagery and predictive modeling. There

are other existing distribution data from U.S. Forest Service (USFS) projects including ADS, WLIS, and FHTET. In addition to existing readily available land cover data, SAIC has worked with members of the AMT to obtain expert knowledge data. This geospatial data can be combined to look at the potential overall distribution of the Five-Needle Pine Assemblage.

The distribution of these species is needed to determine the status and to model future risk throughout the Middle Rockies ecoregion. The distribution of the Five-Needle Pine Assemblage will be modeled to look at the effects or risk of CAs such as insect and disease outbreaks, fire and climate change. Existing distribution is also needed to look ecological attributes of the Five-Needle Pine Assemblage. Ecological attributes like connectivity and patch size will also be analyzed to help determine the species structure and composition. These attributes are also important to predict the possibility of seed dispersal by Clark's nutcracker.

4.4.1.3 Five-Needle Pine Assemblage Conceptual Models

The ecological process model (Figure 4.4-1) is intended to connect information from the system-level model (Figure 4.4-2) to quantifiable spatial data associated with the Five-Needle Pine Assemblage. The information displayed in the conceptual model will be attributed to the Five-Needle Pine Assemblage distribution data. This model identifies the relationship between five-needle pine and the features that affect the distribution of species through CAs.

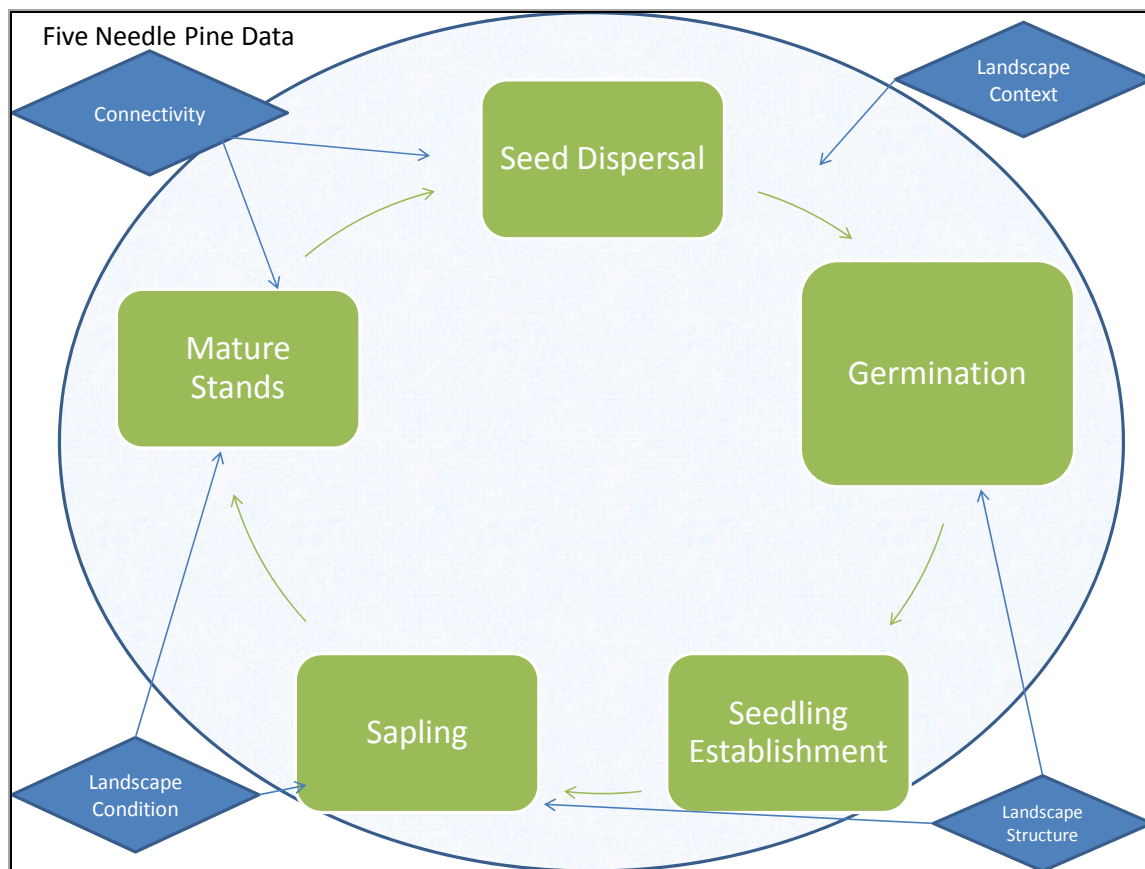


Figure 4.4-1. Five-Needle Pine Ecological Process Model

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

The system-level conceptual model (Figure 4-1-2) illustrates the interactions between the CAs, adjacent vegetation types, and the seed dispersal and colonization dynamics of this assemblage. The three primary CAs are identified across the top in red. Insect outbreaks and disease, change in fire regimes, and climate change are the most important CAs. In order to provide information to fill data gaps, the system-level model includes not only attributes that are anticipated to be represented geospatially but also those that represent data gaps or are at a scale that is not suitable for use in the REA. These attributes are labeled in the model accordingly.

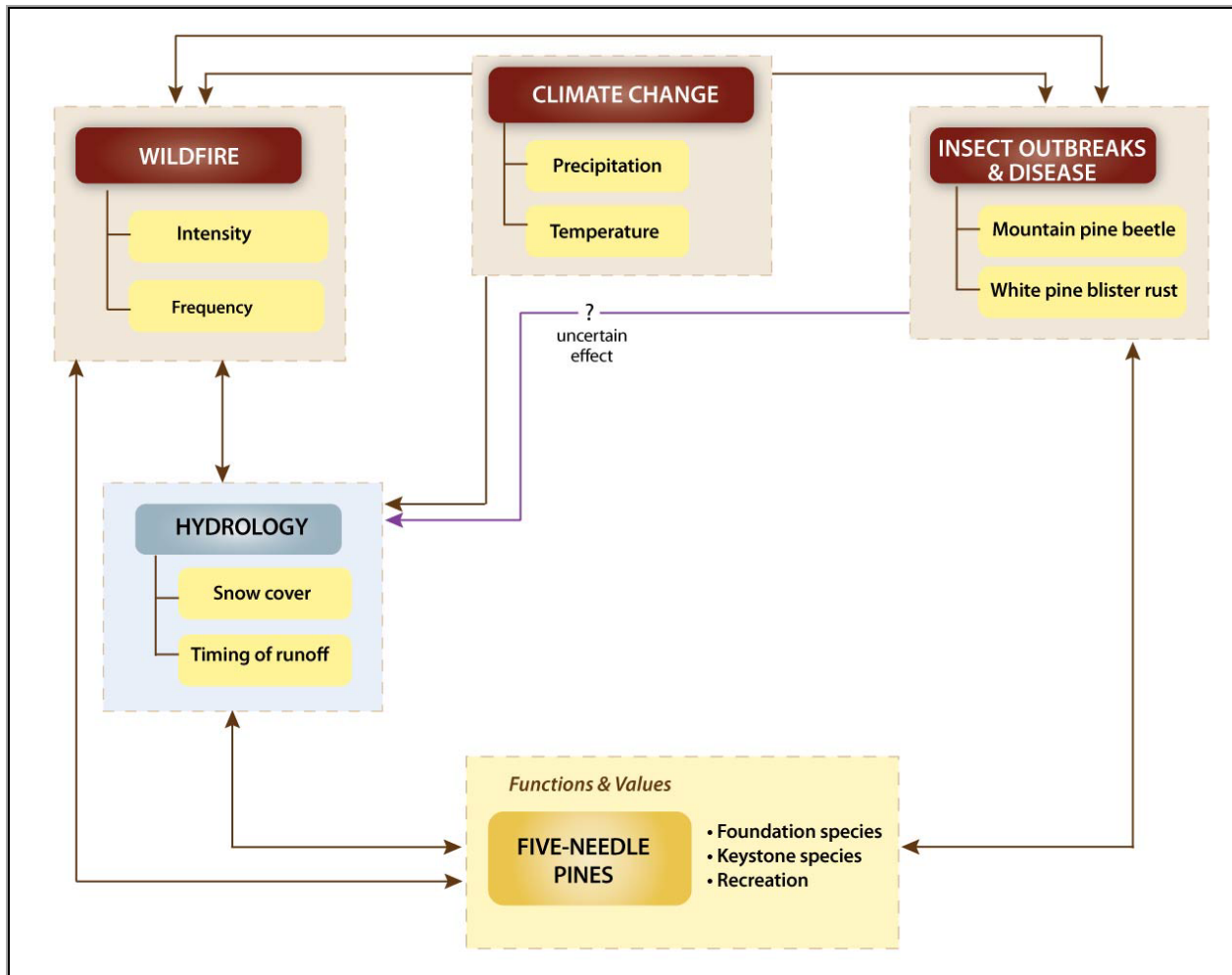


Figure 4.4-2. Five-Needle Pine System-Level Conceptual Model

The defining biological characteristics of these species are large nutritious seeds, with no adaptations for wind dispersal but which are accessible to seed caching birds (in the case of whitebark pine seeds are retained in the cones), variable seed production with

infrequent mast years, a long juvenile period before first reproduction (approximately 50 years), a mixed mating system with the potential for high rates of self fertilization, potentially long-lived, tolerance of xeric appearing conditions, intolerance of shade, lack of tight adaptations to specific fire regimes, and lack of resistance to mountain pine beetles (Bower and Aitken 2007) and white pine blister rust.

At the upper elevation treeline, 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, 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 and fire dynamics associated with adjacent forest types such as the lodgepole/ponderosa pine forest.

The primary biological interactions revolve around a coevolved system of seed collection by Clarks' nutcracker and red squirrels and grizzly bears which raid squirrel middens. Bird dispersal accounts for both long distance and local dispersal of small caches of seed that may or may not be utilized and results in clumped distribution of trees. The birds locate their caches where there are visual cues and tend to choose relatively open sites. The squirrels collect large quantities of seed and tend to consume all of their collected seed unless the midden is raided by a grizzly bear. Grizzly bears, in particular pregnant females, are very dependent on the protein and caloric value of whitebark pine seed and less is known about limber pine seed. In the closed canopy forests that are successional to fir, spruce, and hemlock, the five-needle pines require periodic fires and recolonization by bird dispersed seed. Local dispersal by rodents is relatively less important in this system. The result is a generally uniform age structure of the population. Where these stands occur adjacent to or mixed with ponderosa and lodgepole pine the dynamics of those species, in particular their responses to fire can control stand structure. On xeric sites seed dispersal is both by bird and by rodents which results in stands with a mixed age structure of relatively closely related individuals.

Little is known about the ecology of the lower treeline limber pine woodland (Means 2010). There appears to be a large difference in the maximum age of trees in upper treeline stands (1,500 years) and lower treeline stands (300 years). (Schuester et al. 1994, Means 2010). These lower treeline woodland has been historically treated as a non-desirable invader of rangeland and 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).

The CAs are mountain pine beetle (MPB), white pine blister rust (WPBR), changed fire regimes, and global climate change (GCC). MPB is a native species that has unique eruption outbreak characteristics and is or has been largely confined to lower elevation lodgepole and ponderosa forests except during abnormal climatic events. MPB attacks can be overcome by tree defenses such as sap production so trees that are stressed are more vulnerable targets. MPB also requires larger trees, generally those of reproductive age, and must attack in mass in order to overcome the tree's defenses so developmental synchronization (thermal regimes) and adult communications that coordinate a mass attack are critical to its success. WPBR is an introduced pathogen that kills trees of all age classes and its virulence depends on tree structure (branch

height, single vs. multiple stems), stand structure (open vs. closed), and micrometeorological conditions. GCC is predicted to drive the upper tree line to higher elevations although there may be thermal refugia due to cold air drainage and aspect. The movement of the five-needle pines upslope may be prevented by the corresponding movement of MPB and WPBR but this is poorly understood. Fire, direct anthropogenic controls, GCC effects, and natural fire regimes are expected to have complex effects on these interactions.

The CAs are MPB, WPBR, altered fire regimes, and climate change. MPB is a native species that has unique eruption outbreak characteristics and is or has been largely confined to lower elevation lodgepole and ponderosa forests except during abnormal climatic events. MPB attacks can be overcome by tree defenses such as sap production so trees that are stressed are more vulnerable targets. MPB also requires larger trees, generally those of reproductive age, and must attack in mass in order to overcome the tree's defenses so developmental synchronization (thermal regimes) and adult communications that coordinate a mass attack are critical to its success. WPBR is an introduced pathogen that kills trees of all age classes and its virulence depends on tree structure (branch height, single vs. multiple stems), stand structure (open vs. closed), and micrometeorological conditions. GCC is predicted to drive the upper tree line to higher elevations although there may be thermal refugia due to cold air drainage and aspect. The movement of the five-needle pines upslope may be prevented by the corresponding movement of MPB and WPBR but this is poorly understood. Fire, direct anthropogenic controls, GCC effects, and natural fire regimes are expected to have complex effects on these interactions.

4.4.1.4 Five-Needle Pine Ecological Attributed, Data Needs, and GIS Process Models

Table 4.4-1 identifies KEAs, indicators and metrics that can be used to evaluate factors affecting this CE across the ecoregion. The EAs, indicators, and metrics listed in Table 4.4-1 can be evaluated using geospatial data. It is important to note that some attributes/indicators that could affect this assemblage are not included in this table because either the KEA/indicator is not suitable for a landscape level analysis or data is not available to support the analysis.

Table 4.4-1. Preliminary Listing of Attributes, Indicators, and Metrics for the Five-Needle Pine Assemblage

Ecological Attribute	Indicator	Metric*	Data Source	Citation**
Size				
Size/Extent/Connectivity	Extent (Vegetation cover of Five-Needle Pine in the watershed)	> x% = good	GAP/ReGAP/ LANDFIRE/ NLCD	
		x%-x% = fair		
		< x% = poor		
	Patch Size (Extent of suitable habitat patches w/in each Five-Needle Pine Veg. type in the watershed)	> x% = good	GAP/ReGAP/ LANDFIRE/ NLCD	
		x%-x% = fair		
		< x% = poor		

Table 4.4-1. Preliminary Listing of Attributes, Indicators, and Metrics for the Five-Needle Pine Assemblage (Continued)

Ecological Attribute	Indicator	Metric*	Data Source	Citation**
Condition				
Landscape Structure	Successional/Fire State (FRCC)	FRCC 1 = good	LANDFIRE	Bob Means; Professional Judgment
		FRCC 2 = fair		
		FRCC 3 = poor		
Landscape Condition	Mountain Pine Beetle (Spatial-temporal patterns of mortality)	ADS-FIA data with rating system to be determined during the Forest Mortality Assessment	ADS-FIA	
	White Pine Blister Rust(Spatial-temporal patterns of mortality)	ADS-FIA data with rating system to be determined during the Forest Mortality Assessment	ADS-FIA	
Landscape Context				
Landscape Context/ Connectivity	Seed Dispersal (Spatial-temporal patterns of stand distributions based on LANDFIRE/ReGAPand Clark's nutcracker seed dispersal distance)	< 1 mile = good	GAP/ReGAP/ LANDFIRE	Siepielksi 2008
		1 - 6 miles = fair		
		> 6 miles = poor		
Landscape Context	Fire (Spatial-temporal Patterns of Proximity of Lodgepole/mixed conifer Stands Based on FRCC classes 2 and 3 and Proximity)	> 2 miles = good	GAP/ReGAP/ LANDFIRE	Bob Means; Professional Judgment
		1 - 2 miles = fair		
		< 1 miles = poor		
Landscape Condition	Proximity to Mountain Pine Beetle Outbreaks (Spatial-temporal patterns of mortality)	ADS-FLT data with rating system to be determined during the Forest Mortality Assessment	ADS-FIA	
	Proximity to White Pine Blister Rust Outbreaks (Spatial-temporal patterns of mortality)	ADS-FLT data with rating system to be determined during the Forest Mortality Assessment	ADS-FIA	
Connectivity	Circuitscape	Quantified through the use of Circuitscape and Distribution Data (point observations)	Circuitscape	Circuitscape

Notes:

*Metrics: poor = 1; fair =2; good =3.

**Sources: Identification of Attributes and Indicators is derived from literature review, representative sources cited, coupled with professional judgment; Scales of metrics based on professional judgment.

The KEAs listed in Table 4.4-1 were categorized into the three categories of size, context and condition. This table includes the scoring metrics that will be used to evaluate the CEs habitat across the ecoregion. These metrics were derived from the literature where possible, however in some cases, best judgment was used. It is anticipated that interaction with BLM subject matter experts will help finalize these metrics. Local BLM expert input is sought and encouraged for these numbers as well as additional literature searches. Additionally, significant data for this analysis will be generated during the Forest Mortality Assessment.

In addition to distribution modeling, additional analysis will be required to determine the status of this assemblage across the landscape relative to the CAs and to predict how this assemblage will react to the potential future impact of those CAs. Data required for these predictions will be obtained from a variety of data sources including the USFS forest health ADS, LANDFIRE FRCC data, and PRISM and regional climate model climate change data provided by BLM.

The geospatial modeling will be based on the availability and quality of geospatial data for the states included in the ecoregion (Table 4.4-2). The five-needle pine GIS process models are designed to create a series of intermediate data layers that are based primarily on the CAs and, in some cases, proxies for CAs. The CAs affecting the Five-Needle Pine Assemblage are the MPB, WPBR, altered fire regimes, and climate change.

Table 4.4-2. Data Needs and Availability for the Five-Needle Pine Assemblage

Data Needs	Dataset Name	Source Agency	Type/Scale	Status	Use in REA
Distribution	Healthy Stands	USFS		Acquired	Yes
	Declining Stands	USFS		Acquired	Yes
	Deceased Stands	USFS		Acquired	Yes
	Protected Stands	USFS		Acquired	Yes
	Unprotected Stands	USFS		Acquired	Yes
Predicted Distribution	GAP Vegetation			Acquired	Yes
	LANDFIRE			Acquired	Yes
Insect and Disease Occurrences	ADS 2000-2009	USFS	Polygon	Acquired	Yes
Forest and Disease Risk	FHTET	USFS		Acquired	
Fire History/Fire Occurrence	Fire History 1985-2009	USFS	Polygon Point	Acquired	Yes
	MTBS	MTBS			
	GeoMac	USGS			
Forest Fuels	LANDFIRE	LANDFIRE		Acquired	Yes

Existing data pertaining to the MPB and WPBR will be extracted from USFS ADS data. This data will be used to look at the location of existing outbreaks and to look future potential outbreaks. The FRCC data will be used to analyze altered fire regime to look at the existing five-needle pine stands and their proximity to FRCC classes. The climate

CA layer will be created by taking the results of the 2060 USGS climate change models. These intermediate CA GIS outputs can be combined using a simple overlay analysis or a weighted overlay analysis to investigate the future potential risk of the five-needle pine. The methodology includes combining scores from the intermediate geospatial analysis layers and summing them together. The GIS process model can then be re-run changing necessary inputs for climate, insect/invasive outbreaks, or fire scenarios.

In addition to looking at the future risk of the five-needle pine, GIS analysis will be done to look at the size and landscape context of the CE. Existing patch size can be determined by calculating acreage. The existing patches can be analyzed in comparison to the size and extent of neighboring patches to determine the quality of individual five-needle pine stands and fragmentation of those stands. Neighborhood analysis can be run to determine the extent of five-needle pine in a given area and the different vegetation types within that area. Another important attribute for the five-needle pine is the potential for seed dispersal. Proximity analysis can be run to determine the likelihood of dispersal by the Clark's nutcracker based on the distance from five-needle pine stands.

Since the primary reporting units for final mapping outputs is at a minimum of the 6th level watershed (HUC12) for the CEs the values from the final output maps need to be added as an attribute to the HUC12 watersheds. Zonal statistics will be calculated to determine a value associated with each watershed. Zonal statistics simply calculates the values of the pixels within a given watershed and computes a single output for that watershed.

Table 4.4-2 lists the types and likely sources of data that would be used to help answer the MQs for this community. Some of these data have been obtained and others represent data gaps that would help to build a more complete picture to answer the MQs in a more detailed manner. The data sources for the Five-Needle Pine Assemblage are indicated in Table 4.4-2.

4.4.2 Greater Sage-Grouse

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

The GSG will be evaluated under the following set of assumptions:

1. Due to the ecoregional scale of this analysis, not all of the GSG life cycle phase habitat requirements will be able to be mapped.
2. The emphasis will be on large intact blocks of habitat and how they are connected or how far apart they are from one another and their juxtaposition on the landscape.

4.4.2.1 Management Questions Relative to the Greater Sage-Grouse

MQs pertaining to GSG in the Middle Rockies were identified in Task 1 and can be summarized as: 1) where are important habitat areas for the species? and 2) how will

their condition and suitability for the species change in the future? The processes described below are intended to answer these questions.

4.4.2.2 Greater Sage-Grouse Distribution Modeling

Due to the sensitivity of this species, the AMT and state partners suggested using the state's currently occupied habitat and breeding bird density layers to be consistent across the various programs. Montana FWP has tried to use Maxent to model this species with limited success and recommended using the sources mentioned above for distribution across the ecoregion. These layers will represent the current distribution of GSG and areas of management concern that are relevant at the scale of the REA.

4.4.2.3 Greater Sage-Grouse Conceptual Models

The ecological process model (Figure 4.4-3) was developed to identify and link the key life cycle processes to ecological attributes (EAs) that have the greatest potential to affect GSG habitat throughout the ecoregion. The key processes are identified in the model as the green boxes and following Unnasch et al. (2009), three broad headings or categories of EAs (size, condition and context) are identified in the model as blue diamonds. Size refers to attributes related to habitat or patch size, condition refers to the condition of the habitat and context refers to the spatial structure of the habitat. At the landscape level, the EAs under the condition category will be the most challenging to spatially represent and will primarily depend on the data available to represent this category.

