ALTERNATIVE FUTURES FOR THE UPPER COLORADO

RIVER ECOSYSTEM: PHASE II

by

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ABSTRACT

Alternative Futures for the Upper Colorado

River Ecosystem: Phase II

by

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Wildlife habitat and biodiversity in the Upper Colorado River Ecosystem are threatened by growth of urban areas, subdivision of rural lands, and exploitation of natural resources. The White-Yampa, Colorado Headwaters, and Gunnison River Watersheds within the region were investigated to discover areas supporting high biodiversity that would be possible candidates for conservation efforts by the U.S. Fish and Wildlife Service. Using an alternative futures planning process and principles of landscape ecology, development of energy of the resources in the region was found to be the primary driver for land use and impacts to wildlife habitat. Through application of geospatial modeling techniques, three alternative futures were developed by means of varying scenarios for wildlife habitat conservation and energy resource development. Results were analyzed to find areas of conflict, and futures were evaluated for habitat conservation potential, impacts on agriculture and ranching, and effects on future growth and development. Final recommendations for targeting conservation areas are based on likelihood of land use conflict, habitat value, and connectivity through the landscape. Smaller scale examination of habitat value and targeted species' specific needs will need to be conducted prior to implementation.

(248 pages)

DEDICATION

For Ellen and Turtle, loved and missed.

ACKNOWLEDGMENTS

I would like to thank Landon Profaizer for his assistance in conceptualizing, modeling, and describing the habitat conservation scenarios. I would also like to thank the Bioregional Planning Studio team members who worked on the Upper Colorado River Ecosystem Phase I report, and for the use of the species richness data they generated.

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CHAPTER 1

INTRODUCTION

The United States Environmental Protection Agency (2001) reports that habitat destruction is the main factor responsible for species endangerment. Trends in land use and expansion of urban areas into adjacent open space will continue to consume land and fragment or destroy habitat (U.S. Environmental Protection Agency, 2001). Studies have shown that habitat loss negatively impacts overall species abundance and reduces biodiversity (Andrén, 1997; Fischer & Lindenmayer, 2007; Hansen et al., 2005; McKinney, 2002; Pimm & Raven, 2000; Solé, Alonso, & Saldaña, 2004, and others). Habitat destruction and fragmentation are believed to be core causes for biodiversity decline, although species' responses to fragmentation differs (Debinski & Holt, 2000; Forman & Alexander, 1998). Reasons for desiring to protect biodiversity range from moral to ecological to economic (Ehrlich & Daily, 1993; Spash & Hanley, 1995; Tilman, 2000). Ehrlich (1993) asserts that preservation of habitat and protection from fragmentation is the critical policy prescription for biodiversity preservation and ecosystem functions. Effective, systematic conservation includes efficient use of limited resources toward goals, and defensibility and flexibility when faced with competing land uses (Margules & Pressey, 2000).

In response to a request from the U.S. Fish and Wildlife Service, the Bioregional Planning Program at Utah State University undertook a study to identify wildlife hotspots in the Upper Colorado River Ecosystem (UCRE) that U.S. Fish and Wildlife Service may wish to consider for protection. The work has taken place in phases. This study is the second phase of the larger project. The first year analyzed the entire Upper Colorado River Basin and provided a descriptive foundation, context for further work, and information on possible directions for the future. This Phase II work is focused on an area in the eastern portion of the basin. Moving to a smaller region permitted a process tailored to the specific ecological resources, human influences, and geographical qualities of the area. Because human activities, development, and use of the region for its natural resources impose a great deal of demand and stress on the environment and its systems, this work focused on the effects of anthropogenic factors on habitat.

This study was conducted as an alternative futures analysis. By envisioning what the future might be like, we can choose among the possibilities for the outcome we find most desirable. We can also decide how to further improve those outcomes and take actions in the present that will be of benefit in the long term. In a sense, deciding between a beach vacation in Hawaii and a backpacking trip in Alaska is an alternative futures decision making process. For this study, the future in question is 20-25 years from now, and the decisions are how to balance human growth and resource needs with biodiversity and the habitat needs of wildlife.

Some of the questions we needed to ask in order to develop an understanding of what the possibilities for the future are included the following:

- What are the important components of the human, environmental, and biological landscape?

- What are the significant driving forces for change in the landscape in the future?
- How will future uses of land and resources affect habitat?
- How might wildlife conservation approaches vary?

Using the information gained from that process of inquiry, three alternative futures were developed and mapped through the use of Geographic Information Systems models. Mapping allowed visual representation of spatial aspects of the landscape change and use in the concepts of what might happen in different versions of the future. Important questions following the creation of the alternative futures included:

- Where will there be potential for conflicts between current and future land uses?
- What areas of valuable habitat might be in jeopardy?
- How can growth be accommodated?

Exploration of these questions can bring to light important information that may go overlooked if the process merely stopped after drafting the alternative futures. For instance, we can consider the consequences to farming and agricultural practices and the impacts on the way of life for those whose livelihoods depend on it. We can analyze the effectiveness of the models for finding high value habitat, and look for areas that could be important but did not match the model’s condition. By checking to see if sufficient area has been allowed to accommodate development, we can alleviate concerns over how planning efforts might constrain future growth.

The final step for this project was to consider what the process can tell us about making strategic decisions in the present that will be of benefit in any future. Efforts can be directed toward preventing the undesirable consequences in the future. Many factors are uncontrollable, however, and planning can also help managers anticipate and be prepared with contingent responses for a variety of prospects. Deliberative planning for the long term can be more effective with knowledge about what future pressures might exist and what the drivers of change in the landscape will be. The conclusions in Chapter 7 present an integration of the overall results of modeling and evaluation processes into a map showing areas with high value habitat for the support of biodiversity, and which are also likely to be subjected to pressures of human development. These are the areas suggested as most in need of conservation through this work.

CHAPTER 2

STUDY AREA

The study area covered by the first year's work was approximately 170,000 square miles, or 109,343,247 acres, and spread across seven states (Figure 1). The vast size of the landscape under scrutiny presented challenges in analysis and display of information, and permitted only a general overview of the natural processes and human demands of the region. It became apparent that more focused analysis in the face of regionally specific drivers and resources could yield another layer of knowledge in accordance with the principle of scale sensitivity in landscape ecology. This states that different properties emerge or become apparent, depending on the scale or level at which we examine a system (Bissonette, 1997).

As we move down in scale, regional conditions, processes, and conflicts allow for a more customized and regionally specific analysis. It provides for the ability to tailor analysis to biophysical/ecological conditions, extant natural resources, and the human drivers that act in different ways or may be present in different parts of the UCRE as a whole. For instance, the growth and recreation demands near the Salt Lake urban area are qualitatively and quantitatively different from those in western Colorado. Resources are likewise unevenly distributed throughout the region. The driving forces and important variables change as the study boundaries change.

Figure 1. Upper Colorado River Ecosystem Study Area

Evaluation of a smaller area yields improved illustration in the information displayed in maps, important because the initial phase demonstrated that effective representation of land use was difficult at the larger scale. Most mapping and analysis for both phases was done using data based on a 30 meter by 30 meter grid. This is beneficial for modeling and analysis, but this resolution cannot be discerned on a map when the area is so large. For the Phase I report, the display ratio for maps was 1:4,500,000. Most maps in this report have a ratio of 1:2,500,000. Even at this scale, the data contains more detail than is readily apparent. Figure 15 in Chapter 4 is an example of a close-up showing the resolution that is available.

To this end, three sub-watersheds were selected for the Phase II study area. The White-Yampa, Colorado Headwaters, and Gunnison basins were chosen for several benefits they present. The three watersheds are shown in Figure 2. While still a large, landscape-scale area, the three watersheds encompass roughly 31,000 square miles, or approximately 18% of the first phase UCRE. The three basins are contiguous, and therefore represent a larger-scale ecological whole to enable consideration of the functions of connectedness and scale sensitivity. Although there are small sections in Wyoming and Utah, the majority of the land area and population are located primarily within the state of Colorado. For this reason, it was hoped to have the advantages of datasets with consistency in content, extent, and resolution for our purposes of comparison and analysis. Distribution of population and area of the Phase II study region are shown in Table 1.

Figure 2. Phase II Study Area

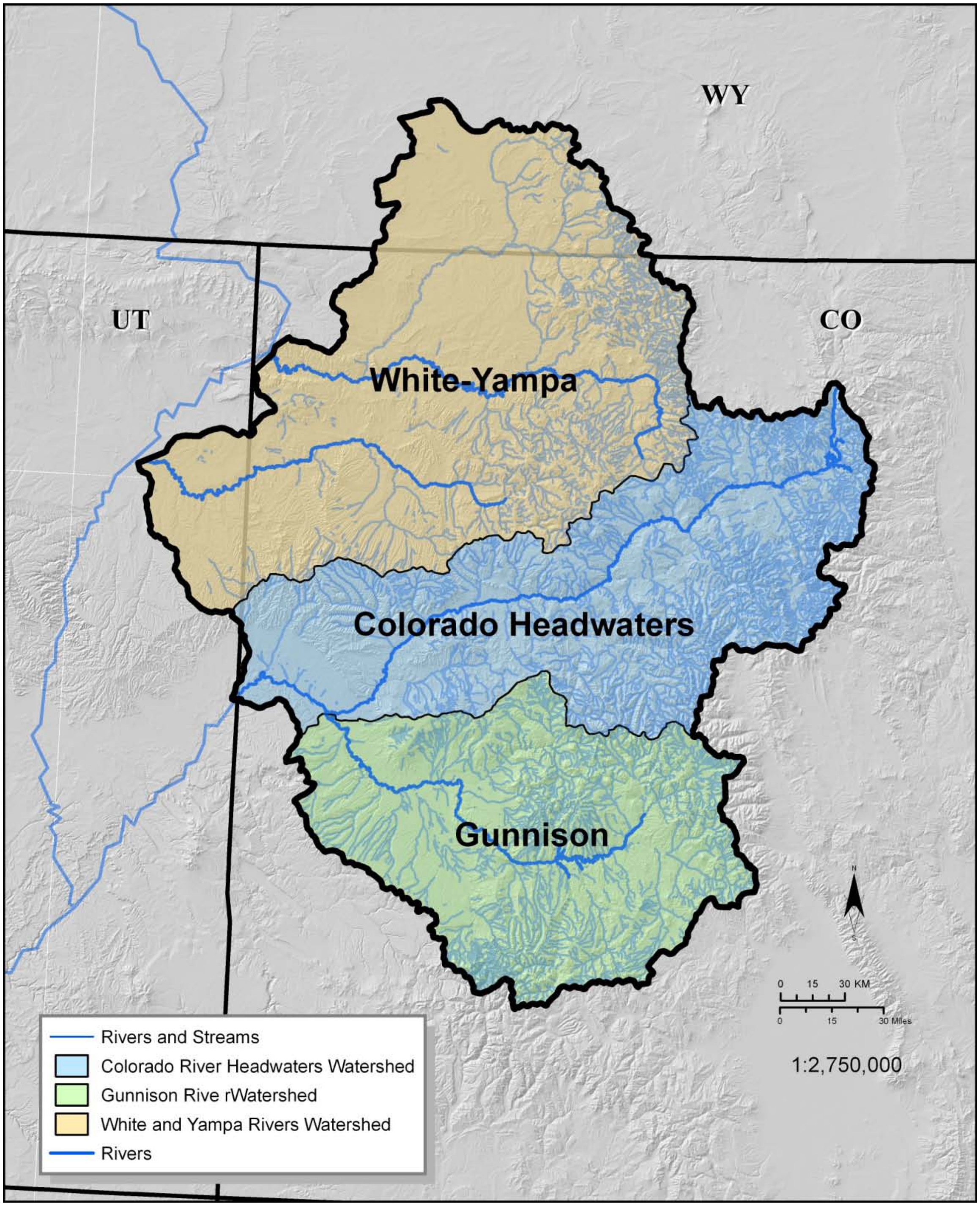


Table 1

Distribution of Population and Area among States in Study Region

	Colorado	Utah	Wyoming	Total
Population	310,526	7,250	6,404	324,180
% Population	96%	2%	2%	100%
Area (Square Miles)	27,425	1,223	2,365	31,013
% Area	88%	4%	8%	100%

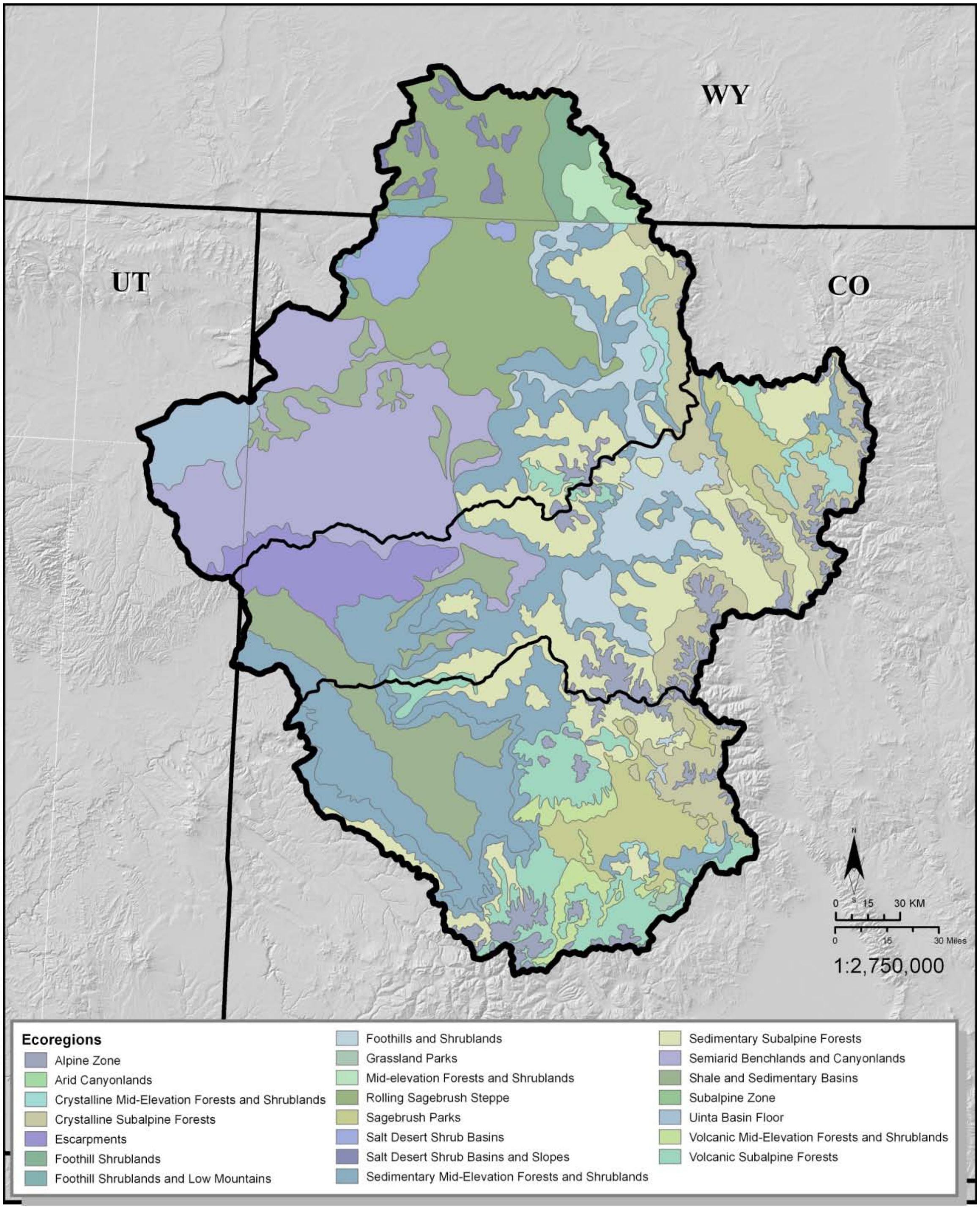
Note. Data from 2000 Census

The subregions represent a variety of geophysical and biological characteristics similar to those of the entire UCRE. Bailey (1976, 1978, 2004, 2009) uses a system to describe ecological units, called ecoregions, with Level 4 being the smallest divisions with the finest level of detail. The ecoregion categories are based on climate, landform, vegetation, and the context of ecological systems. The three watersheds in this study area represent 22 of the 71 total Level 4 ecoregions within UCRE. While this is less than half the total ecoregions present in the entire UCRE, these 22 ecoregion types in the subregion account for 47% of the total land area of the whole. Ecoregions of the Phase II area are shown in Figure 3 and in greater detail in Chapter 2.

Human uses in the study area vary, ranging from the high mountain ranches near the continental divide in the northwest to the increasingly urbanized area of Grand Junction, Colorado. It is anticipated that in designing methods of analysis and modeling by using this portion of the UCRE, the outcome will be a tool that can be applied to other subdivisions of the larger study area. The resulting process for modeling and assessment will have the capability to provide more specificity and customization as the objectives, goals, and biophysical circumstances dictate.

Although the overall objective is to evaluate and specify hotspots for wildlife, the intense human pressures on the region cannot be ignored. Low population density, availability of natural resources, and scenic quality make further growth of settlement and exploitation of resources inevitable activities in the future of this region. For this reason, three primary drivers of change were identified at the end of the first year for further examination: working lands, the collective term for agriculture and ranching, energy, and recreation. These are all human driven factors rather than environmental processes or natural resources. As the scale and focus of studies change, different drivers are likely to emerge as primary issues for different subregions. While climate change and water quality and quantity are issues that will have indisputable effects on this landscape, the selected drivers represent factors that we most directly have the ability to mitigate, change, or avoid.

Figure 3. Ecoregions of the Phase II Study Area



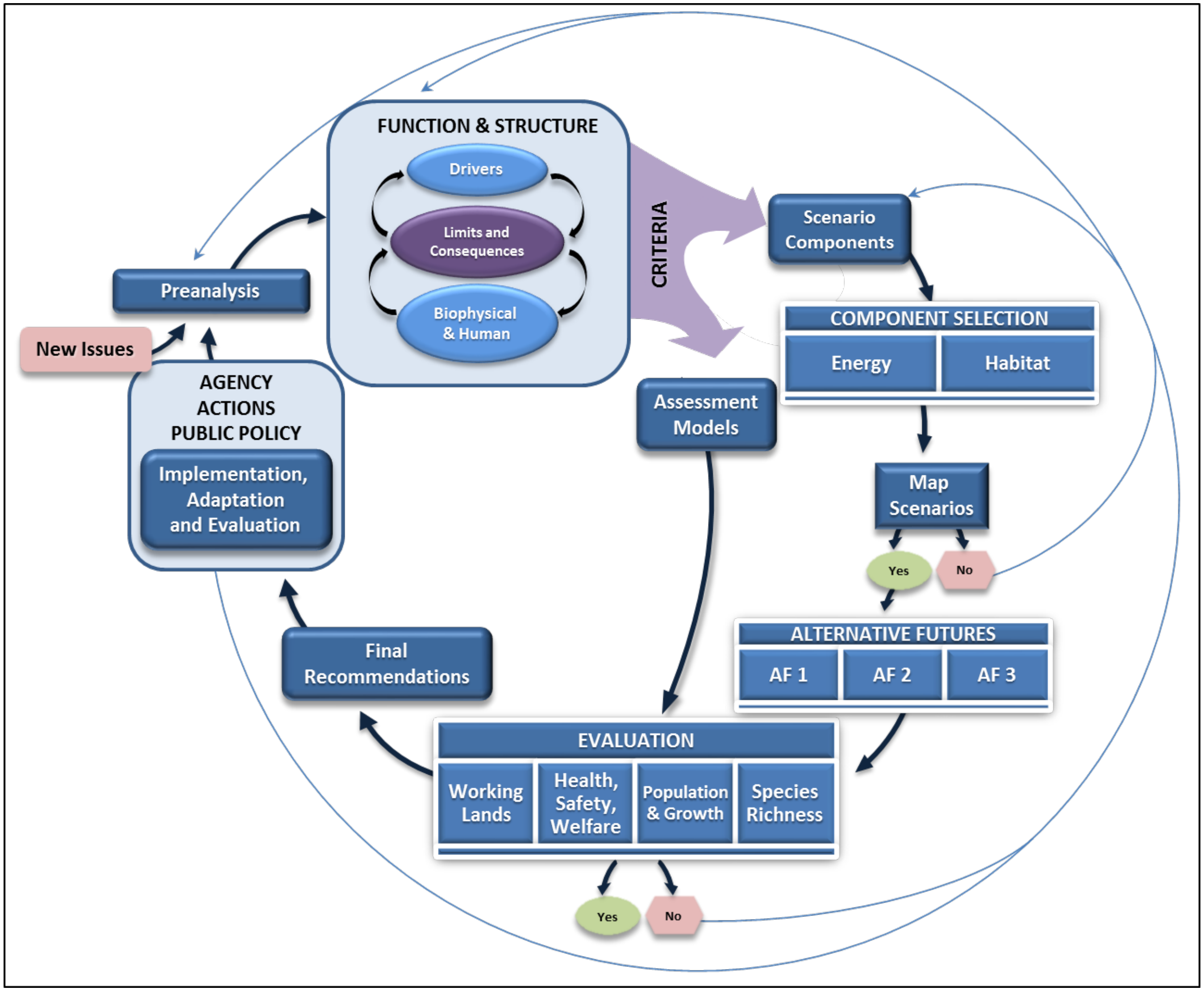
CHAPTER 3

METHODS

Beginning with the basic processes provided by previous projects conducted by the Bioregional Planning Program (Toth, et al., 2005; Toth, et al., 2006; Toth, Covington, Curtis, & Luce, 2007; Toth, et al., 2004), the UCRE Phase II study customized and adapted the work model to the specific needs of the tasks at hand. This closely follows the approach used by Baker, et al. (2004) in the Willamette River Basin. The process model as it was developed and applied to this study is represented in Figure 4, and described through the chapters that follow.

Work took place in three principal stages. The first was a characterization of the geographical region, including biophysical and human systems and interactions. This stage served to clarify the characteristics of the landscape, the context of the study area, to elucidate the operationally significant factors, determine drivers, and to identify data needs (Odum, 1971; Toth, 1988). This work is discussed in Chapter 3, Information Gathering and Analysis of the Region. In the second stage, scenarios were conceived, modeled, and mapped. Scenarios were then selected and combined into alternative futures to represent the trajectories of different management or policy approaches, and the resultant land uses. These were mapped to spatially represent the futures and to provide data for the steps that followed. The results of scenarios building and alternative future projection steps are in Chapter 4. The third stage was an evaluation of likely

Figure 4. Process Diagram



effects and impacts on other systems. This was also conducted as a geospatial process. Outcomes of evaluation models are in Chapter 5. Conclusions and recommendations are in Chapter 6.

As with previous studies conducted in the Bioregional program, the process is iterative and ongoing, designed to incorporate new information, objectives, feedbacks, and obstacles (Peterson, Cumming & Carpenter, 2003). At several junctures, there are interim steps, where an evaluation of the process needs to be made. These are represented as specific yes or no decisions in the process, although they could arise at any point. They symbolize an examination of the process through questions such as:

- Is this process effective?
- Can it be integrated with the other parts of the process?
- Is it providing valuable information?
- Have the critical points been captured?

As an adaptive model, modifications and updates to criteria and scenarios can continue to be made. When the process or results are found to have unsatisfactory answers to these questions, it becomes necessary to return to an earlier stage, adjust the parameters, and reiterate the process.

Alternative Futures

The approach taken with this study is the projection of alternative futures. Alternative futures planning uses factors that are reasonably predictable, such as population growth, and the subsequent need to provide housing, food, and energy for those people. The less predictable questions, such as where, how, and how much, then become the subject of questions designed to envision different possibilities for how the future might unfold (Peterson, et al, 2003; Schwartz, 1996).

The objective of an alternative futures study is to connect policies and decisions made in the present with potential outcomes in the future (Coates, 2000). No certainty of the future is attainable; however, actions, policies, and decisions made in the present will shape and influence that future (Gallopin et al., 1997). In order to create desired outcomes or to evaluate the desirability of possible future states, projection of the long-term effects resulting from various actions in the present is an indispensible tool. In the best circumstances, this will facilitate not only better decisions and greater resilience, but can also prevent irreversible damage (Peterson, et al., 2003). According to Liotta and Shearer (2006, p. 11), the strength in alternative futures modeling allows us to "(1) better understand the opportunities and challenges that might lie ahead and (2) make decisions today that are advantageous to those opportunities and robust against the challenges."

This work presents three alternative futures, or states at a point in time, which are built from scenarios extending from the present into the future. Scenarios in this case are the various storylines for driving forces as they compete against each other in land use decisions in this region. Different groupings of scenario components are possible, and there are multiple possible combinations. It becomes important to identify a small number of variations on a theme and find the significant possible futures among them (Coates, 2000). The results of this selection process are three foreseeable and likely combinations which have been taken through the final futures modeling, mapping, and evaluation. Many of the actions within scenario components will be political and economically driven, dependent not only on regional factors, but also national and global demands, pressures, and constraints. None of them is predictive, but rather, they outline possible paths to futures that have grounding in present circumstances and are plausible, reasonable, and feasible developments through time (Peterson, et al., 2003).

Alternative futures and mapping provide a useful tool to assess future directions and consequences of present policies (Liotta & Shearer, 2006). Through the use of scenarios, we can evaluate the effects of decisions in the present on the trajectories of future worlds. They help us ask questions about the type of society we want to live in and what we will leave to future generations (Gallopin, 1997). They help address questions about what needs to be evaluated and monitored (Coates, 2000), provide direction for future research (Gallopin, 1997; Peterson, et al., 2003), expose opportunities, and make us collectively aware of potential traps (Peterson, et al., 2003). Storylines for futures are fictional, but offer a window into the future based on the current state of science and understanding of systems for those willing to consider the possibilities and choices (Schwartz, 1996). The questions raised can help guide decisions and policies, but also call for a close examination of our goals, motivations, and values, and an openness to change if they prove to be incompatible (Coates, 2000).

Tiering

The Bioregional Planning Program has developed and used a tiered modeling approach in many recent works. The tiering concept ranks outcomes of a model or evaluation, and can happen at different stages and in different ways. It allows for prioritization, flexibility and choices in implementation. Tiering in this study is implemented in the assessments, evaluations, and conclusions in Chapters 5, 6, and 7. In these sections, areas of conflict have been determined to be high, medium, and low, Tiers 1, 2, and 3, respectively. Tier 1 areas have significant and perhaps multiple conflicts and should be prioritized in efforts to ameliorate threats or conserve valuable habitat. Tier 2 has considerable potential for conflict; Tier 3 has moderate conflict, but should rank lower among areas identified. A simplified, overall tiered evaluation is presented in a side-by-side performance summary in the conclusions in Chapter 7.

Once assessments had been conducted and conflicts delineated, final recommendations were developed. These are presented in Chapter 8. The ongoing processes of adaptation, implementation, policy development, monitoring, applied management, and consideration of new issues are important steps in this process, but occur outside of the scope of this planning effort. Ideally, planning and management coincide in an ongoing, dynamic process aiming for a systems approach rather than a static, artificial endpoint. Modeling of activities and impacts may inform the positive and negative valuations associated with various land uses, and inform future decisions and behaviors for long-term planning and management in the region.

Geographic Information Systems (GIS)

Evaluation, analysis, and mapping of spatial data were done using ESRI's ArcGIS. A 30 meter grid, which characterizes land in 30 meter by 30 meter units, was used for all raster data. The projection system used was the Universal Transverse Mercator N13, based on the North American Datum 1983. Where necessary, data were converted to these standards to best maintain consistency and accuracy of representations.

Data were obtained from a wide variety of existing and publicly available sources. These are listed in Appendix A. No original geospatial data were created in the course of this work.

The 30 meter grid gives a very high resolution, or fine grain, for the scale of this study. This level of detail allows analysis, evaluation, and land use projections to be more accurate and effective than would be possible with coarser datasets, even when the detail may be difficult to discern on printed maps. These data would be capable of supporting study of even smaller portions of the region with other, more scale-specific investigations.