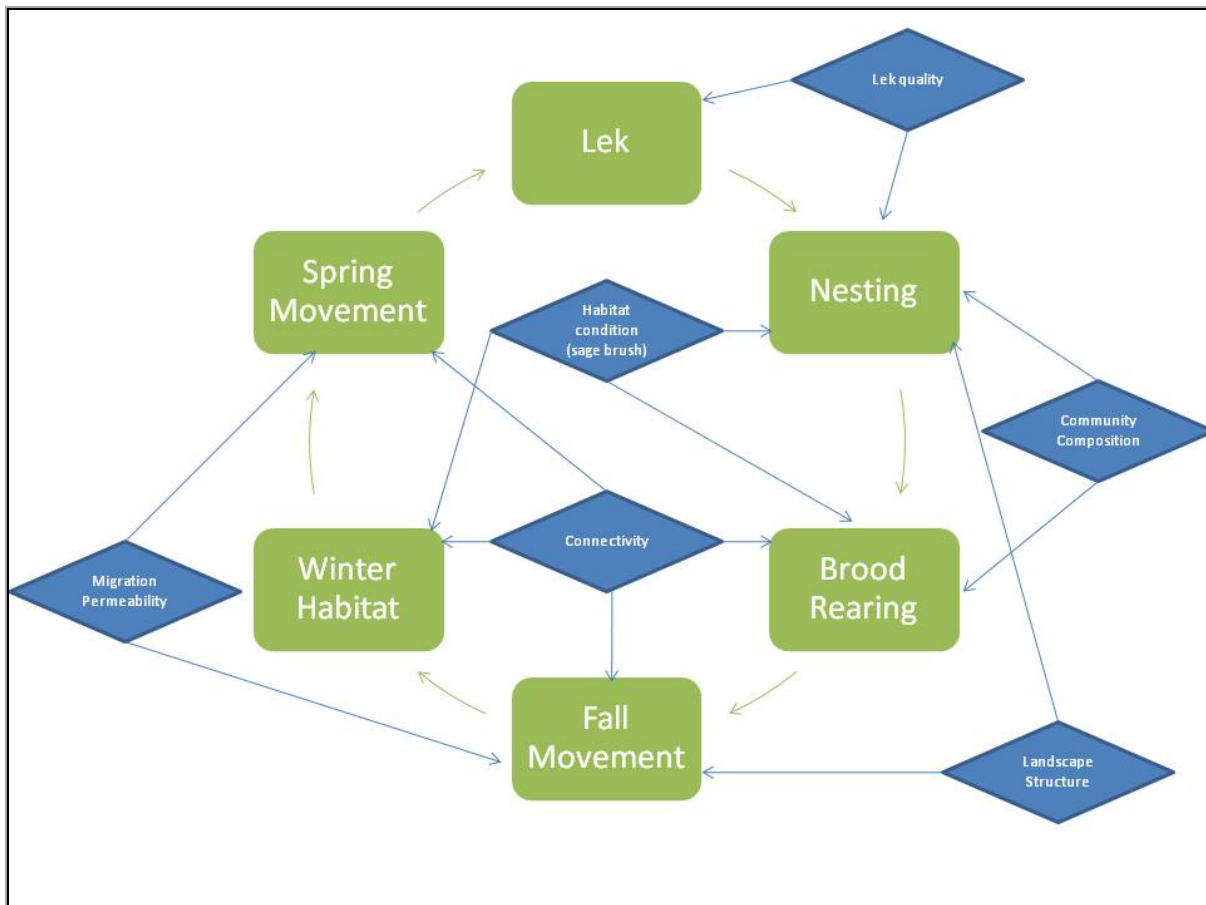
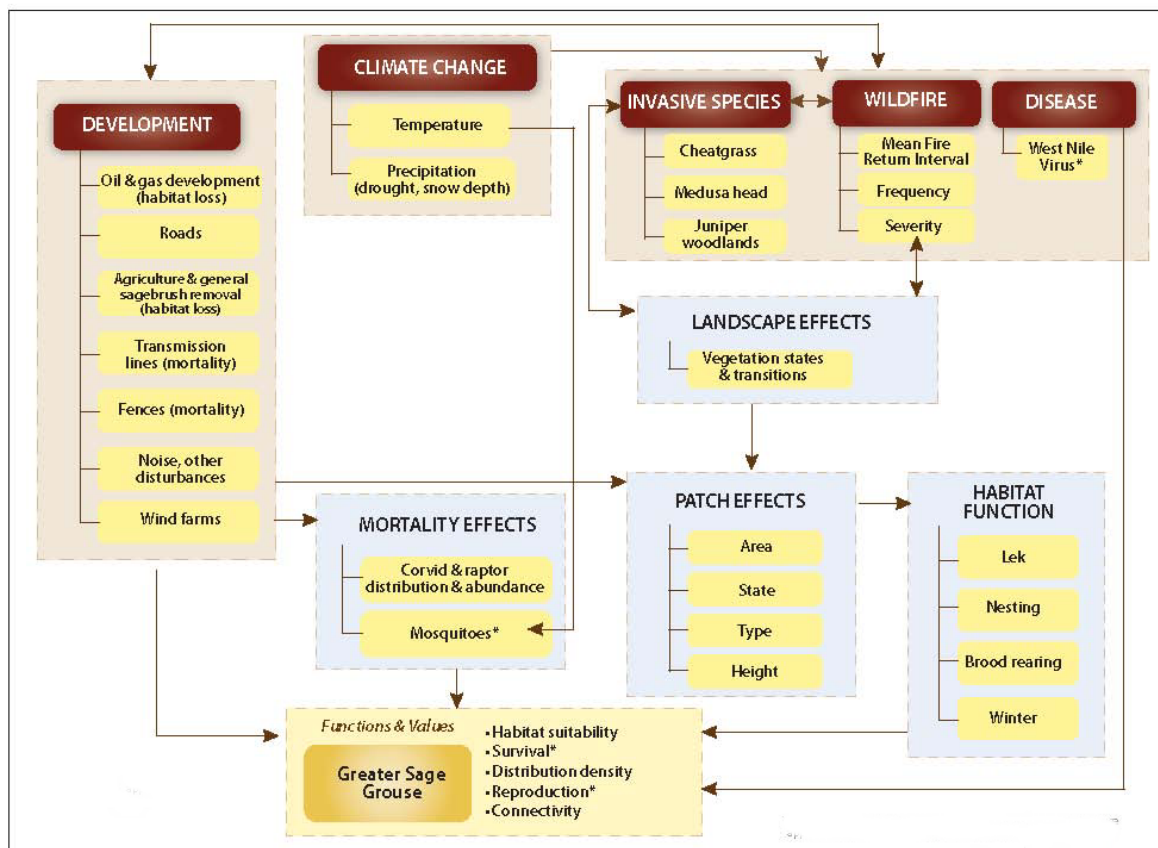


Figure 4.4-3. Greater Sage-Grouse Ecological Process Model

The current breeding density and core area data layers will form the starting point of the change agent (CA) analysis across the ecoregion, to understand how this species will react to the potential future impact of those CAs. The system-level conceptual model (Figure 4.4-4) summarizes the effects of CAs and their interactions on the habitat values and functions for GSG. CAs are identified across the top of the model in red. The suitability and availability of sagebrush communities are the primary factors affecting GSG populations. Change agents, such as climate change, development, wildfire and invasive species affect GSG habitats. The GSG system-level model includes attributes that are geospatially represented, and also documents data gaps where attributes are not expected to be available as geospatial data sets of the appropriate landscape scale. These attributes are labeled accordingly.



* This variable is impractical to model at the ecoregional scale because appropriate geospatial data coverage's are lacking.

Figure 4.4-4. Great Sage Grouse Assemblage System-Level Conceptual Model

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

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

Climate effects are expressed primarily as a range of suitable precipitation (Wisdom et al 2011) and the frequency and duration of drought (Aldridge et al. 2008). Evers (2010) suggested that under projected climate change, cooler and moister sagebrush communities (i.e., nesting and brood rearing habitat) would decrease substantially.

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

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

4.4.2.4 Greater Sage-Grouse Ecological Attributes, Data Needs, and GIS Process Models

Once the ecological process and system-level models were developed, indicators for the EAs were identified with a specific emphasis on the ability to measure the EA using existing geospatial data. The indicators will assist with answering the MQs that relate to what is happening to the CE across the ecoregion.

Table 4.4-3 identifies EAs, indicators and metrics that can be used to evaluate factors affecting this CE across the ecoregion. The EAs, indicators, and metrics listed in Table 4.4-3 can be evaluated using geospatial data. It is important to note that some attributes/indicators that could affect this assemblage are not included in this table because either the EA/indicator is not suitable for a landscape level analysis or data is not available to support the analysis.

Table 4.4-3. Greater Sage-Grouse Ecological Attributes, Indicators, and Metrics

Ecological Attribute	Indicator	Metric	Data Source	Citation
Size				
Lek Quality	Breeding Circle Persistence (% Cover of Artemesia spp within each buffered lek)	>65%=good 20%-65% =fair < 20% =poor	GAP/NLCD	Aldridge et al. 2008

**Table 4.4-3. Greater Sage-Grouse Ecological Attributes, Indicators, and Metrics
(Continued)**

Ecological Attribute	Indicator	Metric	Data Source	Citation
Size (Condition)				
Lek Quality (Continued)	Breeding Circle Persistence (% cropland within each buffered lek)	>65% = good 20%-65% = fair < 20% = poor	GAP/NLCD	Aldridge et al. 2008
Community Composition/Landscape Structure/Habitat Condition/Connectivity	Core Habitat Fragmentation (Sagebrush patch size)	>4000 = good 500-4000 = fair 500 ha = poor	GAP/NLCD	Wisdom et al. 2011
Condition				
Quality/Community Composition/Landscape Structure/ Habitat Condition	Cover Type	Small sagebrush (e.g., low, black); forb-rich mosaics of low and tall sagebrush Riparian meadows; Large, woody, tall sagebrush (e.g., big, silver, and three-tip) trees = good Scrub-willow; sagebrush savannas with tree encroachment= fair Cultivated fields (e.g., alfalfa, wheat, crested wheatgrass) woodlands = poor	GAP/NLCD	Crawford et al. 2004
	FRCC	1 = good 2 = fair 3 = poor	LANDFIRE	LANDFIRE
Landscape Context				
Community Composition/ Landscape Structure/ Habitat Condition/Connectivity/ Migration Permeability	Fragmentation (Edge Density - ratio of edge to interior)	1.5 – 2.5 = good 2.5 – 4 = fair > 4=poor	GAP/NLCD	Wisdom et al. 2011
	Fragmentation (Patch Density - No. of patches per 101,704 ha)	< 62 = poor 62-79 = fair > 79 = poor	GAP/NLCD	Wisdom et al. 2011

**Table 4.4-3. Greater Sage-Grouse Ecological Attributes, Indicators, and Metrics
(Continued)**

Ecological Attribute	Indicator	Metric	Data Source	Citation
Landscape Context (Continued)				
Connectivity/Habitat Condition	Oil and gas well density	< 5 wells within 1.9 miles of a breeding circle center = good 5 to 15 wells within 1.9 miles of a breeding circle center = fair >15 wells within 1.9 miles of a breeding circle center = poor	Oil & Gas Wells	Holloran 2005
	Oil and gas well pad density	< 1 well pad/2.6 km ² = good 1-7 well pad/2.6 km ² = fair > 7 pads/2.6 km ² = poor	Oil & Gas Wells	Naugle et al. 2006
	Road density (km/km2)	< 0.087 = good 0.087-0.112 = fair > 0.112 = poor	Linear Features	Wisdom et al. 2011
	Presence of Powerlines	Not within breeding or core area = good Not within breeding circle but within core area = fair Within breeding circle = poor	Linear Features	Hall and Haney 1997; Wisdom et al. 2011
	Distance to Towers	> 21 km from center of breeding circle and outside core area = good 12-21km from center of breeding circle or within core area = fair < 12 km from center of breeding circle = poor	??	Wisdom et al. 2011
	Distance to Highway	> 8 km from center of breeding circle and outside core area = good 5-8 km from center of breeding circle or within core area = fair < 5 km from center of breeding circle = poor	Linear Features	Wisdom et al. 2011
	% of combined breeding circles and core area in agriculture	< 9% = good 9-25% = fair > 25% = poor	GAP/NLCD, Core Areas & Breeding Circles	Wisdom et al. 2011
	Human Density (persons/km2) within combined breeding circles and core area in agriculture	< 2 = good 2-27 = fair >27 = poor	Census TIGER, Core Areas & Breeding Circles	Wisdom et al. 2011
Lek Quality/Community Composition/ Landscape Structure/ Habitat Condition	Annual Precipitation	< 38 cm = good 40-38 cm = fair < 40 cm=poor	NOAA	Wisdom et al. 2011

The EAs listed in Table 4.4-3 were categorized into the three categories of size, context and condition. This table includes the scoring metrics that will be used to evaluate the CE's habitat across the ecoregion. These metrics were derived from the literature where possible, however in some cases, best judgment was used. It is anticipated that interaction with BLM subject matter experts will help finalize these metrics. Similar efforts of developing ecological attribute tables have been provided by Oliver 2006, the Uinta Basin Adaptive Resource Management Local Working Group (UBARM, 2006), and O'Brian 2007.

Definitions for rankings of indicators were adapted from UBARM (2010) as follows: Poor: Allowing the indicator to remain in this condition for an extended period will make restoration or prevention of extirpation of sage-grouse practically impossible (e.g., it will be too complicated, costly, and/or uncertain to reverse the alteration). Fair: The indicator lies outside of its range of acceptable variation and requires human intervention for maintenance. If unchecked, sage-grouse will be vulnerable to serious degradation. Good: The indicator is functioning within its range of variation, although it may require some human intervention for maintenance.

Some indicators identified in Table 4.4-3 may be important only to breeding circles, while others may apply equally to core areas and breeding circles or may have a higher impact in breeding areas than in core areas. The metrics of the indicators and their applicability to one or both data layers was determined from an exhaustive literature review and based on best professional judgment. The attributes, indicators, and metrics listed in Table 4.4-3 can be evaluated using geospatial data. In some cases a proxy amenable to geospatial analysis has been identified. A data gap exists with regard to invasive species due to the lack of large-scale geospatial datasets covering the ecoregion and inability to identify a suitable surrogate. Table 4.4-4 indicates the data layers, their source, characteristics and acquisition status.

Table 4.4-4. Data Needs and Availability for the Greater Sage-Grouse

Data Needs	Dataset Name	Source Agency	Type/Scale	Status
Modeled Suitable Habitat	GAP Habitat Models	USGS	Raster (30m)	Acquired
	Habitat Model (BpS)	NatureServe	Polygon	Acquired
	Current and Historic Range	Washington Fish and Wildlife	Polygon (1:2 million)	Acquired
	State Derived Models	MT, WY, ND, SD State Agencies	Raster	Require Data
	WGA DSS Models	WGA Pilot Crucial Habitat	Raster	Require Data
Occurrences	State Natural Heritage Databases	MT, WY, ND, SD Natural Heritage Programs and fish & game depts.	Point	Require Data
	Breeding Bird Survey	USGS	Polygon	Acquired
	eBird	Avian Knowledge Network	Point	Acquired

Table 4.4-4. Data Needs and Availability for the Greater Sage-Grouse (Continued)

Data Needs	Dataset Name	Source Agency	Type/Scale	Status
Areas with potential for restoration of habitat or habitat connectivity	Management Plan Areas	USFS, NPS, BLM, USFWS	Polygon	Require Data
Location of Core Areas	Core Greater Sage-Grouse	BLM	Polygon	Acquired
Location of leks, nesting, brood-rearing, and winter habitat	BLM 2006 Compilation of States	BLM; MT, WY, ND, SD fish & game depts.	Point 1:24k	Acquired
Habitat Connectivity	WGA DSS Data	WGA	Polygon	Require Data
Industrial	Oil and Gas Wells	BLM	Point	Acquired
Energy/Transportation	Proposed Energy Developments and Corridors	BLM		Acquired
	Cellular Towers	FCC		Acquired
	Linear Features	BLM	Polyline	Acquired
Human	Urban/Exurban Areas	US Census	Polygon	Acquired

The geospatial modeling will be based on the availability and quality of reference data layers for the states included in the ecoregion. GSG GIS process models are designed to create a series of intermediate data layers that are based primarily on CAs. The development CA will include the extraction of data from multiple source datasets that will be combined using a union process. Linear features such as roads, utility corridors, etc will be buffered, so that all layers are polygons that can be used in GIS overlay analyses. The size of the buffer will be according to functional width estimates from the literature. Absent literature estimates, buffer widths will be relative to the significance of the disturbance by the linear feature. This type of proximity analysis will yield an inverse distance weight that will add greater significance to features such as interstate highway and less significance to an unimproved road.

These intermediate CA layers are then combined to form a single layer outlining areas that may negatively affect suitable GSG habitat. As indicated above, the GSG distribution layer consists of the BLM breeding density layer and the individual State's core areas. Landscape context features (habitat connectivity, etc.) will be incorporated into a GIS dataset for overlay analysis and comparison with the GSG distribution layer. The final step in this process will be the union of these datasets.

Since the analysis will be conducted at the scale of a HUC12 watershed, a layer of 6th level watersheds will be extracted for the ecoregion. A GIS process will iterate through the ecological functions and determine the value associated with each watershed. This value will be added as an attribute to the HUC12 layer. When the process has completed creation of the list of ecological functions it will add a new column with the sum of the values. The final layers will be created by combining the HUC12 watersheds (with ranked ecological functions) with the final suitable habitat layer and the habitat layer with potentially negative influences from CAs. The GIS process model can then be rerun changing necessary inputs for future climate and development scenarios.

4.4.3 Golden Eagle

The Golden Eagle is one of the most widely distributed of all the raptor species. However, western U.S. populations of the species are believed to be in decline. Due to management concerns and potential declining numbers, the AMT recommended the addition of the Golden Eagle as a CE in this REA.

4.4.3.1 Management Questions Relative to the Golden Eagle

A variety of the MQs identified in Task 1 apply to this species. 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? The intent of the process described below is to answer the MQs applicable to this species.

This assemblage will be evaluated under the following set of assumptions:

1. Monitoring for the Golden Eagle will focus on broad landscape factors and not on small-scale local habitat features that may be important at the county level but not important at the broad ecological level.
2. Not every feature of Golden Eagle habitat will be identified through this analysis.
3. The primary driver of distribution and abundance of this CE is loss of habitat due to conversion to agriculture.
4. The emphasis will be on large intact blocks of habitat and how they are connected or how far apart they are from one another and their juxtaposition on the landscape.

4.4.3.2 Golden Eagle Distribution Mapping

In order to answer the MQs regarding the distribution and status of the Golden Eagle across the Middle Rockies ecoregion, Maxent software will be used. SAIC will work with state and federal modeling partners to create a common set of parameters and data standards for the Maxent models.

The goal of the Maxent distribution modeling will be to determine the current distribution and status of this species throughout the Middle Rockies ecoregion. The goal of the post-Maxent process is to model the effects or risk of CAs against the Maxent distribution output. Examples of some ecological attributes are connectivity and patch size. Software such as Circuitscape or Corridors can be used to examine the connectivity between suitable habitats. Patch size can be analyzed in software such as Fragstats or by using various spatial operations such as “area to perimeter ratios” within ArcGIS.

4.4.3.3 Golden Eagle Conceptual Models

The Golden Eagle ecological process model (Figure 4.4-5) was developed to identify and link the key life cycle processes to ecological attributes (EAs) that have the greatest potential to affect Golden Eagle habitat throughout the ecoregion. The key processes are identified in the model as the green boxes and three broad headings or categories of EAs (size, condition and context) are identified in the model as blue diamonds. Size refers to attributes related to habitat or patch size, condition refers to the condition of the habitat and context refers to the spatial structure of the habitat. At the landscape level,

the EAs under the condition category will be the most challenging to spatially represent and will primarily depend on the data available to represent this category.

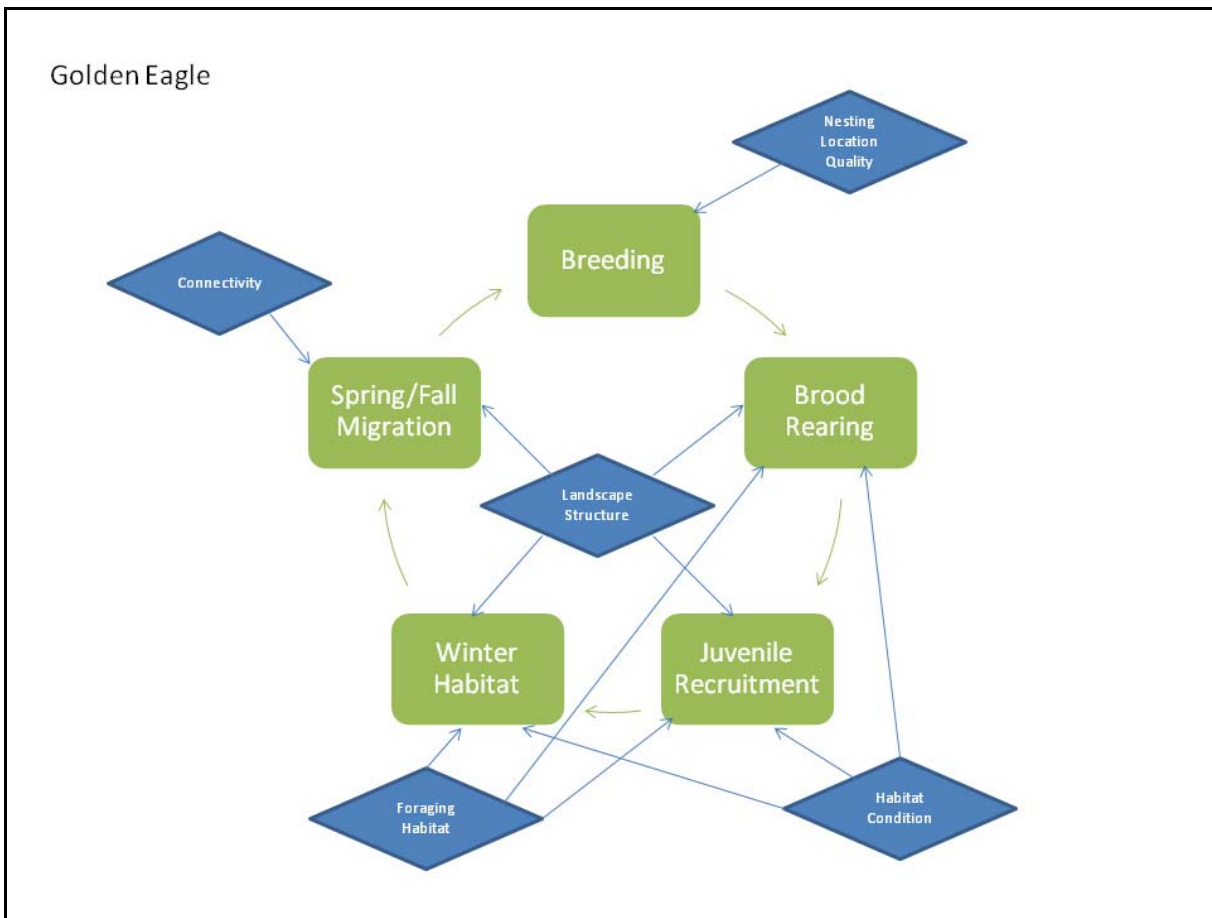


Figure 4.4-5. Golden Eagle Ecological Process Model

The status of the Golden Eagle in the Middle Rockies reflects local factors determining breeding territory occupancy, nesting success, and survivorship. Any agent of change that positively or negatively influences territory occupancy, nesting success, and/or survivorship has the potential to influence Golden Eagle population levels in the region.

Figure 4.4-5 outlines in detail the habitat features that are most closely associated with the Golden Eagle. For the purposes of this REA, these features have been categorized as species identifiers or CAs. The three primary CAs are identified across the top in red. Other indicators are included to identify the key species functions and values. Species identifiers are those features that directly affect the distribution of the Golden Eagle. CAs are current features that have a potential effect on the species both currently, and potentially in the future. Golden Eagle functions and values are characterized by territory occupancy, productivity, and survivorship.

The feature that most significantly affects the distribution of the Golden Eagle is vegetation. Vegetation is one of the key features that drives the breeding and feeding requirements for the species. A vegetation data layer provides information pertaining to prey species availability and nesting habitat. Prey species (e.g. blacktailed jackrabbit, ground squirrel, etc.) are closely associated with open vegetation communities (i.e. grasslands and shrubsteppe).

These vegetation types are excellent indicators of Golden Eagle prey species distribution. Vegetation data is also useful in identifying eagle nesting locations. Although eagle nests are closely associated with rocky cliffs, in the Middle Rockies the species also nests in riparian systems that border open grassland vegetation.

As shown in the system-level conceptual model, the Golden Eagle is threatened by development on a variety of levels (Figure 4.4-6). Direct mortality from transmission lines and wind turbines primarily affect immature and sub-adult eagles, but have also affected mortality of breeding adults (DeLong 2004). Although fire plays a part in short term effects on breeding populations, there is no correlation between fire and long term effects on Golden Eagles. Long term effects of development are closely related to disturbance, urban growth, and agricultural activities (DeLong 2004).

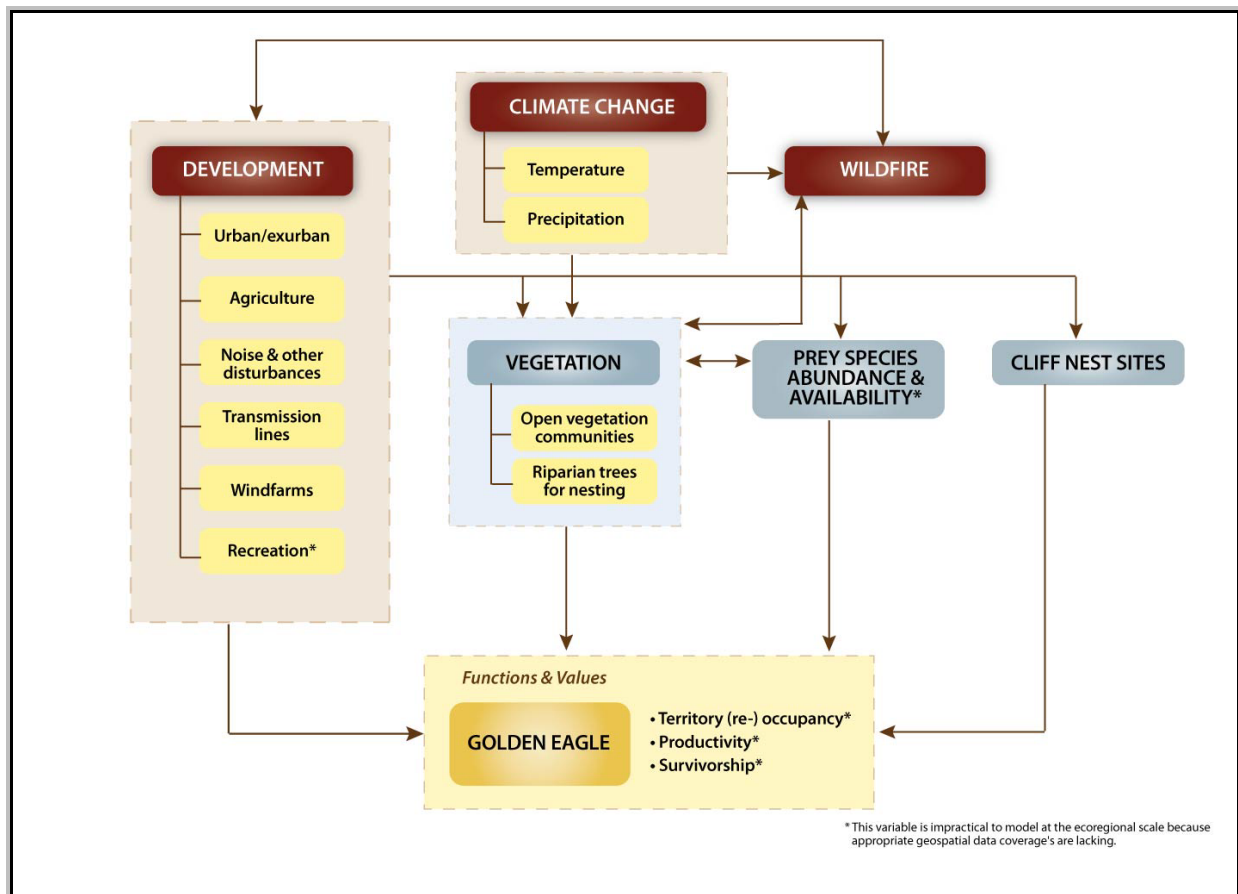


Figure 4.4-6. Golden Eagle System-Level Conceptual Model

Increased temperature leading to wildfires and destruction of natural habitat is a significant detrimental effect of climate change. Despite the potential negative effects associated with wildfire, positive effects to the Golden Eagle are also associated with wildfire. Fire has the potential to eliminate forested habitats and create clearings that Golden Eagles can use as alternative habitat, similar to habitat currently occupied by the species in its natural range in California and the Eastern United States. Generalist species such as the Golden Eagle are readily adaptable, and despite the potential negative short term affects on the breeding population, it is likely that the species would reoccupy historical home ranges once the habitat has recovered (Kochert et al. 1999). Wildfire will not be directly considered as a change agent of the Golden Eagle, because

of the complexity of the relationships involved, and because of its relatively minimal effect on species distribution.

The effect of human disturbance on Golden Eagle nesting remains largely understudied. However, coal mining activities have been known to affect breeding populations of Golden Eagles (Platt 1984). Other types of mining activities could have a potential affect on the breeding population and distribution of the species, but due to a lack of information, all other mining activities have been excluded from evaluation in this analysis. Roads greatly affect eagle mortality, but also play an important and complex role in eagle distribution. Golden Eagles avoid nesting in areas containing high densities of roads. Therefore roads are considered as a negative limiting factor in this analysis. See the appendix for a further discussion on the impact of roads within Golden Eagle habitat.

Agricultural activities also greatly affect Golden Eagle distribution (Marzluff et al. 1997; Beecham and Kocher 1975; Smith and Murphy 1973; McGahan 1968). As predators, eagle habitat is closely related to prey species. The primary prey species of the Golden Eagle inhabit predominately natural areas of shrubsteppe and grassland vegetation. Agricultural activities in these areas severely limit habitat use by Golden Eagles, as prey species habitat quality declines.

4.4.3.4 Golden Eagle Ecological Attributes, Data Needs, and GIS Process Models

Once the ecological process and system-level models were developed, indicators for the EAs were identified with a specific emphasis on the ability to measure the EA using existing geospatial data. The indicators will assist with answering the MQs that relate to what is happening to the CE across the ecoregion.

Table 4.4-5 identifies EAs, indicators and metrics that can be used to evaluate factors affecting this CE across the ecoregion. The EAs, indicators, and metrics listed in Table 4.4-5 can be evaluated using geospatial data. It is important to note that some attributes/indicators that could affect this assemblage are not included in this table because either the EA/indicator is not suitable for a landscape level analysis or data is not available to support the analysis.

Table 4.4-5. Golden Eagle Attributes, Indicators, and Metrics

Ecological Attribute	Indicator	Metric*	Data Source	Citation**
Size				
Foraging Habitat	Extent of suitable habitat patches (Patch size as %/HUC)	100% = good 24%-99% = fair 0%-23% = poor	Maxent	Marzluff et al. 1997; Beecham and Kocher 1975; Smith and Murphy 1973; McGahan 1968
Condition				
Habitat Condition	FRCC	FRCC 3 = good FRCC 2 = fair FRCC 1 = poor	LANDFIRE	LANDFIRE

Table 4.4-5. Preliminary Listing of Key Ecological Attributes, Indicators, and Metrics for the Golden Eagle (Continued)

Ecological Attribute	Indicator	Metric*	Data Source	Citation**
Condition (Continued)				
Nesting Location Quality	Annual Snowfall	Binary (Present = 1/Absent = 0) <500 cm/yr. = 1 ≥ 500 cm/yr. = 0		Platt 1984; Delong 2004
Landscape Context				
Connectivity	Circuitscape	Quantified through the use of Circuitscape and Distribution Data (point observations)	Circuitscape/Maxent	Circuitscape
Landscape Structure	Roads (Road Density)	<5 roads/km ² = good 5 - 9 roads/km ² = fair >10 roads/km ² = poor	Linear Feature	Steenhof et al. 1993 & Professional Judgement
	Transmission Lines (Distance to Transmission Lines)	≥5km = 1 = good 1 - 5km = fair <1km = poor	Transmission Line Point Location/BLM	Delong 2004; Professional Judgement
	Coal Mining (Distance to Coal Mining Activities)	Binary (Present = 1/Absent = 0) ≥1km = 1 <1km = 0	Coal Mine Point Location/BLM	Platt 1984; Delong 2004

Notes:

*Metrics: poor = 1; fair =2; good =3.

**Sources: Identification of Attributes and Indicators is derived from literature review, representative sources cited, coupled with professional judgment; Scales of metrics based on professional judgment.

The EAs listed in Table 4.4-5 were categorized into the three categories of size, context and condition. This table includes the scoring metrics that will be used to evaluate the CEs habitat across the ecoregion. These metrics were derived from the literature where possible, however in some cases, best judgment was used. It is anticipated that interaction with BLM subject matter experts will help finalize these metrics.

The Golden Eagle GIS process model is designed to create a series of intermediate layers that are primarily based on CAs (climate change, development, etc) and the geospatial data that is available (Table 4.4-6). This model was created to represent an oversimplification of the steps used in the geospatial analysis process. The development CA consists of agricultural areas, utility corridors, and roads. The climate CA layer will be created through the results of the 2025 and 2060 USGS climate change models. These models should document areas that may be negatively and positively affected by climate change. Climate change could have some possible positive effects on the suitable habitat for Golden Eagles.

Table 4.4-6. Data Needs and Availability for the Golden Eagle

Data Needs	Dataset Name	Source Agency	Type/Scale	Status
Modeled Suitable Habitat	GAP Habitat Models	USGS	Raster (30m)	Acquired
	NatureServe Habitat Model	NatureServe	Polygon	Acquired
	State Derived Models	ID, MT, WY, SD State Agencies	Raster	Pending DSA
	WGA DSS Models	WGA Pilot Crucial Habitat	Raster	Future Dataset
Occurrences	State Natural Heritage Databases	Natural Heritage Programs – ID, MT, WY, SD	Point	Acquired
	eBird	Avian Knowledge Network	Point	Acquired
	Breeding Bird Survey	USGS	Polygon	Acquired
	Christmas Bird Count	Audubon		Acquired
Sensitive Areas	Audubon Important Bird Areas	Audubon	Polygon	Acquired
	Bird Conservation Areas	Partners in Flight	Polygon	Require Data
Industrial	Coal Mines	BLM	Point	Acquired
Energy/Transportation	Transmission Lines	Sagemap	Polyline	Acquired
	Linear Features	BLM	Polyline	Acquired
Climate	Snowfall	NOAA	Raster	Acquired

Linear features such as roads, transmissions lines, etc will be buffered so that all layers are raster based and can be used in GIS overlay analyses and raster computations. The size of the buffer will be relative to the significance of the disturbance by the linear feature. This type of proximity analysis will yield an inverse distance weight that will add greater significance to features such as interstate highway and less significance to an unimproved road.

These intermediate CA layers are then combined together to form a single layer outlining areas that may negatively affect the suitable habitat for Golden Eagles. The suitable habitat for Golden Eagles will be modeled using Maxent. The Maxent output could optionally be sent out for Expert Review and additional corridor or fragmentation analysis. The final Golden Eagle output model can be used as a standalone layer or can be intersected with areas deemed to be negatively influenced by CAs.

Since the primary reporting units for final mapping outputs is at a minimum of the 6th level watershed (HUC12) for the CEs the values from the final output maps need to be added as an attribute to the HUC12 watersheds. Zonal statistics will be calculated to determine a value associated with each watershed. Zonal statistics simply calculates

the values of the pixels within a given watershed and computes a single output for that watershed.

4.5 ECOLOGICAL INTEGRITY ASSESSMENT

4.5.1 Ecological Integrity Assessment Framework

The concept of EI has a long and complex history but as applied to the REA process, the concept is described as the Ecological Integrity Assessment Framework (EIAF) which was developed by NS and The Nature Conservancy (TNC). The EIAF was developed by TNC through a series of processes with the defined purpose of determining if their conservation, management, and planning goals were being met (Parrish et al. 2003, Unnasch et al. 2008). Specifically, the EIAF was created to determine if “the ecological systems, communities, and species that are the focus of conservation efforts occur with sufficient size, with appropriate functioning ecological processes, and with sufficient natural composition, structure, and function to persist over the long term” (Parrish et al. 2003).

A coarse-filter/fine-filter CE approach is inherent in the implementation of the EIAF with the emphasis on larger-scale relationships and scales such as ecosystems (coarse-scale) and also key species with conservation requirements that are not adequately addressed at coarse-scale level are included in the EIAF (Unnasch et al. 2008). To simplify the analysis, these coarse-filter and fine-filter CEs are generally organized into large-scale coarse filters, vulnerable species assemblages and associate habitats, and vulnerable species (Unnasch et al. 2008).

KEAs that scientific understanding suggests will contribute to the CE’s resistance and resilience are identified after the coarse-scale and fine-scale CEs have been selected. Resistance is defined as the capacity of the CE to tolerate disturbances without a significant change in the state of the CE and resilience refers to the ability to recover to the previous state if a disturbance exceeds the capacity of the CE to resist change (Unnasch et al. 2008). Specifically, a KEA of a CE is a “characteristic of its biology, ecology, or physical environment that is so critical to the persistence of the CE, in the face of both natural and human-caused disturbance that its alteration beyond some critical level of variation will lead to the loss or degradation of the resource within decades or less” (Unnasch et al. 2008). Conceptual ecological models are used to identify a set of hypotheses about the CE’s characteristics and dynamics, as well as its critical environmental conditions and disturbance regimes that may act as drivers for the characteristics and dynamics. Typically, the CE’s KEAs include landscape context, condition, and size.

The EIAF approaches developed by NS and its partners can differ depending on whether the analysis is for terrestrial or aquatic systems and the following examples will first discuss the Unnasch et al. (2008) approach for terrestrial and aquatic systems. Next, the NS Faber-Langendoen et al. (2008) approach created for the Environmental Protection Agency (EPA) for analyzing wetlands will be illustrated to show its significantly different approach. Finally, the Montana Fish, Wildlife and Parks (2010) CAPS approach will be briefly described to illustrate an existing alternative to the NS approaches.

Designating the critical thresholds for all of KEAs of a particular CE establishes an “acceptable range of variation” response envelope within which the attribute can vary

without permanently affecting the CE (Unnasch et al. 2008). Thresholds can be classified as hard (irreversible change over time), soft (within resilience of the CE), and hard and immediate with the imminent loss of the entire CE.

Indicators of the status of the KEAs are necessary for managers to assess the status of the attributes and can be a specific measurable characteristics or a collection of characteristics aggregated into a multi-metric index (Unnasch et al. 2008). Because indicators are established to set limits on the variability of a particular KEA they set a different kind of acceptable range of variation that is only applicable to that particular attribute. Estimating the acceptable range of variation for an indicator establishes how much alteration of a KEA is too much. It is acknowledged that estimating the acceptable range of variation for every indicator may be difficult and it is expressly acknowledged that the estimates represent hypotheses that enable both management and research to improve upon the initial estimates to begin an iterative process (Unnasch et al. 2008). Indicators must be:

1. Specific and not significantly affected by other factors;
2. Reliably, accurately, and repeatedly measurable;
3. Sensitive to changes in the attribute;
4. Comprehensively able to detect the entire potential range of acceptable variation of the attribute;
5. Timely responding to changes in the attribute;
6. Technically feasible;
7. Cost-effective, and;
8. Partner-based.

The indicator scores for the Unnasch et al. form of the EIAF are combined and used to establish the status of the KEAs using the rules indicated in Table 4.5-1. Note that in the Unnasch et al. system the KEA is what determines the status of the CE and if the status of any KEA of a CE is below the acceptable range the status of the CE is less than acceptable and a similar rule exists for any key attribute with the status of imminent loss – i.e. there is no averaging or weighting of attributes. The CE status categories in Table 4.5-1 can be modified to incorporate other thresholds such as high, medium, and low.

Table 4.5-1. Integration of Indicator Information on the Status of the Conservation Element

Measurement at this level...	...informs the assessment of...	...through the application of this rule
Indicators	Key ecological attribute status	If a single indicator is used to assess the status of a KEA, its rating determines the rating of the KEA. If more than one indicator is used, an average of the ratings of all indicators determines the rating of the key attribute (<i>Note that there is no provision for scoring the indicator status in the Unnasch et al. system but TNC has used a system of high=3, medium=2, and low =1</i>). Tied ratings are resolved in favor of the more severe rating increment (<i>It is not clear what Unnasch et al. mean by this</i>).

Table 4.5-1. Integration of Indicator Information on the Status of the Conservation Element (Continued)

Measurement at this level...	...informs the assessment of...	...through the application of this rule
Key ecological attribute status	CE status	- The CE receives a rating of <i>Imminent Loss</i> if any key attribute receives this rating. - The CE receives a rating of <i>Potential Concern</i> if any key attribute receives this rating and none receives a more severe rating. - The CE receives a rating of <i>Acceptable</i> only if all key attributes receive this rating.

Table from Unnasch et al. 2008.

The NS Unnaasch et al. (2008) approach includes a table which is referred to as a scorecard to organize the information describing the attributes, indicators, and indicating rating criteria or metrics (Table 4.5-2). Note that the indicator status rating scores are considered to be hypothetical in the sense that there is generally very little data to support the actual breaks in the ranking and that future research to better estimate the category break points is explicitly anticipated – in other words these criteria are a first approximation and not a finalized rating system. As a hypothetical example using the scoring rules of Table 4.5-1, if the indicator status rating criteria for the landscape context attribute were adjacent land use = 1, buffer width = 3, and landscape predictors of hydrologic alteration = 3 then the status is potential concern. If the landscape pattern attribute indicator score was 3, just considering the landscape context only, the attributes would be potential concern and acceptable so the status of the CE would be potential concern. This is an explicit recognition of the individual importance of each of the KEAs for the CE.

Table 4.5-2. Example of an Ecological Integrity Scorecard for a Hypothetical Wetland System

Key Ecological Attribute	Indicator	Indicator Definition	Indicator Status Rating Criteria		
			Acceptable = 3	Potential Concern = 2	Imminent Loss = 1
Landscape Context					
Landscape Composition	Adjacent land use	Addresses the intensity of human dominated land uses within 100 m of the wetland	Average land use score = 0.80-1.0	Average land use score = 0.4-0.80	Average land use score <0.4
	Buffer width	Wetland buffers are vegetated, natural (nonanthropogenic) areas that surround a wetland	Wide >50 m	Narrow 25-50 m	Very narrow <25 m

Table 4.5-2. Example of an Ecological Integrity Scorecard for a Hypothetical Wetland System (Continued)

Key Ecological Attribute	Indicator	Indicator Definition	Indicator Status Rating Criteria		
			Acceptable = 3	Potential Concern = 2	Imminent Loss = 1
Landscape Context (Continued)					
Landscape Composition (Continued)	Landscape predictors of hydrologic alteration	Onsite or adjacent land uses and water uses that could result in changes to wetland hydrology	Low intensity alteration such as roads at/near grade, small diversion or ditches (< 1 ft. deep) or small amount of flow additions	Moderate intensity alteration such as 2-lane road, low dikes, roads w/culverts adequate for stream flow, medium diversion or ditches (1-3 ft. deep) or moderate flow additions	High intensity alteration such as 4-lane Hwy., large dikes, diversions, or ditches (>3 ft. deep) able to lower water table, large amount of fill, or artificial groundwater pumping or high amounts of flow additions
Landscape Pattern	Percentage of unfragmented landscape within 1 km	Measures extent to which landscape lacks barriers to the movement of species, water, nutrients, etc. between natural ecological systems	Embedded in 60-100% unfragmented natural landscape; internal fragmentation minimal	Embedded in 20-60% unfragmented natural landscape; internal fragmentation moderate	Embedded in <20% unfragmented natural landscape; internal fragmentation high
Condition					
Plant Assemblage Composition	Percent of cover of native plant species	Percent cover of the plant species that are native, relative to total cover (sum by species)	85-100% cover of native plant species	50-85% cover of native plant species	< 50% cover of native plant species
	Invasive species – aggressive plants	Percent of marsh dominated by invasive, aggressive plants	Native species such as <i>Typha</i> and <i>Phragmites</i> and/or other non-native invasive species occupy < 10% of wetland	Native species such as <i>Typha</i> and <i>Phragmites</i> and/or other non-native invasive species occupy 10-50% of wetland	Native species such as <i>Typha</i> and <i>Phragmites</i> and/or other non-native invasive species occupy >50% of wetland

Table 4.5-2. Example of an Ecological Integrity Scorecard for a Hypothetical Wetland System (Continued)

Key Ecological Attribute	Indicator	Indicator Definition	Indicator Status Rating Criteria		
			Acceptable = 3	Potential Concern = 2	Imminent Loss = 1
Condition					
Hydrologic Regime	Flashiness Index	Measures the variability in water depth fluctuations it compared to reference data	Flashiness Index = 1.0 - 2.0	Flashiness Index = between 2.0 - 3.0 if wetland is NOT associated with riverine	Flashiness Index = > 3.0 if wetland is NOT associated with riverine environment
Size					
Absolute Size	Absolute Size	The current size of the wetland relative to other examples of this type	> 25 acres (10 ha)	1 to 25 acres (0.4 to 10 ha)	< 1 acre (<0.4 ha)
Relative Size	Relative Size	The current size of the wetland divided by the total potential size of the wetland multiplied by 100	Wetland area < Abiotic Potential; Relative Size = 90 – 100% ; (< 10% of wetland has been reduced, destroyed or severely disturbed due to roads, impoundments, development, human induced drainage, etc.	Wetland area < Abiotic Potential; Relative Size = 75 – 90%; 10- 25% of wetland has been reduced, destroyed or severely disturbed due to roads, impoundments, development, human induced drainage, etc.	Wetland area < Abiotic Potential; Relative Size = < 75%; > 25% of wetland has been reduced, destroyed or severely disturbed due to roads, impoundments, development, human-induced drainage, etc.

Table from Unnasch et al. 2008.

The more complex NS Faber-Langendoen (2008) approach was developed for the EPA specifically to assess wetlands and is fundamentally different than the simpler NS Unnasch et al. (2008) approach in at least three respects: 1) It establishes a pre-European disturbance baseline for comparison instead of using the concept of the acceptable range of variation response envelope; 2) It expressly includes stressors (Table 4.5-3), and as applied in Roccio (2005); 3) It uses a dual weighting system and averaging (Table 4.5-5) vs. strict KEA condition status (Table 4.5-1). Like the simpler approach, the complex approach also expressly assumes that the indicator scores and weighting methods are first approximations that will be modified through an iterative research program (Faber-Langendoen et al. 2008). Table 4.5-3 illustrates the details of the EIAF and shows the emphasis on direct measures of the physical environment that are thought to be well correlated with key attributes.