CHAPTER 4

INFORMATION GATHERING AND ANALYSIS OF THE REGION

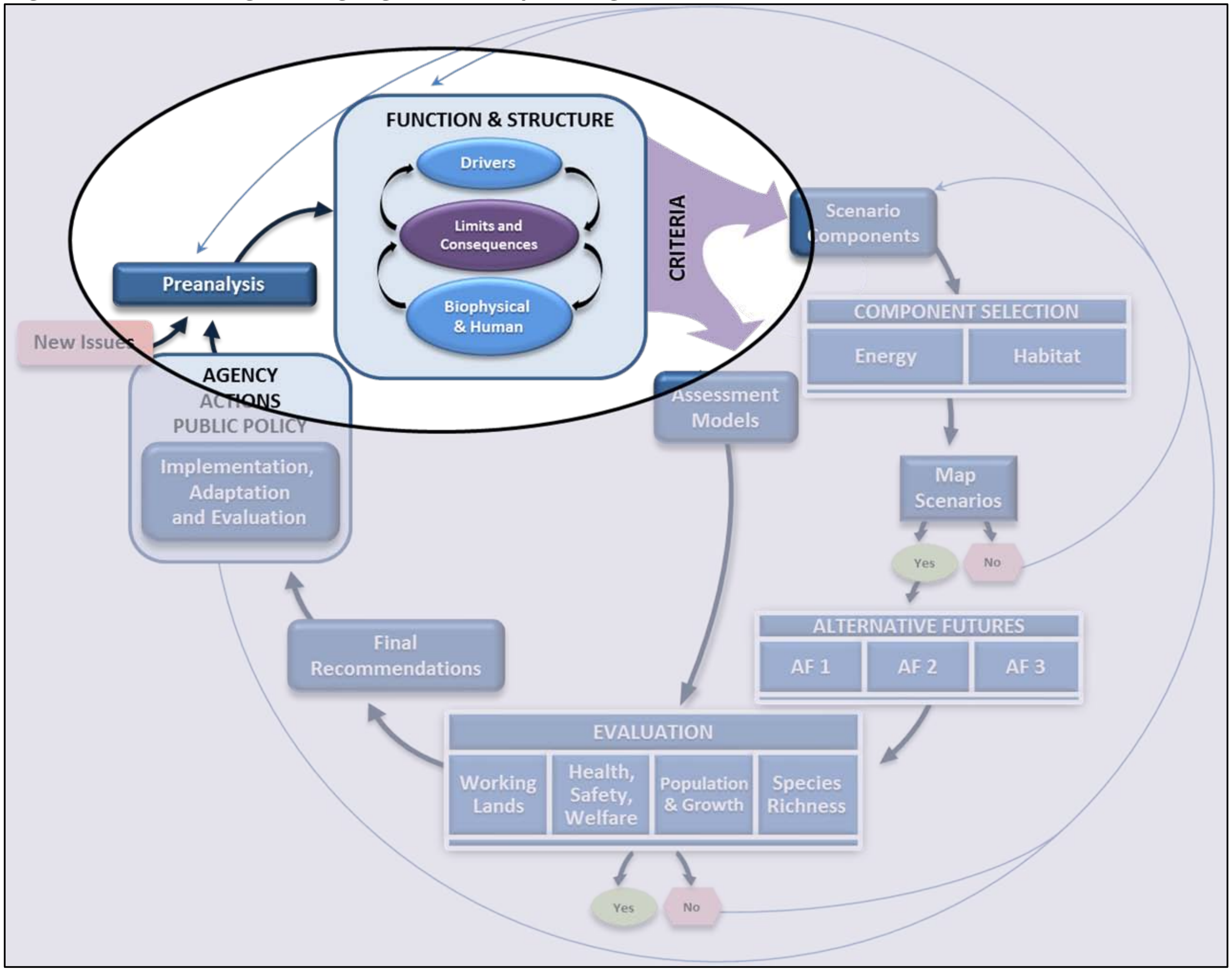
This initial phase of the work was a discovery phase, intended to gain understanding of the region's landscape and resources, to see it firsthand for a contextual reading of its possibilities and problems. During this time, case studies were investigated and data requirements and availability were also explored. The preanalysis phase of work is highlighted in Figure 5.

Preanalysis

Introduction to the study included the report from Phase I work (Toth, et al., 2008), and selected reading designed to provide a theoretical, applied, scientific and historical foundation for the work. Case studies included early, seminal works in the field of large-scale planning, as well as more contemporary studies and works on policy and theory. A list of these resources can be found in Appendix B.

The study began with a preanalysis of the study area and background information. A visual field survey was conducted to observe the project area and context in August 2008. The objective was to delve into the unique character of these watersheds and to identify planning, landscape, and wildlife issues present in the region. Subjects of particular interest included landscapes, historical and physical context, as well as looking for significant conflicts and consequences inherent in land use to use as variables in scenario development.

Figure 5. Process Diagram Highlight - Preanalysis Stages



Observations included the historic settlement patterns and transition of towns historically based in metals mining to tourism economies. Towns based in oil, gas, and coal extraction show signs of boom-and-bust economies, such as ramshackle housing, often mixed with trophy homes, never-occupied retail space, and poorly-conceived sprawl. Conversion of agricultural land to mini-ranches is rampant around recreation areas. Local economies and jobs in the region are closely tied to agricultural/ranching, extraction/energy, service, and construction. Exceptions are Vail, Glenwood Springs, and Grand Junction, which have more diverse economies.

In the lower elevations of the region, agricultural production takes place in irrigated fields. Juxtaposition of farmland against the arid native landscape underscores the dependency on management and manipulation of water for land use and livelihoods. Trees killed by widespread infestation of Mountain Pine Beetle dominate the forests in elevations below roughly 9,000 feet in the areas observed. Outbreaks have been shown to be related to temperature increases (Aukema, et al., 2008), and forest pest infestations are likely to intensify with climate change (Logan, Régnière & Powell, 2003).

The presence of energy is ubiquitous in the landscape. Oil and gas wells, coal mines, and power plants are scattered across the study area. Power lines parallel virtually every major road. Higher capacity lines have often been added alongside an older track of poles, highlighting the growing demand for energy.

Overall, this area appears to be undergoing significant change, and within the process of change, neither ecological aspects nor human activities are independent of the other. For instance, city growth, economic shifts, transportation, and land use conversion are related to natural resources, climate, and geologic barriers. Ecosystems and wildlife are affected by roads, urbanization, pollution, water withdrawals from rivers and streams, and habitat fragmentation.

Throughout the early stages of the process, faculty from the College of Natural Resources provided support in areas of their expertise. Visiting lecturers to the Bioregional Planning Studio, USU Ecology Center, and College of Natural Resources were also enlisted to help provide information and perspectives not available within the college or the university community. These consultations are summarized in Appendix C.

Function and Structure Overview

Theories about complex systems tell us that in order to understand them we must first understand their parts and the working relationships within and among those parts (Miller, 1965; Simon, 1962). These concepts are termed "structure" and "function." Structure is the description of what constitutes a system and where those components are located. Function describes the processes, operations, and interactions of the system. This lens has been applied to landscape ecology (Forman & Godron, 1981; Turner, 1989), but the field has not always included humans in the analysis of landscapes (Nassauer, 1995). Planning fields necessarily integrate the reciprocal relationships of culture and landscape (Flores, Pickett, Zipperer, Pouyat & Pirani, 1998; Leitão & Ahern, 2002; Nassauer, 1995; Steinitz, 1990).

Together, function and structure describe the system, and a change in one brings about changes in the other. By way of a simple example, a healthy forest is made up of diverse species and sizes of trees and plants over a certain area – this is an aspect of its structure at a very basic level. As part of its function, the fire-resistant or dependent species within the forest will help to reestablish a forest following a fire, thereby contributing to a healthy, albeit changing, forest system. If we change the structure of the forest, by planting only a single species of tree, the function of the forest is impaired due to the loss of the ability to recover from disturbance. Conversely, if we change the function of the forest by suppressing fires, the forest may come to have fewer species, mainly those which can dominate the canopy and outcompete the others (Peterson, Allen & Holling, 1998; Scott, 1998; Urban, O'Neill & Shugart, 1987).

Following the preanalysis, attention turned to the function and structure of the system components which had been found to be relevant to the study area. A great deal of function and structure analysis had been completed in Phase I. Therefore, the function and structure work for this phase concentrated on description of regional aspects of the biophysical and human elements and, specifically, the driving forces that provided information about how habitat might be impacted by human activities. Analysis in this way facilitated a greater understanding of the ways in which the biophysical/human aspects of the landscape interact and the inherent limits and consequences of changes to structure and functions within the system.

Three drivers were selected at the end of Phase I work as holding potential for significant landscape impacts: energy, recreation, and working lands. Through the preanalysis, it became apparent that energy as a driver has the greatest ability to transform large tracts of the landscape and influence the quality of habitat over the largest area within the boundaries of Phase II. Future pressures of energy development specific to this region are those most likely to compete with wildlife habitat, and resource decisions associated with energy development will have other direct and indirect consequences to working lands and recreation.

The outcome of this step was a set of criteria which were used to help construct both the scenario components and the assessment models to be applied later in the process. These criteria can be used to create variability in the scenario development, allowing adaptability to changing circumstances and objectives. As a result of the selection of energy as the primary driver, scenario development focused on variations for energy development and wildlife habitat protection. Scenarios are described in Chapter 5.

The criteria were also used to build the evaluation models to gauge the performance of futures, and to spatially identify areas of conflicting land uses in the alternative futures projected. The assessment models are tools designed to represent and quantify public health, safety and welfare with respect to development, impacts on working lands, and aspects of biodiversity conservation. The assessment process is covered in Chapter 6.

Function and Structure:
Landscape Ecological Pattern

The Colorado Plateau is characterized by a series of physiographic provinces that encompass significant biodiversity. Within the UCRE Phase II study area the variety and distribution of ecoregions illustrate the spatial diversity of habitats characteristic of the region. Site visits highlighted the diversity in physical and biophysical attributes found within the study boundaries and set the region in context. The landscape provided a spatial and temporal view of the watershed sub-basins and the variation in plant and animal communities that reside in different ecotypes within them. Site visits also gave perspective to the ways landforms and resources have given rise to the current human settlement patterns and the impacts that anthropogenic uses have had on native plant and animal communities.

Land uses show sharp contrast in the development patterns of historic mining operations and the establishment of small agricultural ranchettes within the region. The agricultural patterns of settlement result in sparse, low-density populations on rich alluvial plains, open valleys and floodplains, wetlands, and rich grazing and rangeland prairies. The historic mining towns in this sub-basin, however, are densely populated and were likely the catalyst for the early settlement patterns and the current urban infrastructure. Both settlement types, while serving different needs, have had negative effects on the biodiversity in this region. Humans and many native species share similar preferences for selection of travel routes, favorable climate, water, and vegetation. These are often the spaces where human needs and habitat conservation collide (Rennicke, 1990).

White and Yampa Rivers Watershed.

The White and Yampa Rivers basin lies in the northwest portion of Colorado. The watershed is bounded where the rivers meet the Green River near the Utah/Colorado border within Dinosaur National Monument. The western portion of the watershed is dominated by semi-arid and sagebrush steppe ecoregions. These areas are characterized by sparse vegetation and low precipitation. In the east, the landscape ascends through foothill and mid-elevation ecoregions, up to the Continental Divide with subalpine and alpine zones. This watershed holds the greatest number of different ecosystems in the Phase II area.

Figure 6 provides a detail of the ecosystems of the White and Yampa Watershed. Table 2 gives a summary of the ecoregion areas and percent of the watershed for all three basins. With two exceptions, Rolling Sagebrush Steppe and Semiarid Benchlands and Canyonlands, all of the ecoregions descriptions list wildlife habitat as a primary land use (Chapman et al., 2004; Chapman et al., 2006).

Figure 6. Ecoregions of the White-Yampa Watershed

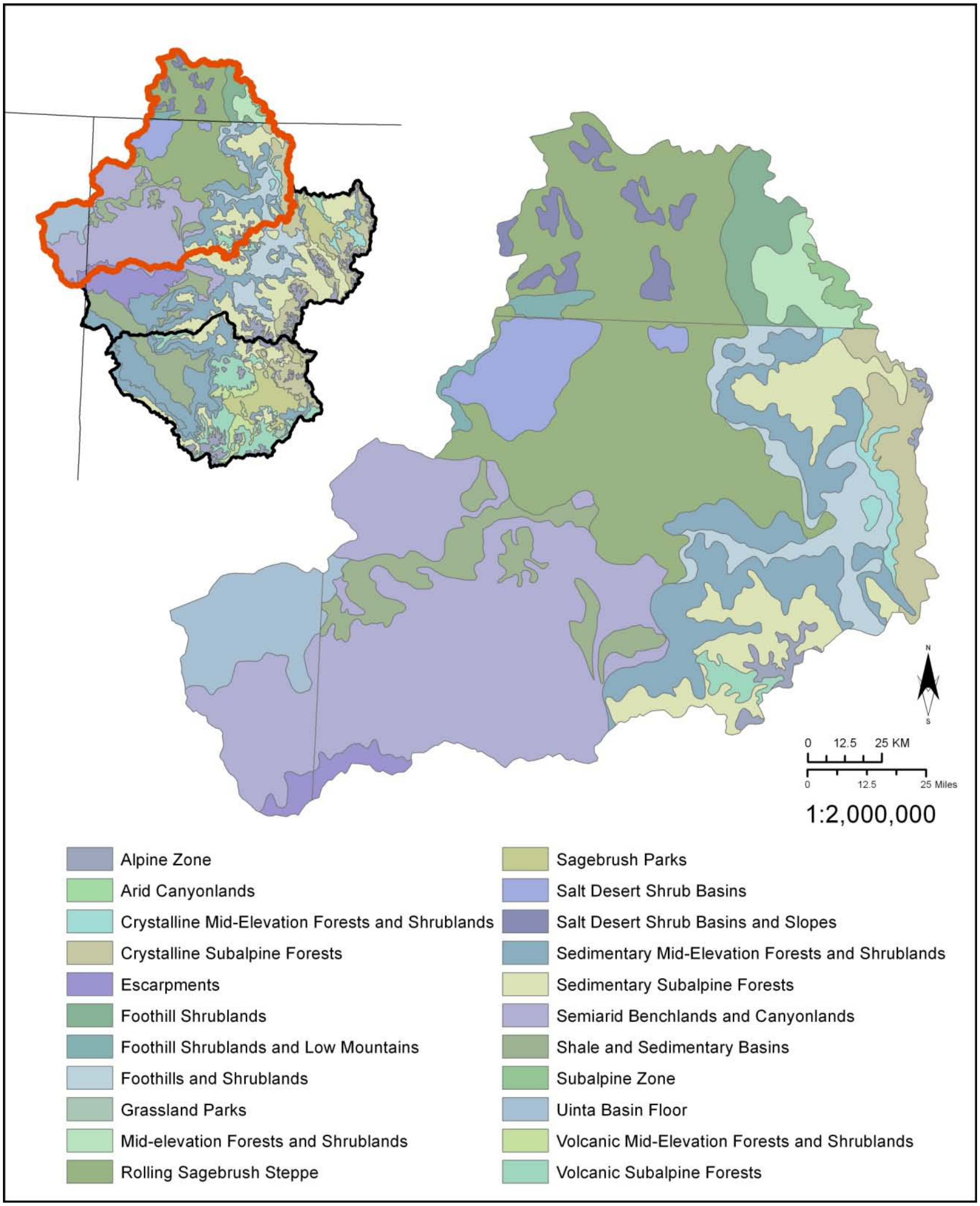


Table 2

Ecoregion Type and Area for All Watersheds in the Region

	White Yampa		Colorado Headwaters		Gunnison	
Ecoregion Type	**Hectares**	**Percent**	**Hectares**	**Percent**	**Hectares**	**Percent**
Alpine Zone	41,630	1%	269,108	6%	147,206	7%
Arid Canyonlands	-		267	0%	-	
Crystalline Mid-Elevation Forests and Shrublands	32,064	1%	47,219	1%	10,922	1%
Crystalline Subalpine Forests	167,420	4%	404,454	8%	136,978	7%
Escarpments	280,493	6%	280,493	6%	-	
Foothill Shrublands	89,577	2%	-		-	
Foothill Shrublands and Low Mountains	29,355	1%	-		-	
Foothills and Shrublands	314,408	7%	360,006	7%	8,285	0%
Grassland Parks	-		-		8,575	0%
Mid-elevation Forests and Shrublands	63,962	1%	-		-	
Rolling Sagebrush Steppe	863,351	19%	-		-	
Sagebrush Parks	-		112,831	2%	217,565	10%
Salt Desert Shrub Basins	132,414	3%	-		-	
Salt Desert Shrub Basins and Slopes	67,657	1%	-		-	
Sedimentary Mid-Elevation Forests and Shrublands	788,275	17%	1,253,408	26%	652,857	31%
Sedimentary Subalpine Forests	328,851	7%	850,212	18%	223,784	11%
Semiarid Benchlands and Canyonlands	1,042,522	23%	735,909	15%	-	
Shale and Sedimentary Basins	154,355	3%	420,411	9%	221,546	11%
Subalpine Zone	19,985		-		-	
Uinta Basin Floor	160,695	3%	-		-	
Volcanic Mid-Elevation Forests and Shrublands	-		-		107,237	5%
Volcanic Subalpine Forests	23,041	1%	81,550	2%	348,059	17%
Total Hectares	4,600,053		4,546,759		2,083,013	

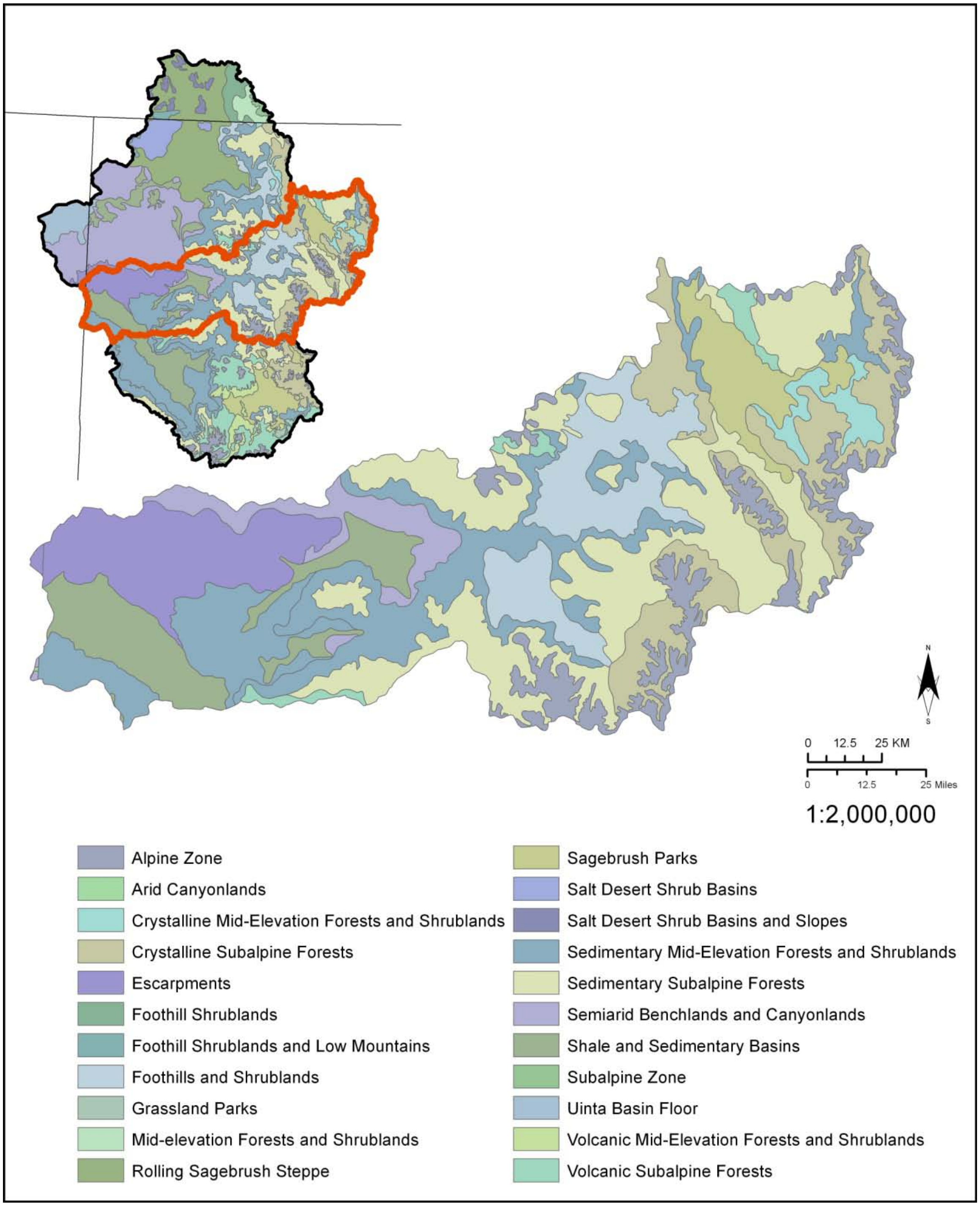
Colorado Headwaters Watershed.

The ecosystems of the Colorado Headwaters range from arid canyonlands to alpine zones. While the western portion of the watershed is characterized by semiarid landscapes, more than half of this region is in forested ecosystems. This is the quintessential Rocky Mountain landscape, with high rugged mountains, wetland valleys, cattle ranches, and ski resorts. It is within this watershed that a flourishing recreation and tourism industry, particularly in eastern counties along I-70, has exerted development pressures resulting in the loss of working lands and habitat.

These forested areas are also susceptible to Mountain Pine Beetle infestation and destruction of dense forest communities that provide critical habitat for wildlife, maintain soil stability, and the infiltration of groundwater. The possibility of wildfires in beetle-killed forests brings with it the threat of erosion and landslides which will have serious consequences to both human and animal populations. In the event of a fire, there will be dramatic losses to property and possibly human life – a critical concern when planning for the public health, welfare, and safety of communities.

The Grand Junction urban area is in the Colorado Headwaters on the border with the Gunnison Basin. Growth and sprawl in Grand Junction and surrounding towns is overlapping both watersheds. Ecoregions of the Colorado Headwaters are shown in Figure 7 and above in Table 2.

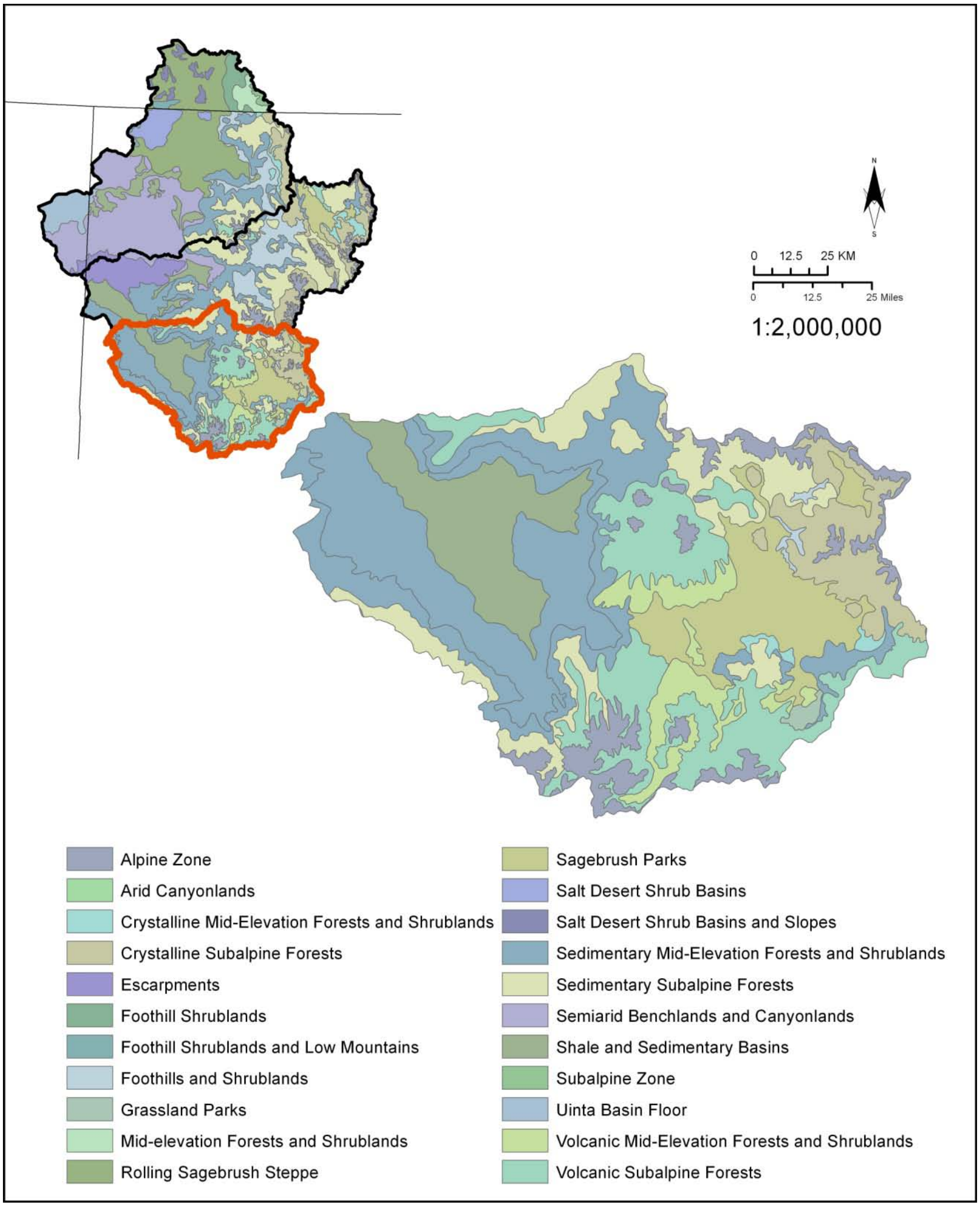
Figure 7. Ecoregions of the Colorado Headwaters Watershed



Gunnison River Watershed.

This region is the smallest of the three watersheds and is characterized by ecoregions similar to those of the Colorado Headwaters. Roughly a third of this landscape is in mid-elevation forests and shrubland, a third is in subalpine forests, with the remaining third distributed between alpine, shrub, and grasslands. Coal mining is prominent, and the proximity of mines, housing, and waterways indicate a potential threat to human and environmental health. There is also a successful move toward smaller-scale agricultural production taking place in the Gunnison basin. The number of vineyards, orchards, and farm stands in the area around Paonia indicate an interest in localized food production and artisanal farm products. Figure 8 and Table 2 give information on the ecoregions of the Gunnison Basin.

Figure 8. Ecoregions of the Gunnison Watershed

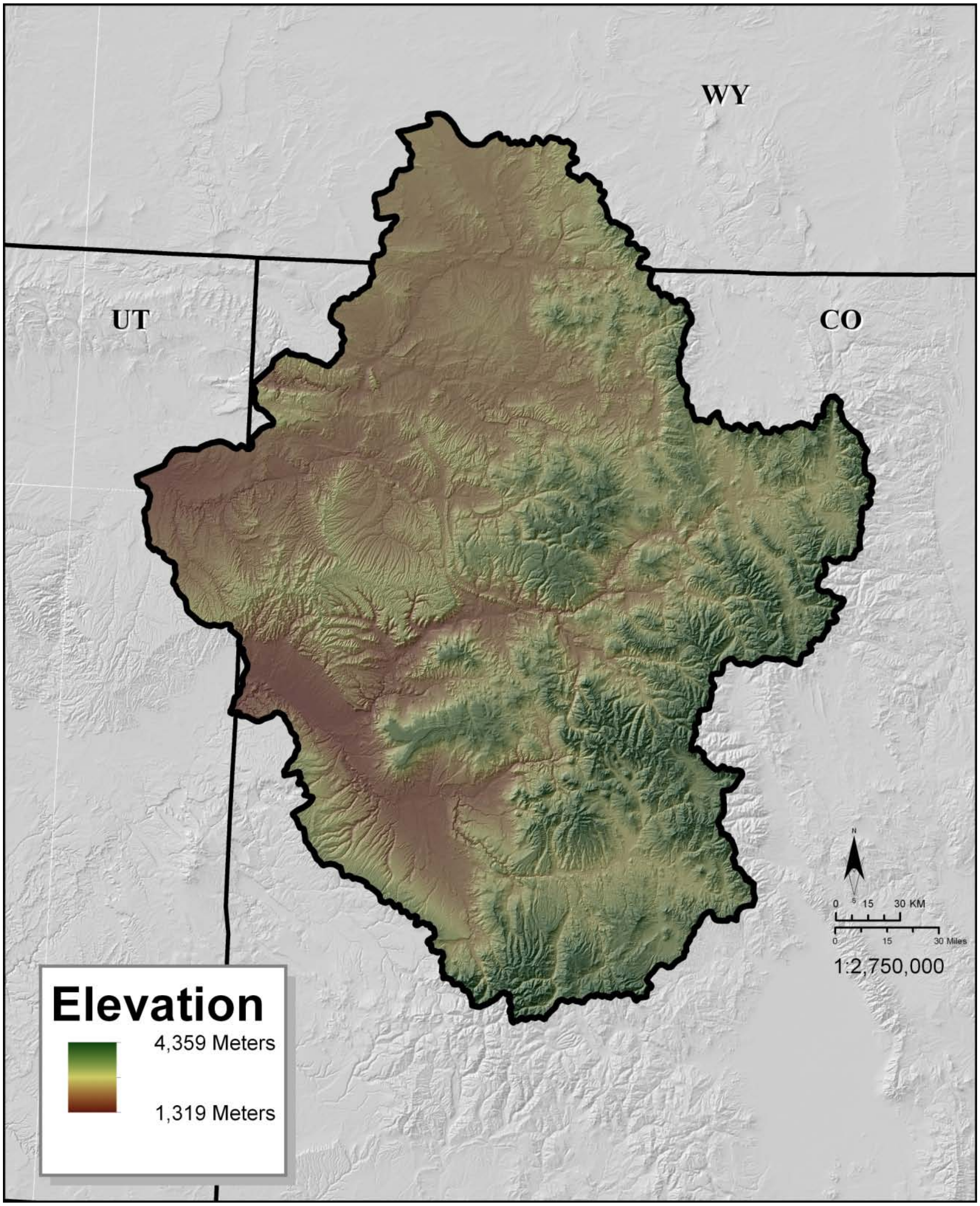


Function and Structure: Climate and Topography

Colorado has the highest mean elevation of any state with more than 1,000 peaks over 10,000 feet above sea level– 54 of which are over 14,000 feet in elevation (Colorado Tourism Office, 2009). The average altitude of the state is around 6,800 feet above sea level (National Oceanic and Atmospheric Administration, 1985). Within fifty miles to the east of the Continental Divide there are six distinct ecological zones, “the equivalent of standing in Florida and seeing all the way to Greenland – a distance of 2,500 miles” (Verrengia, 2000, p. 7). The general climate of Colorado is greatly affected by extreme variations in topography which are shown in the elevation map of the study area in Figure 9. Generally, temperatures are lower and precipitation is higher as elevation increases, and the majority of precipitation falls as snow in the winter months. Due to low levels of humidity, evapotranspiration results in a system with little moisture in summer (National Oceanic and Atmospheric Administration, 1985).

Climate change is expected to result in increased temperatures, and evidence suggests that they are already on the rise (Intergovernmental Panel on Climate Change [IPCC], 2007). Changes in precipitation are less predictable, but in addition to changing amounts, the timing and form of precipitation is expected to be different from the present (IPCC, 2007; Johnson, et al., 2010). Increased temperatures will result in increased transpiration from plants and evaporation from water surfaces. These factors will, in turn, decrease the overall water availability while driving up the demand for water for agriculture and other human uses.

Figure 9. Elevation



With the great uncertainty about the magnitude of temperature and moisture changes, or how species assemblages will change or adapt to new conditions, it is impossible to predict what an altered ecological landscape will look like. The species richness model used in this study is based on the U.S. Geological Survey (USGS) Gap Analysis Program (GAP), which predicts distribution of vertebrates based on available habitat rather than actual species counts. In order to develop alternative futures, the presumption was made that the underlying landscape patterns that create prime habitat in the present are likely to continue to support the richest habitat among those available, providing resilience and refuge for adapting species.

Function and Structure:
Surface Water

A significant concern facing this region is the impact that climate change will have on the social, environmental, and economic systems within Colorado and the surrounding states that depend on water supplied by the Colorado River. The river provides water to ~27 million people in the southwest United States and Mexico (Barnett & Pierce, 2009). Climate models predict that by 2070-2100, the anticipated 2.3-5.6° C increase in average annual land temperature will have dramatic impacts on water storage through reduced snowpack and ultimately less water delivered to a system that today is nearly completely subscribed (Barnett & Pierce, 2009; Met Office Hadley Center, 2010). Increased temperature also has potential to affect the timing and form of precipitation, which may fall as rain rather than snow. Earlier snowmelt, shorter accumulation periods, and rain on snow can reduce snowpack. This is important in a region that relies on the runoff from melting snow for water (Leung, et al., 2004). Construction of reservoirs to store water for use throughout the summer may become necessary to maintain municipal and agricultural water supply.

This region is expecting significant growth in population by the year 2030, adding to the demand for municipal and industrial water. Colorado’s Department of Natural Resources estimates shortfalls totaling between 47,980 and 136,830 acre feet per year by 2050 in the three watersheds, even after scenarios take into account projects and processes that might serve to improve water availability (Morea, Rowan, & Turner, 2010).

The Yampa has the reputation for being the last undammed river in the Colorado River system. It is also one of the few water sources considered to have available water rights. There have been several proposals to pipe water to Colorado’s Front Range, although no applications for water rights have been filed. Pumping water across the Continental Divide would permanently remove the water from the Colorado River Basin – no return flows or reuse would remain in the system. The Yampa is critical habitat to four endangered, endemic fish (U.S. Fish and Wildlife Service, 2004). The U.S. Fish and Wildlife Service has a management plan that allows for development of an additional 54,000 acre feet of water each year before mitigation efforts must be implemented (Smith, 2009).

Water usage in the study area is governed by multiple layers of policy and law. It is the subject of one international agreement, the Mexican Treaty on Rio Grande, Tijuana, and Colorado Rivers–1945, and two interstate compacts, the Colorado River Compact of

1922 and the Upper Colorado River Basin Compact of 1948. It is further regulated by the states and at division, district and watershed levels. Surface water is shown in Figure 10.

Function and Structure:
Ownership and Land Cover

The landscape in the study area consists of diverse land cover and uses including forest land, crop land, pasture, and rangelands. As in much of the west, vast tracts of steep and rugged terrain are managed by federal agencies in the public trust. Figure 11 and Table 3 show ownership within the UCRE Phase II study area. Ownership is roughly balanced between private lands, Bureau of Land Management, and U.S. Forest Service, and the mixed pattern demonstrates the need for collaborative planning and land-use strategies. Federal lands are made available for energy development, minerals mining, grazing, logging, and recreation.

Table 3

Land Ownership and Agency Management of the Region

Ownership	Hectares	Percent
Bureau of Land Management	2,732,425	34%
Private	2,403,973	30%
State	209,299	3%
U.S. Forest Service	2,543,401	32%
Bureau of Reclamation	1,247	0%
Other	2,671	0%
National Parks Service	99,178	1%
State Trust	41,227	1%
Bureau of Indian Affairs	15,638	0.20%
Total	8,049,059	100%

Figure 10. Surface Water

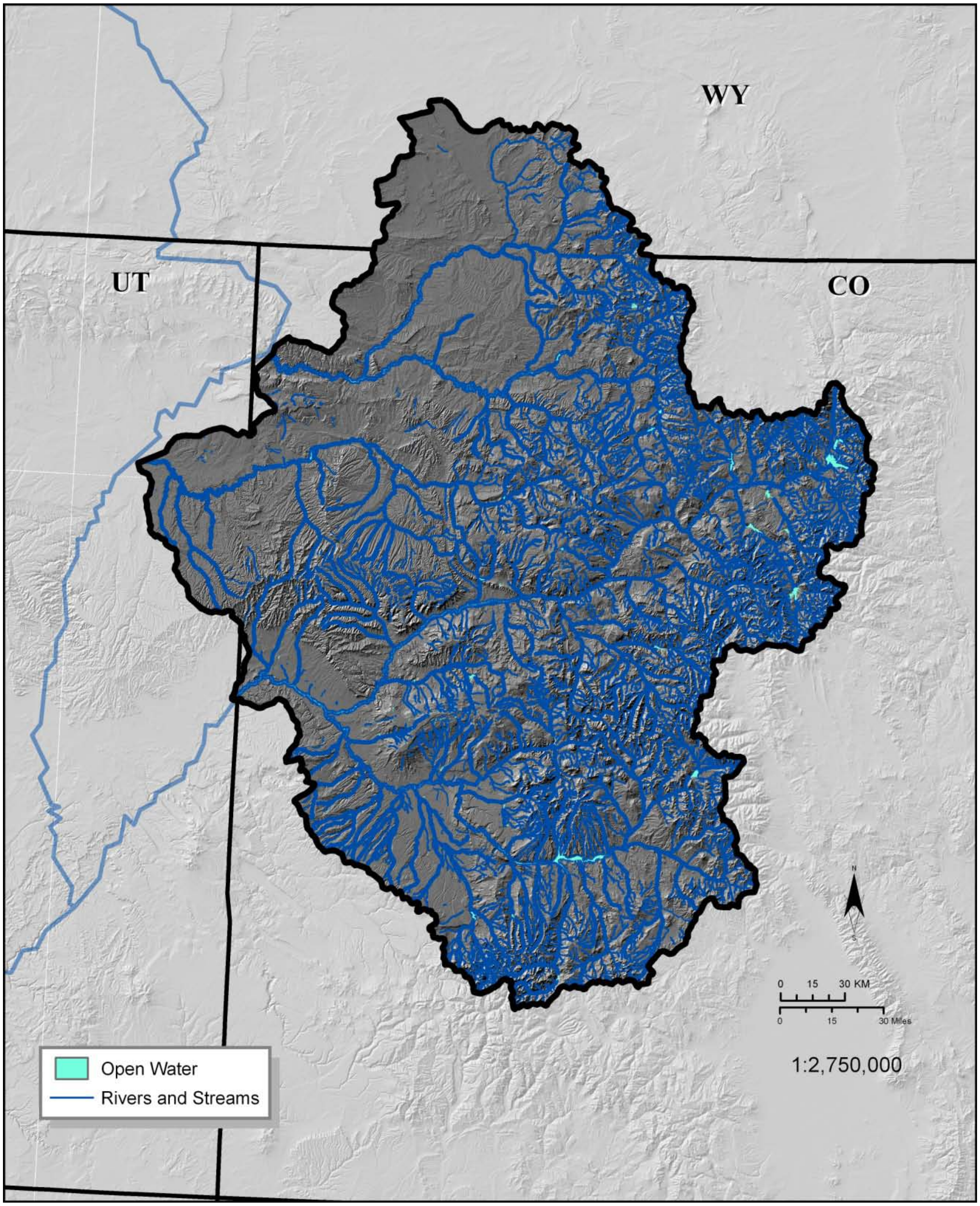
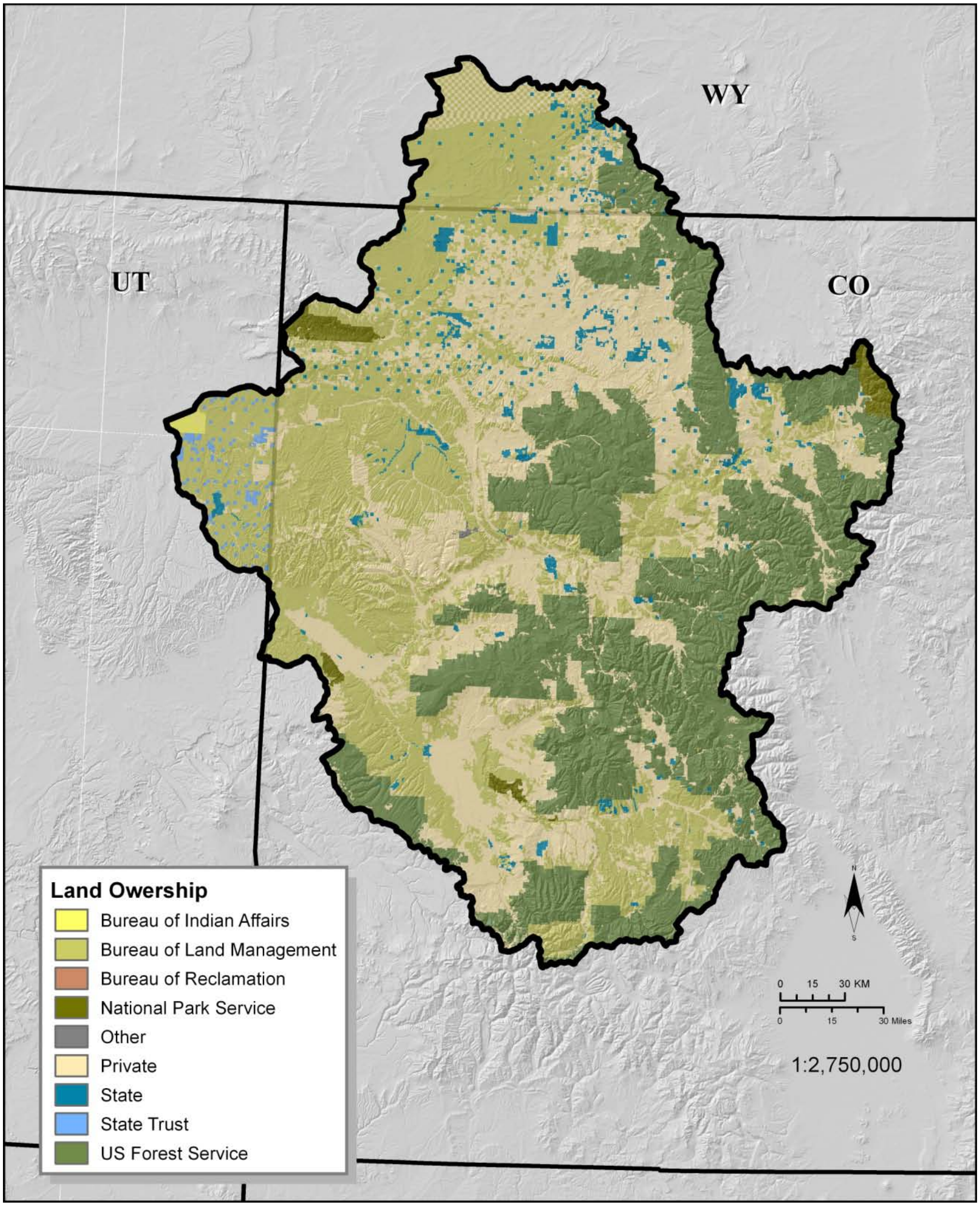


Figure 11. Land Ownership



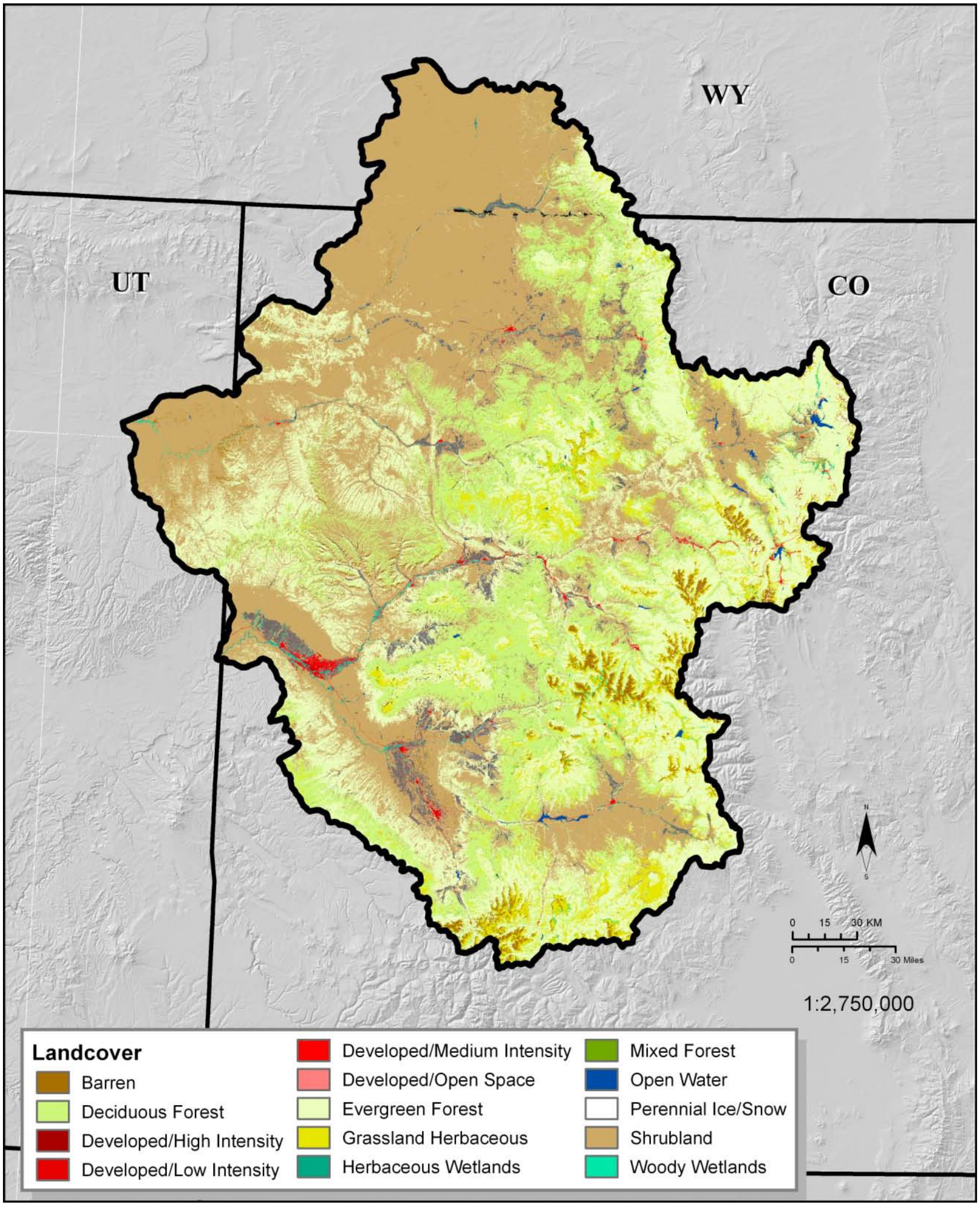
Development and urbanization takes place primarily on private lands. While land cover is influenced by land ownership, such as with development or farming, land cover types do not necessarily follow land ownership patterns. As a result, habitat and wildlife cross ownership boundaries as well. Development tends to occur along waterways, with clusters in valleys and near confluences. Table 4 summarizes area in each land cover type. Figure 12 shows land cover in the study area, but excludes agriculture, which is discussed in a separate section below. Differences in total area are due to dataset variations and rounding.

Table 4

Summary of Land Cover Types in the Region

Land Cover Type	Hectares	Percent
Shrubland	3,172,693	39.0%
Evergreen Forest	2,431,402	30.0%
Deciduous Forest	1,326,185	16.0%
Grassland Herbaceous	517,455	6.0%
Agriculture	219,823	3.0%
Barren	156,872	2.0%
Woody Wetlands	56,877	0.7%
Mixed Forest	46,100	0.6%
Developed/Low Intensity	33,740	0.4%
Developed/Open Space	30,118	0.4%
Perennial Ice/Snow	29,465	0.4%
Open Water	23,059	0.3%
Developed/Medium Intensity	7,916	0.1%
Herbaceous Wetlands	2,833	<0.01%
Developed/High Intensity	1,396	<0.01%
Total	**8,055,934**	

Figure 12. Land Cover



Function and Structure: Wilderness Areas and National Parks

The Wilderness Act of 1964 allowed for setting aside undeveloped federal lands:

> for the use and enjoyment of the American people in such manner as will leave them unimpaired for future use as wilderness, and so as to provide for the protection of these areas, the preservation of their wilderness character, and for the gathering and dissemination of information regarding their use and enjoyment as wilderness (LexisNexis, 2011, §1131(a)).

Although it does not specifically include habitat or wildlife protection, designated Wilderness Areas act as conservation areas by the nature of their protections and restrictions. The Act restricts uses such as building development, road and dam construction, timber cutting, motorized vehicles, and new mining patents. Allowable activities include hiking, horseback riding, camping, fishing, hunting, non-mechanized recreation, watershed protection, and livestock grazing. By the year 1980, nearly 20 million acres of an estimated 95 million of potential wilderness in the continental U.S. was designated for protection (Walsh, Loomis, & Gillman, 1984).

The Phase II study area contains 26 designated Wilderness Areas. Together they constitute 1,702,080 acres, or 2,660 square miles, and are managed by the National Park Service, Bureau of Land Management, U.S. Forest Service, and U.S. Fish and Wildlife Service under many different resource management plans. These plans regulate such things as group size, length of use, fires, camping areas, firearms, trail use, and animals.

There are five National Park Service units in the study area – two national parks, two national monuments, and one national recreation area. They constitute 293,049 acres, or 458 square miles of National Park Service lands in the study region. Wilderness and

National Park lands are represented in Figure 13. Both the designations of Wilderness and National Parks lands are intended by federal law to provide for human use and to protect the character and resources of natural places for the long term.

Function and Structure:
Working Lands

Agriculture in Colorado represents an important economic sector. Roughly half of the overall land in Colorado is either farmed or ranched, contributing over $6 billion annually to the state and $1 billion in exports to countries such as South Korea, Canada, Japan, and Taiwan (U. S. Department of Agriculture [USDA], 2009). Within the state, agriculture is viewed by the public as important to quality of life and is perceived as the most important economic sector, followed by tourism and technology (Colorado Department of Agriculture, 2009).

According to the U.S. Department of Agriculture’s National Agriculture Statistics Service (2009), the study region encompasses approximately 219,823 hectares of agricultural land. The leading single use is hay and pasture. Alfalfa is the largest crop grown in the region, with 7,479 acres in 2008, followed by corn and other hay crops. Agricultural land is represented in Figure 14. Figure 15 is a close-up view of the map in the area around Grand Junction, Colorado, an area of intensive agricultural use. It also shows the level of detail available in this and all maps. Table 5 shows the complete cropland data for the area.

Figure 13. Wildnerness and National Parks

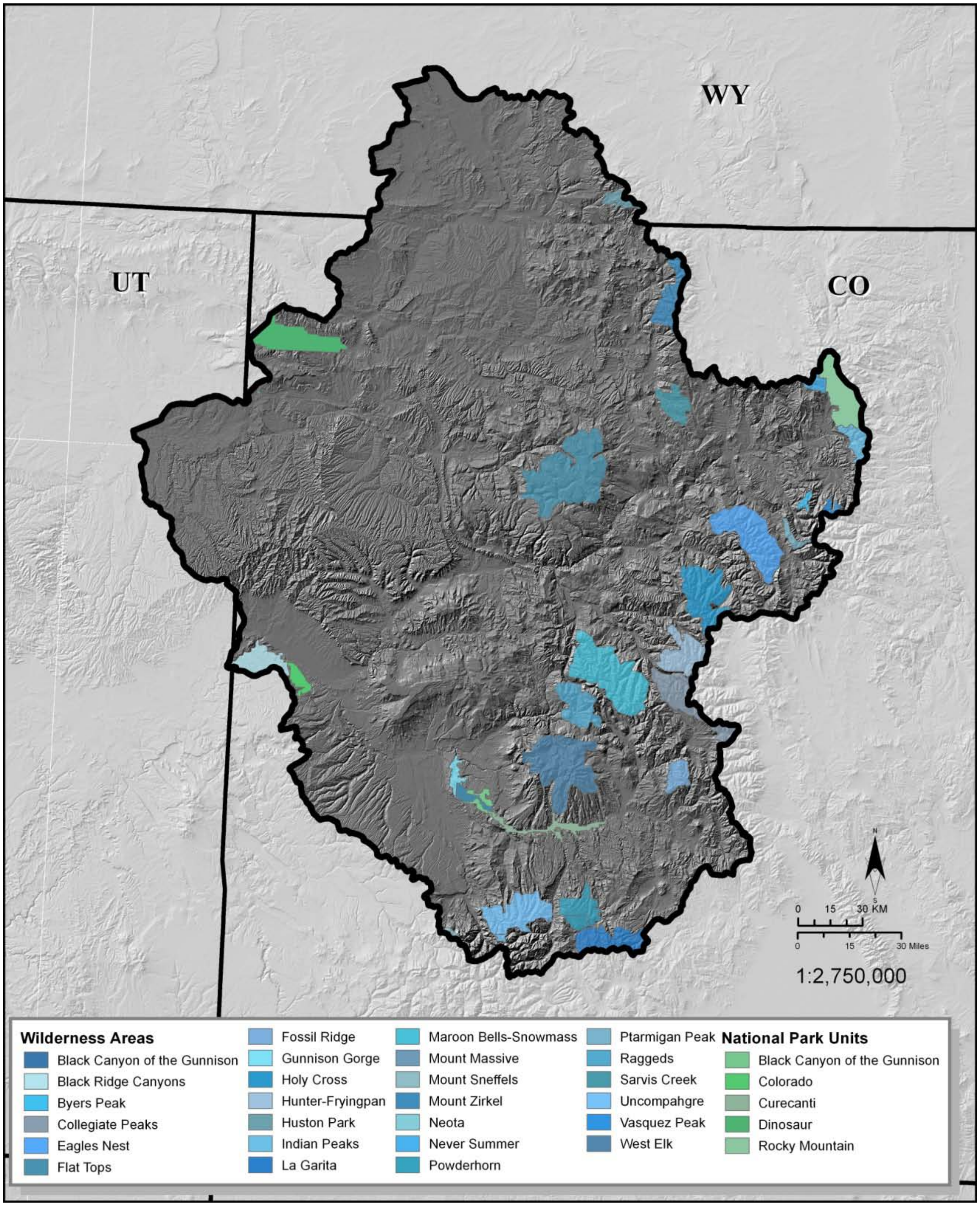


Figure 14. Agricultural Lands

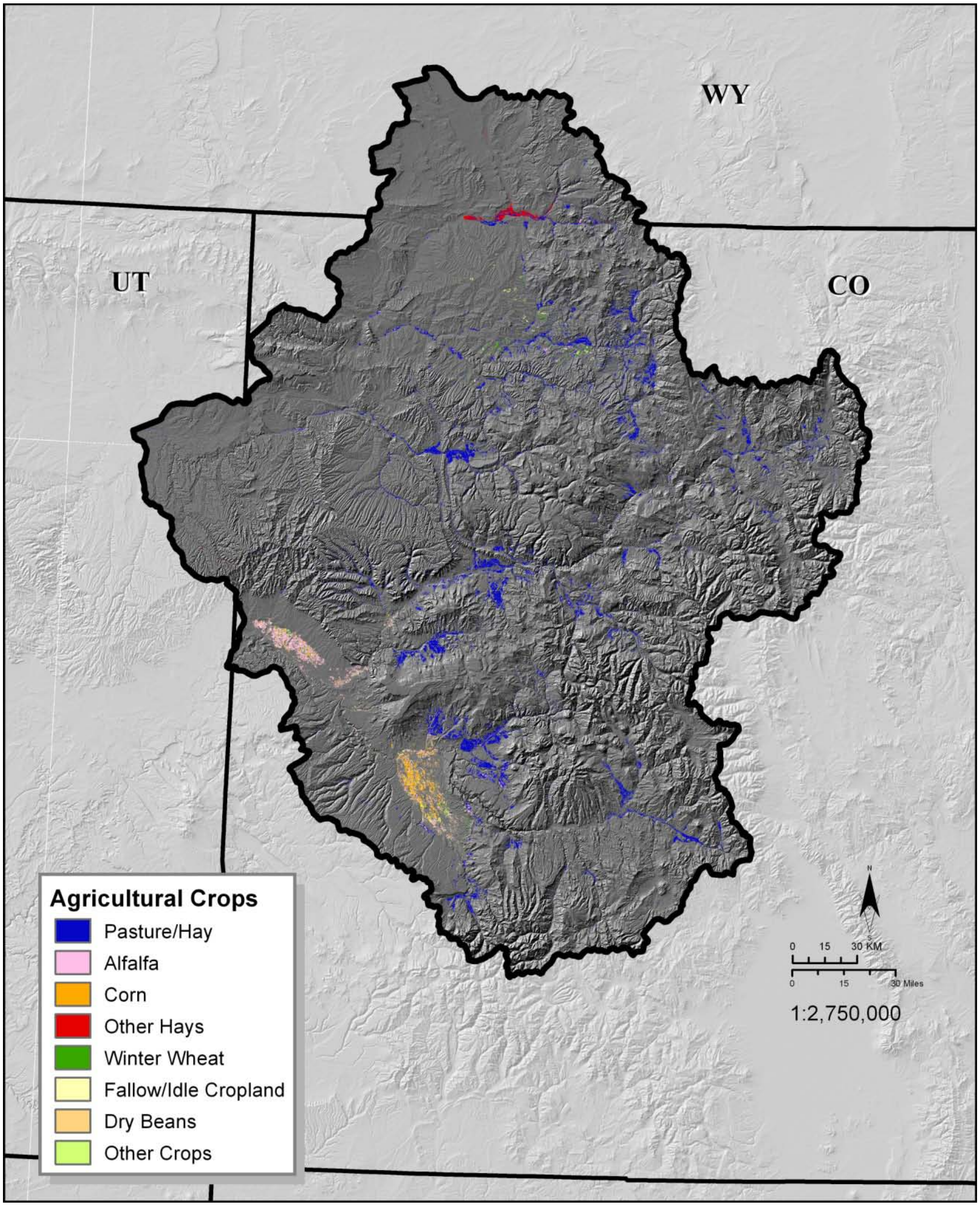


Figure 15. Agricultural Lands (Detail)