Table 4.5-3. Example of an Ecological Integrity Table for Wetland Ecosystems

Status Factor	Key Ecological Attribute	Indicator
Landscape Context	Landscape Structure	Landscape Connectivity
		Buffer Index
		Surrounding Land Use Index
	Landscape stressors	Landscape Stressors Checklist
Size	Size	Patch Size Condition
		Patch Size
Condition	Vegetation (Biota)	Vegetation Structure
		Organic Matter Accumulation
		Vegetation Composition
		Relative Total Cover of Native Plant Species
	Vegetation (Biota) Stressors	Vegetation (Biota) Stressors Checklist
	Hydrology	Water Source
		Hydroperiod
		Hydrologic Connectivity
	Hydrology Stressors	Hydrology Stressors Checklist
	Soils (Physicochemical)	Physical Patch Types
		Water Quality
		Soil Surface Condition
	Soils (Physicochemical) Stressors	Soils (Physicochemical) Stressors Checklist

Table from Faber-Langendoen et al. 2008.

The NS Faber-Langendoen et al. (2008) did not include an example scorecard illustrating how indicator metric data that is not obtained through field work would be converted into status scores, how those scores would be combined, or how the indicator scores would affect the status of the KEAs. However, on the NS web site a number of the prototype analyses that led to the completion of the report are available that illustrate the approach. Table 4.5-4 shows the attributes, indicators, and indicator scores or metrics used by one of the NS/partner Colorado-based studies (Roccio 2005).

Table 4.5-4. Metrics and Rating Criteria for the Rocky Mountain Lower Montane Riparian Woodland and Shrubland System

Category	Key Ecological Attribute	Indicator	Definition	Metric Ranking Criteria			
				Excellent (A)	Good (B)	Fair (C)	Poor (D)
Landscape Context	Landscape Composition	Adjacent land use	Addresses the intensity of human dominated land uses within 100 m of the wetland	Average Land Use Score = 1.0-0.95	Average Land Use Score = 0.80-0.95	Average Land Use Score = 0.4-0.80	Average Land Use Score < 0.4
		Buffer width	Wetland buffers are vegetated, natural (nonanthropogenic) areas that surround a wetland	Wide > 100 m	Medium 50 - 100 m	Narrow 25 - 50 m	Very Narrow < 25 m
	Landscape Pattern	Percentage of unfragmented landscape within 1 km	An unfragmented landscape has no barriers to the movement and connectivity of species, water, nutrients, etc. between natural ecological systems	Embedded in 90- 100% unfragmented , roadless natural landscape; internal fragmentation absent	Embedded in 60- 90% unfragmented natural landscape; internal fragmentation minimal	Embedded in 20- 60% unfragmented natural landscape; Internal Fragmentation moderate	Embedded in < 20% unfragmented natural landscape. Internal fragmentation high
		Riparian Corridor Continuity	Indicates the degree to which the riparian area exhibits an uninterrupted vegetated riparian corridor	< 5% of riparian reach with gaps / breaks due to cultural alteration	> 5 - 20% of riparian reach with gaps / breaks due to cultural alteration	>20 - 50% of riparian reach with gaps / breaks due to cultural alteration	> 50% of riparian reach with gaps / breaks due to cultural alteration

Table from Roccio 2005.

Table 4.5-5 shows how the indicators for the landscape context were weighted, both by the A-D metric ranking criteria weights and by the explicit weighting column. Also note that the weights for the indicators are relative for all of the KEAs and sum to 1. This scoring system represents a fundamental change from the (Unnasch et al. (2008) approach which defined and modeled each of the KEAs as critical to the status of the CE. Thus, using this rating approach, the two systems are not equivalent ecological indicator assessment frameworks.

Table 4.5-5. Landscape Context Key Ecological Attribute Indicator Rating Calculation

Key Ecological Attribute	Indicator	Definition	A	B	C	D	Weight	Score (weight x rating)
Landscape Composition	Adjacent land use	Addresses the intensity of human dominated land uses within 100 m of the wetland	5	4	3	1	0.30	
	Buffer width	Wetland buffers are vegetated, natural (nonanthropogenic) areas that surround a wetland	5	4	3	1	0.30	

Table 4.5-5. Landscape Context Key Ecological Attribute Indicator Rating Calculation (Continued)

Key Ecological Attribute	Indicator	Definition	A	B	C	D	Weight	Score (weight x rating)
Landscape Pattern	Percentage of unfragmented landscape within 1 km	An unfragmented landscape has no barriers to the movement and connectivity of species, water, nutrients, etc. between natural ecological systems	5	4	3	1	0.10	
	Riparian corridor continuity	Indicates the degree to which the riparian area exhibits an uninterrupted vegetated riparian corridor	5	4	3	1	0.30	
	Landscape Context Rating	A = 4.5 - 5.0; B = 3.5 - 4.4; C = 2.5 - 3.4; D = 1.0 - 2.4						Total = sum of N scores

Table from Roccio 2005.

Montana Fish, Wildlife and Parks (2010) created an EI framework of its own design as part of its CAPS initiative. Unlike the NS approaches, the CAPS approach is not limited to a natural ecological system and expressly incorporates recreational value, game species quality, connectivity, and species of concern. Thus it specifically incorporates non-ecological values. While a number of data layers have been generated and individually scored and ranked for each of the attributes, the overall prioritization process where the data layers are categorized, weighed, and combined remains to be completed.

4.5.2 Application to Conservation Elements

EI is considered a CE in the SOW and is related to core CEs which are described as belonging to the suite of renewable natural resources and values that represent EI across terrestrial, riparian/wetland, and aquatic landscape units of the ecoregion. Conservation of the core CEs is intended to serve as a coarse-filter/fine-filter framework for conservation of the whole of the renewable natural resources and values within the ecoregion. The same core CEs are also intended to serve as a coarse-filter/fine-filter framework of surrogate indicators for conserving the EI of landscapes within the extent of the REA.

Similar to its use with the core CEs, the coarse-filter/fine-filter approach will be used to develop ecological models, or indices, of EI specific for the ecoregion at multiple scales. Also, unlike the core CEs, the ecological models will represent the integrity of the ecosystems within the ecoregion, regardless of whether or not a particular variable is a concern of local land managers.

Landscape units, 5th level HUC watershed, are the ecoregion landscape components used for reporting and mapping status and potential for change for all ecoregions, for aggregates of CEs (classes) and for EI across subregions and the ecoregion. Within an ecoregion, there are multiple watershed units within which CE attribute/indicator status will be integrated to determine EI. As discussed in the EIAF section above, the different methods used to integrate CE attribute/indicator status result in very different status

conclusions and we are assuming that the method described by Unnasch et al. (2008) will be used for this REA.

Landscape units include the following classes:

1. Conservation unit classes
 - a. Native, intact vegetation communities CEs class
 - b. Aquatic and riparian/wetland CEs class
 - c. Native fish and wildlife species CEs class
 - d. Others regionally identified CEs class
2. CA classes
 - a. Development CA class
 - b. Climate CA class
 - c. Wildland fire CA class
 - d. Invasive species CA class
 - e. Insects and disease CA class

Each CE/CA class contains one or more CEs/CAs, with each being defined by its KEAs, and with measurable indicators used to describe each indicator.

4.5.2.1 Status

Status of the landscape units is characterized by attributes and indicators for:

- Landscape Context (i.e., relationship to surrounding landscape),
- Condition (i.e., quality),
- Size (e.g., magnitude, proportion, density), and
- Trend (i.e., current change with no additional [i.e., future] CA forcing.)

4.5.2.2 Potential for Change

Potential for change will describe how status potentially may change in the future especially due to CA ecological system drivers.

Potential for Change is relevant to:

- Understanding the potential cumulative impacts of proposed land use allocations,
- Identifying the potential trade-offs associated with such allocations, and
- Developing potential on- and off-site mitigation strategies for such allocations.

Potential for change is characterized by attributes and indicators for:

- Direction of change (i.e., increasing/decreasing),
- Magnitude or scope of change,
- Likelihood of change, and
- Certainty of change.

Potential for change relative to the development CAs will be considered with respect to two time horizons:

- Short term, as indicated by the potential for change in 15 years, and
- Long term, as indicated by the potential for change in 50 years.

For the climate change CA, only the 2060 horizon will be used. Categorical information will be the primary information type tabulated and displayed (on maps) for the output

products of EI, status, and potential for change. Categories are established by setting thresholds delineating the acceptable range of variation for attributes/indicators as described in the EIAF section above.

Example tables describing the KEAs, indicators, and metrics are provided in the Section 4.0 describing each CA, core CE and its example system models. As described in the EIAF section above, each core CE will be assessed individually for its EI status. Currently, it has not determined how to standardize the overall EI assessment which is referred to in the SOW simply as the EI CE. The process that SAIC will use to conduct the overall EI analysis is described in Appendix 2.

THIS PAGE INTENTIONALLY LEFT BLANK

5.0 RECOMMENDED MODELS, METHODS, AND TOOLS FOR THE RAPID ECOREGIONAL ASSESSMENT ANALYSIS

5.1 SCALE AND SCOPE

5.1.1 Spatial Scales

One of the purposes of this REA is to determine the distribution of CEs and the potential effect of CAs on CEs. Therefore, the scale of the analysis is limited to the scope of the distribution of species across the ecoregion. The intent of the REA is to produce a rapid response to MQs in an attempt to produce output layers that are useful at the landscape scale. The scale at which data is derived is drawn from the efficiency with which it is required. Therefore, large-scale assessment of the data (6th level watershed) will be undertaken during the modeling phase of the REA.

GIS offers the ability to interpret and produce fine-scale results of modeling analysis. However, fine-scale assessments are not always practical. In the case of the REAs management of entire ecoregions covers multiple states and is limited in the available distribution, cohesion, and accuracy of the data. Landscape-scale analysis offers the ability to interpret information based on data overlap and habitat similarities across boundaries. Fine-scale data analysis often results in more accurate models, but is much more constrained by scale than landscape level analysis.

The difficulties associated with landscape-scale analysis result primarily from a lack of availability of uniform data sources. In the Memo 2 we identified potential data sources that were perceived to be relevant or pertinent to useful model outputs. It is important to understand the limitations in the accuracy of data at this scale, due to the lack of uniform data. Despite this limitation, landscape-scale analysis is also forgiving in its interpretation of data, specifically as a result of scale. Any analysis at the 6th-level watershed scale will not be limited by minor scale variations in ecosystem functions and values. The resulting output will therefore not be affected by small-scale fluctuations and anomalies.

5.1.2 Time Horizons

Many of the MQs identified for this REA involve questions related to potential for change over time. For all of the CAs except climate change, the BLM has determined that datasets should be evaluated for their viability to forecast for two future timeframes. These two timeframes will provide information related to change potential for the near term and the long term. The near term horizon is a 15 year outlook through the year 2025 and the long term horizon is a 50 year outlook through the year 2060. Specifically for the climate change CA, the current condition will be 2010 and the future condition to be assessed will be 2060.

For the forest mortality projections the BLM specifically indicated that the near term would be a five-year outlook through the year 2015. However in the proposal for this task order, the SAIC Team recommended that the BLM consider a 10 year historical window because insect induced tree mortality (primarily MPB) has been relatively high during this period.

5.1.2.1 Proximity Analysis

The primary factor affecting spatial analysis is proximity. The intent of all spatial modeling is the identification of a point or location within a spatial framework, and its spatial relationship to other features within that framework. For this REA, proximity not only relates to the modeling result we seek, but also to the methods of analysis. We intend to model the distribution of our CEs through Maxent or through the use of adopted datasets. In this case the features that overlap one another will be either selected or not selected from the analysis based on a positive or negative effect on the particular CE.

In geospatial software there are numerous tools available for the purpose of proximity analysis. These tools offer a variety of options depending upon the desired outcome of the procedure. For example, in the case of the Golden Eagle there are many factors that could affect its distribution. A few are listed below:

- What is the distance between conspecific nesting pairs?
- Do roads intersect ideal prey habitat?
- Do utility poles exist within 20 feet of major roads?

All of these questions can be answered through proximity analysis using geospatial tools designed to interpret spatial data. GIS allows the user to extract proximity information at both actual and interpolated distances. Actual distance can be measured using a number of tools that calculate various levels of proximity from basic point to point distance to weighted mean averaging for a large distribution of points.

Proximity analysis can be used on both vector and raster data. Feature-based proximity analysis is typically done by creating buffers to delineate distances around feature. An example of this analysis is if a resource manager wanted to determine vegetation types 30m from a stream. Another example of Feature-based proximity is to create a “multi-ring” buffer to classify distances away from a road as close or far away.

There are several raster-based analysis available also. One of the simpler distance base tools used is the Euclidean distance tool. Euclidean distance measures things in a straight line where a distance value is calculated for a given cell (ESRI 2009). Rather than simply measuring the minimum distance between two points, this tool is able to determine the direct minimum distance between multiple points (Figure 5.1-1). This tool is useful when relating distance to a feature type with multiple locations. Cost and path distance tools differ from Euclidean and account for other factors than just distance. This type of analysis can evaluate topography, elevation, land cover etc. and provide the user a least cost path layer output. This type of analysis is used to predict animal movement and enables raster output distance measurement data for multiple feature locations.

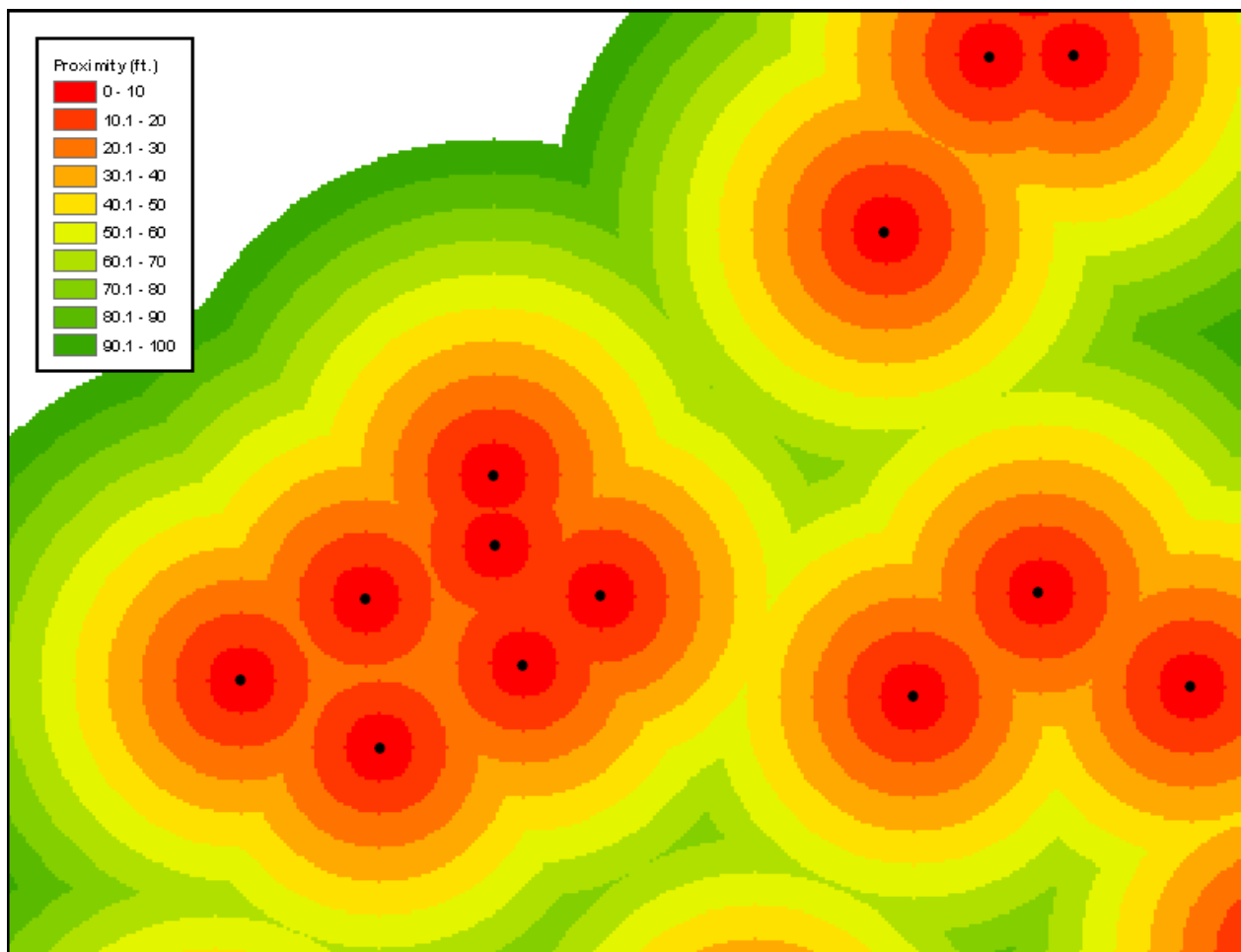


Figure 5.1-1. Example Euclidean Distance Proximity Analysis on Feature Locations

Another raster-based proximity tool is the distance decay model. This type of model assumes that the further away from a particular feature the strength in the relationship diminishes (de Smith et al. 2011). A commonly used distance decay method is the inverse distance weighted (IDW) model. The IDW is dependent on the inverse distance raised to a power giving the user the authority to control the significance between known points. The IDW method is a complex form of proximity analysis that enables the user to predict probable effects of various distance-related factors on spatial features. Interpolations also allow for weighted effects or bias caused by proximity, such as cluster of nests associated with a feature. This function operates through the assignment of a value to a feature. A feature's value is taken into account in the analysis relative to distance (Figure 5.1-2). This tool is useful in identifying features through weighting that would have a greater ecological effect on a CE, where distance is applicable.

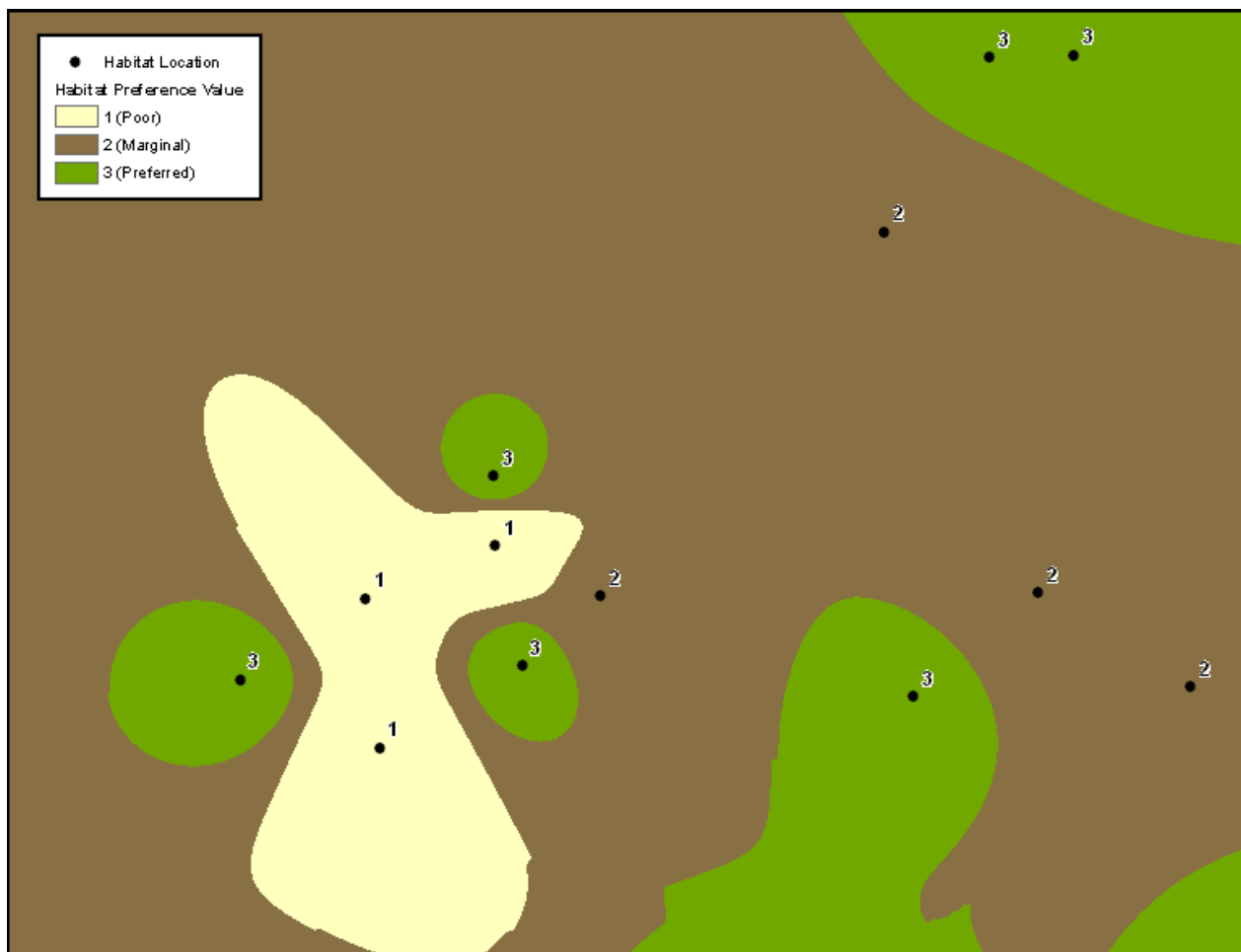


Figure 5.1-2. Example of Inverse Distance Weighting on Feature Locations

Figure 5.1-2 illustrates arbitrary values assigned to random locations and the relationship between location and value. This illustration demonstrates the influence of power on a feature location (i.e. habitat) and its effect on proximity to features of related values. For instance the three locations labeled 1 have equally weighted values and are therefore classified into the same category. As these areas become closer in proximity to the features labeled 3, the classification changes from poor to marginal to display their relationship based on these assigned values. This gives the user the ability to identify habitat areas based on assigned values (weights) and enables quantitative spatial evaluation. Areas containing no value information are interpolated to provide key evaluation information where data is lacking. To apply this in a practical sense, we will use a hypothetical example using Figure 5.1-2. Areas assigned a value of 1 are considered to be areas of poor habitat quality, those assigned a 2 are marginal, and those assigned a value of 3 are preferred. The interpolated data provides spatially quantitative results for use in further analyses. Using this approach it is possible to create spatial layers for comparable analysis with other important ecological layers. Although this example applies specifically to a habitat preference value, it can be applied to CAs (i.e. development, roads, etc.) or other factors affecting CE distribution.

The process of comparing features related to proximity in this REA requires that the data either be associated with positive or negative features. A positive association indicates that proximity to a feature would result in a positive (increase) effect on the

CE. A negative association would indicate the opposite. One example, related to the Golden Eagle is the occurrence of cliffs in close proximity to suitable habitat for prey species. This relationship has the potential to positively affect Golden Eagles. On the other hand, for this same CE, a road constructed through breeding territory could cause negative affects through disturbance and or increased mortality. Although this relationship can be evaluated in a simple linear analysis, the ecological interactions can be more complex. For example, although roads are often thought of as a negative effect for this CE, the combination of a road with utility poles can sometimes provide suitable nesting habitat and hunting perches for this species. Both of these associations are clearly positive relative to proximity to suitable habitat. These complex interactions will require resolution through expert opinion and analysis.

An additional factor that influences proximity is the impact of the feature. Some spatial features will have a greater positive or negative association with a CE than other features. For example, in general, roads are considered to cause negative effects to CEs. However, a small single lane gravel road is likely to have less of a negative effect than a four lane freeway. Therefore structures such as these will be evaluated using a weighted analysis. Referring to the road example, the single lane gravel road would undergo analysis based on buffering of the road edges to create a polygon associated with that feature. The gravel road would be expected to have a lesser effect on the CE, thus receiving a smaller buffer area surrounding the centerline. The freeway would be assigned a larger buffer area, based on the expected effect on the CE. Various studies have identified weighting factors that could be applied to linear, point or polygon features (Comer and Hak 2009, Kotliar et al. 2008 Appendix B Greater Sage-Grouse disturbance model, Charry and Jones 2010 traffic volume).

This form of weighted analysis would directly relate to the proximity analysis. In order to determine the proximity effect of a feature on a CE, IDW interpolations are proposed. This method enables the analyst to determine the potential effect of increased or decreased distance between features. Simply put, features nearest the CE attributes will be assigned greater weight than those farther away, or the larger the feature the greater the weight. These tools are integral to geospatial software, enabling simple transitions between data input, analysis, and output.

5.2 STATISTICAL APPROACHES (E.G., MULTIVARIATE, LOGISTIC, OR GLM ANALYSES)

5.2.1 Introduction

Numerous statistical software packages have been created for analysis of habitat fragmentation and species distribution indexes. The difficulty lies in implementing a method that is conducive to a species or ecosystem. With regard to the REA process further complications arise as a result of the complexity of the topics, broad representation of CE species, and landscape scale.

Due to the variation of these factors, statistical analysis will be limited by subject. A good example of this limitation applies to the pine marten. In order to determine a statistically significant result in comparison of predicted distribution with known distribution, an adequate sample size (n) must exist. A simple student's t-test would be adequate to make this comparison, however, given the probable low number of known observations compared with a low number of predicted observations, it is probable that a statistically significant result will not be attained. This would be more amplified in an

analysis of a species like the wolverine that is limited in number and distribution. Additionally, the lack of ability to verify presence through field verification makes this statistical comparison impossible. Some species will provide opportunities for statistical analysis, and where applicable, these exercises will be implemented as appropriate to the availability of species data.

Similar difficulties apply relative to habitat statistical analysis. Although several statistical packages exist that enable landscape-scale analyses, the inability to obtain ground verification information for predicted habitat makes statistical comparisons less powerful.

5.2.2 Potential Statistical Analyses

The potential variation in data quality, results, scope, and scale requires a multifaceted approach to statistical analysis. The REA process will result in predictions based on habitat fragmentation, species distribution, and climate change. In order to account for statistically significant analysis of spatial information several standard statistical formats will be used as appropriate. The following is a list of preferred spatial statistical methodologies which are readily available for use:

- ESRI ArcGIS Geostatistical Analyst
- Hawth's Tools
- FRAGSTATS
- Other Ecological and Biological Statistical Methodologies

ESRI is the leading developer of geospatial software, and this position has afforded them the ability to create specific modeling tools for use in geospatial analysis. Additionally, ArcGIS is one of the primary tools used in the spatial analysis, therefore it is important to obtain statistical tools that can be used in conjunction with this software. ArcGIS Geostatistical Analyst provides numerous tools that enable spatial statistical analysis. When appropriate we recommend the use of this tool based on interoperability, accessibility, and suitability.

Hawth's Tools is an add-on feature for ArcGIS developed by the Department of Biological Sciences at the University of Alberta. Although this toolset is limited in its statistical analysis capabilities, it offers numerous tools which are useful in the REA process. Additionally, some statistical tools are included in the toolset and could be useful in data analysis.

Ecologists studying habitat fragmentation predominately rely on FRAGSTATS for habitat variation analysis. This program was created specifically for analysis of heterogeneous landscapes, and will be useful in the REA coarse-scale assessments.

In addition to the various software programs other statistical analysis will be implemented when applicable. These statistical exercises will be dependent upon the species or ecosystem. Because of the broad range of CEs, landscape scale, and diversity, the statistical method used to determine significance will be customized appropriately for each subject.

5.3 DECISION-SUPPORT MODELS

5.3.1 Multi-Criteria Evaluation

One of the major difficulties of the REA process is to develop the framework to investigate the CEs and CAs to attempt the answer the MQs finalized in the first Memorandum. The REA process lends itself using GIS as tool for both visualization of what is on the landscape, but also to aid in investigating an area for preservation and restoration of the resources. For this memorandum a decisions support model is a GIS-based method for combining spatial data and expert knowledge framework to aid in the evaluation of the landscape for the CEs. Decision support models give managers the power of GIS support and a methodology in the decision making process.

There are several spatial decision support models available and a few will be discussed below. The overall approach SAIC recommends using is a GIS-based MCE model. This approach has been well documented in land use planning, landscape ecosystem analysis, and regional and urban planning.

MCE is a method to combine the information from several criteria to form a single index or map (Voogd 1983 and Carver 1991). Each criterion can be multiplied by a weight and then summed to arrive at a final suitability map. The most common MCE technique is the weighted linear combination (WLC). Using the WLC, weights are applied to each factor and then summed for a final suitability score (Eastman et al.1995 and Eastman 1997).

$$S = \sum w_i x_i$$

Where S=Suitability
 W_i= Weight of criteria i
 X_i=Score of Criteria i

As discussed earlier in our system models, several criteria will need to be integrated and evaluated, so this approach seems to fit appropriately. The MCE approach can be easily implemented with the ArcGIS platform using ModelBuilder. The ability to build models with ArcGIS is of significant value because contractually deliverables are to be ESRI compatible. ModelBuilder allows the users to change and add parameters, change data and data processes within ArcGIS. In addition it allows the user to add weights to the criteria to be evaluated.

5.3.2 Spatial Analytical Tools

Each of the spatial decision support systems described have their strengths and weaknesses. When evaluating the analysis tools we investigated several factors:

1) model interoperability, 2) flexibility, 3) ease of use, 4) costs, and 5) the ability to duplicate. The overall goal of our decision support modeling approach is to provide a product that can be easily used by BLM staff without a high learning curve. The idea is to create an approach that allows a methodology that is easy to duplicate without having to learn new software, but allows for the flexibility to incorporate other analysis tools if needed.

5.3.2.1 NatureServe Vista

NS Vista is a free decision-support system created to assist users in the integration of conservation into the resource planning processes. Vista is used by land use and

resource managers in conducting resource assessments, land use planning and allocating development activities while accounting for conservation values. One key benefit of NS Vista is Vista's interoperability with the ESRI ArcGIS platform as an extension. <http://www.natureserve.org/prodServices/climatechange/ccvi.jsp> SAIC does not anticipate using Vista in this REA.

5.3.2.2 *Vegetation Dynamics Development Tool*

The Vegetation Dynamics Development Tool (VDDT) was created by ESSA Technologies. The VDDT provides a current state and transition modeling framework for examining how the affects of CAs and management decisions will alter the vegetative landscape. VDDT provides a common platform for multidisciplinary specialists to collectively define the roles of various processes and CAs on landscape-level vegetation dynamics. SAIC does not anticipate using VDDT in this REA.

5.3.2.3 *The Ecosystem Management Decision Support*

The Ecosystem Management Decision Support (EMDS) system provides decision support for integrated landscape evaluation and planning. The system provides decision support for landscape-level analyses through logic and decision engines integration. EMDS integrates two commercial applications, NetWeaver Developer and Criterium DecisionPlus. SAIC does not anticipate using EMDS in this REA.

5.3.2.4 *Circuitscape*

Circuitscape is a free, open-source program which borrows algorithms from electronic circuit theory to predict patterns of movement among plant and animal populations in heterogeneous landscapes. Circuitscape uses the least-cost theory in predicting connectivity across a landscape. Circuitscape can be used to identify areas of habitat connectivity. Circuitscape also allows the data to be exported into ArcGIS to evaluate potential corridors with other resource information. SAIC may use Circuitscape in this REA.

5.3.2.5 *IDRISI-Land Use Change Modeler*

Land Use Change Modeler for ArcGIS is created by IDRISI GIS and image processing tools. Though IDRISI is a standalone GIS, the land use change modeler does possess the interoperability to work as an extension with ESRI's ArcGIS. Land use change modeler offers a suite of tools for land cover change analysis, landscape scenarios, allowing the user to project future impacts on habitat and diversity. IDRISI and extensions are not free and costs vary depending on number of licenses and use.

As stated above SAIC is recommending a GIS-based MCE model for analysis and scoring of criteria to form a single index. The MCE can be used within the ArcGIS platform using Modelbuilder. The models created within ModelBuilder can be easily duplicated and given to BLM GIS analysts to use and/or modify. The MCE approach integrated with the ArcGIS Modelbuilder also has the flexibility to use data outputs from other spatial decision support systems. Another benefit of this approach is ESRI ArcGIS is the most widely used GIS platform and Modelbuilder is "out of the box" technology, therefore the learning curve is minimal. In addition, ESRI has a large support center including on call technical support and a large knowledge base forum.

6.0 REFERENCES

- Agee, J.K. 1993. Fire ecology of Pacific Northwest forests. Island Press, Washington, D.C., USA.
- Aldridge, C.L., and M.S. Boyce. 2007. Linking occurrence and fitness to persistence: a habitat-based approach for Greater Sage-Grouse. *Ecological Applications* 17:508-526.
- Aldridge, C.L., S.E. Nielsen, H.L. Beyer, M.S. Boyce, J.W. Connelly, S.T. Knick, and M.A. Schroeder. 2008. Range-wide patterns of Greater Sage-Grouse persistence. *Diversity and Distributions* 14: 983-994.
- Allen, T.F.H., and T.W. Hoekstra. 1992. Towards a unified ecology. Columbia University Press, New York. 384 pp.
- Andelman, S., I. Ball, F. Davis, and D. Stoms. 1999. SITES V1.0: An analytical toolbox for designing ecoregional conservation portfolios. An unpublished manual prepared by the National Center for Ecological Analysis and Synthesis, University of California at Santa Barbara, CA.
- Anonymous. 2010. Bias corrected and downscaled WCRP CMIP3 climate projections. <http://gdo-dcp.ucllnl.org/>. Web site accessed 12/29/2010.
- Ashton, I.W., S. Ostermann-Kelm, T. Rodhouse, K. Tonnessen, E. Porter, and D. McWethy. 2010. Observed and projected ecological response to climate change in the Rocky Mountains and upper Columbia Basin. USDI, NPS, Natural Resource Report NPS/ROMN/NRR-2010/220.
- Baglien, J. W. 1975. Biology and habitat requirements of the nesting Golden Eagle in southwestern Montana. M.S. thesis. Montana State University, Bozeman, Montana. 63 pages.
- Baker, W.L. 2006. Fire and Restoration of Sagebrush Ecosystems. *Wildlife Society Bulletin* 34:177-185.
- Baker, W.L. 2009. *Fire Ecology in Rocky Mountain Landscapes*. Island Press.
- Barrett, S., D. Havlina, J. Jones, W. Hann, C. Frame, D. Hamilton, K. Schon, T. Demeo, L. Hutter, and J. Menakis. 2010. Interagency Fire Regime Condition Class Guidebook. Version 3.0 [Homepage of the Interagency Fire Regime Condition Class website, USDA Forest Service, US Department of the Interior, and The Nature Conservancy]. [Online], Available: www.frcc.gov.
- Bartlein, P.J., S.W. Hostetler, S.L. Shafer, J.O. Holman, and A.M. Solomon. 2003. The seasonal cycle of wildfire and climate in the western United States, 5th Symposium on Fire and Forest Meteorology, American Meteorological Society available online at <http://umbearfacts.com/publications/18seasonalwildfire.pdf>.
- Bates, J.D., R.F. Miller, and T. Svejcar. 2000. Understory vegetation response and nitrogen cycling following cutting of western juniper. *J. Range Manage.* 53:119-126.
- Beck, J.L., K.P. Reese, J.W. Connelly, and M.B. Lucia. 2006. Movements and survival of juvenile Greater Sage-Grouse in southeastern Idaho. *Wildlife Society Bulletin* 34:1070–1078.

- Beecham, J. J., and M. N. Kochert. 1975. Breeding biology of the Golden Eagle in southwestern Idaho. *Wilson Bulletin* 87:506-513.
- Bentz, B.J., J. Regniere, C.J. Fettig, E.M. Hansen, J.L. Hayes, J.A. Hicke, R.G. Kelsey, J.F. Negron, and S.J. Seybold. 2010. Climate change and bark beetles of the western United States and Canada: direct and indirect effects. *Bioscience* 60:602-613.
- Berger, J. 2004. The last mile: How to sustain long distance migration in mammals. *Conservation Biology* 18:320-331.
- 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.
- Braake, M., and M. McCaffrey. 2010. Lessons Learned Report: Ecoregional Assessment Processes. Unpubl. Document available online at http://www.blm.gov/pgdata/etc/medialib/blm/wo/Communications_Directorate/public_affairs/landscape_approach/documents1.Par.51236.File.dat/20101110_EcoregionalAssessment_Lessons_Learned_Report_FINAL.pdf.
- Braun, C.E. 1998. Sage Grouse declines in western North America: what are the problems? *Proceedings of the Western Association of State Fish and Wildlife Agencies* 78:139-156.
- Brown, J.K. 1995. Fire regimes and their relevance to ecosystem management. Pages 171-178 In *Proceedings of Society of American Foresters National Convention*, Sept. 18-22, 1994, Anchorage, AK. Society of American Foresters, Wash. DC.
- Caffrey C., Smith SCR., Weston TJ. 2005. West Nile virus devastates an American crow population. *Condor* 107:128–132.
- Cameron, E.S. 1908. Observations on the golden eagle in Montana. *Auk* 25: 251-268.
- Carpenter, J., C. Aldridge, and M.S. Boyce. 2010. Sage-Grouse Habitat Selection During Winter in Alberta. *The Journal of Wildlife Management*, 74: 1806–1814.
- Connelly, J. W., W. J. Arthur, and O. D. Markham. 1981. Sage grouse leks on recently disturbed sites. *Journal of Range Management* 52:153-154.
- Carver, S. J. 1991. Integrating Multi Criteria Evaluation into Geographic Information Systems *International Journal of GIS* 5(3) pp 321-339.
- Centers for Disease Control and Prevention. 2011. National Center for Emerging and Zoonotic Infectious Diseases, Division of Vector-Borne Diseases
- Charry, B., and J. Jones. 2010. Traffic volume as a primary road characteristic impacting wildlife: A tool for land use and transportation planning. In *Proceedings of the 2009 International Conference on ecology and transportation*, edited by P.J., Wagner, D. Nelson and E. Murray. Raleigh, NC: Center for Transportation and the Environment, North Carolina State University.
- Colorado Greater Sage-Grouse Conservation Plan Steering Committee. 2008. Colorado Greater Sage-Grouse Conservation Plan. Colorado Division of Wildlife, Denver, Colorado. (Unpublished report.)

- Comer, P.J. and J. Hak. 2009. NatureServe Landscape Condition Model. Technical documentation for NatureServe Vista decision support software engineering. NatureServe, Boulder CO.
- Connelly, J.W., A.D. Apa, R.B. Smith, and K.P. Reese. 2000a. Effects of predation and hunting on adult Sage Grouse *Centrocercus urophasianus* in Idaho. *Wildlife Biology* 6:227-232.
- Connelly, J.W., and C.E. Braun. 1997. Long-term changes in Sage Grouse *Centrocercus urophasianus* populations in western North America. *Wildlife Biology* 3/4:123-128.
- Connelly, J.W., K.P. Reese, R.A. Fischer, and W.L. Wakkinen. 2000a. Response of sage grouse breeding population to fire in southeastern Idaho. *Wildlife Society Bulletin* 28:90-95.
- Connelly, J.W., M.A. Schroeder, A.R. Sands, and C.E. Braun. 2000b. Guidelines to manage Sage Grouse populations and their habitats. *Wildlife Society Bulletin* 28(4):967-985.
- Connelly, J.W., S.T. Knick, M.A. Schroeder, and S.J. Stiver. 2004. Conservation assessment of greater sage-grouse and sagebrush habitats. Western Association of Fish and Wildlife Agencies. Unpublished Report. Cheyenne, WY, USA.
- Dale, V., L. Joyce, S. McNulty, R. Neilson, M. Ayres, M. Flannigan, P. Hanson, L. Irland, A. Lugo, C. Peterson, D. Simberloff, F. Swanson, B. Stocks, and B. Wotton. 2001. Climate change and forest disturbance. *BioScience* 51: 723-734. doi: 10.1641/0006-3568(2001)051[0723:CCAFD]2.0.CO;2.
- Daly, C., W.P. Gibson, G.H. Taylor, G.L. Johnson and P.A. Pasteris. 1998. New methods for mapping climate in complex regions. *J. Appl. Meteor.* (In Review).
- Daly, C., and G. Johnson. 2008. Climate mapping with PRISM. Oregon State University. Corvallis, OR.
- Daly, C., D.R. Conklin, and M.H. Unsworth. 2009. Local atmospheric decoupling in complex topography alters climate change impacts. *International Journal of Climatology*. DOI:10.1002/joc.2007.
- Daly, C., M.D. Halbleib, J.L. Smith, W.P. Gibson, M.K. Doggett, and D. Ojima. 2008. Physiographically sensitive mapping of climatological temperature and precipitation across the coterminous United States. *International Journal of Climatology*. DOI:10.1002/joc.1688.
- DeLong, J.P. 2004. Effects of management practices on grassland birds: Golden Eagle. Northern Prairie Wildlife Research Center, Jamestown, ND. Northern Prairie Wildlife Research Center Online. <http://www.npwrc.usgs.gov/resource/literatr/grasbird/goea/goea.htm> (Version 28MAY2004).
- de Smith, M., Goodchild, M. F., & Longley, P. A. (2008). *Geospatial analysis: A comprehensive guide to principles, techniques, and software tools*. (2nd ed.) Leicester: Matador Press.

- Doherty, K.E., D.E. Naugle, B.L. Walker, and J.M. Graham. 2008. Greater Sage-Grouse winter habitat selection and energy development. *Journal of Wildlife Management* 72:187-195.
- Eastman J.R., 1995. Decision Support. In: Idrisi for Windows: User's guide version 1.0. Clark Labs for Cartographic Technology and Geographic Analysis. Clark University, Worcester, Mass: 10.1.10.6.
- Eastman, J. R. 1997. Idrisi for Windows, Version 2.0: Tutorial Exercises, Graduate School of Geography – Clark University, Worcester, MA.
- Elguindi, N., X. Bi, F. Giorgi, B. Nagarajan, J. Pal, F. Solmon, S. Rauscher, and A. Zaakey. 2010. RegCM Version 4.0 Users Guide. Trieste, Italy.
- Ellis, K.L. 1987. Effects of a new transmission line on breeding Sage Grouse at a lek in northwestern Utah. In J. Roberson, chairman. Fifteenth Sage Grouse Workshop Transactions of the Western States Sage Grouse Committee, Western Association of Fish and Game Agencies.
- Ellis, C.R., J.W. Pomeroy, R.L.H. Essery, and T.E. Link. 2010. Effects of needleleaf forest cover on radiation and snowmelt dynamics in the Canadian Rocky Mountains. *Canadian Journal of Forest Research*. 41:608-620.
- ESRI (Environmental Systems Resource Institute). 2009. ESRI, Redlands, California
- Evers, L. 2010. Modeling Sage Grouse habitat using a state and transition model Ph.D. Dissertation, Oregon State University, Corvallis, OR
- Faber-Langendoen, D., G. Kudray, C. Nordman, L. Sneddon, L. Vance, E. Byers, J. Rocchio, S. Gawler, G. Kittel, S. Menard, P. Comer, E. Muldavin, M. Schafale, T. Foti, C. Josse, J. Christy. 2008. Ecological Performance Standards for Wetland Mitigation: An Approach Based on Ecological Integrity Assessments. Report to the Environmental Protection Agency by NatureServe, Arlington, VA. January 2009.
- Fagre, D.B., C.D. Allen, F.S. Chapin, P.M. Groffman, G.R. Guntenspergen, A.K. Knapp, A. D. McGuire, P.J. Mulholland, D.P.C. Peters, D.D. Roby, and G. Sugihara. 2009. Thresholds of climate change in ecosystems: Final report, synthesis and assessment product 4.2. Report by the U.S Climate Change Science Program and the Subcommittee on Global Climate Change Research, lead agency U.S.G.S. Washington D.C. January 2009.
- Fielding, D.J., and M.A. Brusven. 1996. Historical trends in grasshopper populations in Southern Idaho. United States Department of Agriculture, Animal and Plant Health.
- Fisher, R.J. and Stephen K. Davis. 2011. Habitat Use by Sprague's Pipits (*Anthus Spragueii*) in Native Pastures and Planted, Non-native Hay Fields. *The Auk* Vol. 128, No. 2 (April 2011), pp. 273-282.
- Flannigan, M.D., and Wotton, B.M. 2001. Climate, weather and area burned. In: *Forest Fires: Behavior & Ecological Effects* (eds Johnson EA, Miyanishi K) pp. 335–357. Academic Press, New York.
- Flannigan M.D., K.A. Logan, B.D. Amiro, et al. 2005. Future area burned in Canada. *Climatic Change*, 72,1-16.