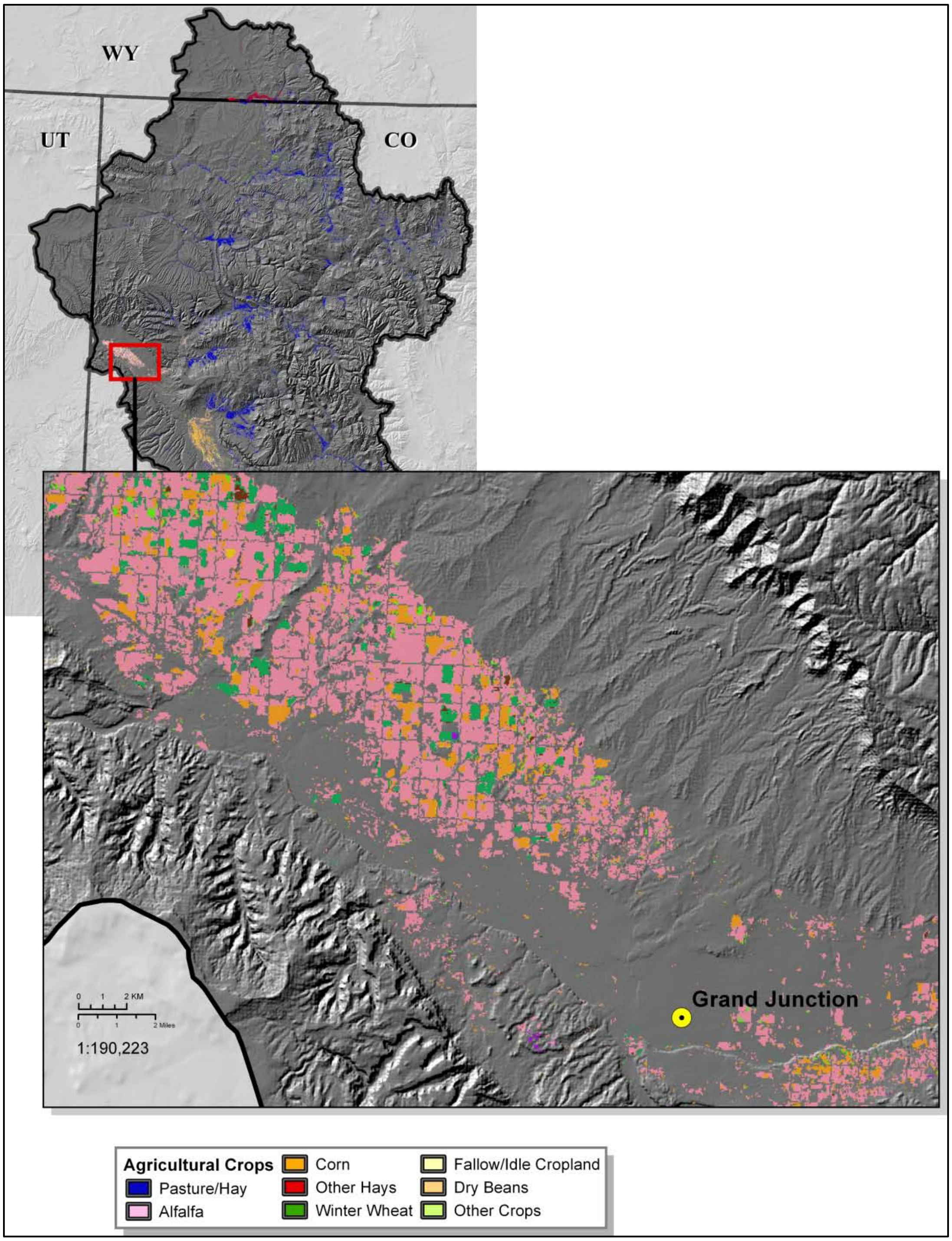


Table 5

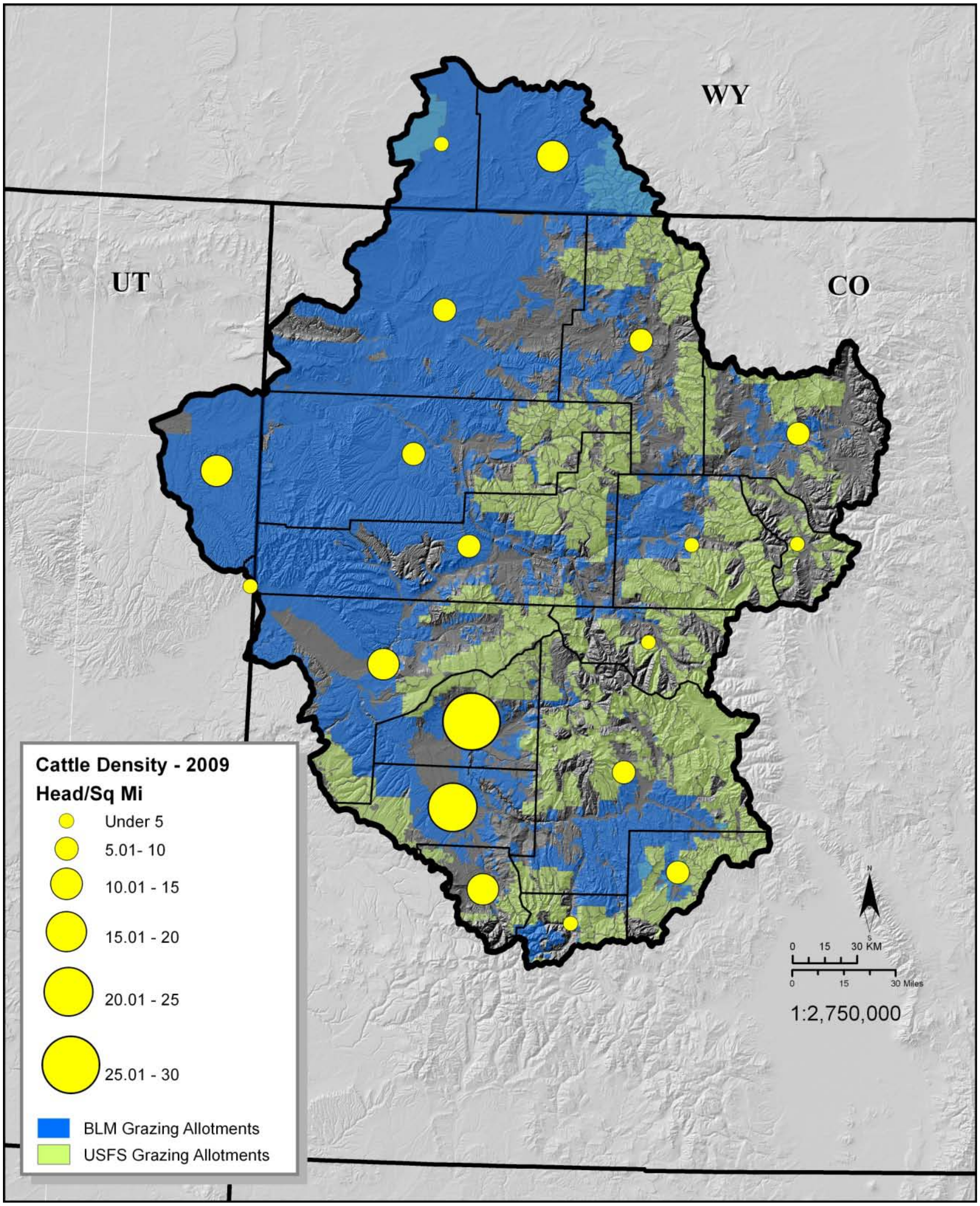
Agricultural Production and Area in the Region

Agricultural Product	Hectares	Percent
Pasture/Hay	153,318	70%
Alfalfa	30,217	14%
Corn	11,856	5%
Other Hays	5,684	3%
Winter Wheat	5,017	2%
Fallow/Idle Cropland	5,007	2%
Dry Beans	2,424	1%
Sweet Corn	1,622	0.74%
Oats	1,516	0.69%
Spring Wheat	1,098	0.50%
Other Crops	641	0.29%
Barley	376	0.17%
Seed/Sod Grass	248	0.11%
Peaches	230	0.10%
Woodland	154	0.07%
Sorghum	110	0.05%
Onions	80	0.04%
Rye	55	0.02%
Soybeans	47	0.02%
Other Small Grains	47	0.02%
Cherry Orchard	21	0.01%
Safflower	21	0.01%
Speltz	15	0.01%
Other Tree Fruits	8	<0.01%
Potatoes	4	<0.01%
Sunflowers	2	<0.01%
Misc. Vegs. & Fruits	2	<0.01%
Apples	1	<0.01%
Total	219,823	100%

Grazing takes place on private and public land, in forests, open range, and pastures. It takes advantage of landscapes that provide little opportunity for crop cultivation for reasons such as soil type, topography, or climate. Livestock production in this way provides a source of feed for animals that contribute to the food economy in the form of beef and other food and fiber products (USDA, 2003). Between the Bureau of Land Management and the U.S. Forest Service, there are reported to be14,608,594 acres leased in grazing allotments in the study area (U.S. Department of the Interior, 2009a). Grazing allotments and cattle density for each county are shown in Figure 16.

In the state of Colorado, irrigation is the main water use and constitutes about 90% of total consumption (Natural Resources Law Center, 2006; U.S. Census Bureau, 2004). Despite crop diversification and conservation practices, there are a number of challenges for the long-term sustainability of farming and ranching in the region. The most important regional concerns are whether water shortages will drive up farming costs and increase pressure from municipalities and energy development interests to acquire water rights from the agricultural sector. With rising energy prices, there may be added pressure for farmers and ranchers who can no longer sustain a way of life with increasing costs to sell off agricultural lands and water rights. The Bureau of Land Management predicts that water is likely to be transferred from agricultural to industrial uses to support a growing energy industry (Bureau of Land Management, 2008b). Regardless of the environmental or economic pressures facing agricultural production in the region, cities and developers will be looking for land and water to accommodate projected population growth and increases in recreation, tourism, and energy industries, and they are likely to look to conversions from agricultural uses as the source.

Figure 16. Ranching and Grazing Lands



Function and Structure: Population, Projections, and Demographics

Population projections were made by using state regional data for the year 2030. Wyoming data was obtained from the Wyoming Department of Administration and Information, Economic Analysis Division (2008). Utah population projections are from the Governor's Office of Planning and Budget (n.d.). Projections for Colorado are from the Colorado Division of Local Government, State Demography Office (2008). Data were obtained for counties and, where available, at the sub-county level.

Areas of the counties were corrected to account for differences in scale and different originating datasets. Percentages of the area of counties within the Phase II study area were then calculated. To account for density of cities and towns in partial counties, where available in sub-county data, city and town projections inside the study area were included intact and those outside were eliminated from the calculations. The area percentages were applied to the modified projection data from each county's data for population forecasts as shown in Table 6 and mapped in Figure 17.

Current population in the three-watershed area was estimated to be 401,149 as of July 1, 2008. Total population for the study region in 2030 is predicted to increase by 304,919, or 76% growth over the current estimates. Counties within Colorado are expected to experience population growth, while the rural areas that are within Utah and Wyoming are forecast to lose population while cities and towns grow. These county level data are projected by states on the basis of extending past trends as constant in the future. For this study, the alternative futures presented in Chapter 6 use the population numbers

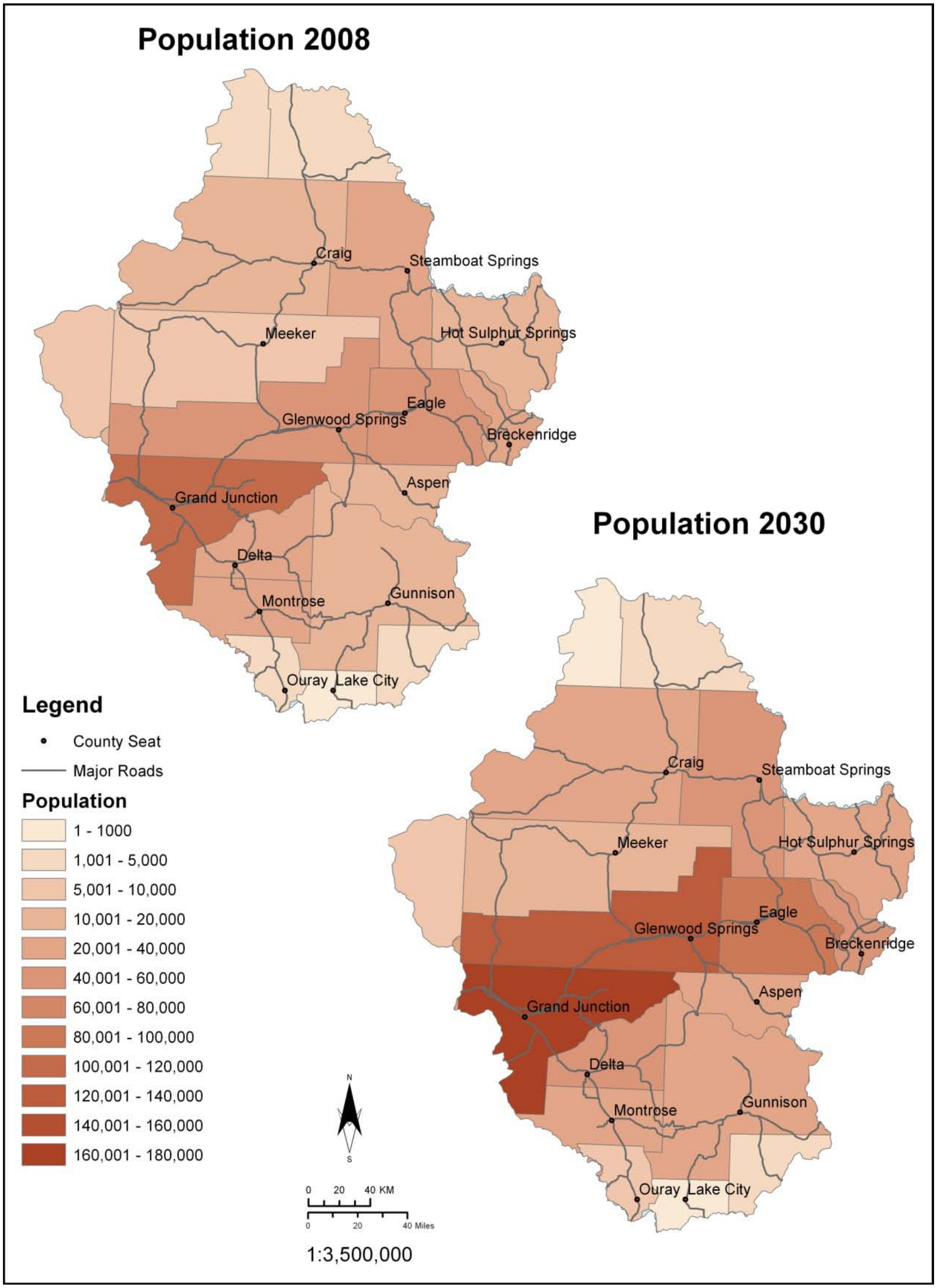
Table 6

Population Forecasts for the Region

State	County	Population Estimates July 1, 2008	Population Projection 2030	Change	Percent Change
Colorado					
	Delta	30,923	56,486	25,563	83%
	Eagle	52,331	88,074	35,743	68%
	Garfield	55,426	128,847	73,421	132%
	Grand	13,781	25,533	11,752	85%
	Gunnison	15,147	20,411	5,264	35%
	Hinsdale	392	606	214	55%
	Mesa	109,027	175,216	66,188	61%
	Moffat	11,404	21,132	9,729	85%
	Montrose	20,738	38,079	17,342	84%
	Ouray	4,560	6,876	2,316	51%
	Pitkin	15,474	26,047	10,573	68%
	Rio Blanco	6,340	16,756	10,416	164%
	Routt	22,980	40,531	17,551	76%
	Saguache	1,678	2,258	580	35%
	Summit	26,843	50,749	23,906	89%
	Subtotal	387,044	697,601	310,557	80%
Utah					
	Grand	1	0	-1	-100%
	Uintah	7,938	6,788	-1,150	-14%
	Subtotal	7,938	6,788	-1,151	-14%
Wyoming					
	Carbon	2,984	1,013	-1,971	-66%
	Sweetwater	3,183	666	-2517	-79%
	Subtotal	6,167	1,679	-4,488	-73%
Totals		**401,149**	**706,069**	**304,918**	**76%**

Note: Allocation of population in partial counties is based on population density in rural areas. Low population numbers in some counties result from small land areas and low densities.

Figure 17. Population Projections

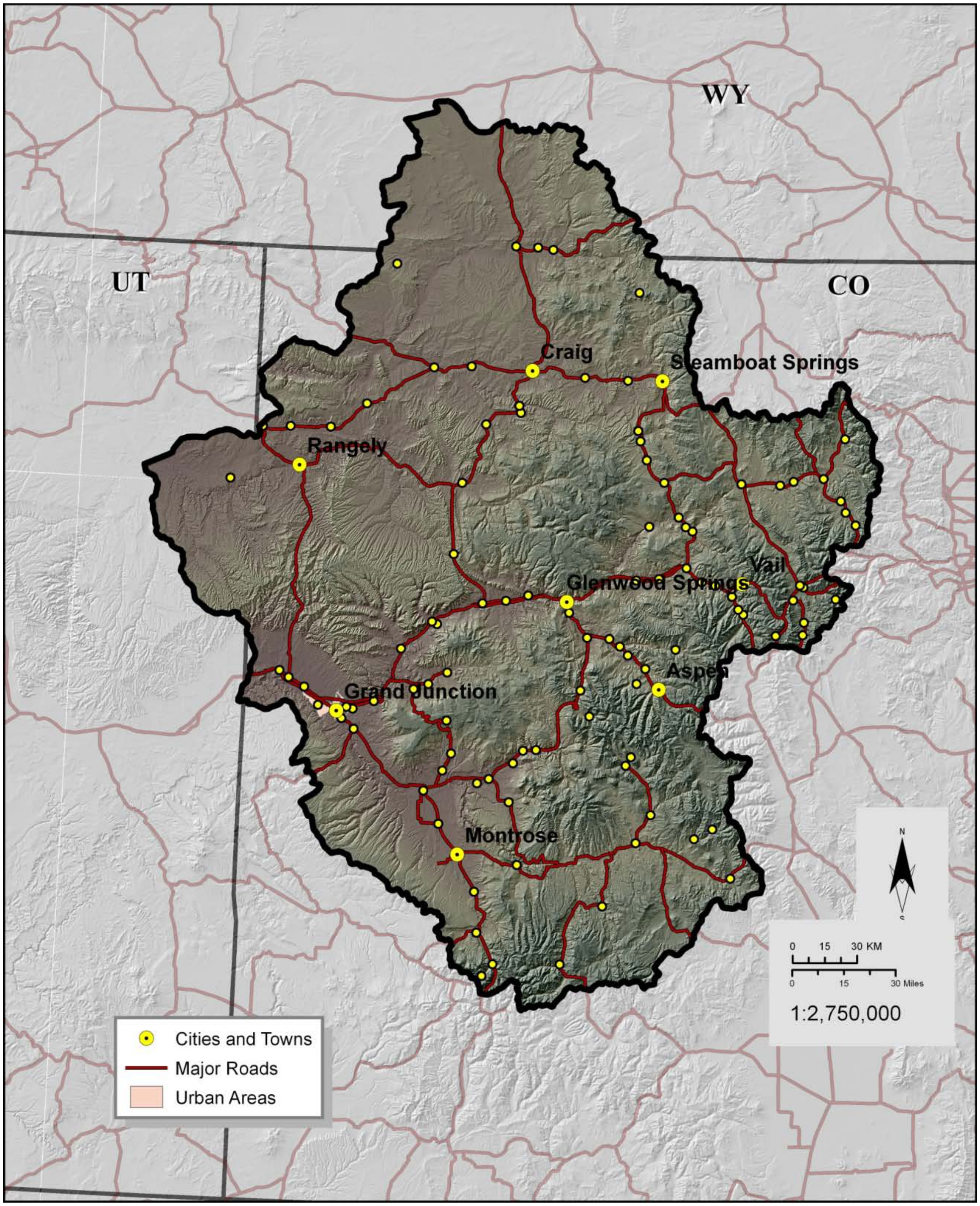


forecast for the entire region in 2030 but distribute the growth throughout the area in ways that will be determined by the scenarios on which they are based, rather than restricting the growth to specific counties. The rationale behind this distribution is to project the location of settlement patterns near the employment opportunities offered by the variations modeled in the alternative futures. Existing cities and towns are shown in Figure 18.

According to the Colorado State Demography Office (2010a, 2010b, 2010c), the counties of Colorado partially or entirely within the study region are more rural than the state average. For the state of Colorado, population is 85% urban and 15% rural, with 1.1% living on farms. In the study region, 61% of the population is urban, 39% reside in rural areas, and 2% live on farms. Based on county-level data from the Colorado State Demography Office, agriculture in the region makes up about 4% of the jobs in the region, mining provides 2%, and combined tourism sectors account for about 22%. Agricultural earnings are notably lower than average. For the counties combined, in 2009 employment in government sectors was the highest single category, providing 13% of total jobs, followed by accommodation and food with 12%, and retail trade and construction tied with 11%.

As evidence of the growth of the energy industry, employment in mining and support activities, including oil and gas, grew from 1,077 in 2001 to 9,174 in 2009. In testament to the volatility of that industry, mining sector jobs in Gunnison County decreased from 726 in 2005 to 95 in 2010. Mining activities are concentrated in counties in the western and southern parts of the study area. Construction was in the top three job

Figure 18. Cities, Towns and Major Highways



sectors across the region in 2009, despite recent losses on the order of 20% (Colorado State Demography Office, 2010a, 2010b, 2010c). This is indicative of the growth and development taking place even with a slower economy.

Tourism is by far the largest employer in the counties along the eastern edge. These counties also have the highest per capita income, higher than the national average, and the 51% housing vacancy rate reflects the high number of second and recreational homes. Average age in the region is slightly higher than the state average (Colorado State Demography Office, 2010a, 2010b, 2010c).

Although employment in agriculture is low, these figures may not be entirely reflective of the number of people engaged in farming and ranching activities. The National Agriculture Statistics Service reports that in 2007 for the state of Colorado, 74% of principal farm operators were employed in some off-farm work, and 60% of principal farm operators reported another job as their primary occupation (National Agriculture Statistics Service, 2009). Sheridan (2007) writes of the transforming effect of the vulnerability of ranchers and the skyrocketing price of their land. In this new west, as land is converted into subdivisions and amenity ranches, politics of the regions shift away, and often against, the traditional land uses (Sheridan, 2007).

Function and Structure:
Wildlife and Habitat

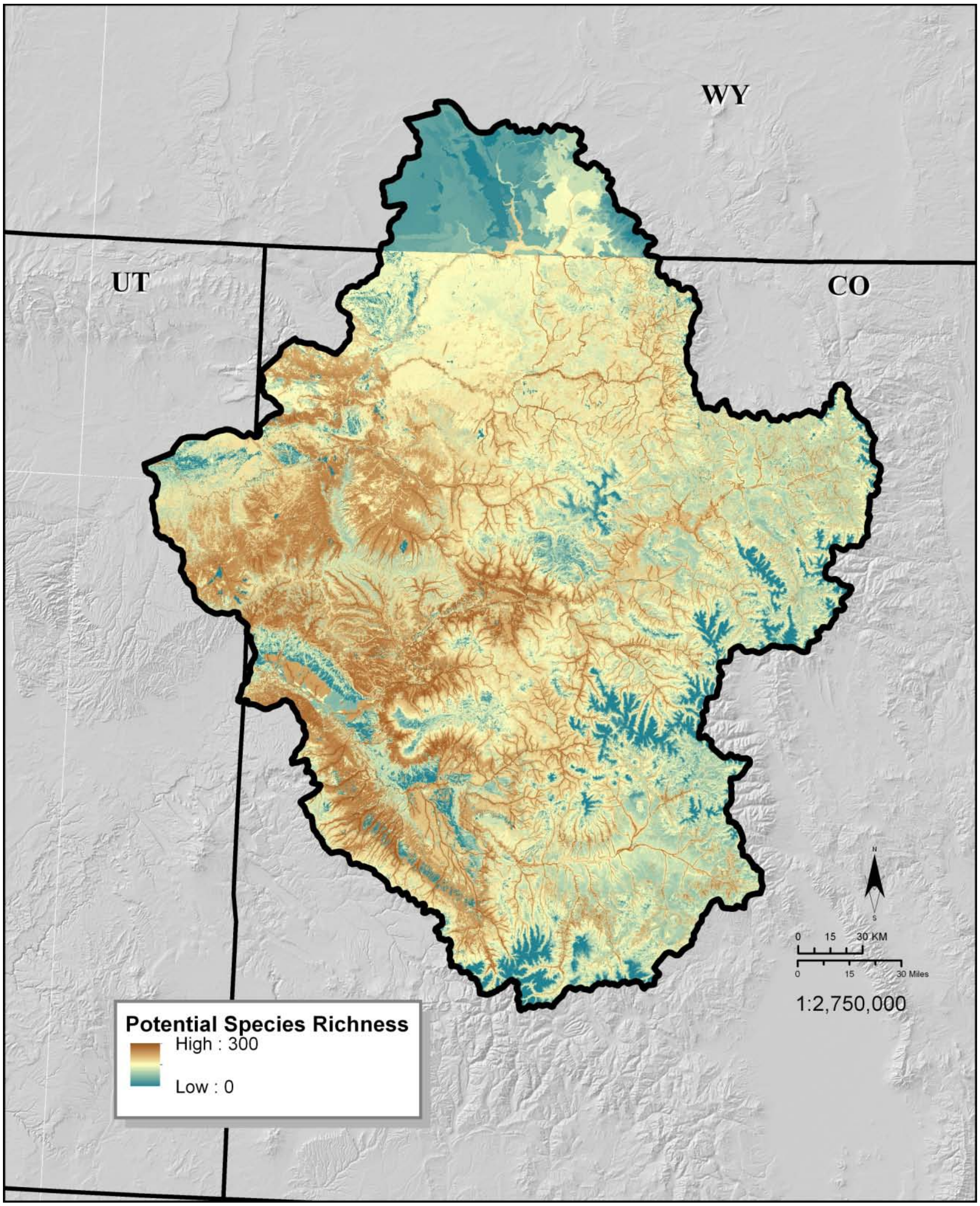
Residents of Colorado are becoming increasingly aware of threats to native ecosystems and to quality of life issues, both of which they have great desire to preserve. As tourists and new residents flock to the state each year, the irony facing Colorado is that the same qualities which draw people to the region are being altered, degraded or destroyed as a result of the desire to experience the character and opportunities the state has to offer. With pristine habitat for a large number of terrestrial and aquatic wildlife species, as well as popular recreation and tourism opportunities, the state will continue to experience significant conflict in the coming decades.

There is a growing understanding of the values provided by natural ecosystem services. Ecosystem services are benefits or subsidies provided by the environment and are often taken for granted, such as climate regulation, flood control, erosion control, water supply, waste treatment, pollination, or spiritual values (Costanza, et al., 1997; Kemkes, Farley & Koliba, 2009; Southern Rockies Ecosystem Project, 2004). Although most of these ecosystem services exist outside the market and cannot be purchased, economists assign their global worth to be between 16 and 54 trillion dollars each year (Costanza, 1997; Kemkes, et al., 2009). In responses to public surveys, Coloradans have expressed interest in preserving native habitat, protecting or restoring threatened and endangered species, protecting open space and strengthening environmental laws, and have indicated support for increased costs for such efforts (Southern Rockies Ecosystem Project, 2004). As a result of the public willingness to recognize and connect the costs of the values citizens hope to sustain, there are opportunities to address habitat and wildlife issues with public opinion in support of such efforts.

Despite public opinion in favor of conservation values, land owners and conservationists often have conflicting views regarding preservation of habitat to support native species biodiversity. It is estimated that as many as two-thirds of endangered species are dependent on habitat on private lands (Doremus, 2003). Private property owners are concerned by government regulation regarding the protection of threatened or endangered species, and see efforts to secure habitat as a threat to private property rights. Biodiversity is being reduced due to the impacts of grazing and other commercial activities (Verrengia, et al., 2000). Habitat loss negatively impacts overall species abundance and reduces biodiversity (Andrén, 1997; Fischer & Lindenmayer, 2007; Hansen et al., 2005; McKinney, 2002; Pimm & Raven, 2000; Solé, Alonso, & Saldaña, 2004; and others).

In recognition of the human threats to biodiversity, federal organizations have begun to implement management and conservation strategies. One of the aims is to inform the general public about the threats that exist to public lands and critical natural resources. The U.S. Forest Service has identified the most severe threats to our nation's forests and grasslands, and these have been incorporated into an educational campaign initiated by the USDA. The Environmental Protection Agency (EPA) also has similar strategies for making information easily accessible in order to educate and inform the public about management and policy decisions throughout the entire U.S.

Figure 19. Species Richness Potential



Function and Structure: Species Richness Potential

The terrestrial vertebrate species richness model (Figure 19) is based on data obtained by the Remote Sensing/Geographic Information Systems Laboratory (RS/GIS) at Utah State University. The model identifies areas of potential species habitat based on conditions conducive to the occurrence, reproduction, and persistence of vertebrate species (USGS National Gap Analysis Program, 2007). Information on species range and location is often limited. By identifying those areas containing a large number of potential species through suitable habitats, the model can be used to represent biodiversity though predicted species richness and be used to identify priority "hotspots" for future conservation/restoration strategies. The species richness map shows the range of species richness/habitat suitability values ranging from 0 to 300, representing the number of different terrestrial vertebrate species the habitat in a specific location is capable of supporting. These species are listed in Appendix D. It is important to note that the model overestimates actual species richness because it is based on potential habitat and not observed occurrences. This information is useful, however, for analyzing habitat patterns across large landscapes and identifying potential future impacts or anthropogenic stressors to species in the study area.

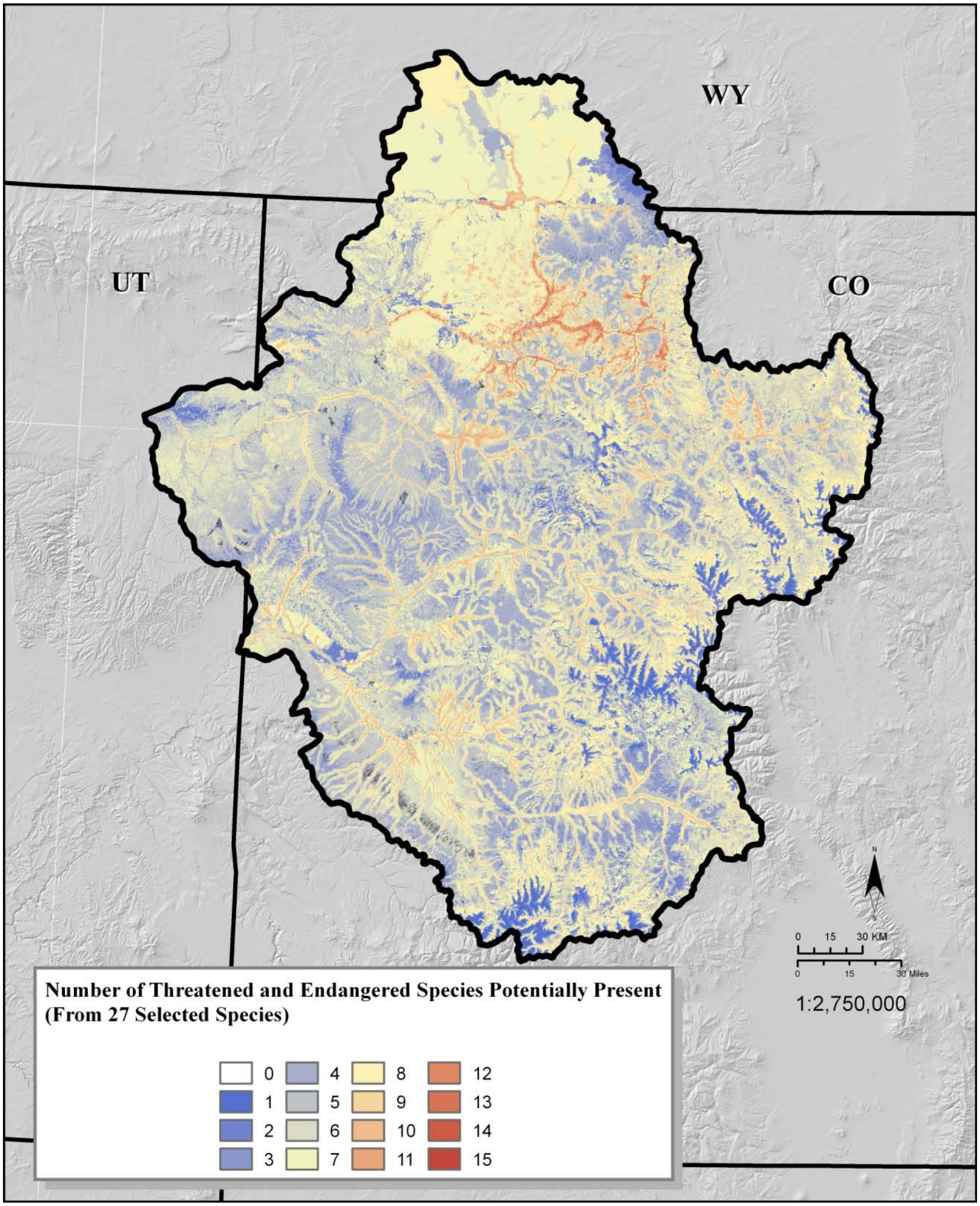
While conservation strategies vary in their scope and intent, managing for ecosystems capable of supporting high species richness is the key to preservation of biodiversity in the region. The model shows that riparian and aquatic areas associated with canyons, and the escarpments, canyonlands, and forest and shrub ecosystems in the west of the region tend to support the highest potential for species richness. These areas are imperative to consider for conservation due to the relatively greater human impacts that take place in lower versus higher elevation ecosystems. Because these productive areas of the landscape are most conducive to human land-use and development, the result is often higher levels of species imperilment (Southern Rockies Ecosystem Project, 2004). This approach provides a starting point for targeting areas for increased conservation and management, as well as providing an assessment model to evaluate proposed changes and the associated impacts to potential species habitat.