- Frankel, O., and M.E. Soulé. 1981. Conservation and evolution / O.H. Frankel and Michael E. Soule Cambridge University Press, Cambridge [England] ; New York.
- Friedel, M.H. 1991. Range condition assessment and the concept of thresholds: A viewpoint. *Journal of Range Management* 44:422-426.
- Gentile, J.H., M.A. Harwell, W. Cropper, Jr., C.C. Harwell, D. DeAngelis, S. Davis, J.C. Ogden, and D. Lirman. 2001. Ecological Conceptual Models: A Framework and Case Study on Ecosystem Management for South Florida Sustainability. *Science of the Total Environment*. 274:231-253.
- Gilmer, D.S., and J.M. Wiehe. 1977. Nesting by ferruginous hawks and other raptors on high voltage powerline towers. *Prairie Naturalist* 9(1):1-10.
- Good, R.E., R.M. Nielson, H.H. Sawyer, and L.L. McDonald. 2004. Population level survey of Golden Eagles (*Aquila chrysaetos*) in the western United States. Final report prepared by Western EcoSystems Technology, Inc.. U. S. Fish and Wildlife Service, Arlington, VA.
- Haire, S.L., and K. McGarigal. 2009. Changes in fire severity across gradients of climate, fire size, and topography: a landscape ecological perspective. *Fire Ecology* 5(2): 86-108. doi: 10.4996/fireecology.0502086
- Hall, F., and E. Haney. 1997. Distribution and trend of Sage Grouse (*Centrocercus urophasianus*) in relation to overhead transmission lines in northeastern California. Draft. California Department of Fish and Game.
- Hardy, C.C., K.M. Schmidt, J.M. Menakis, and N.R. Samson. 2001. Spatial data for national fire planning and fuel management. *International Journal of Wildland Fire* 10:353-372.
- Harju, S.M., M.R. Dzialak, R.C. Taylor, L.D. Hayden-Wing, and J.B. Winstead. 2010. Thresholds and Time Lags in Effects of Energy Development on Greater Sage-Grouse Populations. *Journal of Wildlife Management* 74(3):437-448.
- Hayes EB, Komar N, Nasci RS, Montgomery SP, O'Leary DR, Campbell GL. 2005. Epidemiology and transmission dynamics of West Nile virus disease. *Emerg Infect Dis*. 11:1167–1173.
- Holloran, M.J. 2005. Greater Sage-Grouse (*Centrocercus urophasianus*) Population Response to Natural Gas Field Development in Western Wyoming. Doctoral Dissertation, University of Wyoming, Laramie, WY.
- Hostetler, S. Personal Communication.
- 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.
- Hunt, W. G., R. E. Jackman, T. L. Brown, D. E. Driscoll, and L. Culp. 1997. A population study of Golden Eagles at the Altamont Pass Wind Resource Area: second year progress report. Report to National Renewable Energy Laboratory, Subcontracts XAT-5-15174-01 and XAT-6-16459-01, Predatory Bird Research Group, University of California, Santa Cruz, California. 93 pages.
- IPCC. 2007. Climate Change 2007: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental

- Panel on Climate Change [Parry, Martin L., Canziani, Osvaldo F., Palutikof, Jean P., van der Linden, Paul J., and Hanson, Clair E. (eds.)]. Cambridge University Press, Cambridge, United Kingdom, 1000 pp.
- Kaiser, R.C. 2006. Recruitment by Greater Sage-Grouse in Association with Natural Gas Development in Western Wyoming. Masters thesis, Department of Zoology and Physiology, University of Wyoming, Laramie.
- Kliskey, A.D., E.C. Lofroth, W.A. Thompson, S. Brown, and H. Schreier. 1999. Simulating and evaluating alternative resource-use strategies using GIS-based habitat suitability indices. *Landscape and Urban Planning* 45:163-175.
- Karr, J.R. 1991. Biological integrity: a long neglected aspect of water resources management. *Ecological Applications*. 1: 66-84.
- Keane, R.E. 2000. The importance of wilderness to whitebark pine research and management. Pp. 84-92 in S.F. McCool, D.N. Cole, W.T. Borrie, and J. O'Loughlin (compilers), *Proceedings of the Conference on Wilderness Science in a Time of Change—Volume 3: Wilderness as a Place for Scientific Inquiry*. 1999 May 23-27. Publication RMRS-P-15:3. USDA Forest Service, Rocky Mountain Research Station, Missoula, MT.
- Keane, R., K. Ryan, T. Veblen, C. Allen, J. Logan, and B. Hawkes. 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.
- Kochert, M. N., K. Steenhof, L. B. Carpenter, and J. M. Marzluff. 1999. Effects of fire on golden eagle territory occupancy and reproductive success. *Journal of Wildlife Management* 63: 773-780.
- Kolar, J.L., J.J. Millsaugh, and B.A. Stillings. 2011. Migration patterns of pronghorn in southwestern North Dakota. *The Journal of Wildlife Management*, 75: 198–203.
- Kotliar, N.B., Z.H. Bowen, D.S. Ouren, and A.H. Farmer. 2008. A regional approach to wildlife monitoring related to energy exploration and development in Colorado. US Geological Survey Open File Report 2008-1024.
- Lanning, S.G. 2005. Developing a GIS Model (SPEEDGOAT) to predict suitable habitat and migration corridors within the state of Wyoming. M.A. thesis, Department of Geography, University of Wyoming, Laramie.
- Leu, M., S. E. Hanser, and S. T. Knick. 2008. The human footprint in the west: A large-scale analysis of anthropogenic impacts. *Ecological Applications* 18(5):1119-1139.
- Lightfoot, D.C., A.D. Davidson, C.M. McGlone, and D.G. Parker. 2010. Rabbit abundance relative to rainfall and plant production in northern Chihuahuan Desert grassland and shrubland habitats. *Western North American Naturalist* 70: 490-499.
- Littell J.S, E.F. Oneil, D. McKenzie, J.A. Hicke, J.A. Luz, R.A. Norheim, and M.M. Elsner. 2010. Forest ecosystems, disturbance, and climatic change in Washington State, USA. *Climatic Change* 102:129-158.
- Logan, J.A., and J.A. Powell. 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 climate change altered forest insect disturbance regimes. Pages 98-109 in Wagner, F.H. (ed.) Climate warming in western North America. University of Utah Press, Salt Lake City, UT.
- Logan, J.A., W.F. Macfarlane, and L. Wilcox. 2010. Whitebark pine vulnerability to climate-driven mountain pine beetle disturbance in the Greater Yellowstone ecosystem. *Ecological Applications* 20:895-902.
- MacArthur, R.H., and Wilson, E.O. 1967. *The Theory of Island Biogeography*. Princeton, N.J.: Princeton University Press.
- MacLaren, P. A., S. H. Anderson, and D. E. Runde. 1988. Food habits and nest characteristics of breeding raptors in southwestern Wyoming. *Great Basin Naturalist* 48:548-553.
- Martin, R.E., and D.B. Sapsis. 1991. Fires as agents of biodiversity: pyrodiversity promotes biodiversity. In: R.R.Harris, D.C. Erman, technical coordinators. *Proceedings of the symposium on biodiversity of northwestern California; 1991 October 28-30; Santa Rosa, CA. Report 29.* Berkely CA: Wildland Resources Center, Univ. Calif.; 150 p.
- Marzluff, J.M., S.T. Knick, M.S. Vekasy, L.S. Schueck, and T.J. Zarriello. 1997. Spatial use and habitat selection of Golden Eagles in southwestern Idaho. *Auk* 114:673-687.
- Maurer, E.P. 2007. Uncertainty in hydrological impacts of climate change in the Sierra Nevada, California under two emissions scenarios.
- McGahan, J. 1968. Ecology of the golden eagle. *Auk* 85:1-12.
- McGarigal K., S. Cushman, and C. Regan. N.d. Quantifying Terrestrial Habitat Loss and Fragmentation: A Protocol. Unpublished manuscript online at http://www.umass.edu/landeco/teaching/landscape_ecology/labs/fragprotocol.pdf
- McWethy, D.B., S.T. Gray, P.E. Higuera, J.S. Littell, G.T. Pederson, A.J. Ray, and C. Whitlock. 2010. Climate and terrestrial ecosystem change in the U.S. Rocky Mountains and upper Columbia Basin. USDI, NPS, Natural Resource Report NPS/GRYN/NRR-2010/260.
- 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.
- Messinger, F., G. DiMego, E. Kalnay, K. Mitchell, P.C. Shafran, W. Ebisuzaki, D. Jovic, J. Woollen, E. Rogers, E.H. Berbery, M.B. Ek, Y. Fan, R. Grumbine, W. Higgins, H. Li, Y. Lin, G. Manikin, D. Parrish, and W. Shi. 2006. North American Regional Reanalysis. *Bulletin of the American Meteorological Society*: DOI:10.1175/BAMS-87-3-34:343-360.
- Miller, M. 2000. Fire Autecology. 2000. In: Brown, J., K. Smith, and J. Kapler . *Wildland fire in ecosystems: effects of fire on flora.* Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT. Pp 9-34
- Miller, R.F., and R.J. Tausch. 2001. The role of fire in pinyon and juniper woodlands: A descriptive analysis. In: Galley, K.E.M.; Wilson, T.P., eds. *Proceedings of the*

- invasive species workshop: The role of fire in the control and spread of invasive species. Misc. Pub. 11. Tallahassee, FL: Tall Timbers Research Station: 15-30.
- Montana Fish, Wildlife and Parks. 2010. Crucial Areas Assessment Layer Documentation Summary. Crucial Areas Planning System (CAPS). Helena, MT. <http://fwp.mt.gov/wildthings/conservationInAction/crucialAreas.html>.
- Mosher, J.A., and C.M. White. 1976. Directional exposure of golden eagle nests. *Canadian Field-Naturalist* 90: 356-359.
- Mote, P.W., and E.P. Salathé Jr. 2010. Future climate in the Pacific Northwest. *Climatic Change* 102:29-50.
- Murphy, D.D., and B.R. Noon. 1992. Coping with uncertainty in wildlife biology. *J. Wildl. Manage.* 55:773-782.
- Naugle., D. E., C. L. Aldridge, B. L. Walker, T. E. Cornish, B. J. Moynahan, M. J. Holloran, K. Brown, G. D. Johnson, E. T. Schmidtman, R. T. Mayer, C. Y. Kato, M. R. Matchett, T. J. Christiansen, W. E. Cook, T. Creekmore, R. D. Falise, E.T. Rinkes, and M. S. Boyce. 2004. West Nile virus: pending crisis for greater sage-grouse. *Ecology Letters: In Press*.
- Naugle, D.E., K.E. Doherty, B.L. Walker, M.J. Holloran, and H.E. Copeland. 2009. Energy development and Sage Grouse. *Studies in Avian Biology*. Available at: <http://sagemap.wr.usgs.gov/Docs/SAB/Chapter21.pdf>.
- Nelle, P.J., K. P. Reese, and J.W. Connelly. 2000. Long term effects of fire on sage grouse habitat. *Journal of Range Management* 53:586-591.
- Northwest Colorado Greater Sage-Grouse Working Group. 2006. Northwest Colorado Greater Sage-Grouse Conservation Plan. 28
- Noss, R.F., and A.Y. Cooperrider. 1994. *Saving Nature's Legacy*. Island Press, Wash. D.C. 416 pp.
- Parrish, J.D., D.P. Braun, and R.S. Unnasch. 2003. Are we conserving what we say we are? Measuring ecological integrity within protected areas. *Bioscience* 53:851-860.
- Pavao-Zuckerman, M.A. 2000. The conceptual utility of models in human ecology. *Journal of Ecological Anthropology* 4:37-56
- Platt, S. W. 1984. Energy development and raptor populations on and adjacent to the Black Butte Coal Company mine permit area. Unpublished progress report. Black Butte Coal Company, Point of Rocks, Wyoming. 71 pages.
- Poor, E. 2010. Modeling Pronghorn Migration Corridors in the Northern Great Plains. M.A. thesis, Nicholas School of the Environment, Duke University, Durham, NC.
- Powell, J.A., and B.J. Bentz. 2009. Connecting phonological predictions with population growth rates for mountain pine beetle. *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.
- Pyne, S. 1997. *Fire in America: a cultural history of wildland and rural fire*, 2nd ed. Seattle, WA: University of Washington Press. 680 p.

- Raffa, K.F., Aukema, B.H., Bentz, B.J., Carroll, A.L., Hicke, J.A., Turner, M.G. & Romme, W.H. 2008. Cross-scale drivers of natural disturbances prone to anthropogenic amplification: the dynamics of bark beetle eruptions. *Bioscience*, 58(6): 501–517.
- Raffa, K.F., B.H. Aukema, B.J. Benz, 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.
- Ray, A.J. 2008. Climate change in Colorado. Report for the Colorado Conservation Board University of Colorado at Boulder. Boulder, CO.
- Ray, A.J., J.J. Barsugli, K. Wolter, and J. Eischeid. 2010. Rapid-response climate assessment to support the FWS status review of the American Pika. USFWS, Boulder, CO.
- Reap, R.M., 1986. Evaluation of cloud-to-ground lightning data from the western United States for the 1983–84 summer seasons. *J. Climate Appl. Meteor.*, 25:785–799.
- Roccio, J. 2005. Rocky Mountain Lower Montane Riparian Woodland and Shrubland Ecological System Ecological Integrity Assessment. Report to the Colorado Natural Heritage Program. Fort Collins, CO. December 2005.
- Rowland, M., M. Wisdom, B. Johnson, and M. Penninger. 2004. Effects of roads on elk: Implications for management of forested ecosystems. Pgs. 42-52 in Wisdom, M.J, technical editor, *The Starkey Project: a Synthesis of Long-Term Studies of Elk and Mule Deer*. 2004. Transactions of the North American Wildlife and Natural Resources Conference, Alliance Communications Group, Lawrence, Kansas, USA.
- Rowland, Mary M.; Wisdom, M.J.; Suring, L.H.; Meinke, C.W. 2006. Greater sage-grouse as an umbrella species for sage-brush associated vertebrates. *Biological Conservation*. 129: 323-335.
- Saha, S., S. Moorthi, H-L Pan, X. Wu, J. Wang, S. Nadiga, P. Tripp, R. Kistler, J. Woollen, D. Behringer, H. Liu, D. Stokes, R. Grumbine, G. Gayno, J. Wang, Y-T Hou, H-Y Chuang, H-M H. Juang, J. Sela, M. Iredeli, R. Treadon, D. Kleist, P. Van Delst, D. Keyser, J. Derber, M. Ek, J. Meng, H. Wei, R. Wang, C. Long, M. Chelliah, Y. Xue, B. Huang, J-K Schemm, W. Ebisuzaki, R. Lin, P. Xie, M. Chen, S. Zhou, W. Higgins, C-Z Zou, Q. Liu, Y. Chen, Y. Han, L. Cucurull, R.W. Reynolds, G. Rutledge, and M. Goldberg. 2010. The NCCP climate forecast system reanalysis. *Bulletin of the American Meteorological Society*: DOI:10.1175/2010BAMS3001.1:1015-1057.
- Sampson, N.R., R.D. Atkinson, and J.W. Lewis, editors. 2000. Mapping wildfire hazards and risks. The Hawthorn Press, Binghamton, New York, USA.
- Sawyer, __, and __ Nielsen. 2010. Mule Deer Monitoring in the Pinedale Anticline Project Area: 2010 Annual Report. Western Ecosystems Technology, Cheyenne, WY online at http://www.wy.blm.gov/jio-papo/papo/reports/2010annualreport_muledeer.pdf.
- Schmidt, K.M., J.P. Menakis, C.C. Hardy, W.J. Hann, D.L. Bunnell. 2002. Development of coarse-scale spatial data for wildland fire and fuel management. General

Technical Report, RMRS-GTR-87, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

- Schoettle AW. 2004a. Ecological roles of five-needle pine in Colorado: Potential consequences of their loss. In: Snieszko RA, S Samman, SE Schlarbaum, HB Kriebel (eds) Breeding and genetic resources of five-needle pines: growth, adaptability, and pest resistance; 2001 July 23-27; Medford, OR, USA. IUFRO Working Party 2.02.15. Proceedings RMRS-P-32. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. Pp 124-135. Available at: http://www.fs.fed.us/rm/pubs/rmrs_p032/rmrs_p032_124_135.pdf
- Schoettle AW. 2004b. Developing proactive management options to sustain bristlecone and limber pine ecosystems in the presence of a non-native pathogen. In: Shepperd WD, LG Eskew, compilers. Silviculture in special places: Proceedings of the National Silviculture Workshop; 2003 September 8-11; Granby, CO. Proceedings RMRS-P-34. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. Pp 46-155. Available at: http://www.fs.fed.us/rm/pubs/rmrs_p034/rmrs_p034_146_155.pdf
- Schoettle, A.W., Snieszko, R.A. 2007. Proactive intervention to sustain high elevation pine ecosystems threatened by white pine blister rust. J. For. Res. 12: 327-336. <http://www.springerlink.com/content/9v91t44278w74430/fulltext.pdf>.
- Schroeder, M.A., C.L. Aldridge, A.D. Apa, J.R. Bohne, C.E. Braun, S.D. Bunnell, J.W. Connelly, P.A. Deibert, S.C. Gardner, M.A. Hilliard, G.D. Kobriger, S.M. McAdam, C.W. McCarthy, J.J. McCarthy, D.L. Mitchell, E.V. Rickerson, and S.J. Stiver. 2004. Distribution of sage-grouse in North America. Condor 106:363-376.
- Schroeder, M.A., J.R. Young, and C.E. Braun. 1999. Sage grouse (*Centrocercus urophasianus*). Pages 1-28 In: Poole, A., and F. Gill, eds. The birds of North America, No. 425. The Birds of North America, Philadelphia, PA, USA.
- 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.
- Shugart, Sedjo and Sohngen NEED FIRST INITIAL FOR EACH AUTHOR. 2003. Forests & Global Climate Change: Potential Impacts on U.S. Forest Resources Pew Center for Climate Change. Available: www.pewclimate.org/docUploads/forestry.pdf.
- Smith, D. G., and J. R. Murphy. 1973. Breeding ecology of raptors in the eastern Great Basin of Utah. Brigham Young Univ., Provo. Sci. Bull. Biol. Ser. 18, No. 3. 76pp.
- Smith, G.W., and D.R. Johnson. 1985. Demography of a Townsend ground squirrel *Spermophilus townsendi* population in southwestern Idaho, USA. Ecology 66: 171-178.
- Steenhof, K., M. N. Kochert, and J. A. Roppe. 1993. Nesting by raptors and common ravens on electrical transmission line towers. Journal of Wildlife Management 57(2):271-281.

- Swetnam, T.W., and J. L. Betancourt. 1997. Mesoscale disturbance and ecological response to decadal climatic variability in the American Southwest. *Journal of Climate* 11: 3128-3147.
- Tomback, D.F., and P. Achuff. 2010. Blister rust western forest biodiversity: ecology, values and outlook for white pines. *Forest Pathology* 40:186-225.
- Turrell MJ, Dohm DJ, Sardelis MR, O'Guinn ML, Andreadis TG, Blow JA . An update on the potential of North American mosquitoes (Diptera: Culicidae) to transmit West Nile virus. *J Med Entomol* 2005;42:57-62.
- USGS (U.S. Geological Survey). 2010. National GAP. National Land Cover Gap Analysis Project. http://lc.gapanalysisprogram.com/landcoverviewer/PDF/LandCover_Metadata.pdf [2010, February].
- USGS. 2011. LANDFIRE 1.1.0. Biophysical Setting Layer. U.S. Department of Interior, Geological Survey. [Online]. Available: <http://www.landfire.gov/NationalProductDescriptions20.php> [2011, April 15].
- Unnasch, R.S., D.P. Braun, P.J. Comer, and G.E. Eckert. 2008. The ecological integrity framework: a framework for assessing the ecological integrity of biological and ecological resources of the National Park System. Report to the National Park Service. NatureServe. January, 2009.
- Vance, Linda. Personal Communication.
- Voogd, H., 1983. Multi-criteria evaluations for urban and regional planning, London Princeton University.
- Walker, B.L., D.E. Naugle, and K.E. Doherty. 2007. Greater sage-grouse population response to energy development and habitat loss. *Journal of Wildlife Management* 71:2644-2654.
- 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.
- Westoby, M., B. Walker, and I. Noy-Meir. 1989. Opportunistic management for rangelands not at equilibrium. *J. Range Manage.* 42(4):266-274.
- Whisenant, S.G. 1990. Changing fire frequencies on Idaho's Snake River Plains: ecological and management implications. Pages 4-10 in E.D. McArthur, E.M. Romney, S.D. Smith, and P.T. Tueller, compilers, *Proceedings-Symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management*. USDA Forest Service General Technical Report INT-276. Intermountain Research Station, Ogden, UT. 351 pp.
- Williams, J.W., and S.T. Jackson. 2007. Novel climates, no-analog communities, and ecological surprises. *Frontiers in Ecology and the Environment* 5:475-482.
- Wood, A.W., L.R. Leung, V. Sridhar, and D.P. Lettenmaier. 2004. Hydrological implications of dynamical and statistical approaches to downscaling climate model outputs. *Climatic Change* 62:189-216.
- Wotton B.M., and M.D. Flannigan. 1993. Length of the fire season in a changing climate. *Forestry Chronicle*, 69,187-192.

Young, B., E. Byers, K. Gravuer, K. Hall, G. Hammerson, and A. Redder. 2010. Guidelines for using the NatureServe Climate Change Vulnerability Index, Release 2.0. NatureServe. Arlington, VA.

APPENDIX 1
MIDDLE ROCKIES GAP VEGETATION SYSTEMS

THIS PAGE INTENTIONALLY LEFT BLANK

Table A1-1. Idaho Land Cover Classification System Cross-walk With Middle Rockies Level 3 Ecological Systems					
Information: Where the Northwest ReGap mapping unit (ecological system) included more than one formation (Forest, Woodland, Mesic Shrubland, etc.) we assigned it to the structurally taller or denser formation. For example, forested ecological systems that include "forest and woodland" descriptors (e.g. Rocky Mountain Aspen Forest and Woodland) were assigned to the appropriate forest division (e.g. Deciduous Forest) rather than woodland division for mapping. Where an ecological system had "woodland and savanna" or "woodland and partkland" in its title it was assigned to the woodland division rather than a grassland division for mapping. In addition, some ecological systems listed here are not listed on the NatureServe website as being in Idaho. These are identified with an * after the ecological system name and are likely mis-classified if mapped in Idaho.					
Class	Formation	LCCS Division	Middle Rockies REA Coarse-Filter Name	Middle Rockies Level 3 Ecological Systems*	Percent of Area
1. Forest & Woodland	Forest	Deciduous Forest	Deciduous Forest and Woodland	Rocky Mountain Aspen Forest and Woodland	1.6
		Evergreen Forest	Evergreen Forest and Woodland	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	1.4
				Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland	0.3
				Northern Rocky Mountain Mesic Montane Mixed Conifer Forest	0.3
				Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland	0.0
				Middle Rocky Mountain Montane Douglas-fir Forest and Woodland	5.1
				Rocky Mountain Lodgepole Pine Forest	7.5
				Rocky Mountain Poor-Site Lodgepole Pine Forest	0.1
				Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	2.7
				Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	4.7
		Mixed Evergreen Deciduous Forest	Mixed Evergreen Deciduous Forest	Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland	0.2
	Woodland	Deciduous Woodland	Deciduous Forest and Woodland	Western Great Plains Floodplain	0.1
				Western Great Plains Floodplain Systems	0.0
				Northwestern Great Plains Floodplain	0.0
				Rocky Mountain Lower Montane Riparian Woodland and Shrubland	0.8
				Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland	0.1
				Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	0.7
				Northwestern Great Plains Riparian	0.7
				Western Great Plains Riparian Woodland and Shrubland	0.2
				Rocky Mountain Subalpine-Montane Riparian Woodland	0.1
				Rocky Mountain Bigtooth Maple Ravine Woodland	0.0
				Western Great Plains Wooded Draw and Ravine	0.1
				Northern Rocky Mountain Conifer Swamp	0.0
				Western Great Plains Dry Bur Oak Forest and Woodland	0.0
				Inter-Mountain Basins Curl-leaf Mountain Mahogany Woodland and Shrubland	0.6
			Evergreen Forest and Woodland	Northwestern Great Plains - Black Hills Ponderosa Pine Woodland and Savanna	3.0
				Northern Rocky Mountain Ponderosa Pine Woodland and Savanna	0.7
				Southern Rocky Mountain Ponderosa Pine Woodland	0.0
				Northern Rocky Mountain Foothill Conifer Wooded Steppe	0.4
				Rocky Mountain Foothill Limber Pine-Juniper Woodland	0.8

Table A1-1. Idaho Land Cover Classification System Cross-walk With Middle Rockies Level 3 Ecological Systems (cont'd)					
Class	Formation	LCCS Division	Middle Rockies REA Coarse-Filter Name	Middle Rockies Level 3 Ecological Systems*	Percent of Area
1. Forest & Woodland (cont'd)	Woodland (cont'd)	Deciduous Woodland (cont'd)	Evergreen Forest and Woodland (cont'd)	Northern Rocky Mountain Subalpine Woodland and Parkland	0.2
				Columbia Plateau Western Juniper Woodland and Savanna	0.0
				Inter-Mountain Basins Juniper Savanna	0.0
				Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland	0.2
				Harvested Forest - Northwestern Conifer Regeneration	0.4
				Recently burned forest	1.1
2. Mesic Shrubland & Grassland	Mesic Shrubland (Deciduous & Evergreen)	Mesic Shrubland (Deciduous & Evergreen)	Mesic Shrubland and Grassland (Deciduous and Evergreen)	Rocky Mountain Lower Montane-Foothill Shrubland	0.0
				Introduced Riparian and Wetland Vegetation	0.1
				Northern Rocky Mountain Montane-Foothill Deciduous Shrubland	0.4
				Western Great Plains Sandhill Steppe	0.0
				Introduced Upland Vegetation - Shrub	0.0
				Rocky Mountain Subalpine-Montane Riparian Shrubland	0.1
				Harvested forest-Shrub Regeneration	0.2
				Northwestern Great Plains Mixedgrass Prairie	6.9
	Mesic Grassland	Perennial Grassland		Recently burned grassland	0.1
				Western Great Plains Tallgrass Prairie	0.0
				Western Great Plains Shortgrass Prairie	0.1
				Introduced Upland Vegetation - Perennial Grassland and Forbland	1.5
				Harvested Forest - Grass/Forb Regeneration	0.3
				Northern Rocky Mountain Lower Montane, Foothill and Valley Grassland	5.1
				Northern Rocky Mountain Subalpine-Upper Montane Grassland	1.0
				Columbia Basin Foothill and Canyon Dry Grassland	0.0
				Columbia Plateau Steppe and Grassland	0.0
				Inter-Mountain Basins Semi-Desert Grassland	0.0
				Southern Rocky Mountain Montane-Subalpine Grassland	0.2
		Emergent Wetland	Emergent Wetland	Western Great Plains Closed Depression Wetland	0.0
				Western Great Plains Open Freshwater Depression Wetland	0.1
				Great Plains Prairie Pothole	0.0
				Western Great Plains Saline Depression Wetland	0.2
				Northern Rocky Mountain Wooded Vernal Pool	0.0
				North American Arid West Emergent Marsh	0.1
				Inter-Mountain Basins Alkaline Closed Depression	0.0
				Western Great Plains Depressional Wetland Systems	0.0
				Eastern Great Plains Wet Meadow, Prairie, and Marsh	0.0
				Rocky Mountain Subalpine-Montane Mesic Meadow	2.0
				Rocky Mountain Alpine-Montane Wet Meadow	0.5
				Rocky Mountain Subalpine-Montane Fen	0.0
				Columbia Plateau Vernal Pool	0.0

Table A1-1. Idaho Land Cover Classification System Cross-walk With Middle Rockies Level 3 Ecological Systems (cont'd)					
Class	Formation	LCCS Division	Middle Rockies REA Coarse-Filter Name	Middle Rockies Level 3 Ecological Systems*	Percent of Area
3. Semi-desert Shrubland & Grassland	Semi-desert Shrubland	Deciduous Shrubland	Semi-desert Shrubland and Grassland	Inter-Mountain Basins Greasewood Flat	0.3
				Inter-Mountain Basins Mat Saltbush Shrubland	0.4
				Inter-Mountain Basins Mixed Salt Desert Scrub	0.1
				Northern Rocky Mountain Subalpine Deciduous Shrubland	0.2
				Northwestern Great Plains Shrubland	0.4
				Inter-Mountain Basins Montane Sagebrush Steppe	13.0
				Inter-Mountain Basins Big Sagebrush Steppe	11.3
				Inter-Mountain Basins Big Sagebrush Shrubland	1.1
				Wyoming Basins Dwarf Sagebrush Shrubland and Steppe	0.7
				Columbia Plateau Low Sagebrush Steppe	0.0
				Great Basin Xeric Mixed Sagebrush Shrubland	0.0
				Inter-Mountain Basins Semi-Desert Shrub Steppe	0.0
	Semi-desert Grassland	Perennial Grassland		Western Great Plains Sand Prairie	0.3
		Annual Grassland			Introduced Upland Vegetation - Annual Grassland
4. High Montane Vegetation	High Montane Shrubland	High Montane Shrubland	High Montane Vegetation	Rocky Mountain Alpine Dwarf-Shrubland	0.4
	High Montane Grassland	High Montane Grassland		Rocky Mountain Dry Tundra	2.0
				Rocky Mountain Alpine Fell-Field	0.6
5. Sparse Vegetation & Natural Barren Areas		Unconsolidated Materials	Sparse Vegetation & Natural Barren Areas	Western Great Plains Badland	0.3
				Inter-Mountain Basins Shale Badland	0.2
				Inter-Mountain Basins Active and Stabilized Dune	0.0
		Columbia Plateau Ash and Tuff Badland		0.0	
		Inter-Mountain Basins Volcanic Rock and Cinder Land		0.1	
		Rocky Mountain Alpine Bedrock and Scree		0.5	
		Western Great Plains Cliff and Outcrop		0.0	
		Inter-Mountain Basins Cliff and Canyon		0.1	
		Rocky Mountain Cliff, Canyon and Massive Bedrock		0.0	
		Southwestern Great Plains Canyon		0.0	
		6. Agriculture			Crops
Pasture, hayland, etc.	Pasture/Hay		2.7		
7. Urban & Other Developed Lands	Urban / Industrial / Excavation Areas		Urban		Urban & Other Developed Lands
		Developed, Low Intensity		0.3	
		Developed, Medium Intensity		0.1	
		Disturbed, Non-Specific		0.0	
		Developed, High Intensity		0.0	
		Industrial, Excavation & Other Areas	Quarries, Mines, Gravel Pits and Oil Wells	0.0	
8. Open Water		Open Water	Open water	Open Water	0.6
				Geysers and Hot Springs	0.0
			No Data	No Data	5.5
				Total	99.8

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX 2
ECOLOGICAL INTEGRITY ASSESSMENT

THIS PAGE INTENTIONALLY LEFT BLANK

ECOLOGICAL INTEGRITY ASSESSMENT

The concept of ecological integrity (EI) has a long and complex history. Recent applications of EI directly trace their origins to the site specific concept of an Index of Biological Integrity that have been used in riparian studies (Faber-Langendoen et al. 2008, Faber-Langendoen et al. 2009, Roccio 2007, Tiner 2004). Those early site specific assessments were subsequently modified into less field work intensive rapid assessments and ultimately to assessments that use only existing data sources, primarily remote sensing imagery, and adopt a landscape level approach instead of a site level approach.

EI is defined in the SOW as: “The ability of ecological systems to support and maintain a community of organisms that have the species composition, diversity, and functional organization comparable to those of natural habitats within the ecoregion range (or area).” In this definition, “functional organization” refers to the dominant ecological characteristics and processes that “occur within their natural (or acceptable) ranges of variation and can withstand and recover from most perturbations” (Parrish et al. 2003).

Defined as a CE in the SOW, EI belongs to the suite of renewable natural resources and values that characterize the terrestrial and aquatic landscape units of the REA ecoregion. While conservation of the CEs is intended to serve as a coarse-filter/fine-filter framework for conservation within the ecoregion, EI uses only a coarse-filter approach that utilizes surrogate indicators for the key ecological attributes of the fine-filter and coarse-filter CEs which results in the conservation of the EI of landscapes within the REA.

Similar to its use with the species specific CEs, the EI approach will develop ecological models and EI values that are specific to the ecoregion that represent the EI of landscapes. Unlike the CEs which were specified because of their relevance to management questions, EI ecoregional models describe the key ecological attributes (KEAs) that maintain the integrity of the ecosystems within the ecoregion, regardless of whether or not a particular variable is directly related to management questions. The ecoregional conceptual model forms the basis for the EI assessment (EIA) and the KEAs and metrics are based on the drivers and stressors illustrated in the respective model, to the extent that data are available.

Ecological Integrity Assessment Framework

The three hierarchical types of EI assessments are often characterized as Level 1 Remote Assessment, Level 2 Rapid Assessment, and Level 3 Intensive Assessment (Faber-Langendoen et al. 2008, Faber-Langendoen et al. 2009, Roccio 2007, Vance 2009). The EIA for the REA will use a Level 1 landscape assessment approach that is based on very general conceptual ecosystem models that capture key ecological attributes that directly affect EI. For most KEAs, surrogate variables will be used to capture the important ecosystem properties that correlate with KEAs for the landscape unit under assessment.

EI will be calculated and mapped at the 5th level HUC resolution for two generalized land cover classes, aquatic/riparian/wetland systems and terrestrial systems and the results for those two classes will be combined to calculate overall EI for each watershed.

Aquatic/Riparian/Wetland Ecological Integrity

There are no standardized methods for conducting a Level I landscape assessment of EI of an aquatic ecosystem like those that have been developed for Level II and Level III Index of Biological Integrity protocols for EPA regulated activities (Faber-Langendoen et al. 2008, Vance 2009). Generally, landscape level aquatic EI has been assessed primarily through the extent, duration, and intensity of human alterations of the environment (“human footprint”) with the effects attenuated through various buffer, decay, and distance models (Annis, et al. 2010, Gordon and Gallo 2011, Faber-Langendoen et al. 2008, Potyondy and Geier 2010, Roccio 2007, Stagliano 2007, Tiner 2004, Vance 2005, Vance 2009, Wang et al. 2008, Weitzell et al. 2003). Each of those cited studies has had a different spatial scope with different data availability and the results of the various studies have been reported in different ways. A Level I landscape EI analysis is valuable for identifying where impacts are currently occurring (Vance 2005) or where they may occur in the future which ensures that a Level I EIA is very useful for the purpose of this REA.

Terrestrial Ecological Integrity

The terrestrial EIA of this REA will adopt the methods adopted by the state of Washington, the Montana Natural Heritage Program, and the Forest Service Watershed Condition Classification Technical Guide to the extent practicable given the greater extent of this REA and the diversity and non-overlapping data sources (Potyondy and Geier 2010, Stagliano 2007, Vance 2005, Vance 2009). Methods developed for other regions such as those in Annis, et al. (2010), Tiner (2004), Wang et al. (2008), and Weitzell et al. (2003) will be adapted to the REA, to the extent practicable. Additionally, data developed during the coarse-filter CEs status assessment will be incorporated into the assessment when relevant and practicable.

Combined Aquatic/Riparian/Wetland and Terrestrial Ecological Integrity

The AMT provided guidance that an overall score representing the combined EI values of the aquatic/riparian/wetland and terrestrial land units could be based on a weighted average of the terrestrial and aquatic EI scores. As a first approximation a range of different weights could be used to determine how the contribution of each of the EI values affects the overall value. The first approximation for the weighted average scoring method for the combined aquatic and terrestrial EI analysis, will be calculate using the weighted averages averages: 75:25, 50:50, and 25:75. Because the outcome of the combined analysis is unknown, comparing three weighted averages will provide a better understanding of how the weighting affects the overall EI score for a watershed.

GIS Analytical Approach to Ecological Integrity

The EIA will be conducted using ESRI ArcGIS as the primary tool for EI spatial analysis. SAIC will follow a similar approach used by the State of Montana in its EI assessments (Vance 2009). ESRI’s Spatial Analyst tool will be used extensively throughout the analysis process. This tool will focus primarily on three main components used in the EI spatial analysis: vegetation cover, hydrology, and anthropogenic effect. These spatial components are directly correlated to KEAs that affect aquatic and terrestrial EI.

EI is characterized at the landscape level and is independent of the species analysis. The focus of the EIA will be on “natural” areas within the REA region. For this REA, the

intent of the EIA is to describe, quantify, and assess those natural areas within the ecoregion as they are represented within HUC 10 boundaries.

The REA analysis for fine-filter CEs relies on a series of modeling approaches ranging from Maxent to Natural Heritage Program distribution data to express the spatial extent of each species. Similarly, the EI approach to modeling natural habitat must be applied in order to determine the distribution of the natural areas within an ecoregion. Therefore a method of obtaining data for natural areas based on existing vegetation and/or hydrology is required prior to application of metrics and scoring analysis. This modeling approach will focus on identifying areas of high EI value which corresponds to minimal anthropogenic impacts and contiguous natural vegetation types (see Figure A2-1 below).

It is important to caveat the steps listed below with specific statements regarding the quality and availability of spatial data. The value of the terrestrial and aquatic EIA to the REA will depend on the quality and availability of data available for running the assessment. EIAs at the landscape level are completely reliant on existing data quality and availability and must be denoted as such so that field managers and others understand the limitations of these assessments.

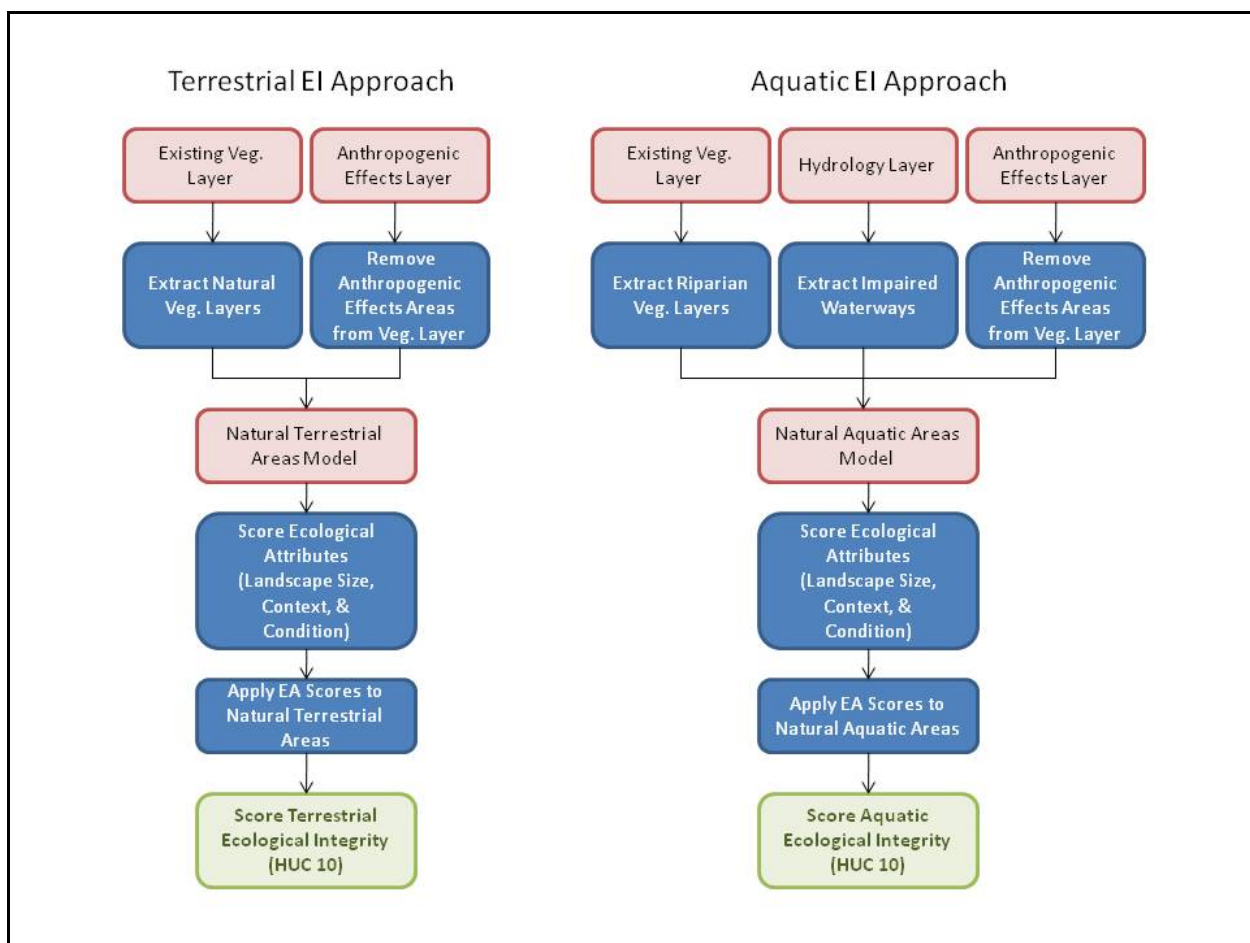


Figure A2-1. Conceptual Model for the GIS Analytical Approach to Terrestrial and Aquatic Ecological Integrity.

TERRESTRIAL ECOLOGICAL INTEGRITY ANALYSIS APPROACH

The terrestrial habitat modeling for EI will focus on use of landcover data sets (GAP) to extract relevant information regarding large intact natural vegetation within each 5th level watershed. This factor is important in determining the EI score for each watershed and will be used to account for the departure of each watershed from its natural state. The approach generally follows the Washington Wildlife Connectivity Study that was also adopted by Montana. The goal is to find the “best of what’s left” of the remaining landscape. The methodology also uses spatial tools to identify small fragmented patches that are more susceptible to conversion to development or agriculture uses. The following steps (1-10) outline the spatial analytical approach that will be used in this REA analysis to model the natural areas within the ecoregion:

1. Begin with an appropriate land cover (GAP Vegetation) for the ecoregion
2. Remove agricultural areas and other non-natural habitat
3. Remove additional anthropogenic impacts (buffered road areas, energy production areas, superfund sites, mines, urban areas and other features associated with anthropogenic effects)
4. Remove sites with less or dispersed development infrastructure that significantly impacts natural areas within them including wind development areas, coal mines, etc.
5. Overlay the removed areas on the raster grid map and expand them by one cell.
6. For any overlapping 100 meter grid cells, buffer an additional 100 meter area for potential impact of vehicles, structures, etc, and inaccurate data layers
7. Remove the grid cells that fall within the buffered areas to show how roads, etc are removed.
8. Using grid cells of the appropriate size, conduct a moving window analysis on surrounding areas by using the appropriate sized moving window.
9. Select all areas within the moving window that contain native habitat cell information above an appropriate percent threshold.
10. Calculate acreage for all intact, connected natural areas within the ecoregion boundary. Intact natural areas of an appropriate minimum size will be identified as the best available natural habitat areas within the ecoregion. (*This step will not be used to model the natural areas, but is used in the EI A scoring approach and additionally to identify ecoregion-wide areas of importance).

The next step of the terrestrial EIA will be to apply a set of surrogate variables for KEAs to the selected natural areas in order to obtain a score or relative ranking of the natural areas located throughout the ecoregion. Due to the scale of the REA and the timeframe associated with completion of the REA, the KEAs will be based completely on readily available and processed imagery and on existing GIS data. The attributes and indicators associated with EI can be categorized by size, landscape context, and condition. The KEAs for the terrestrial EIA and potential scores for metrics are located in Table A2-1.

Table A2-1. Example Terrestrial Ecological Integrity Key Ecological Attributes

Ecological Attribute	Indicator	Metric	Data Source	Citation
Size				
Naturalness	Proportion of Natural Vegetation Remaining (Size as % of HUC) ¹	90% = good 81-89% = fair 0%-80% = poor	GAP	MT and WA State EI Analysis
Absolute Size	Extent of Natural Vegetation (acres)	>10,000 ac = good 5,000-9,999 ac = fair <5,000 ac = poor	GAP	MT and WA State EI Analysis
Condition				
Habitat Condition	FRCC	FRCC 1 = good FRCC 2 = fair FRCC 3 = poor	LANDFIRE	LANDFIRE; Direction from AMT
	Vegetation Structure	Varies by Coarse-Filter Analysis (see Coarse-Filter Analysis)	LANDFIRE	MT and WA State EI Analysis
	Protected Areas (Degree of Habitat Protection; Wildlife Areas, National Parks, State Parks, etc.)	High Degree of Protection = good Moderate Degree of Protection = fair Low Degree of Protection = poor	PADS	Best Professional Judgment
Landscape Context				
Connectivity	Intact Areas (Intact areas with continuous corridors)	Circuitscape Analysis	GAP/ LANDFIRE	MT and WA State EI Analysis
	Riparian/Wetlands	>50 % of HUC 10 = good 10 to 49% of HUC 10 = fair 0 to 9% of HUC 10 = poor	GAP, NHD, NWI	Best Professional Judgment

¹ Metrics are applied after deducting agricultural and other anthropogenic altered areas from the total land cover of the region as described in Section 2.0, steps 2-7.

AQUATIC ECOLOGICAL INTEGRITY ANALYSIS APPROACH

The aquatic EIA will focus predominantly on the hydrology data layers (NHD and NWI). Landcover data layers will also provide relevant information in determining EI scores for aquatic ecosystems in areas where riparian and wetland vegetation is important in determining aquatic EI. The format and steps used in the aquatic analysis will be similar to those used for the terrestrial analysis with modifications required because of the spatial heterogeneity of the hydrology layer. Note that in contrast to the aquatic GIS data which generally is linear in spatial extent, the terrestrial GIS data are more extensive and cover greater portions of each HUC 10 unit than the aquatic data, requiring a simpler analysis.

1. Begin with an appropriate land cover (GAP Vegetation) for the ecoregion
2. Remove all non-aquatic land cover areas.
3. Remove additional anthropogenic impacts (buffered road areas, buffered agricultural areas, energy production areas, superfund sites, mines, urban areas and other features associated with anthropogenic effects)
4. Add the NHD (hydrology) layer for the ecoregion.
5. Remove impaired waterways.
6. Add NWI data layer. Exclude all non-natural wetland areas.
7. Overlay the combined riparian, NHD, and NWI layer on the raster grid map and expand them by one cell.
8. For any overlapping 100 meter grid cells, buffer an additional 100 meter area for potential impact of cars, structures, etc, and inaccurate data layers
9. Remove all of those grid cells with the buffers to show areas adjacent to roads, etc are removed.
10. Using grid cells of the appropriate size, conduct a moving window analysis on surrounding areas by using the appropriate sized moving window.
11. Select all areas within the moving window that contain native habitat cell information above an appropriate percent threshold.

Upon completion of the spatial analysis listed above, Circuitscape or another analogous program will be used to conduct a least cost path analysis for the purposes of determining connectivity of the selected natural areas across the landscape. The third step to completion of aquatic EIA will be to apply a set of surrogate variables for KEAs to the selected natural areas in order to obtain a score or relative ranking of the natural areas located throughout the ecoregion. Due to the scale of the REA and the timeframe associated with completion of the REA, the KEAs will be based completely on readily available and processed imagery and on existing GIS data. The attributes and indicators associated with EI can be categorized by size, landscape context, and condition. The KEAs for the aquatic EIA and potential scores for metrics are located in Table A2-2.