Function and Structure: Threatened and Endangered Species

In 1973, Congress passed the Endangered Species Act (ESA), which made listed species eligible for protection against any action that would harm them, or alter habitat critical to their survival; several subsequent modifications to the act followed its passage (U.S. Fish and Wildlife Service, 2008). The Act came about for several reasons, primarily in response to the understanding that numerous species in the United States had suffered extinction as a result of human activities. There were growing concerns over the depletion of several species that were in danger of extinction, as well as increased attention to the aesthetic, ecological, educational, historical, recreational, and scientific value of native species to the nation and its people (ESA, 1973). In Colorado, there are currently several threatened and endangered species. The Colorado Division of Wildlife maintains a listing of all wildlife species in the state that are threatened, endangered or of special concern at the state or federal level (Appendix E).

GIS data provided by the Colorado Division of Wildlife and Wildlife Habitat Relations (WHR) models from the Southwest Regional GAP Analysis were used to model species distribution for overlapping habitat for 27 species listed in Appendix F. The results of the model are shown in Figure 20, with a maximum density of 15 overlapping habitats. Similar to the overall combined species richness map, this model emphasizes the importance of riparian and aquatic ecosystems as core critical habitat.

Figure 20. Threatened and Endangered Species Richness Potential



Function and Structure: Energy

Sources of energy fall into three primary categories: traditional, exploratory, and alternative. Traditional energy resources in the region are coal, natural gas, oil, and hydropower. Sources being explored, although they may be used elsewhere, are new to the study area and include commercial production of coal bed methane (CBM), oil shale, and tar sands. Alternative sources of energy are primarily solar, wind, biomass, and geothermal. These do not fall neatly into categories, however. Some sources, such as beetle-killed forest timber for use as biofuels, may be strictly renewable, but in practice are unlikely to be sustained or sustainable in supply. Geothermal can be considered to be either renewable or non-renewable but, in either case, it may provide a long-term clean energy source.

Alternative sources of energy depend on invention and innovation to increase their returns to the point that they are economically and socially feasible. While initial investment may always be high, the returns for renewable energy are a long-term and lower-cost operation. A transition to renewable sources for meeting future needs stems from a long-term view and a willingness to prioritize continuation of energy supply over current conveniences and the urgency of high demands. Research and development in energy production will increase yields, and large-scale productions and standardization will reduce costs. However, the ability to innovate to maximize production will face limits and diminishing returns over time.

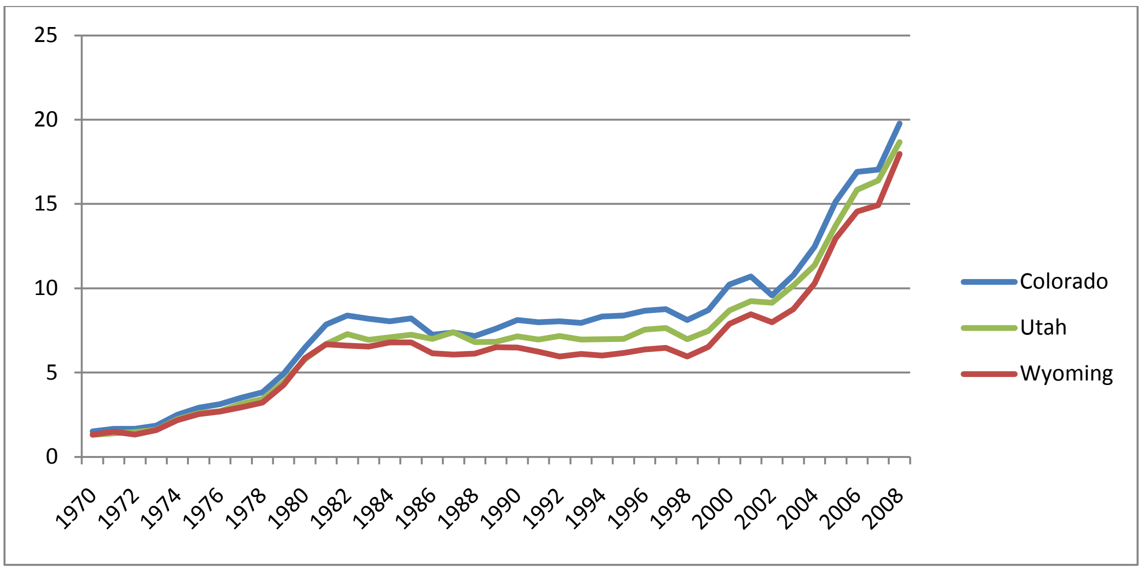
One of the benefits of alternative and renewable energy systems is that it results in fewer steps in the pathway, or fewer transformations in form. A transformation takes place when we change the form of energy, and we lose efficiency with every step. Burning coal to produce heat to generate electricity, transmitting that power, and then using electricity to create heat in a toaster requires several transitions, each one of which has energy losses. When alternative energy can be generated on-site, the transmission steps are removed and some energy can be used directly, such as with solar water heating.

After the energy crisis of the 1970s, prices remained relatively constant through the 1980s and 1990s, although adjusted prices actually decreased. Drastic increases in energy prices since 2000, coupled with increased transportation costs for importation of fuels, make the energy resources in the region more profitable and appealing. National security concerns increase the desire for domestic exploration and production. Coal provides the majority of the area's energy, as well as accounting for the most readily available and abundant reserves. The region has high value for wind, biofuels, and geothermal energy potential as well. No nuclear facilities are currently planned for the region and, given the length of time for nuclear power generation to become operational, it is not considered to be a factor in energy development for this time horizon. The region has two active uranium mine permits, but neither has had recent production of materials. Function and structure information for specific energy resources in the region are in the following sections.

Statewide price trends for energy in the region are shown in Figures 21 and 22. Consumption and production are charted in Figure 23. Projections of consumption in this figure are based on increases over past periods for which data is available, 1960-2008.

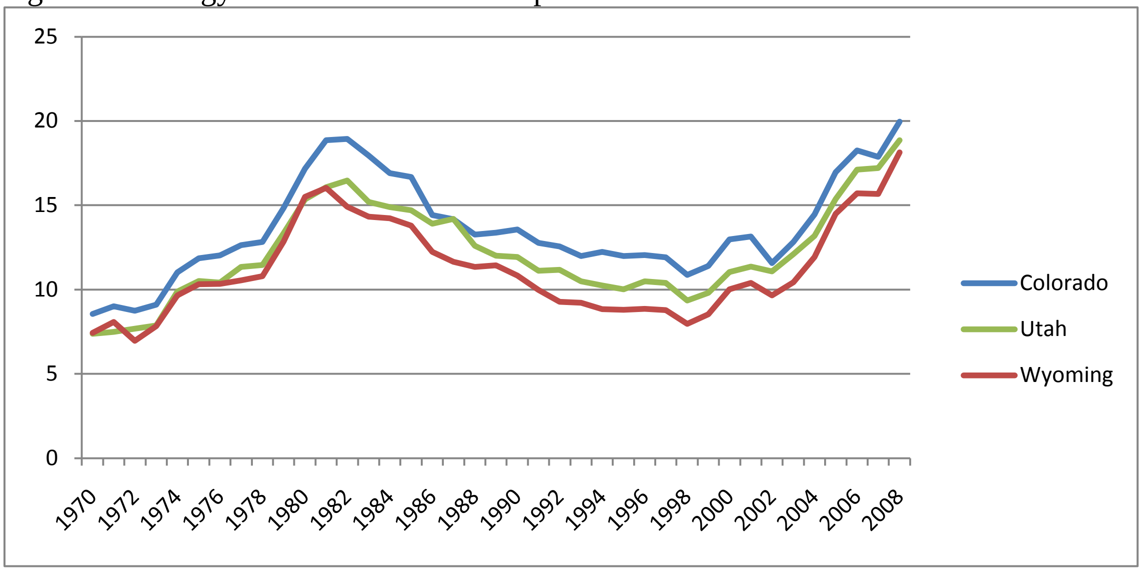
All data were retrieved from the Energy Information Administration of the U.S. Department of Energy (U.S. Energy Information Administration, 2010).

Figure 21. Energy Prices in Nominal Dollars per Million BTU



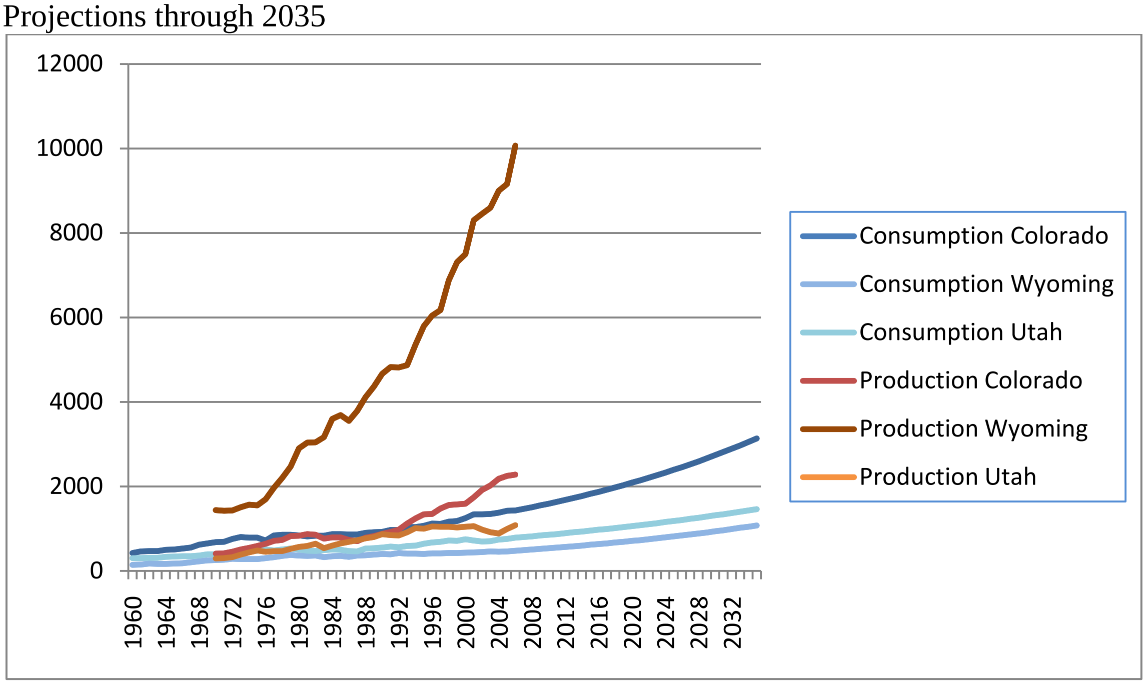
Price trends in actual dollars. Data from the U.S. Energy Information Administration (2010).

Figure 22. Energy Prices in 2010 Dollars per Million BTU



Price trends in 2010 dollars. Data from the U.S. Energy Information Administration, (2010).

Figure 23. Energy Production and Consumption in Study Area with Consumption Projections through 2035



Data from the U.S. Energy Information Administration (2010).

In addition to cost of energy, the energy return on investment (EROI) is a critical factor in the development and use of energy resources. EROI expresses the net energy, or the energy gained in relation to the energy required for production from a given source (Hall, Balogh, & Murphy, 2009). The lower the EROI is, the lower the yield of overall energy.

With traditional energy resources becoming harder to obtain, the energy invested in mining, drilling, pumping, et cetera, must increase. As the amount of investment goes up, the ratio of net energy produced decreases. Because the resources which provide the highest quality energy and are easiest to obtain are generally used first, this means that not only must more energy be put into finding and developing new sources, but also that the gross yields are lower. In general, pollutants also increase as EROI decreases. For instance, if coal energy is used to extract and refine a usable product from oil shale, the carbon and emissions of extraction energy as well as those of the oil shale products must be taken into account.

In November 2004, Colorado voters approved a ballot initiative of a state renewable portfolio standard (RPS), setting a benchmark requirement for investor-owned utility providers (IOUs) to obtain 10% of electrical power from renewable sources by 2020. This was the first time that a citizen effort had enacted such a measure, and the issue was placed before voters after the state legislature had repeatedly failed to pass RPS legislation due to opposition from utility and coal industries (Rabe, 2007). Despite initial opposition, Xcel Energy, the state's largest producer, met the requirements eight years ahead of schedule and then supported the state governor's efforts to double the standard to 20% and set a 10% standard for municipal and cooperative utilities (MCUs) (Rabe, 2007; Slevin, 2008). In 2010, portfolio standards were again increased to 30% for commercial utility companies. Support for these efforts came from anticipated environmental, employment, and economic benefits, and garnered endorsements from bipartisan political leadership, environmental, public health, agriculture, ranching, religious, and renewable energy sectors. (Rabe, 2007)

RPS legislation provided tax credits to customers who install renewable power generation, and also required net metering, allowing customers who generate solar power to sell excesses to utility companies. Utility providers unable to meet the requirements through their own renewable energy investments can purchase credits from other providers who are exceeding the standards.

The support for RPS law has demonstrated an interest and desire to shift to cleaner energy and to develop a renewable energy economy. However, the future of renewable energy in the region is not certain. In January, 2011, a bill was introduced in the Colorado State Senate that would roll back RPS requirements to 10% on the premise that the standards create higher prices for electricity. The bill was struck down in committee, but political opposition remains. Possible variations in political action and public opinion are used as uncertainties in the scenarios for energy development.

Function & Structure: Coal

According to the U.S. Department of Energy, coal is the most abundant source of energy on earth, exceeding the known reserves of recoverable oil (U.S. Department of Energy, 2005). The United States has come to be commonly referred to as the Saudi Arabia of coal, with an estimated 28% of the world's coal (U.S. Energy Information Administration, 2009a). Coal is the most readily available and abundant of the carbon energy sources in the subregion. The vast majority of Colorado's potentially mineable coal lies within the study area, and is valued for being high quality and exceptionally clean (Colorado Geological Survey, 2008; U.S. Energy Information Administration, n.d.-a). Potentially mineable coal deposits and existing coal mines in the study area are shown in Figure 24.

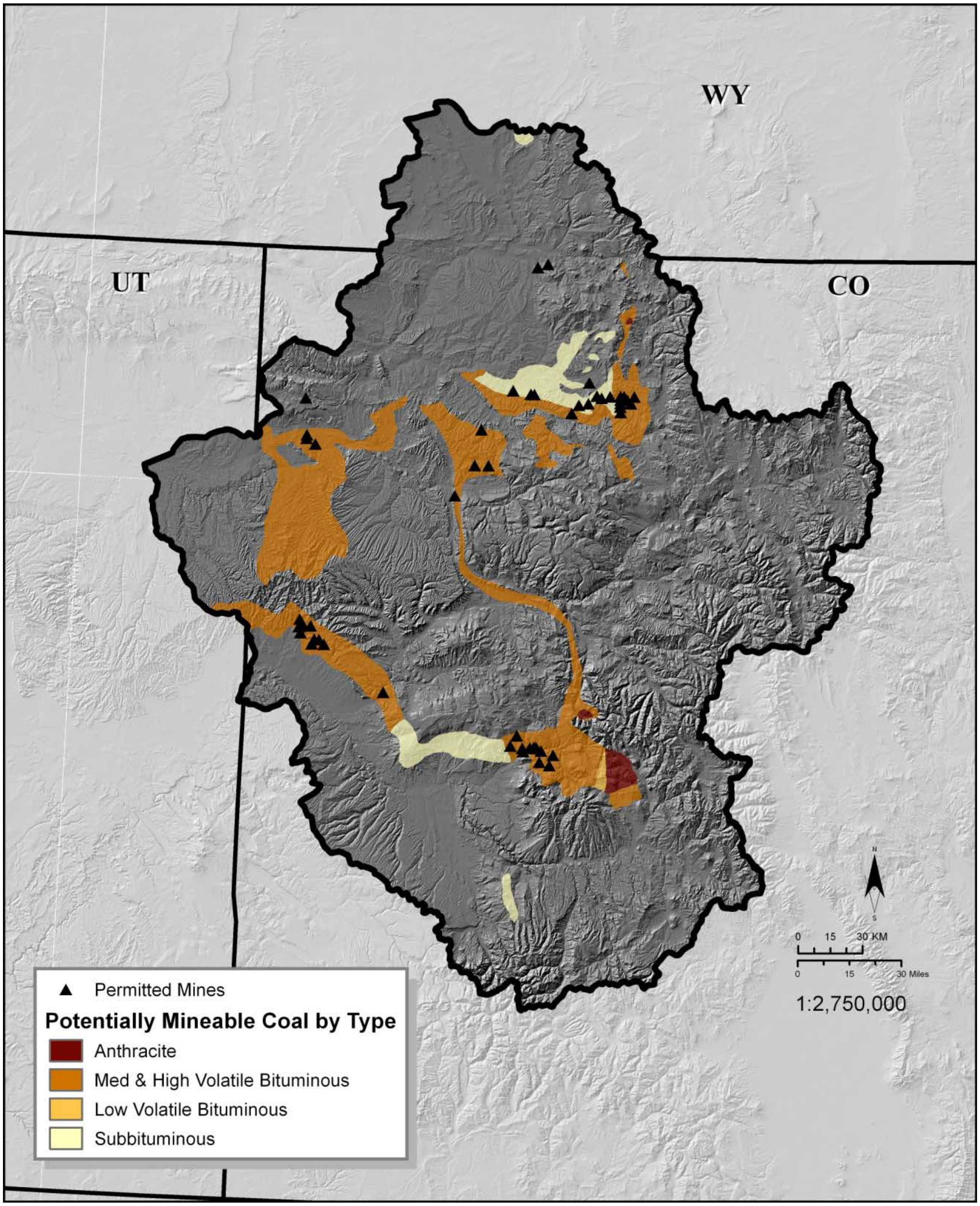
In Colorado, which makes up the majority of the focus area, 80% of the electricity generated in Colorado comes from coal (Bureau of Land Management, 2008). There is also an abundant supply of coal in the Utah regions of the focus area, but coal is not currently extracted in those locations. A small amount of coal exists in the northern section which lies within the state of Wyoming; no mines currently exist there. EROI for coal is among the highest available, at 1:80 at the source (Murphy & Hall, 2010). Because of the high returns, and the existing facilities and technology for coal extraction and use, it will remain a significant source of energy.

Colorado ranks seventh among the largest coal-producing states in the country (Colorado Geological Survey, 2004). In 2007, eight underground and four surface mines produced a total of 363,840,000 short tons of coal and employed 2,249 people (U.S.

Energy Information Administration, 2008). According to the Bureau of Land Management, 62.2% of coal mined in Colorado is transported to other states, and 2.8% goes to foreign export (Bureau of Land Management, 2008).

Pollutants and environmental impacts come as a result of mining and burning of coal. Extraction of coal and CBM (described below) can disrupt groundwater systems and affect quality and quantity of water in aquifers. When coal is burned, sulfur and nitrogen are released into the air, creating sulfuric and nitric acid, major contributors to “acid rain.” Technologies exist to filter out approximately 95% of these pollutants (U.S. Department of Energy, n.d.-a). Carbon dioxide, a primary greenhouse gas, is not addressed by “clean coal technologies” at this time. Modern designs for burners are more efficient but have not yet managed to sufficiently control carbon emissions. Coal combustion is also the leading source of mercury pollution in the U.S. Different types of coal plants can provide better control of mercury emissions but, currently, only about 35% of mercury is captured (U.S. Geological Survey, 2009).

Figure 24. Coal Deposits and Mines



Function and Structure: Oil and Gas

Two highly productive oil and gas fields lie in the study region, crossing through the states of Colorado, Utah, and Wyoming. Approximately half of the Uinta-Piceance fields and the southeastern section of the Greater Green River Basin fields are within the boundaries of the three watersheds. These fields yield both oil and natural gas, but they produce far more gas than oil.

The Uinta-Piceance Basin has 180 fields and a total estimated reserve of oil and gas of 1,451,274,000 barrel oil equivalent (BOE). The Greater Green River Basin had 281 fields and 2,294,533,000 BOE (U.S. Energy Information Administration, 2005). The study region holds 15 of the top 100 gas fields in the United States, and two of the top 100 oil fields. Millions of acres are already under leases and agreements for oil and gas exploration and development. Figures 25 and 26 show oil and gas density and areas under contract for exploration and extraction.

Current practices in the region include drilling of wells on a 40 acre grid. As production slows, 20 acre infill wells are drilled directionally from existing well pads. This serves to reduce impacts and habitat fragmentation. However, the impacts of any well field are significant. They include erosion, chemical contamination, dust, depletion of ground water, production and disposal of toxic water byproducts, acute and chronic health impacts, noise and environmental justice issues (O’Rourke & Connolly, 2003). Air quality is adversely affected, and the effects in areas of Utah and Wyoming

Figure 25. Oil Deposits

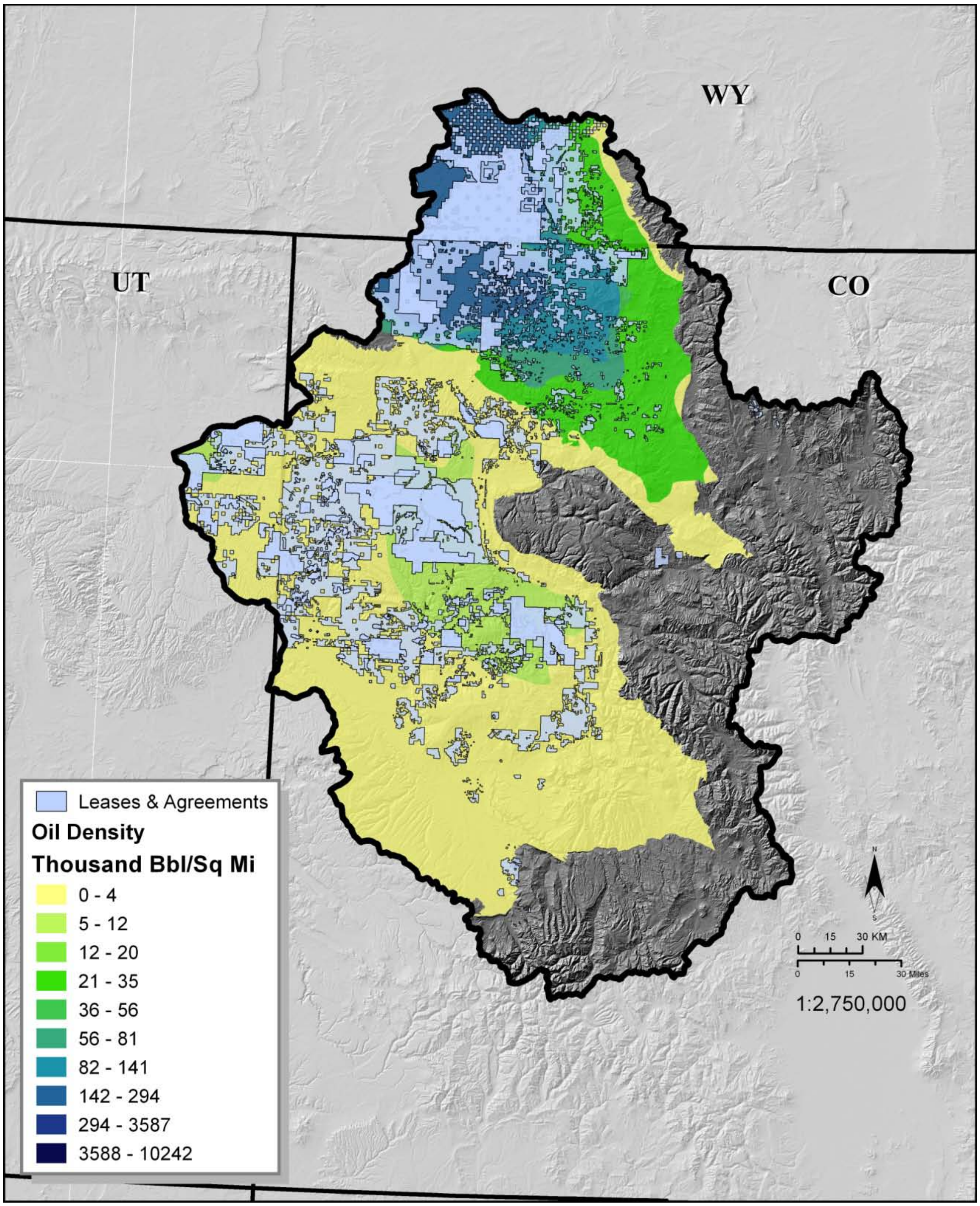
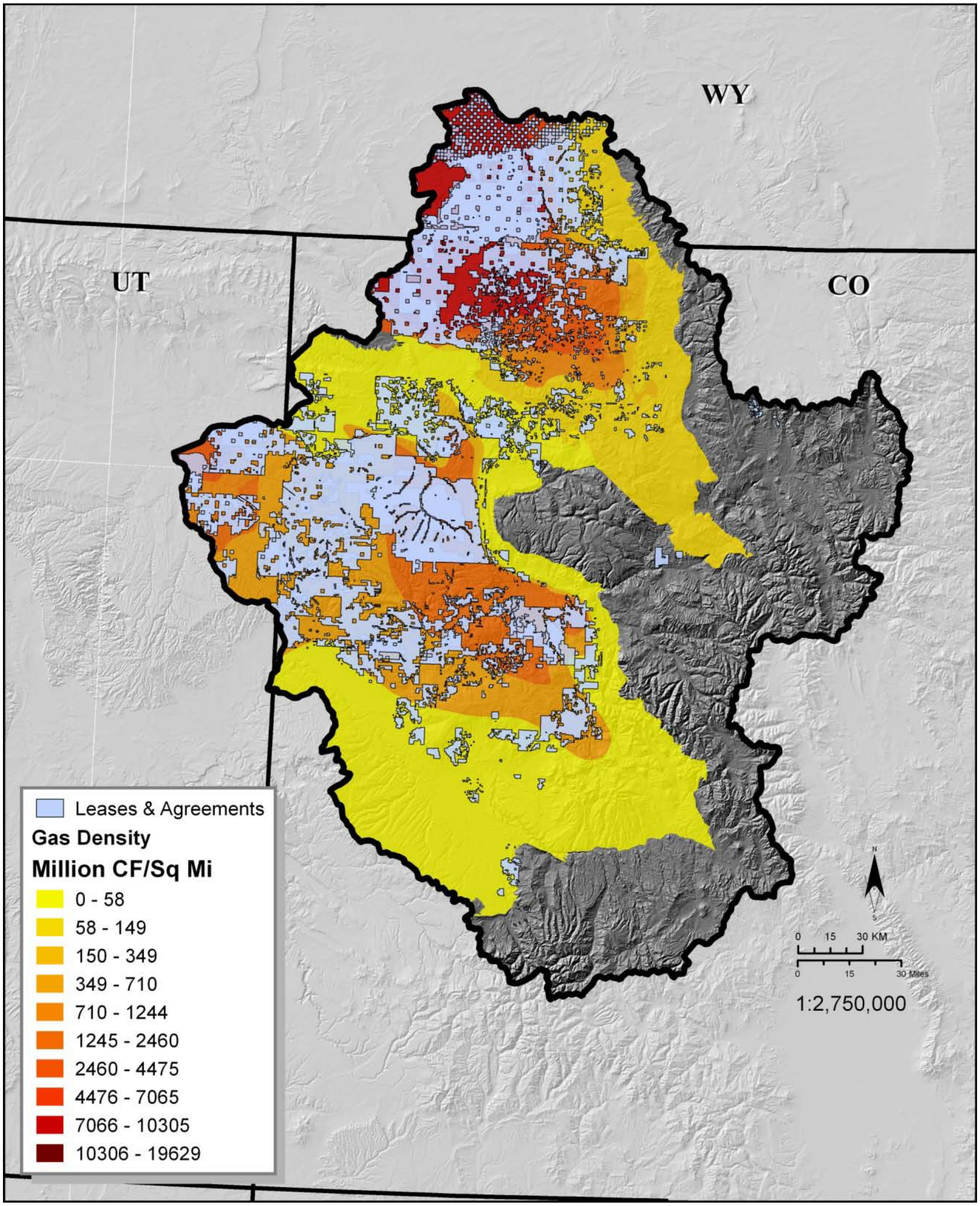


Figure 26. Gas Deposits



are so severe that they threaten to impede planned drilling activities (O'Rourke & Connolly, 2003; Streater, 2010).

Coal bed methane is a nontraditional source of natural gas. While it is not currently used in the study area, Colorado is one of the top three states for CBM production. Because methane is an extremely potent greenhouse gas, use of CBM provides the benefit of capture and use of methane that could otherwise be released into the atmosphere. It is also a cleaner source of energy than coal or oil and creates less pollution when burned. CBM potential exists where mineable and non-mineable coal deposits exist in conjunction with commercially viable gas densities. CBM has impacts similar to those of other oil and gas wells, but the biggest drawback to CBM is the large quantities of highly saline and toxic water that are pumped out of the coal formations in the process of producing CBM. No ecologically and economically feasible solution currently exists for treatment or disposal of this produced water. While not unique to CBM, hydraulic fracturing is used in CBM wells and is a very controversial practice due to groundwater pollution and disturbance, and the consequent public health concerns.

Hydraulic fracturing is a process of injecting high pressure fluids into a well bore to cause cracks in the oil or gas bearing formation. This allows oil or gas to move more freely through the substrate and is used to improve the yield of a well. The fluids often contain sand or ceramic particles which help to hold open the fractures. Chemical composition of fluids used is considered proprietary information. The EPA concluded in 2004 that the technique of hydraulic fracturing poses little or no threat to groundwater (U.S. Environmental Protection Agency, 2004). Critics and residents in several states have claimed that it does in fact have negative consequences to their wells and drinking water. The EPA has recently begun backing away from the 2004 findings, after the New York Times reported that water contamination and environmental risk from hydraulic fracturing is greater than previously revealed (Urbina, 2011; Zeller, 2011)

The study area contains some of the lands leased for oil and gas exploration by the Bush administration, which were subsequently canceled in February of 2009 by Secretary Salazar pending further review. Given the urgency for continued sources of inexpensive energy and the resources abundant in this region, it can be expected that a great deal of pressure and resources will be brought to bear in developing the oil and gas resources of these areas. EROI of domestically produced oil and gas in 2005 ranged from 1:10-18, significantly lower than coal but with different use values, such as liquid fuels and direct home heating (Murphy & Hall, 2010). Because of the sunk costs of existing infrastructure and the technological advantages of oil and gas development, oil and gas, along with coal, are likely to be the continuing targets to support existing production needs and consumption trends.

Function & Structure: Oil Shale

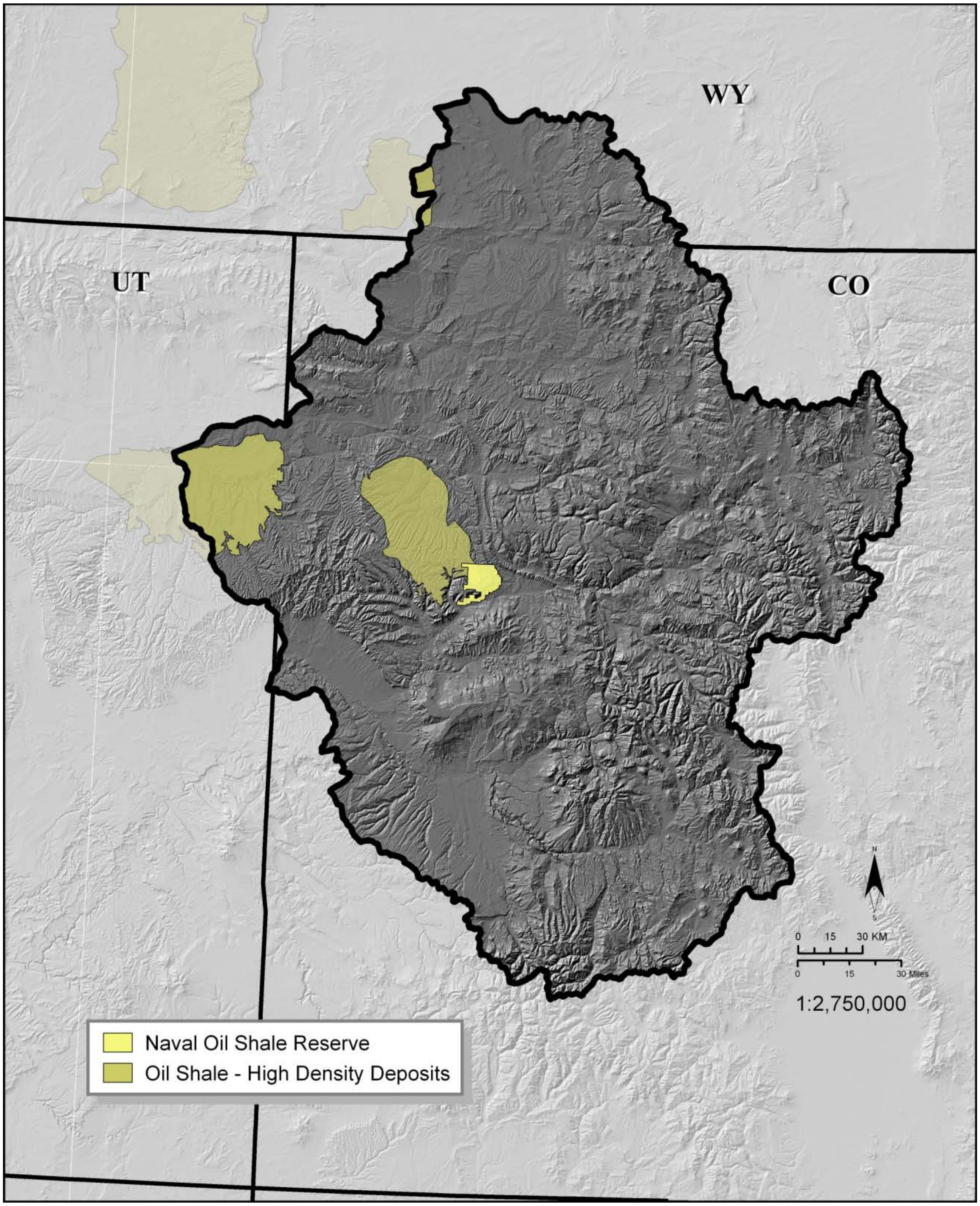
Oil shale is the name for fine-grained sedimentary rock, which is not necessarily shale, generally younger than oil-bearing formations, and which contains high amounts of organic material called kerogen. When extracted, this material can be converted into jet fuel, diesel, and other petroleum products. Oil shale resources in Colorado, Utah, and Wyoming are among the most concentrated and potentially useful deposits in the United States (U.S. Energy Information Administration, 2009a). The Piceance Basin in the western portion of the study area holds more than 80% of its recoverable kerogen within an area of 35 square miles (Office of Petroleum Reserves, n.d.-d). A high yielding deposit can produce 0.6 barrels (25 gallons) of oil per ton of oil shale (University of Utah Heavy Oil Program, 2007). Oil Shale deposits are shown in Figure 27.

Executive Orders in the early 1900s established the Naval Oil Shale and Petroleum Reserves to ensure supply of petroleum products to the Navy in times of shortage. In the late 1990s, these reserves were no longer seen as contributing to national defense. The Oil Shale Reserves in Colorado were transferred to the Bureau of Land Management and are now offered for commercial mineral leasing (U.S. Department of Energy, n.d.-b). Because oil shale resources in the region are richer than tar sands (U.S. Energy Information Administration, 2009b), and because existing tar sands technology cannot be directly applied to resources in the region, it can be expected that efforts will be primarily focused on oil shale extraction if policy and energy prices support it. Extraction of oil shale requires heating, also known as retorting, of the rock. This can take place at the surface or in situ. Because of the depth of overburden, and the better yields and lesser impacts of in situ retorting, it is expected that these techniques will continue to be pursued (U.S. Energy Information Administration, 2009b). While the feasibility of in situ retorting has been demonstrated, commercial scale application is not in the immediate future. The EIA estimates that 2023 is the earliest date for any likelihood of commercial production (U.S. Energy Information Administration, 2009b).

There has long been interest and hope for the commercial development of oil shale. The first oil shale boom took place between 1918 and 1925, but declined when oil fields were discovered in California, Texas, and Oklahoma. Interest in oil shale grew through the 1950s, and a plant was operated for 18 months near Parachute, Colorado but was shut down in 1961 in part due to price uncertainty (Shell Oil, 2007).

Between 1964 and 1972, another operation was built and produced oil but was closed due to high costs (Andrews, 2006). Throughout the 1970s plans and attempts to create industrial-scale production failed (Shell Oil, 2007). In 1980 Congress approved a synthetic fuels program with $14 billion in funding, which sparked a new wave of interest in oil shale. In 1981, another project near Parachute was built. On May 2, 1982, a day referred to as "Black Sunday," the plant was suddenly shut down, with blame placed on high costs and low demand for oil. The closure put 2,600 people out of work and threw the local economy into a downspin (Gulliford, 2010; Haefele & Morton, 2009). Although there is hope that oil shale will bring jobs and prosperity to the region, there is a history of disappointment brought on by the boom and bust cycles.

Figure 27. Oil Shale Deposits



In the early 1970s when interest was renewed in oil shale as a commercial source of petroleum products, the U.S. Department of the Interior estimated surface impacts of an oil shale industry. Over a 40 year production period, a projected cumulative total of approximately 31 square miles for each million barrels/day production capacity would be impacted, depending on the methods of production used (U.S. Department of Energy, n.d.-b).

Environmental impacts of oil shale include surface impacts of mining, drilling, and associated construction requirements. Surface retorting creates large amounts of spent rock and creates subsidence risk. Release of naturally occurring nitrogen oxides (NOX), sulfur oxides (SOX), carbon dioxide (CO2), particulate matter, and creation of dust, as well as additional carbon from energy required for retorting, production, and refining are concerns for air and water quality (Office of Petroleum Reserves, n.d.-b).

Water is a primary concern for oil shale production. Surface and groundwater may be contaminated by runoff from mining (U.S. Department of Energy, n.d.-b). Retorting of oil shale poses a threat to groundwater quality, especially for in situ processes. For production, current estimates are that 1 to 3 barrels of water are required for each barrel of oil produced. Total water requirements for an industry producing 2.5 million barrels per day range from 105 to 315 million gallons per day for extraction (Office of Petroleum Reserves, n.d.-c). Additional water needs to accommodate anticipated population growth associated with such an industry could demand 58 million gallons per day (Office of Petroleum Reserves, n.d.-c). In anticipation of development, Shell Exploration and Production Co. filed a bid for a 15 billion gallon water right. They proposed to pump 375 cubic feet per second from the Yampa River into a 1,000 acre reservoir near Maybell, Colorado. This sparked protest from many sectors, including those who want the water to stay in the river for wildlife and recreation, as well as other interests who are vying for rights to use available water (Harmon, 2009; Jaffe, 2009a, 2009b). Shell's application has been withdrawn, but the controversy brought to light the amount of water a mature oil shale industry is expected to require.

EROI of oil shale is low, estimated at 1:3.5, assuming a 60% efficient energy source. Current new coal fired technology is 35% efficient, making realistic ratios only 1:2 (University of Utah Heavy Oil Program, 2007). Even more optimistic estimates of 1:5 pale in comparison with EROIs of conventional fuels: currently 11-18 for oil and gas, and 80 for coal (Murphy & Hall, 2010). Oil shale shares complications similar to tar sands in terms of net carbon, development of technology, water, environment, economics, and policy.

Function and Structure: Tar Sands

Commercial extraction of usable petroleum products from tar sands is in practice in Canada. U.S. tar sands are of a lower quality, and the technology is not directly applicable for cost-effective production at the present. Although the current capabilities make production unlikely in the near future, the U.S. Department of Energy estimates that governmental support of technology development could lead to production levels of 350,000 barrels per day by 2035. Costs of extraction are expected to be equivalent to or higher than those in Canada, but may decrease with scale and as the technologies are improved (Office of Petroleum Reserves, n.d.-e).

Tar sands yield bitumen, a hydrocarbon that must be upgraded and refined in order to be useful. Methods used for extraction depend on the characteristics and location of the deposit. Ten thousand acres of land are required for 50 MBbl/day production from a surface mine. It takes two tons of tar sands to produce one barrel of oil, and approximately 90% of the bitumen will be extracted. Bitumen can yield synthetic crude oil, asphalt, gasoline, jet fuel, and various chemicals. Refineries in Utah currently process 260,000 barrels per day of Canadian petroleum products, and it is expected that capacity could be expanded to accommodate domestic production (University of Utah Heavy Oil Program, 2007).

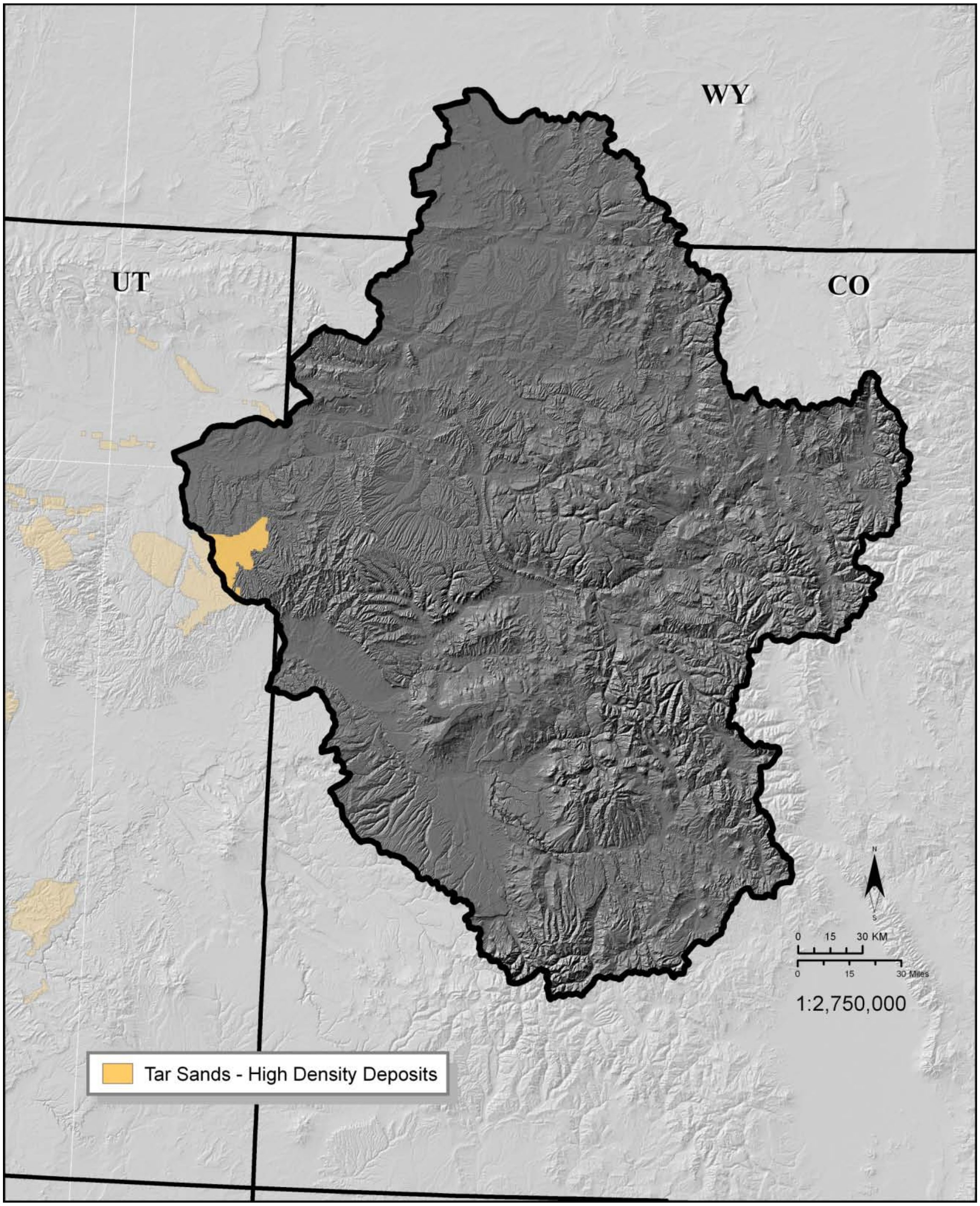
Emissions from tar sands production and refinement include CO2, NOX, and SOX. Emissions control technology can bring sulfur emissions to acceptable levels, provided the source is originally low in sulfur. Extraction and refining of tar sands requires energy and hydrogen, both of which can be produced from natural gas. Coal is also a readily available source of energy in the region.

The quantity of water needed for tar sands production is unclear, as the extraction process is not yet operational for U.S. tar sands. A portion of the water needed can be reprocessed, yet the quantity consumed is substantial for Canadian production - approximately 2-3 units per unit of bitumen (University of Utah Heavy Oil Program, 2007). In a water-strapped environment, the needs of a tar sands industry could have significant effects on water supply and quality.

Rich deposits of tar sands lie in the Utah portions of the larger UCRE study area and along the borders of the three watersheds area of Phase II (Figure 28). If recovery technology for tar sands provides for the effective and viable extraction at large-scale production levels, it can be expected that the deposits in the Yampa Basin in the western part of the study region will also be exploited.

Development of tar sands will be expensive and require pipelines, refineries, and electrical generation facilities. Rapid development may create areas of boom economics in areas where commercial production from tar sands takes place. The volatility of oil prices may create boom-and-bust economies in these places, as well as placing strain on local housing, infrastructure, schools, et cetera.

Figure 28. Tar Sand Deposits



EROI for tar sands is very low at ratios between 1:2 and 1:4. Similar to the challenges of oil shale, economically feasible technologies and commercially viable levels of production for tar sands have yet to be achieved (U.S. Department of Energy, Office of Petroleum Reserves, n.d.-a). Technology and cost effectiveness for use of these potential energy sources is not sufficient to make use of them and would require the input of large amounts of water as well as energy. The energy necessary for extraction and processing would create a pollution output cycle, using carbon-based sources of energy to extract these fuels that would by their use release additional carbon. Net carbon therefore would be very high for both of these sources.

Function and Structure: Wind

Wind energy is the result of uneven heating of the earth's surface. The power of wind has been used in direct applications for millennia to sail ships, to pump water, and for milling (U.S. Department of Energy, 2005). Modern wind harvesting uses turbines to convert kinetic energy of wind by driving a generator to produce electric energy.

The U.S. Department of Energy released a report in May 2008 with its findings on achieving the goal of obtaining 20% of the U.S. energy supply from wind power by 2030. The agency found that no material constraints exist, and that costs would be modest, estimated to be less than 0.5 cents per kWh. Challenges will be in increasing the annual installation rate to reach the goal, as well as problems of transmission. By doing so, the country will avoid the cumulative release of 7,600 million metric tons of CO_2 up to 2030, and an additional 825 million metric each year from 2030 onward. This benchmark will also nationally eliminate the use of four trillion gallons of water (a 17% decrease), a matter of extreme concern within the Colorado River Basin and its dependent states (U.S. Department of Energy, 2008a).

Larger and taller turbines are more efficient; the largest (2.5 MW) turbine manufactured in 2007 is capable of generating enough power for 800 households, depending on the site and wind speeds (Gillis, 2008). Height of the hub of a typical 1.5 MW turbine is 84 meters, with a rotor diameter of 70 meters. By 2015, hub height is expected to reach 128 meters with 64 meter rotor blades (Gillis, 2008). EROI of wind is presently estimated to be 1:18, equivalent to the high end of the range for oil and gas (Murphy & Hall, 2010). Because of its high returns and the available technologies, wind power has been the primary source for Colorado’s success in achieving RPS goals.

Concerns regarding wind energy include wildlife impacts caused by turbines, namely the mortality rates of bats and birds. Interim guidelines have been issued by the U.S. Fish and Wildlife Service while a Wind Turbines Guidelines Advisory Committee studies the issue. Current wind generation is estimated to account for a very small percentage, less than 0.003%, of avian human-caused deaths (U.S. Department of Energy, 2008a). Where design problems contributing to wildlife threats have been identified, modifications to design and equipment have been made, such as the color of rotor blades, adding perch guards, tower design, and burial of power lines (American Wind Energy Association, 2009; Pasqualetti, 2004). Less is known about causes and remedies for bat mortality. Factors such as spring and fall migrations, wind speed, and weather patterns have been shown to increase turbine-induced bat mortality, and mitigation measures have been proposed (Arnett et al., 2008; Baerwald, 2009; Kunz, et al., 2007). This problem appears at present to be concentrated on the east coast but will need to be addressed to avoid problems as wind generation increases. Research on wildlife impacts and protection will need to continue as new designs and larger turbines come into use as well.

As beneficial as wind power stands to be, it is inconsistent in that it generates electricity only when the wind is blowing. Therefore, it is essential that it be integrated into a power grid relying on various forms of energy or networking different areas in order to provide reliable service. Storage of energy is not efficient or optimal, and therefore the power must be replaced when wind generation is low or not producing. Pumped hydro storage, which uses surplus energy to pump water into reservoirs for later release, thereby providing hydro power, is currently the most economical method of energy storage but involves an entirely new set of complications and expenses to build, maintain, and use. Wind generation technology, similar to solar power, would be highly compatible with plug-in electric cars, allowing cars to be charged when electricity is plentiful (MacKay, 2009).

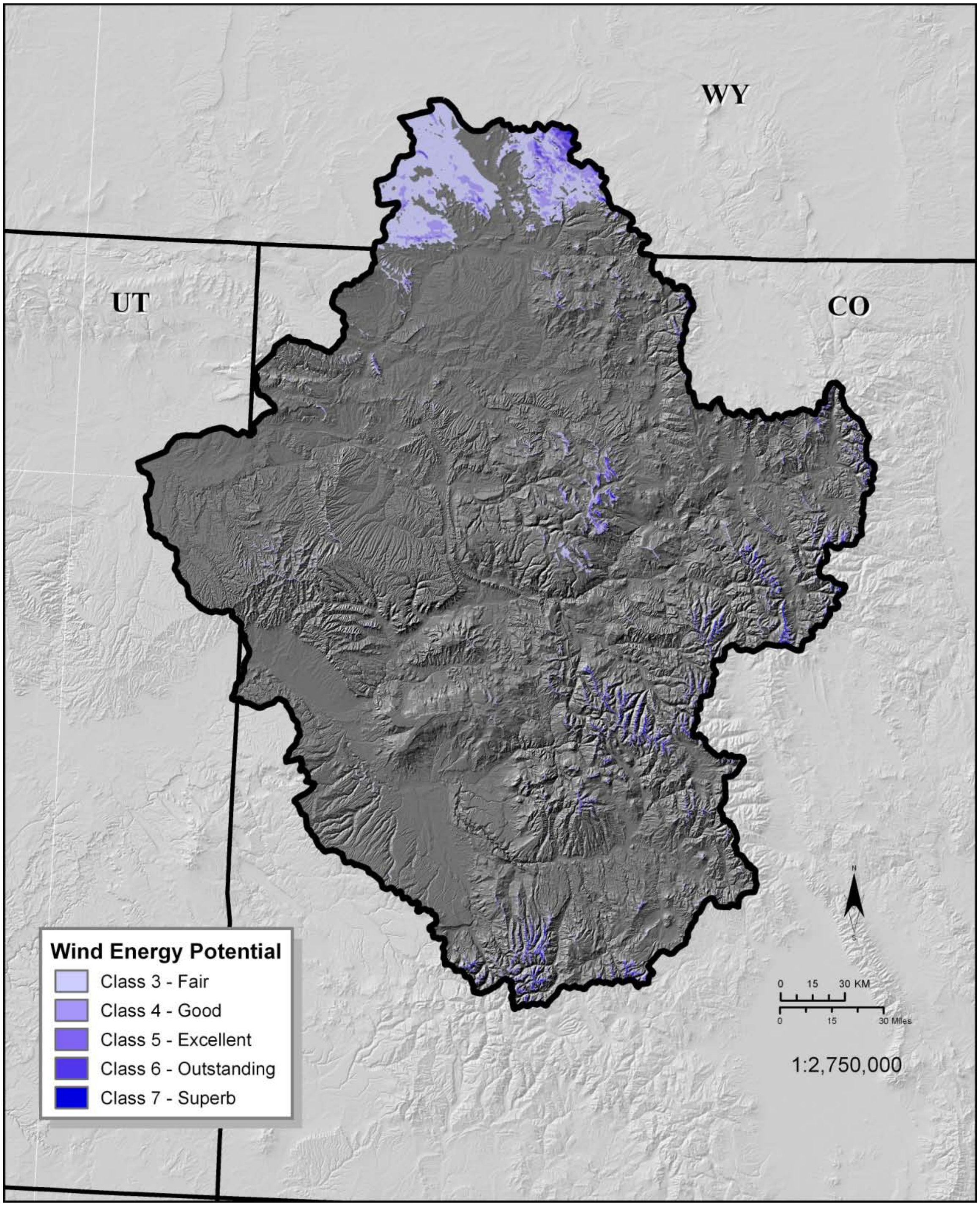
Fragmentation of habitat and edge effects can be consequences of wind generation. However, generation of wind power does not consume the land in ways that non-renewable energy sources do, produces no waste or emissions, and allows for more complementary activities to be co-located with the projects. This can be of great benefit to farmers and ranchers, and can help sustain these activities and ways of life, especially during drought years when other productivity is low (Kuvlesky, et al., 2007). Typical leasing agreements provide landowners royalties of 2-4% of annual gross revenue, or approximately $2,000-$4,000 per turbine per year (Haley, n.d.). This could bring in additional income up to $14,000 per year for a 250-acre farm with minimal impact on farming and livestock (U.S. Department of Energy, 2004).

Properly sited, a wind turbine can use as little as 2 acres of land per megawatt of capacity for actual construction of roads, foundations, and infrastructure, with additional acreage necessary for setbacks and spacing, depending on terrain. The footprint of a turbine is typically less than half an acre, but roads built in association with wind farms are likely to adversely affect biodiversity (Kuvlesky, et al., 2007). Turbines in a wind farm are sited perpendicular to prevailing wind direction, 5 to 9 rotor diameters apart to reduce wake losses, but as close as possible to minimize building and infrastructure costs (Wagner & Mathur, 2009). Along ridgelines they are typically built in a single row, but in broad open areas they can be placed in rows 3 to 5 rotor diameters apart (New York State Energy Renewal and Development Agency, 2005; Wagner & Mathur, 2009). Height and density are restricted by local ordinances.

Wind energy potential is graded into wind power classes by using measurements of the energy that can be captured from wind at a specified height above ground. These rankings indicate the usefulness of sites for wind power generation. Classes range from 1 (low) to 7 (high); classes 1 and 2 are too low to be suitable for utility-scale wind development. Higher categories, provided other conditions are favorable, are preferable. Figure 29 shows potential wind production sites in the study region.

Additional benefits of wind include the domestic production of energy, insulation from price variability, benefits to ranchers and farmers in potential for additional income, and the health benefits of cleaner energy. Objections center on visual effects, which can be largely overcome by careful siting. Impacts of noise are concerns for both humans and wildlife that has not been well researched. Some studies suggest that for humans, perceived noise annoyance is strongly related to visual evaluation of impacts from wind generation (Pedersen & Larsman, 2008; Pedersen & Waye, 2004; Wolsink, 2007).

Figure 29. Wind Energy Potential



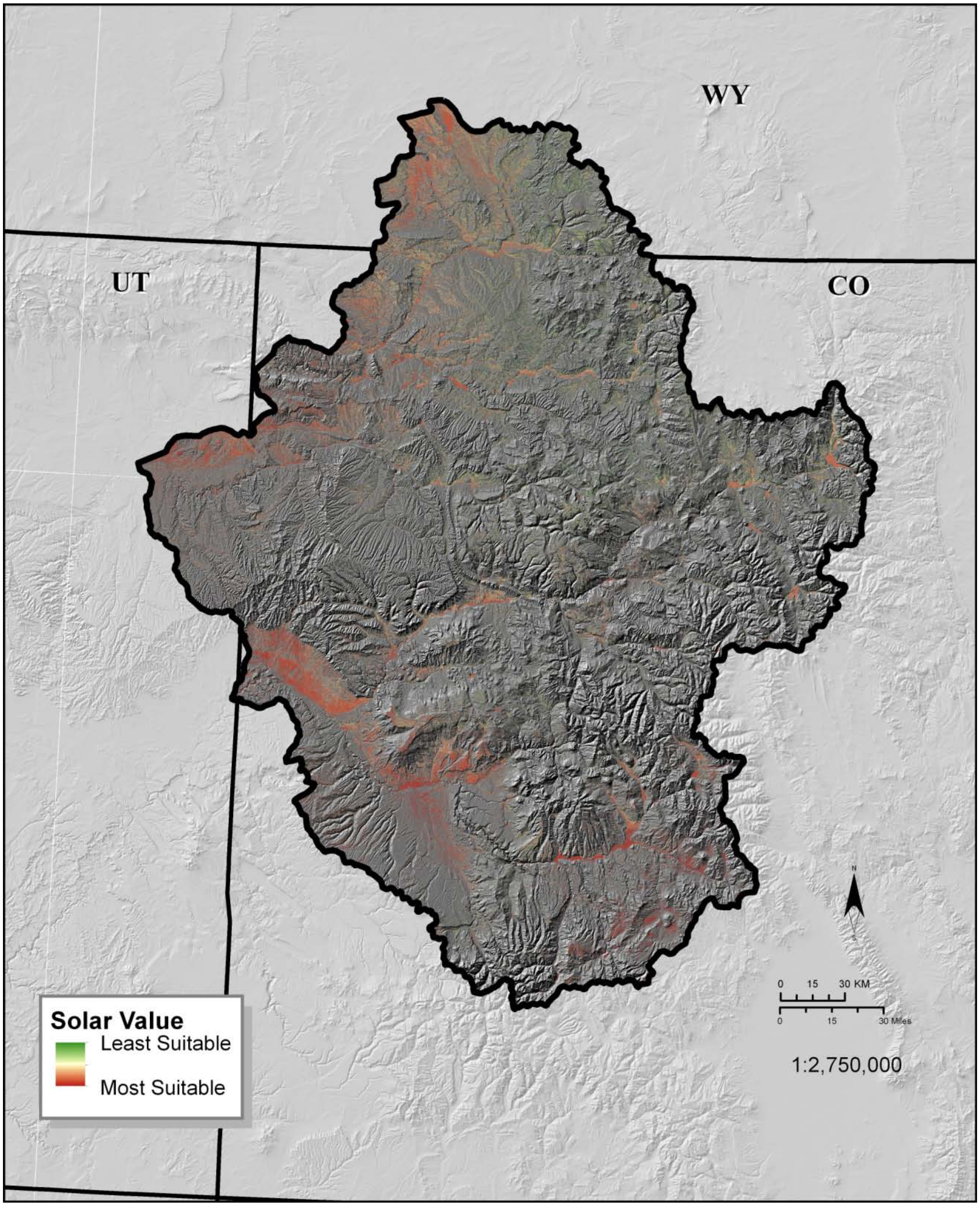
Function and Structure: Solar

In June 2009, Secretary of the Interior Ken Salazar announced an initiative within the Bureau of Land Management to identify tracts of land with prime solar potential. This effort will be focused on facilitation of the utility-scale development of solar power. An in-depth evaluation of previously identified Solar Energy Study Areas in western states will provide information on targeted areas for solar power, as well as landscape-scale planning and zoning on lands administered by the Bureau of Land Management (U.S. Department of the Interior, 2009c).