Table A2-2. Example Aquatic Ecological Integrity Key Ecological Attributes

Ecological Attribute	Indicator	Metric	Data Source	Citation
Land Cover	Urban (Buffer distance in meters)	>2000 m = good	GAP	MT NWI EI Analysis
		1000-1999 m = fair		
		0-999 m = poor		
	Crop Agriculture (Buffer distance in meters)	>500 m = good	GAP	MT NWI EI Analysis
		300-499 m = fair		
		0-299 m = poor		
Anthropogenic Disturbance	4-wheel Drive Roads (Buffer distance in meters)	>200 m = good	Linear Features	MT NWI EI Analysis
		100-199 m = fair		
		0-99 m = poor		
	Local Roads, City Streets (Buffer distance in meters)	>300 m = good	Linear Features	MT NWI EI Analysis
		100-299 m = fair		
		0-99 m = poor		
	Highways (Buffer distance in meters)	>500 m = good	Linear Features	MT NWI EI Analysis
		200-499 m = fair		
		0-199 m = poor		
	Mines (Buffer distance in meters)	>500 m = good	Mines	MT NWI EI Analysis
		200-499 m = fair		
		0-199 m = poor		
	Oil or Gas Wells (Buffer distance in meters)	>500 m = good	Oil & Gas Wells	MT NWI EI Analysis
		200-499 m = fair		
		0-199 m = poor		
Hydrology	Artificial Source (Buffer distance in meters)	>200 m = good	NHD	MT NWI EI Analysis
		100-199 m = fair		
		0-99 m = poor		
	303d listed water (Buffer distance in meters)	>500 m = good	NHD/303d	MT NWI EI Analysis
		300-499 m = fair		
		0-299 m = poor		

Vance, L. 2009. Assessing Wetland Condition with GIS: A Landscape Integrity Model for Montana.

Data Analysis and Scoring

The procedure used by the state of Montana to score EI by watershed focused on EI geospatial features at the 5th level watershed. The series of figures below relate specifically to the terrestrial EI approach, but similar methods will be employed in the aquatic EIA approach. The first four figures represent the steps indicated in Section 2.0. Figure A2-2 is simply an existing vegetation (EVT) layer showing all combined vegetation raster imagery for a small area within this ecoregion. The following figure (Figure A2-3) displays the natural vegetation layers extracted from the EVT and then overlain on a shaded relief background data layer. This figure shows the distribution of the natural vegetation layer with respect to anthropogenic features and elevation. Figure

A2-4 represents the buffered linear features associated with anthropogenic effects. This layer is used in the process of extracting anthropogenic areas that possibly affect the quality of natural vegetation due to proximity to areas influenced by human activity. The final figure in this group (Figure A2-5) shows the final natural areas layer as derived from the EVT and anthropogenic feature layers. Although this model has been simplified for illustrative purposes, the general process illustrated here will be employed in the EIA.

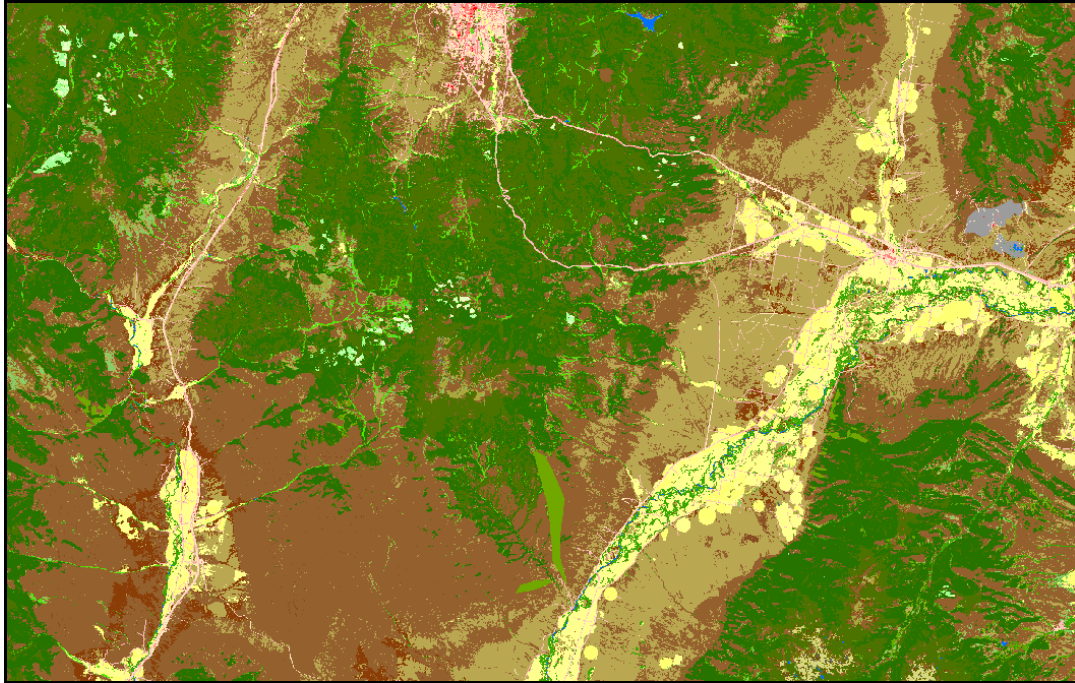


Figure A2-2. GAP vegetation landcover layer containing all vegetation communities.

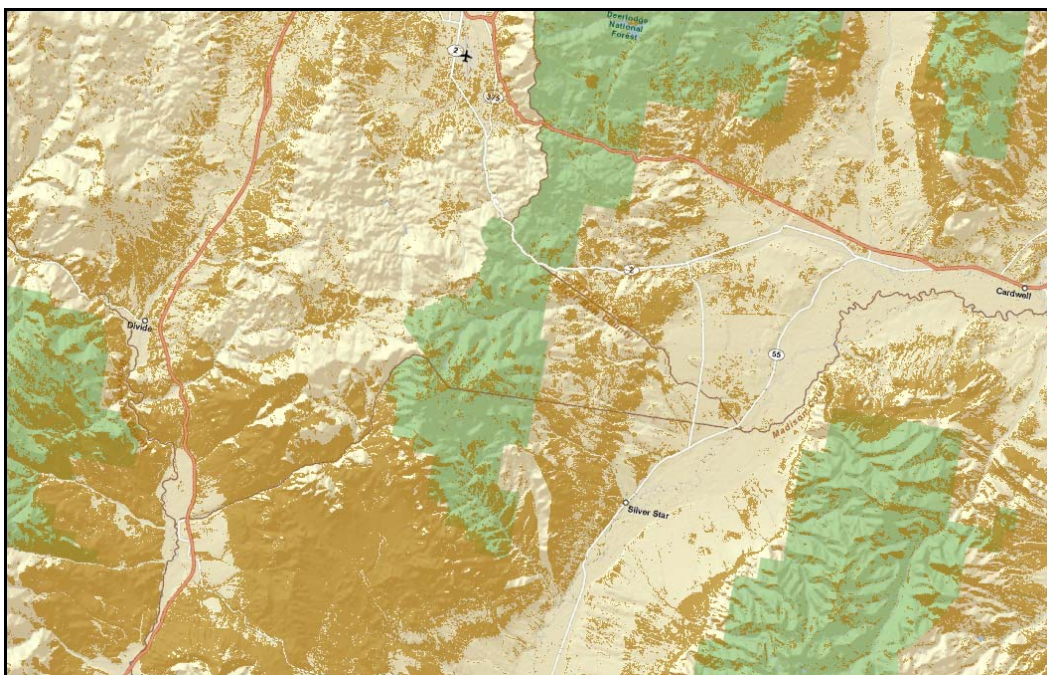


Figure A2-3 Remaining natural vegetation layer.

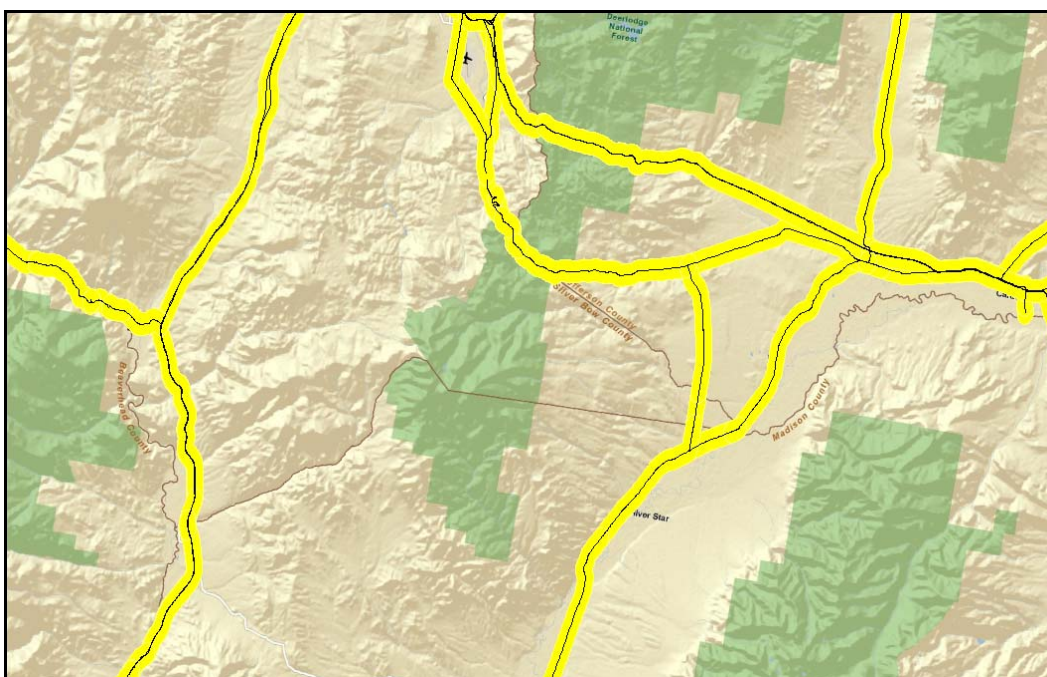


Figure A2-4. Anthropogenic features buffered for extraction.

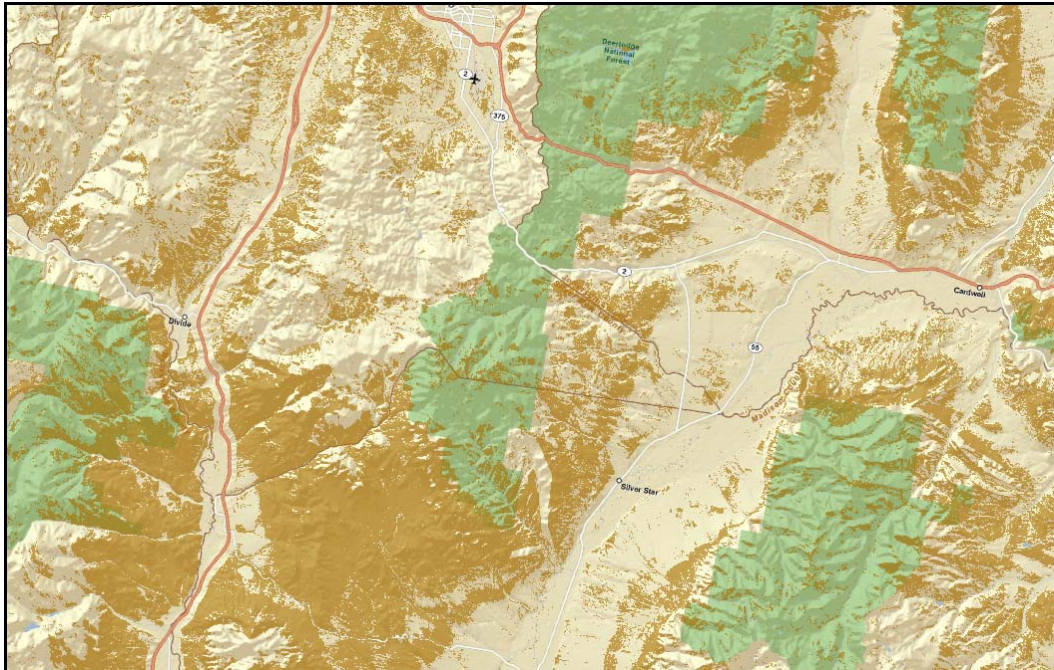


Figure A2-5. Natural vegetation remaining with areas influenced by anthropogenic effect removed.

The next group of figures illustrate the remainder of EIA GIS process. The EIA guidelines in the SOW indicate that the ecoregion-wide HUC 10 areas are to be scored as part of the REA process. This is accomplished by overlaying the HUC boundaries on the natural areas layer and using combinations of key ecological attributes to score each watershed unit. Figure A2-6 shows the HUC 10 watershed unit boundaries overlaid on the completed natural areas data layer. At this stage of the analysis, the HUC 10 boundaries are intersected with the indicated data layer (i.e. natural vegetation layer) in order to attribute the raster imagery features to HUC 10 boundaries. This enables the partitioning and analysis of the data layers with regard to their inclusion in the HUC 10 area. The following figure (Figure A2-7) illustrates this process at the HUC 10 scale through incremental coloration. Using the resulting percent cover of natural vegetation (or other combinations of KEAs), it is possible to assign EI ranks to each HUC 10 watersheds (Figure A2-8).

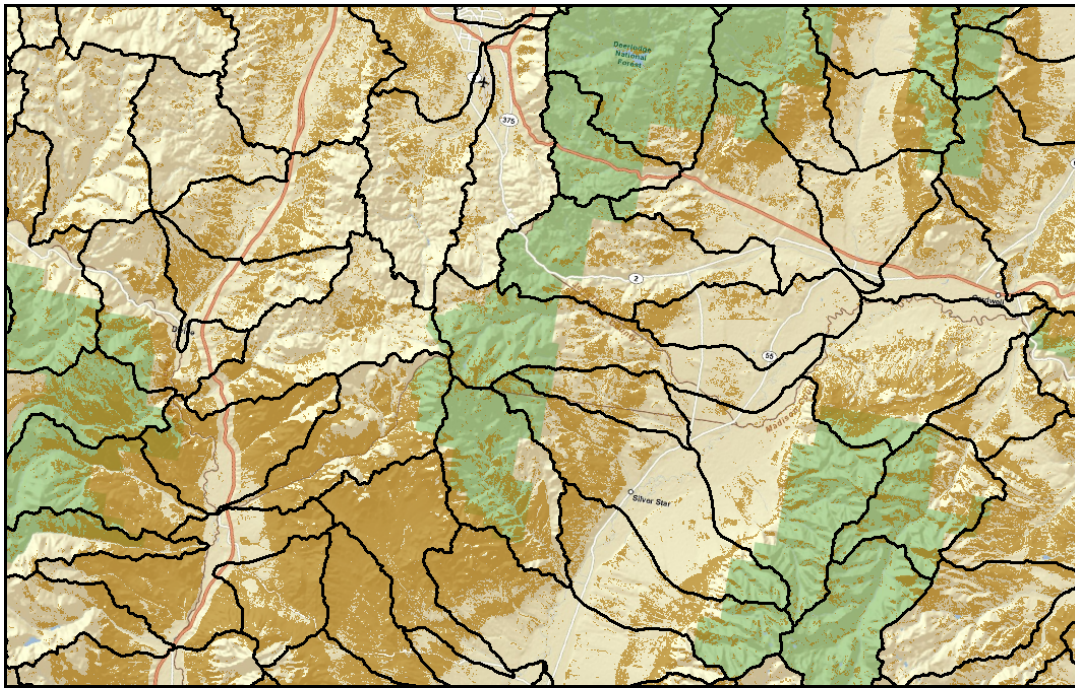


Figure A2-6. Natural vegetation layer overlaid by 5th Level Watershed boundaries.

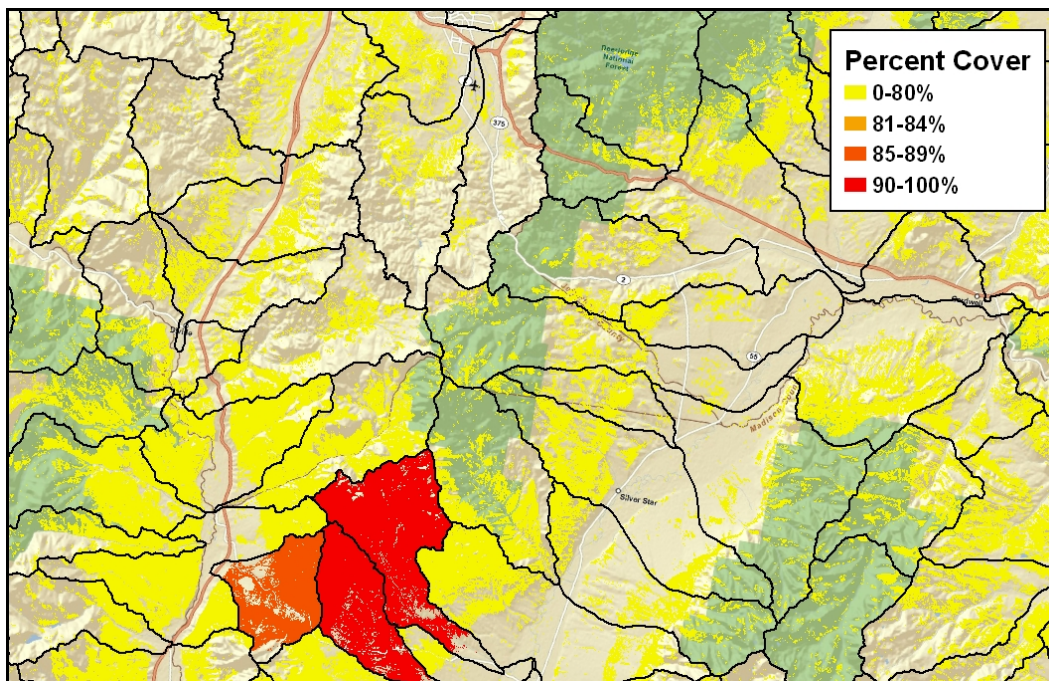


Figure A2-7. Percent cover of natural vegetation per watershed.

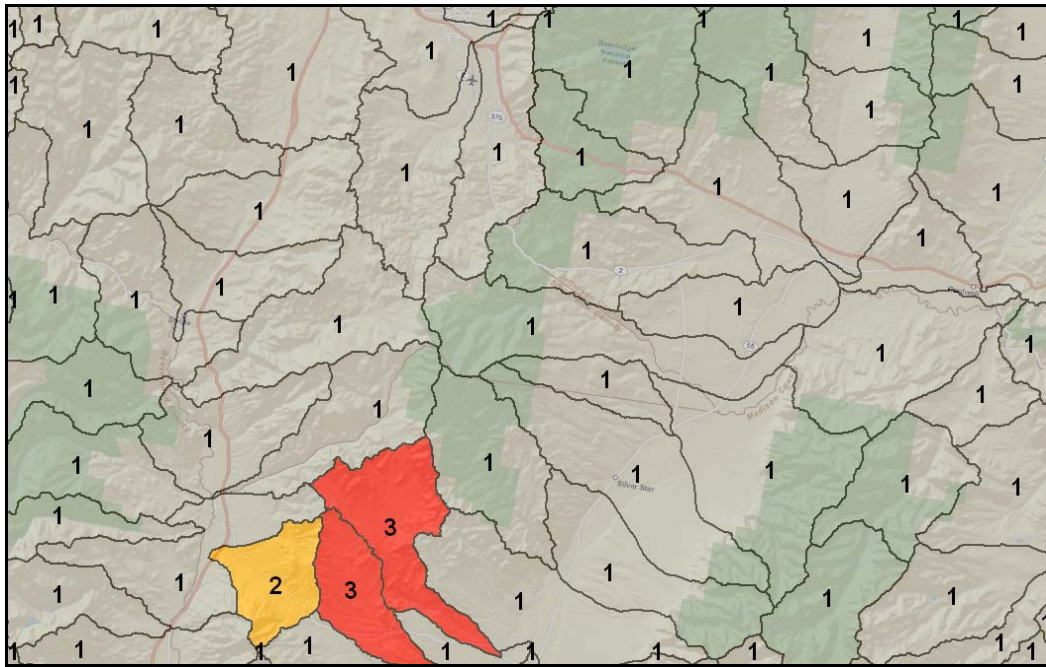


Figure A2-8. Natural Vegetation scoring based on watershed area.

REFERENCES

- Annis, G. M., S. Sowa, D. Diamond, M. Combes, K. Doisy, A. 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. Kansas City, KS. May 2010.
- Faber-Langendoen, D., G. Kudray, C. Nordman, L. Sneddon, L. Vance, E. Byers, J. Rocchio, S. Gawler, G. Kittel, S. Menard, P. Comer, E. Muldavin, M. Schafale, T. Foti, C. Josse, and J. Christy. 2008. Ecological performance standards for wetland mitigation: an approach based on ecological integrity assessments. Report to the Environmental Protection Agency . NatureServe, Arlington, VA.
- Faber-Langendoen, D., G. Kudray, C. Nordman, L. Sneddon, L. Vance, E. Byers, J. Rocchio, S. Gawler, G. Kittel, S. Menard, P. Comer, E. Muldavin, M. Schafale, T. Foti, C. Josse, J. Christy. 2009. Assessing the condition of ecosystems to guide conservation and management: an overview of NatureServe's ecological integrity assessment methods. Draft report. NatureServe, Arlington, VA.
- Gordon, S. and K. Gallo. 2011. Structuring expert input for a knowledge-based approach to watershed condition assessment for the Northwest Forest Plan, USA. Environmental Monitoring and Assessment 172:643–661.
- Parrish, J.D., D.P. Braun, and R.S. Unnasch. 2003. Are we conserving what we say we are? Measuring ecological integrity within protected areas. Bioscience 53:851-860.
- Potyondy, J. and T. Geier. 2010. Forest service watershed condition classification technical guide: Draft. U.S. Forest Service, Washington, DC. October 25, 2010.
- Roccio, J. 2007. Assessing ecological condition of headwater wetlands in the southern Rocky Mountains using a vegetation index of biotic integrity (Version 1.0). Report to Colorado Department of Natural Resources and the Environmental Protection Agency. Colorado Natural Heritage Program, Ft. Collins, CO. May 22, 2007.
- Stagliano, D. 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.
- Tiner, R. 2004. Remotely-sensed indicators for monitoring the general condition of "natural habitat" in watersheds: an application for Delaware's Nanticoke River watershed. Ecological Indicators 4: 227–243.
- Vance, L. 2005. Watershed assessment of the Cottonwood and Whitewater Watersheds. Report to the Malta Field Office, Bureau of Land Management. Montana Natural Heritage Program, Helena, Montana.
- Vance, L. 2009. Assessing wetland condition with GIS: a landscape integrity model for Montana. A report to the Montana Department of Environmental Quality and the Environmental Protection Agency. Montana Natural Heritage Program, Helena, MT.
- Wang, L., T. Brenden, P. Seelbach, A. Cooper, D. Allan, Richard Clark Jr., and M. Wiley. 2008. Landscape based identification of human disturbance gradients and

reference conditions for Michigan streams. *Environmental Monitoring and Assessment* 141:1–17.

Weitzell, R., M. Khoury, P. Gagnon, B. Schreurs, D. Grossman, and J. Higgins. 2003. Conservation priorities for freshwater biodiversity in the Upper Mississippi River Basin. A report to the McKnight Foundation and the Environmental Protection Agency. NatureServe and The Nature Conservancy, Arlington, VA.

WHCWG (Washington Wildlife Habitat Connectivity Working Group). 2010. Washington connected landscapes project: statewide analysis. Washington Departments of Fish and Wildlife, and Transportation, Olympia, WA.