In consultation with the energy industry and state-level organizations, the Bureau of Land Management established initial criteria for this assessment which includes: potential for generation of 10 or more megawatts of electricity, solar insolation of 6.5 kilowatt-hours/m2/day or more, slope less than 5%, and minimum area of 2,000 acres of Bureau of Land Management-administered lands (U.S. Department of the Interior, 2009b). While there are areas within the larger UCRE that meet these requirements, none exist within the three watershed area. Solar insolation is just below the cutoff in a few areas of the region. The mountainous nature of the landscape presents problems for finding large areas with acceptable slope.

Although there is virtually no commercial potential for solar power with existing technologies in the study area, small-scale solar may still be practical. Such uses may include photovoltaic electricity generation (which may be especially important with the advent of plug-in electric automobiles), or solar thermal heat for uses such as water heating. Cumulatively, these small installations may eventually offset some of the demand for municipal or commercial energy, but to be effective they will need to be closely tied to development and the built landscape. Solar energy uses are not expected to compete as a primary factor for large-scale land use. For the purpose of displaying the best general areas for application of this small production solar, areas with highest potential in the region are mapped (Figure 30). The model shows that places with the greatest potential are around Grand Junction and Montrose. This presents an opportunity to integrate solar energy into existing and new buildings or small-scale production. However, because of the absence of sites for large-scale solar energy development, it has not been included as part of the energy scenarios or futures.

Figure 30. Solar Energy Potential



Function and Structure: Biomass

Biomass is a versatile energy source that can be converted into different energy forms for various applications. With the exception of hydropower generation, it constitutes the largest source of renewable electrical power in the U.S., but technology to make use of it is still in the beginning stages of development and application. It is often used in combined heat and power (CHP) applications, which generate electricity and at the same time make use of the heat produced in that process. This makes it a highly efficient supply which can tap into the potential of unused or waste products.

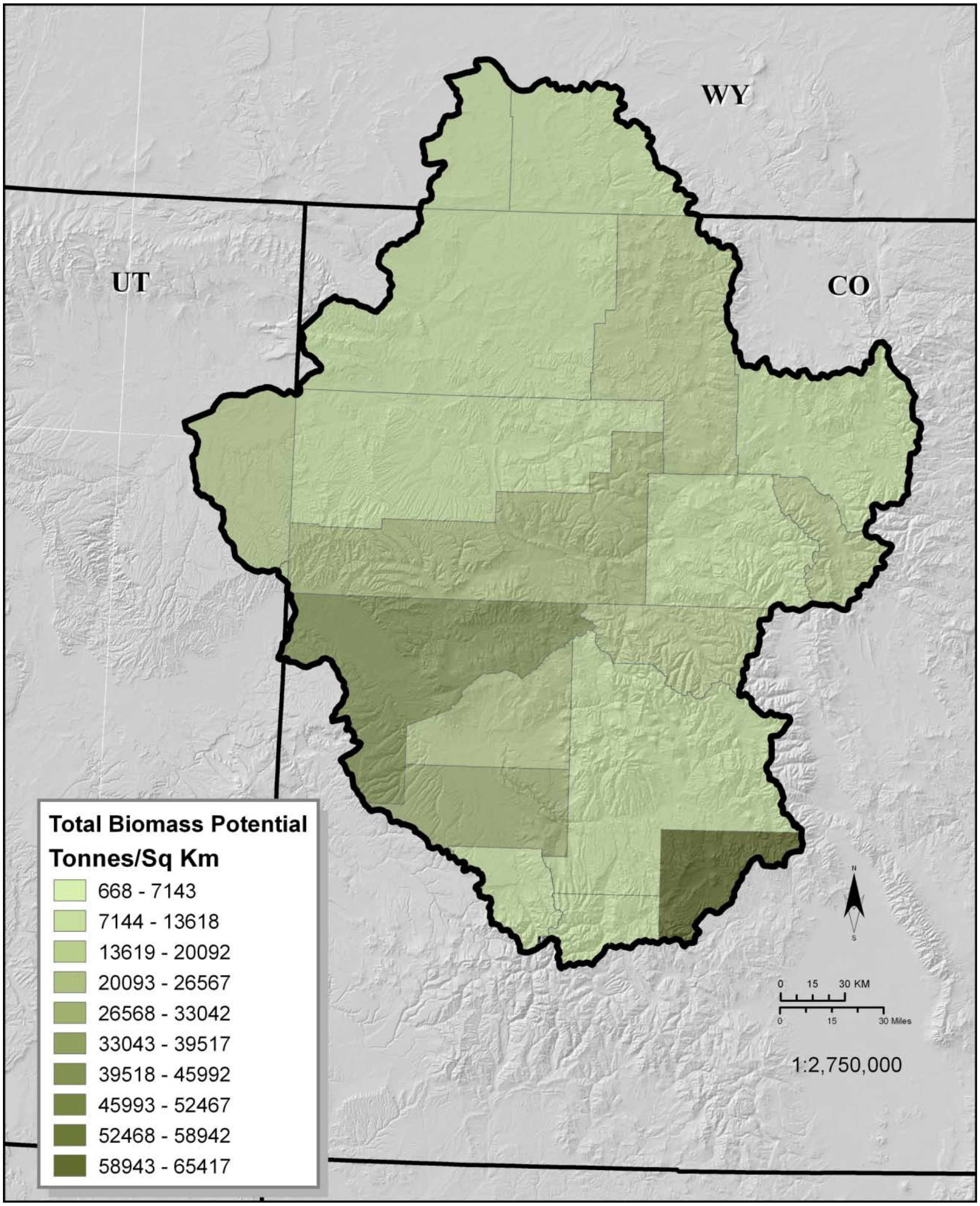
While growth of plant crops is a possibility for fuel stocks, the energy invested and the land and water required to produce those crops has questionable yields. Wastes and byproducts which may be used as resources include forest residues, wood waste, crop residues, manure biogas, wastewater treatment biogas, municipal solid waste, landfill gas ,and food processing residues. These can be turned into solid, liquid or gaseous fuels through direct combustion, anaerobic digestion, or gasification (U.S. Environmental Protection Agency, 2007).

Biomass has many benefits. It is a locally produced, domestic energy source. It can be produced on demand, avoiding the variability of some other renewable sources. Biomass is considered to have a zero net carbon effect, since any carbon released in energy production is only a return of the CO2 that was absorbed during the growth of the material. It reduces the need for waste disposal sites and helps local economic stability. Biomass is readily available, and facilities can be customized to make use of the stocks that are locally available.

Because of the dispersed and diverse nature of fuelstock, small, perhaps even movable plants capable of using variable bioresources are desirable. Because of resource variability, design of plants that can switch between sources or use combined fuelstock, including traditional sources, are under consideration to provide greater reliability. These could be used in small, local applications which power local households. Plants are currently in development for such applications in the 5MW to 100MW range (B. Phillips, interview, February 26, 2008).

Figure 31 displays potential biomass totals from all fuel sources, based on total biomass available in each county. These totals include crop residues, forest residues, secondary mill residues, urban wood waste, and methane emissions from manure management, landfills, and domestic wastewater treatment. Individual counties may have higher levels of specific resources and require different or specialized technologies to exploit the particular fuelstocks available. Because transportation costs account for a large share of the fuelstock expenses, locations closest to both sources and energy users will minimize the expenses of production.

Figure 31. Biomass Energy Potential



In February 2009, the town of Vail began planning to build a biomass-fueled plant that would provide electricity and heat. The cogeneration plant would use beetle-killed timber as a fuelstock, with the added benefit of reducing fire danger by the harvesting of dead trees. There were concerns about the effects of logging, truck traffic and emissions, but opinion was generally in favor of the plant. Developers applied for U.S. Department of Energy funding for startup costs, but the project was not selected (Williams, 2010). Town officials and developers plan to seek other funding (Glendenning, 2010).

Function and Structure: Hydropower

Hydropower is generated when water passes through a turbine, driving a generator that produces electricity. Water impounded behind dams creates an opportunity to tap the stored energy of the water cycle. Power can be generated at approximately one kilowatt per gallon of water per second falling 100 feet (Union of Concerned Scientists, 2006). Energy from hydropower is available as needed, not only when conditions such as wind or sunshine permit generation. It provides a predictable, reliable, and clean source of power.

Retrofitting existing dams helps mitigate and alleviate the impacts of building new dams for power – most of the environmental impacts have already been or are currently being made. It can reduce the time, money, and regulatory processes required in building entirely new facilities. Improving existing hydroelectric generation for greater efficiencies can yield a significant source of new energy as well.

Peak power demands, however, can cause adverse impacts on fish and river ecosystems, and generation releases must be carefully managed in order to preserve the health of the river system and maximize water conservation. Dam retrofits can be supported by environmental groups because they often include improvements on the dam that support environmental and wildlife concerns (American Rivers, 2009; Galbraith, 2009).

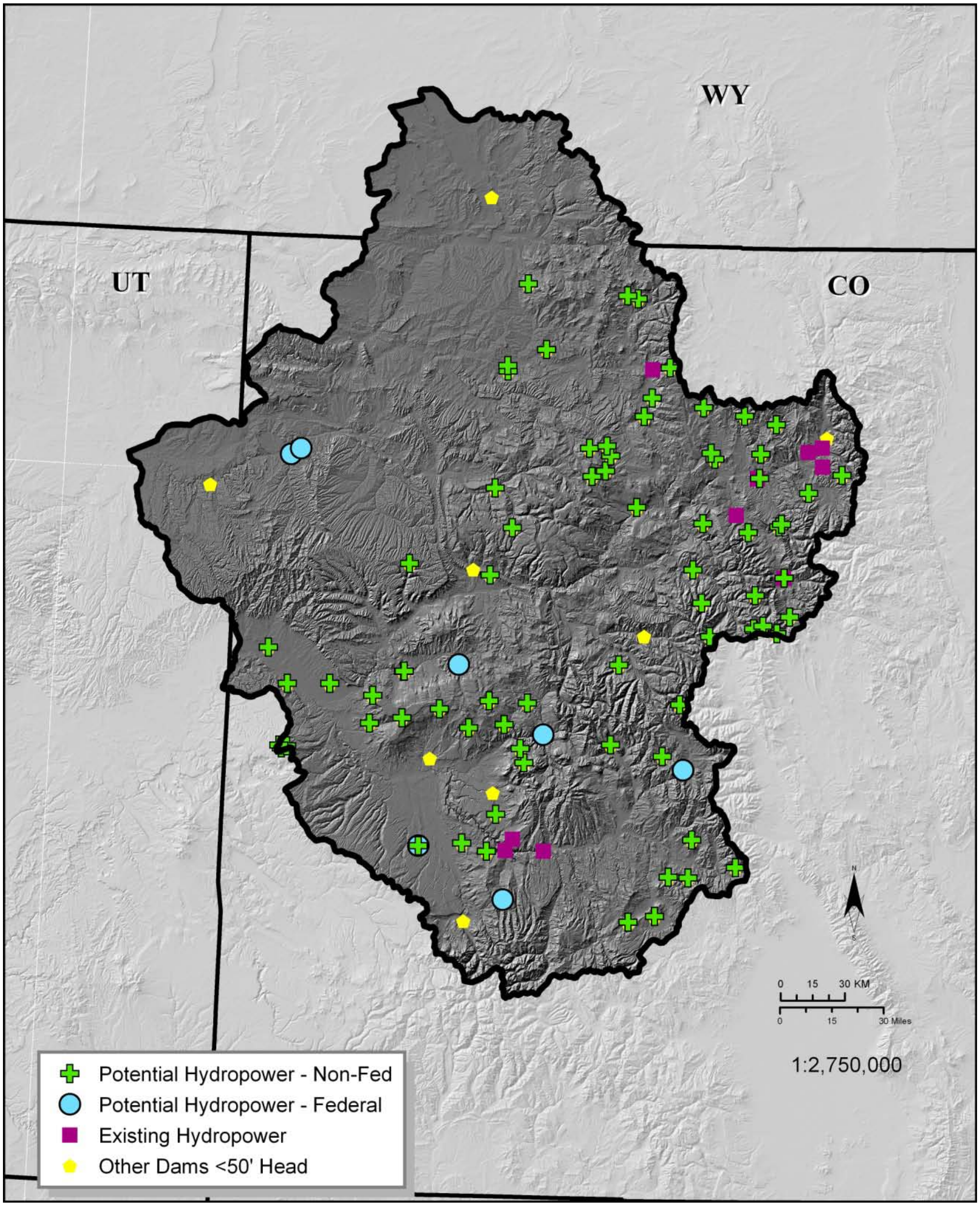
Section 1834 of the Energy Policy Act of 2005 required that a study be conducted "assessing the potential for increasing electric power production at federally owned or operated water regulation, storage, and conveyance facilities" (LexisNexis, 2011, §1834(a)). The U.S. Department of Interior, U.S. Department of Energy, and the U.S. Army Corps of Engineers completed a report detailing their findings in May 2007 (U.S. Department of the Interior, U.S. Department of the Army, U.S. Department of Energy, 2007).

The report assessed the opportunities for retrofitting or upgrading hydropower generation at existing federal facilities. Analysis was based on the physical and economic feasibility of such installations. The screening took place in three stages. The first stage eliminated all sites that had less than 1MW potential; the second, any sites that are subject to land or water use laws that would prohibit hydropower development; the third, predicted generation capacity based on the specific hydrological record for each site.

Because hydropower generation is not within the mission of the U.S. National Park Service, no dams within national parks were included. Likewise, the land use mandates of the U.S. Fish and Wildlife Service are inconsistent with this use; additionally, no FWS dams were reported to be large enough for consideration. The Bureau of Land Management did not have sufficient hydrological data to be analyzed, and dams owned by that agency were not included. The report did not cover any private facilities.

In the three watershed study area, 19 of 99 dams listed in state databases are federally owned. Seven of those 19 were identified by the Energy Policy report as having potential for retrofitting or upgrading, and two Bureau of Land Management dams were not screened. Of the remaining 80 privately owned facilities, only four currently show hydropower capacity. Seventy-five have dam height over 50 feet, making them well over the 35 foot minimum head for a potential 5 MW generation plant. These dams are represented in Figure 32. Detailed analysis will need to be conducted in consideration with going power rates in order to select viable sites and projects for retrofit projects.

Figure 32. Hydropower Energy Potential



Function and Structure: Geothermal

For thousands of years, people have been using geothermal energy for bathing and cooking. Geothermal wells are known to have heated buildings in Paris more than six hundred years ago (Geothermal Education Office, 2004). Earliest commercial use of geothermal energy in the U.S. dates back to 1960, and to 1913 in Italy (U.S. Department of Energy, 2006a).

Geothermal reservoirs occur naturally when water is trapped under pressure in rock layers where the heat from the earth’s core raises the temperature. When tapped, the heated water can provide geothermal energy. Similar to solar energy uses, geothermal energy has two methods of application – direct and electrical generation.

Smaller-scale applications of geothermal potential are direct use and geothermal heat pumps. Direct use is the practice of using naturally heated water or steam for heating buildings or in industrial applications. This use is implemented when naturally occurring springs or geysers bring heated water near to or above the earth’s surface.

The most common current technology for large-scale commercial power generation, flash-steam plants, uses water at temperatures over 360°F to drive turbines and generators for electrical production. A new type, known as a binary cycle generation plant, is capable of producing power at lower temperatures – from 225°F to 360°F – and is expected to become the primary technology (Idaho National Laboratory, 2009; U.S. Department of Energy, 2006b).

The definition of geothermal energy as a renewable resource is debatable. Water is reinjected into the geothermal zone, where it maintains the pressure and prolongs the life of the reservoir. Geothermal energy relies on the heat generated by the earth's core, which is an abundant resource. Geothermal reservoirs can decline in productivity due to human use. The U.S. Department of Energy does, however, define geothermal energy as sustainable.

Geothermal energy is reliable and consistent. It has the advantage of being available 24 hours a day and, with potential capacity at 90-95%, it does not have the variability of wind or solar power. Power generation plants do not require transportation, storage, or combustion of fuel. It is a clean technology, which releases only 1% of the carbon dioxide of fossil fuel generation methods. Scrubbers are used to remove any hydrogen sulfide, and sulfur compounds are 97% less than fossil methods (U.S. Energy Information Agency, n.d.-b). Binary steam plants create no emissions (U.S. Department of Energy, 2006b). Some plants generate sludge waste, which does require disposal.

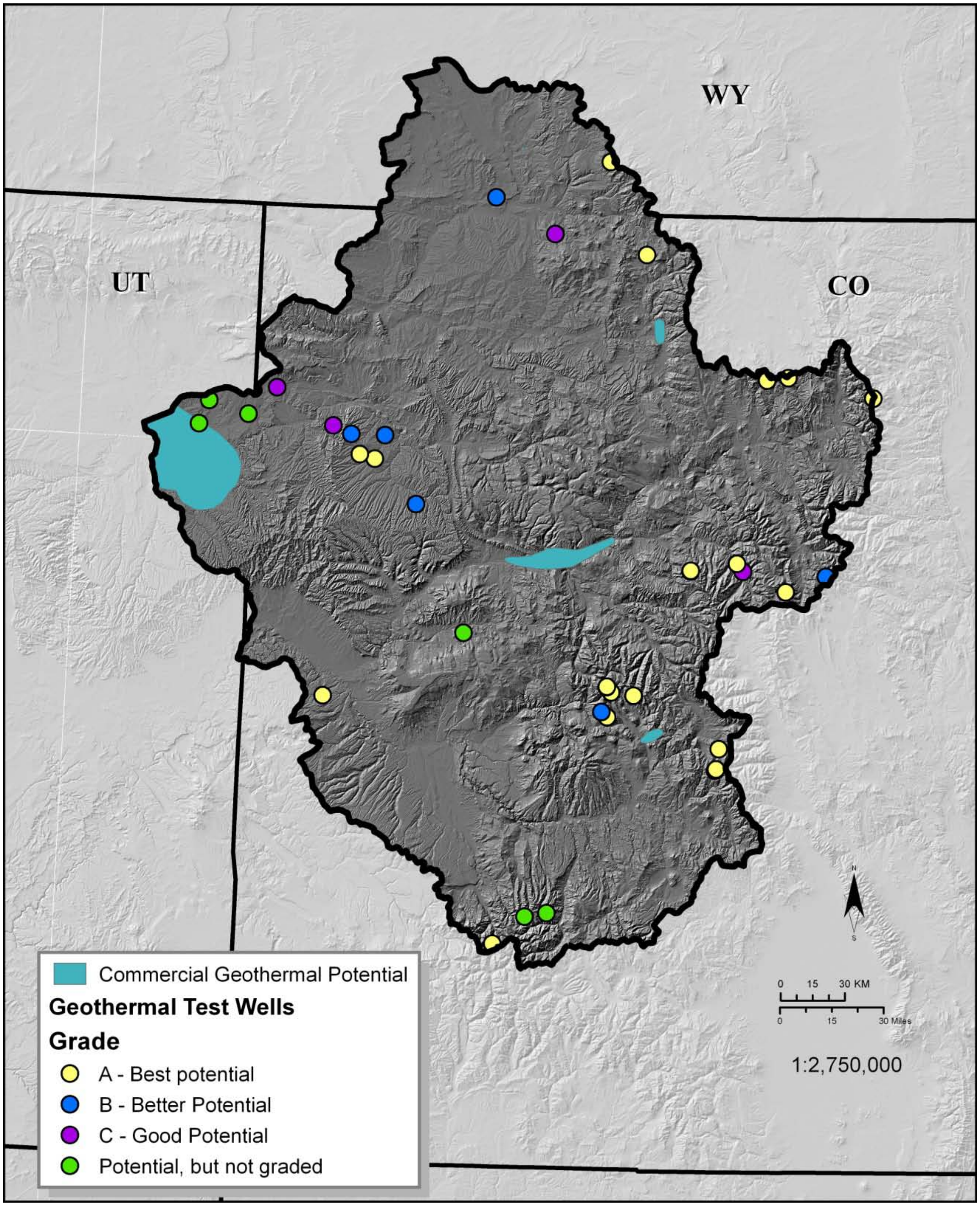
Enhanced Geothermal Systems (EGS) is a theoretical way in which the natural systems that create geothermal reservoirs are mimicked. EGS requires drilling wells into hot rocks in a geologic site, which would allow water to be pumped into the ground, maintained at pressure, where it would be heated and used as a natural geothermal facility. These systems are largely in developmental stages, and the viability, economy, and environmental costs of EGS–produced energy are still to be determined (U.S. Department of Energy, 2008b).

Optimal sites for electrical plant development occur where the geothermal resources are shallow, within one to two miles of the surface, and temperatures above 300°F. The heated water should have low mineral and gas content. Location on private lands facilitates development due to simplified permitting processes (U.S. Department of Energy, 2006b). As with all power generation facilities, location with access to distribution networks increases viability and reduces costs. Water is necessary for geothermal construction and operations, estimated to range from 0.01 to 0.73 gallons per MW produced over the lifetime of a plant (U.S. Department of Energy, 2006b). This compares well to 0.26 to 1.53 for coal or 0.24-0.99 for natural gas (Clark, Harto, Sullivan, & Wang, 2010). Argonne National Laboratory concludes that, “Overall, geothermal technologies appear to consume less water on average over the lifetime energy output than other power generation technologies” (Clark, Harto, Sullivan, & Wang, 2010, p. 27)

The Geothermal Steam Act of 1970 authorized the leasing of public lands for geothermal development, provided that there is no unnecessary degradation of public lands or resources. Lands that are part of the National Park System, U.S. Fish and Wildlife Service lands, and any other lands prohibited from leasing by the Mineral Leasing Act of 1920 are excluded.

Little geothermal development has taken place within the Phase II study area. Test wells that have been drilled and deemed possible sites are shown in Figure 33. This map also shows areas deemed to be promising according to data from Idaho National Engineering & Environmental Laboratory. Furthermore, town or feature names often indicate that early settlers found geothermal resources in the area, such as Steamboat Springs, Glenwood Springs’ Vapor Caves, Waunita Hot Springs, Sulfur Hot Springs, Juniper Hot Springs, and Brimstone Corner.

Figure 33. Geothermal Energy Potential



CHAPTER 5

SCENARIO DEVELOPMENT AND ALTERNATIVE FUTURES MAPPING

This section focuses on scenarios and alternative futures for energy development and habitat conservation in the study area. It deals with developing scenario storylines, combining scenarios from the energy development and habitat conservation selections, and developing and mapping alternative futures. This stage of the process is shown in Figure 34.

Due to the great potential of both renewable and fossil resources, energy will be a primary driver of human activity in this region. Whether we continue to tap the fossil fuel resources or the plentiful wind energy, or explore the geothermal potential, this area will be expected to provide for energy needs into the future. Internal growth and outside needs for its energy resources will demand it.

Habitat in the region is subject to disturbance and fragmentation due to exploitation of energy resources, population growth, and conversion of existing land and water uses. Pollution and a warming climate, along with possible changes in the water regime, put stress on wildlife and the habitats that they depend on, and it is unclear how ecosystems and species assemblages will respond. Scenario components presented in the habitat models are an effort to address growing concerns surrounding climate change and native species response, as well as future growth, development, and energy extraction in the region. Land managers, urban and rural planners, and conservationists will all face difficult challenges in the future. Modeling may help them anticipate changes and inform future management decisions regarding the concerns that have been identified.

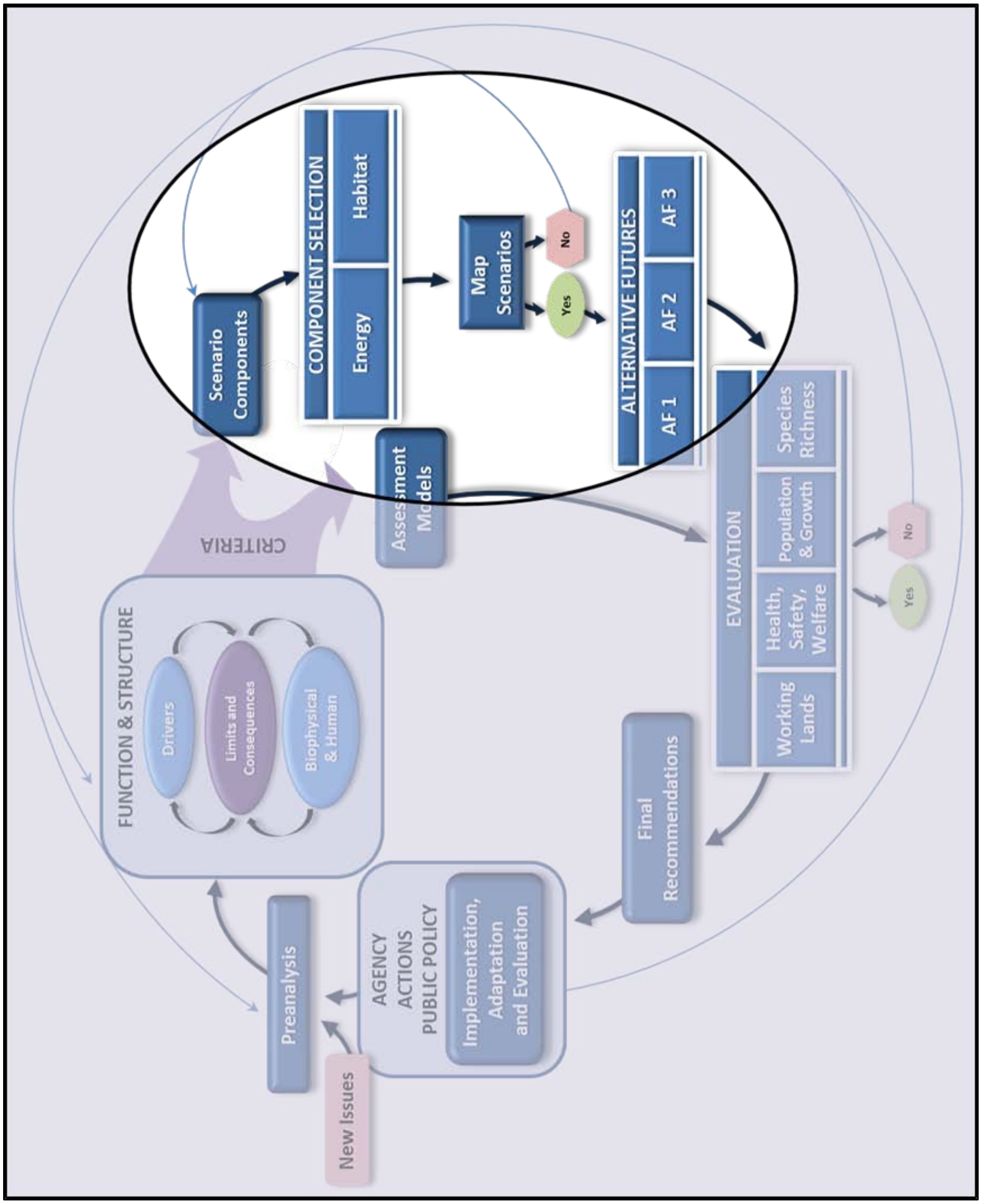


Figure 34. Process Diagram Highlight - Scenarios and Alternative Futures

The following sections and the criteria shown in Table 7 outline models and criteria compiled to build scenarios for conservation priority locations in the UCRE Phase II study area. The analysis is spatial, and therefore descriptions of components represent spatial data layers to be included in a Geographic Information System (GIS) model for the creation of several output maps. In this section, the scenarios represent alternative strategies for targeting wildlife conservation priority hotspots. They comprise large patches of natural habitat and corridors important to the movement of wildlife species (Forman, 1995).

The strategies have been broken down into three "storylines" that represent unique challenges and approaches to conservation of wildlife priority hotspots as follows:

- Protection of large natural areas to conserve biodiversity.
- Management of moderately disturbed natural areas to protect biodiversity.
- Restoration of highly disturbed natural areas to increase biodiversity.

The costs of these strategies are highly variable and are presented in increasing order of management and intervention costs. They are anticipated to have inversely proportional acquisition costs and management expenses. These three scenarios are used to identify areas of the landscape that range from large undisturbed patches of native plant and animal species, to smaller patches of highly disturbed and fragmented natural areas. For example, the protection of existing conditions represents the least cost approach to the protection of native biodiversity. If conditions are favorable, simple methods of conservation can be enlisted to preserve those areas of natural and pristine habitat to promote the persistence of high species richness.

Table 7

Habitat Conservation Scenarios

Conservation Strategy	Criteria
Protection of Natural Areas This model identifies large natural patches of 40,000 ha or greater that are not yet bisected by roads or development. These patches represent the areas of greatest conservation potential due to their current natural state, and the least cost to manage.	Patches of contiguous natural areas that are 40,000 hectares or greater Removal of built and disturbed landscapes
Management of Natural Areas This model identifies moderately sized natural patches of 20,000-40,000 ha that are not yet bisected by roads or development. These patches represent areas that are experiencing increased use and consumption for human activities and may require active management to balance natural productivity and future land-uses.	Patches of contiguous natural areas that are 20,000–40,000 hectares Removal of built and disturbed landscapes
Restoration of Natural Areas This model identifies moderately sized natural patches of 2,000-20,000 ha that are not yet bisected by roads or development. These patches represent those areas that have experienced significant fragmentation in the past, and may lead to costly restoration of natural systems and critical ecosystem services.	Patches of contiguous natural areas that are 2,000–20,000 hectares Removal of built and disturbed landscapes

Identifying Natural Areas

A key component of the conservation models is identification of large contiguous patches of the landscape that exist in a relatively natural state – not yet transformed by anthropogenic uses or severely fragmented by roads. Natural areas are important to landscape function and structure for a variety of reasons. Such areas maintain critical ecosystem services, create connectivity and corridors, and potentially provide refuge for species in a changing climate, allowing for the migration or adaptation of native organisms (Hoctor, Carr, & Zwick, 2000). Conservation of these areas supports the diversity of organisms and habitats through a rich landscape mosaic (Forman, 1995).

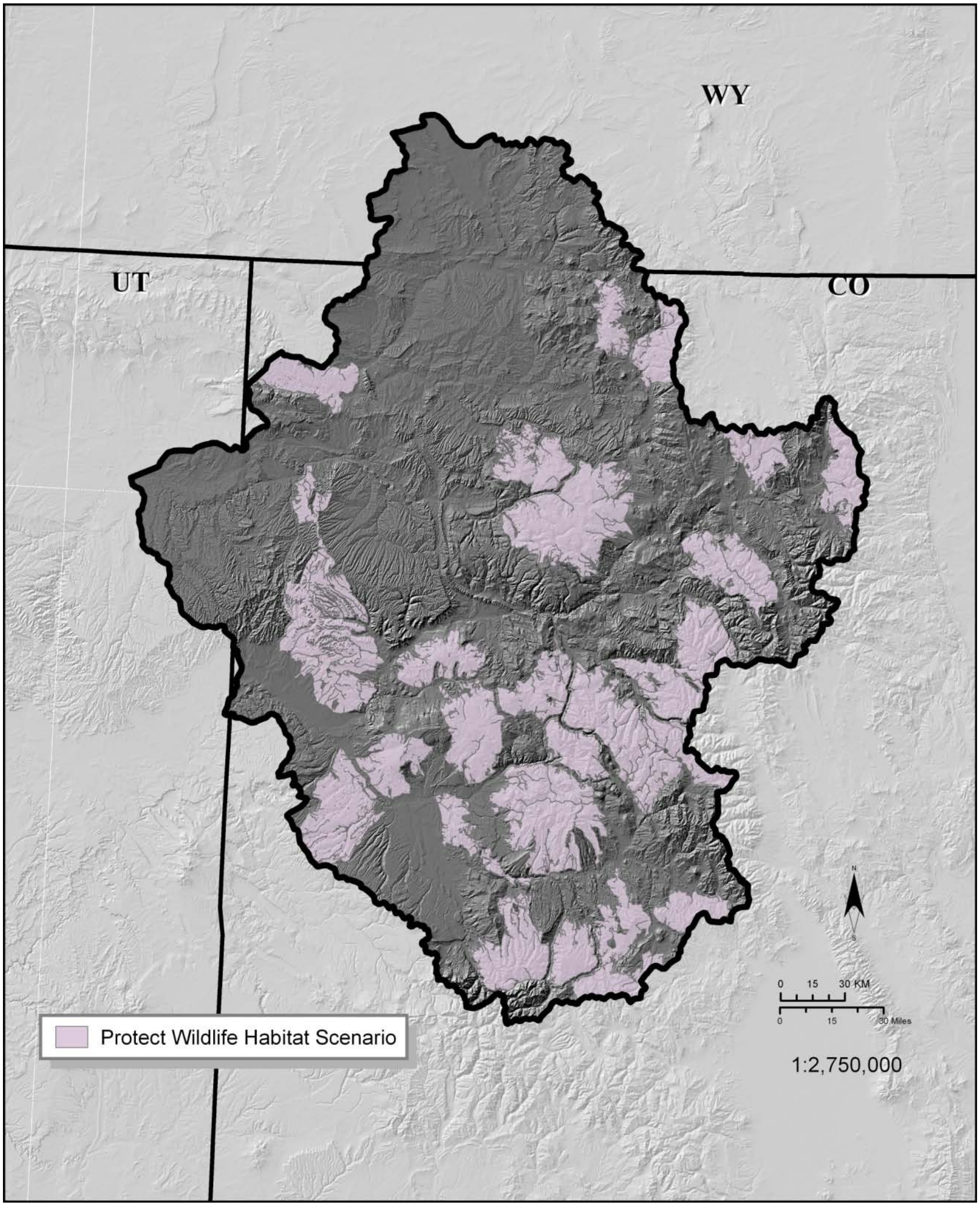
Patch sizes ranging from 2,000 to 40,000 hectares or greater were used to identify areas that meet the minimum to maximum habitat requirements for a range of organisms. Natural patches and roadless areas in the study area were identified using the National Land Cover Dataset (NLCD), developed in cooperation by the United States Geological Survey (USGS), and the Environmental Protection Agency (EPA). These datasets identify all built and disturbed landscapes comprised of Developed High, Medium, and Low intensity, Open Space, and Agricultural Hay/Pasture/Crop Lands. USGS Tiger Line files were also used to identify all road networks in the study area. Once these areas had been identified, they were extracted from the land cover layer in ArcGIS with associated impact zones to show where there are potential undisturbed natural areas in the landscape (Reijnen, Veenbaas, & Foppen, 1995). This methodology is attributed to similar modeling approaches found in the case study *Alternative Futures for Changing*

Landscapes: The Upper San Pedro River Basin Arizona and Sonora (Steinitz, et al., 2003).

Protect Wildlife Habitat Scenario

The Protection Model shown in Figure 35 identifies the largest contiguous and undisturbed patches in the landscape. With these large patches identified, stakeholders or wildlife agencies have the opportunity to validate the pristine nature of these large natural areas and then promote the protection of those areas through a host of conservation strategies.

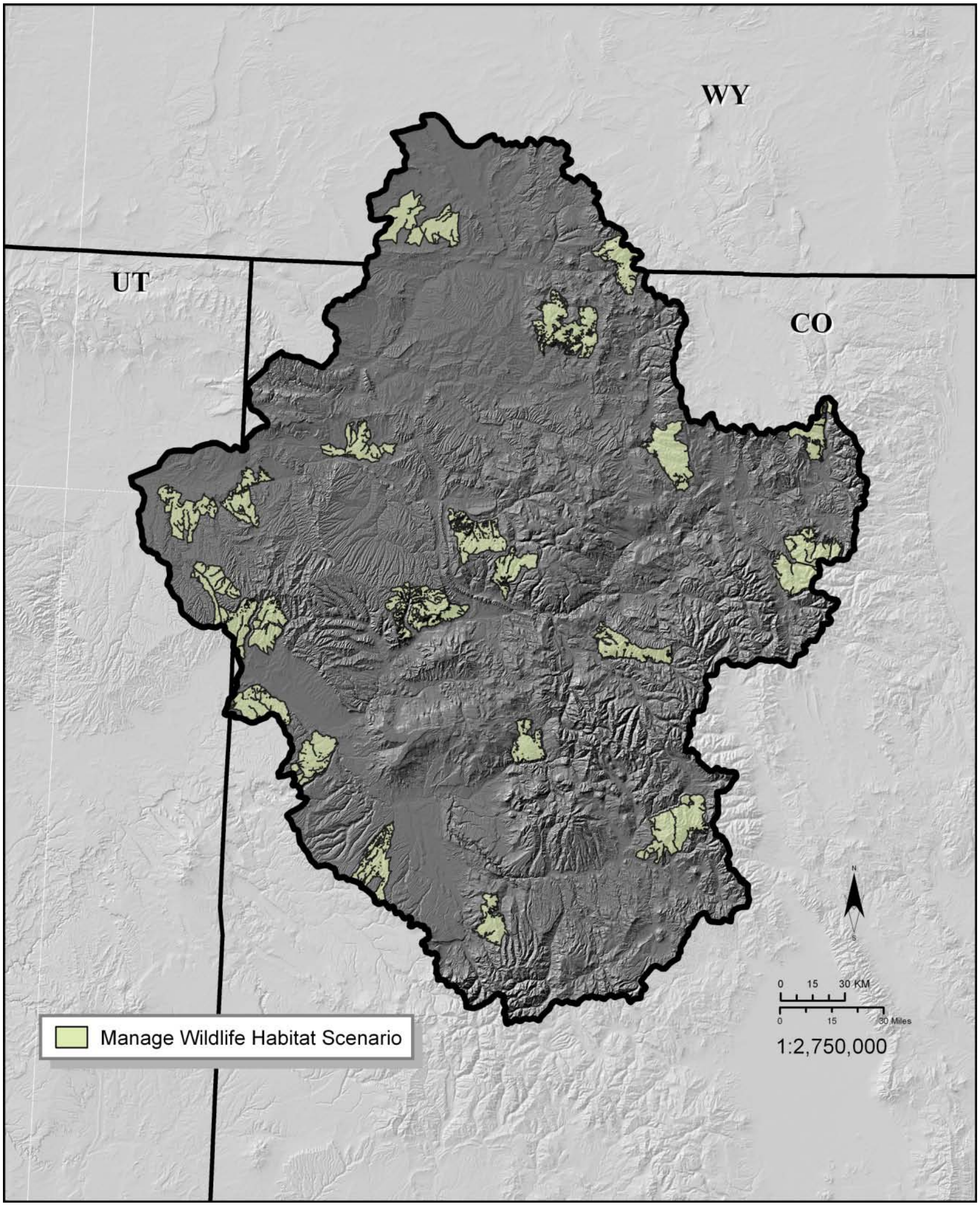
Figure 35. Wildlife Habitat Conservation Scenario - Protect



Manage Wildlife Habitat Scenario

The second strategy, the Management Model shown in Figure 36, identifies moderately sized natural areas of 20,000–40,000 hectares that are somewhat disturbed or fragmented by roads and human land use. These areas may continue to provide important ecosystem services and meet the habitat requirements of a range of local biota. As a wildlife conservation area, however, there may be long-term effects of those impacts that lead to restoration costs, or more costly and aggressive management. The cumulative effects of a range of activities and permitted uses over time will require mitigation, increased monitoring, and costly surveying or field research. This more involved land management strategy represents a higher-cost approach than Protection when addressing the conservation of native species and critical ecosystem services. Rather than setting aside large pristine areas, the Management scenario's goal is to correct unfavorable changes that have taken place or practices which no longer contribute to land management strategies or conservation goals in areas with relatively viable habitat.

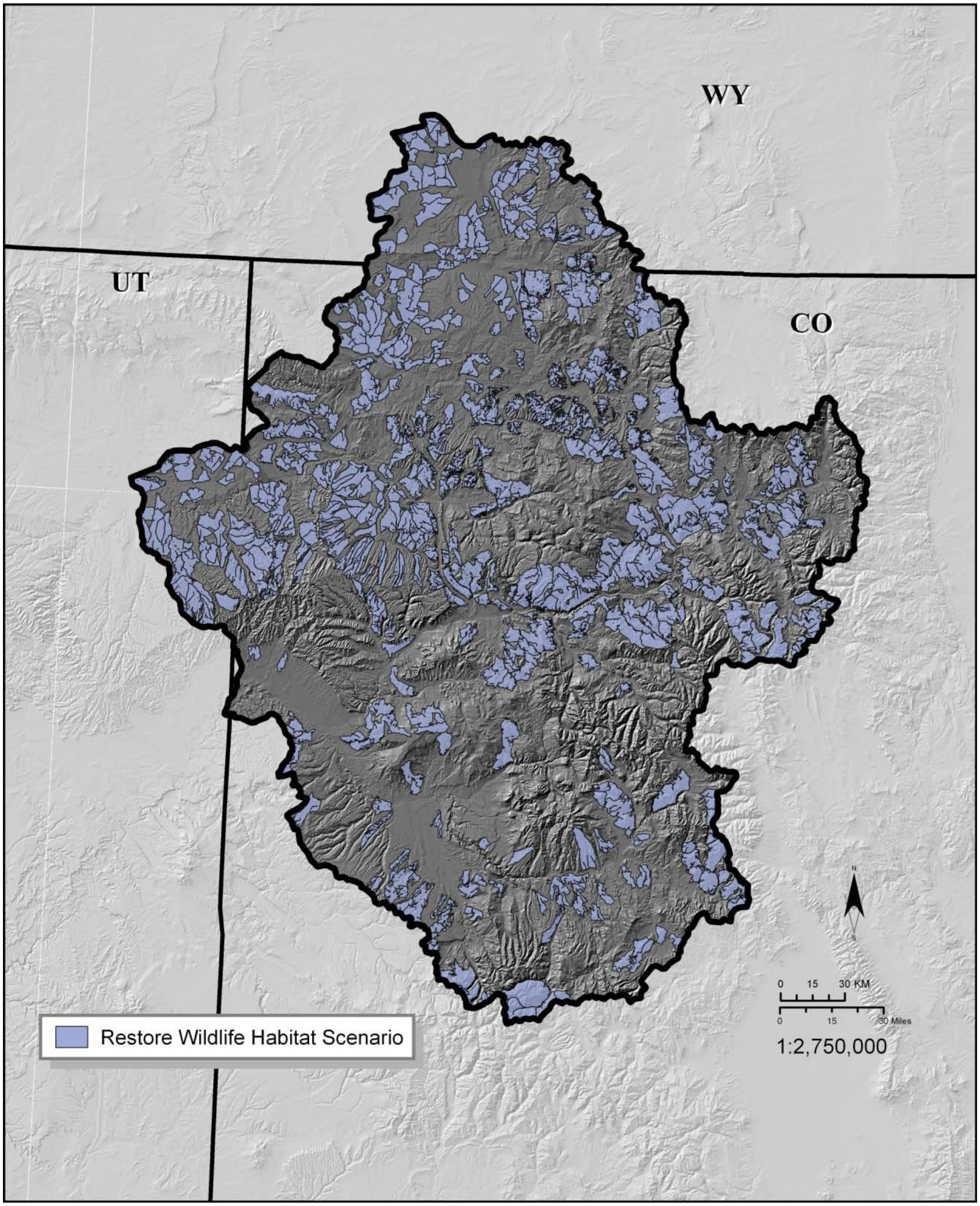
Figure 36. Wildlife Habitat Conservation Scenario - Manage



Restore Wildlife Habitat Scenario

The third strategy is the Restoration Model shown in Figure 37 which identifies small natural areas that are from 2,000–20,000 hectares in size. These patches represent those natural areas of the landscape with the highest degree of disturbance and fragmentation by roads and human land use. Once again, while these areas may continue to provide valuable ecosystem services and contribute to native biodiversity, they are likely to be the areas of the landscape under the greatest threat from human disturbance and use. They also represent the most costly areas to restore when conditions are such that habitat has been altered or where critical ecosystem services are being compromised and intervention or mitigation is required. Increasing threats to natural systems in these areas jeopardize the productivity of lands and natural resources, resulting in reduced and fragmented habitat and cumulative impacts to air quality and the water regime.

Figure 37. Wildlife Habitat Conservation Scenario - Restore



Energy Scenarios Overview

Scenarios have been described for energy development and resources in the region. Narrative of scenarios aims for creation of possible, reasonable, and feasible storylines which represent pathways into the future based on knowledge of the present (Liotta & Shearer, 2006). Scenarios are meant to objectively explore possibilities, yet they can never be entirely value-free (Gallopin, Hammond, Raskin, & Swart, 1997). All scenarios acknowledge and make use of the inherent and rich energy resources in different ways. The regional resources, energy demands, politics, and economic needs were used as controlling processes (Holling, 2001). These considerations range from local factors to global impacts and markets and include such matters as population, size and location, and types of resources. Circumstances, choices, and decisions could follow these storylines into any one of these, or an infinite number of other possible futures. For the sake of evaluation, assessment, and planning, these three have been developed as significant trajectories among the options. They are summarized in Table 8. Criteria for resource selection are listed in Appendix G.

Table 8

Energy Development Scenarios

Buildout Energy extraction as priority	Coal is mined voraciously for both domestic and foreign export. Oil and natural gas and coalbed methane are extracted where coal does not compete. Tar sands and oil shale are explored and aggressively developed in areas not suitable for more readily available energy sources and where water is available. Purchase of water rights for these activities displaces agriculture, and extraction activities on the land take priority over recreation, agriculture, and development. Local power needs continue to be met primarily from non-renewable sources, mainly coal-fired power plants. Requirements for renewables under state law are largely met by buying renewable energy credits rather than new sources. Population and urban growth is concentrated around the extractive energy industries.
Business-as-Usual Energy production levels follow current patterns	Energy production meets RPS requirements by 2020, but does not exceed them. Local energy remains at similar production levels, 70% for IOUs and 90% for MCUs from non-renewables (coal and gas-powered electricity), and reaches 30% (IOUs) and 10% (MCUs) for renewable, primarily from wind power. Exports of coal grow to keep pace with moderate increases in energy demands. Oil and natural gas are tapped for levels of continuing production. Exploration of oil shale and tar sands continue, but remain largely uneconomical for large scale production due to water and energy input requirements.
Moderate Conservation Trends toward increasing efficiencies and % renewable continue	Renewable energy goals are increased to 40% (IOUs) and 20% (MCUs) by 2040. Oil shale and tar sands are abandoned as unfeasible. Coal, oil, and natural gas reserves are mined cautiously in order to extend domestic energy supplies. Conservation measures are legislated and regulated, with the goal to level off and begin decreasing net carbon output and decrease the need for new energy production. Site-based solar and geothermal replace some commercial demand. Dams and reservoirs may be built to hold back water in the upper basin and could generate hydropower. Potential from unused but available resources such as biomass and retrofit of existing dams begins to be exploited.

Note. RPS=Renewable Portfolio Standards, IOU=Investor Owned Utilities, MCU=Municipal and Cooperative utilities.

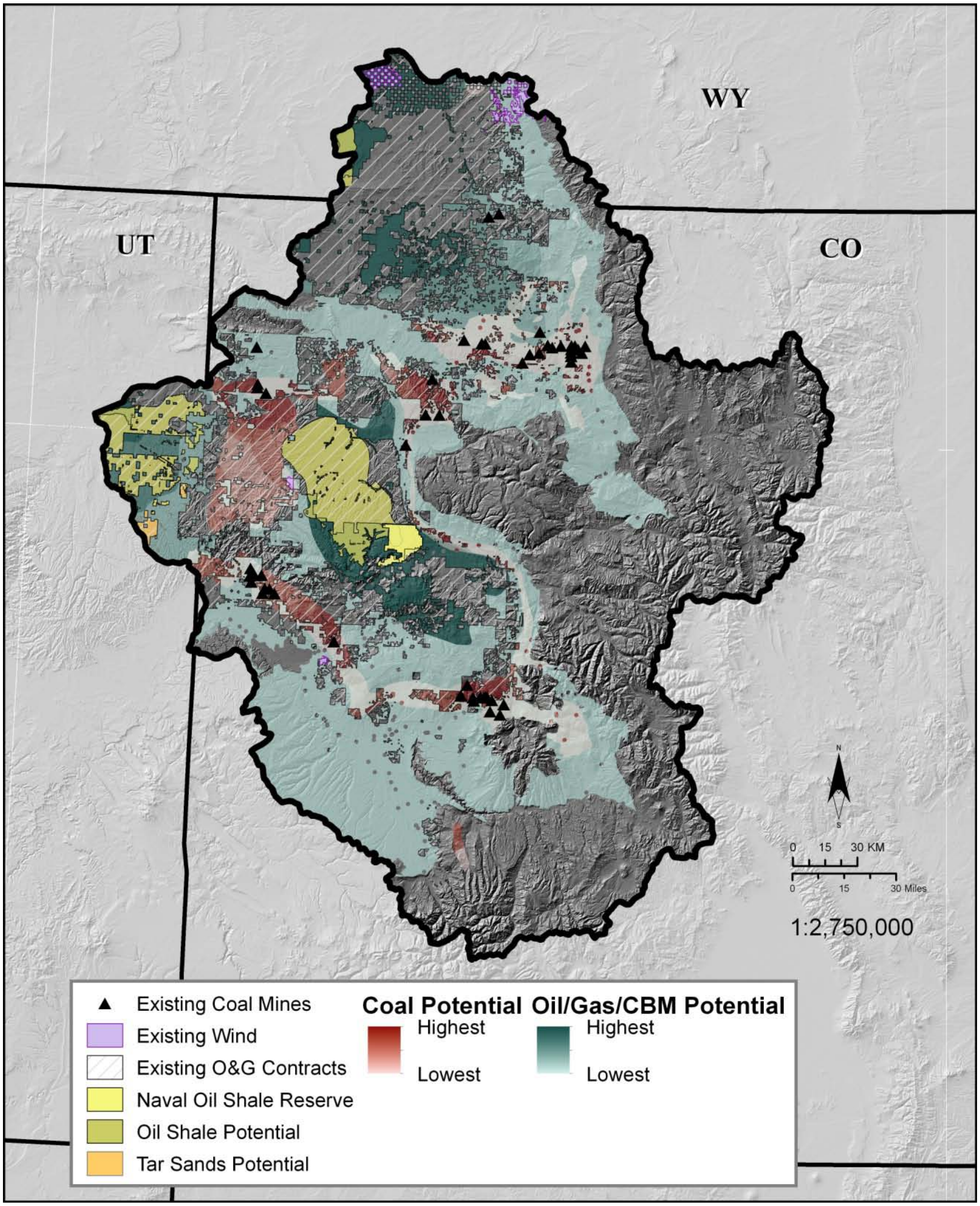
Buildout Scenario

A Buildout scenario (Figure 38) takes place in a future hungry for energy, with many still in doubt of the scientific evidence supporting global climate change and an even greater number unwilling to make significant changes to ways of life. In this storyline, policies and decisions lead to full exploitation of high-yield fossil energy sources. Powerful corporate and industrial agendas, political support from leaders who believe that innovation and discovery will prevail, and the perceived economic imperative to support international trade serve to create momentum for achieving the highest energy returns possible from the region.

This scenario concentrates on extraction of high-yield energy sources. These forms of energy are highly subsidized and concentrated, essentially consisting of the accumulated solar resources of ancient biomass. This take-no-prisoners approach to energy exploitation has very high externalized costs in terms of environmental damage. Although sources vary in the pollutants they create, carbon outputs for both the energy required for extraction of these resources and for the processes of using them are high. The methods of obtaining these resources tends to be very destructive, impinging on habitat and visual quality in addition to degrading other natural resources, such as watersheds and aquifers.

As resources become more difficult to extract, investment in traditional carbon-based energy yields diminishing returns. Responses to compensate and adapt in turn lead to increasing complexity. For instance, distribution networks must become more complex in order to deliver more distant fuels and energy to users, and methods of refinement and

Figure 38. Energy Development Scenario - Buildout



use must be developed to accommodate less suitable resources. Pressure to keep energy prices low and supplies freely available for increasing demand is unrelenting.

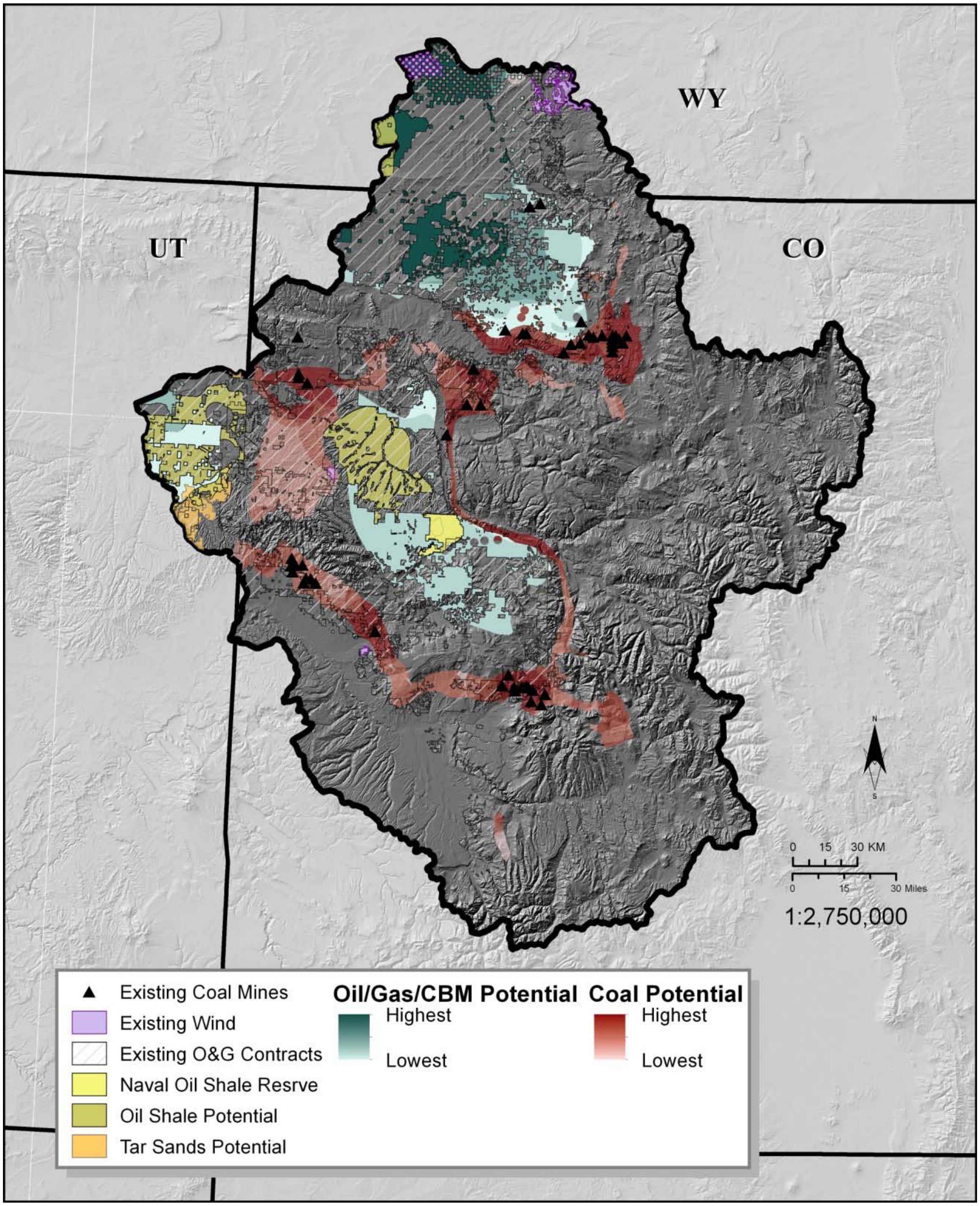
This approach may support increased energy production and economics and, along with resistance to change, could be the justification for supporting such a direction. Regional economics would benefit from jobs in extraction, energy distribution, and energy production. National economics would gain through cheaper energy, and global economics would be bolstered through international trade.

The Buildout scenario supports patterns of increasing energy consumption that depend on a continuing supply of inexpensive energy. This approach would serve to maintain these existing values and lifestyles for those in the region. The existing sunk costs of the current energy structures would be followed by further sunk costs, making it even more difficult to redirect toward a different future.

Business-as-Usual Scenario

In a Business-as-Usual scenario (Figure 39), Colorado meets its RPS standards by the deadline in 2020. Voters and elected officials do not choose to implement any increases in renewable energy requirements for various reasons of convenience, technology, economics, or not-in-my-backyard attitudes. This scenario continues along the trajectory set by present attitudes and policies, with growth in energy demand moderated by basic but minimal steps toward efficiency. In this storyline, energy needs continue to increase after 2015, but at a slower pace than the past 40 years. Fossil energy sources continue to be the primary source of energy in the region and are exported

Figure 39. Energy Development Scenario - Business-as-Usual



according to current patterns. A small number of enthusiasts pursue renewable energy on their own through site-based solar, wind, and geothermal retrofits and new building. Economic pressures and availability of cheaper energy (due to externalized costs) prevent a large-scale move to a new system of production.

In this scenario, fossil fuels are becoming more scarce and expensive to extract, and interest in domestic energy reserves is high. Research and development for production levels of petroleum extracts from tar sands and oil shale continues but is hindered by extraction economics and availability of water. To a lesser degree, concern over carbon from these sources exists but does not pose as big an obstacle as water or technology. Coal, oil, and natural gas will continue to be primary sources of energy in the region. Coal bed methane production begins on a large scale in the Uinta-Piceance Basin in the western portion of the study area.

Exports of coal and natural gas will continue to provide a great deal of the economic activity for the region. Extractive industries are predicted to drive growth and jobs, but growth of this type is particularly subject to a boom and bust cycle dependent on energy prices and availability. This imposes a great vulnerability on the stability of local economies reliant on extractive activities.

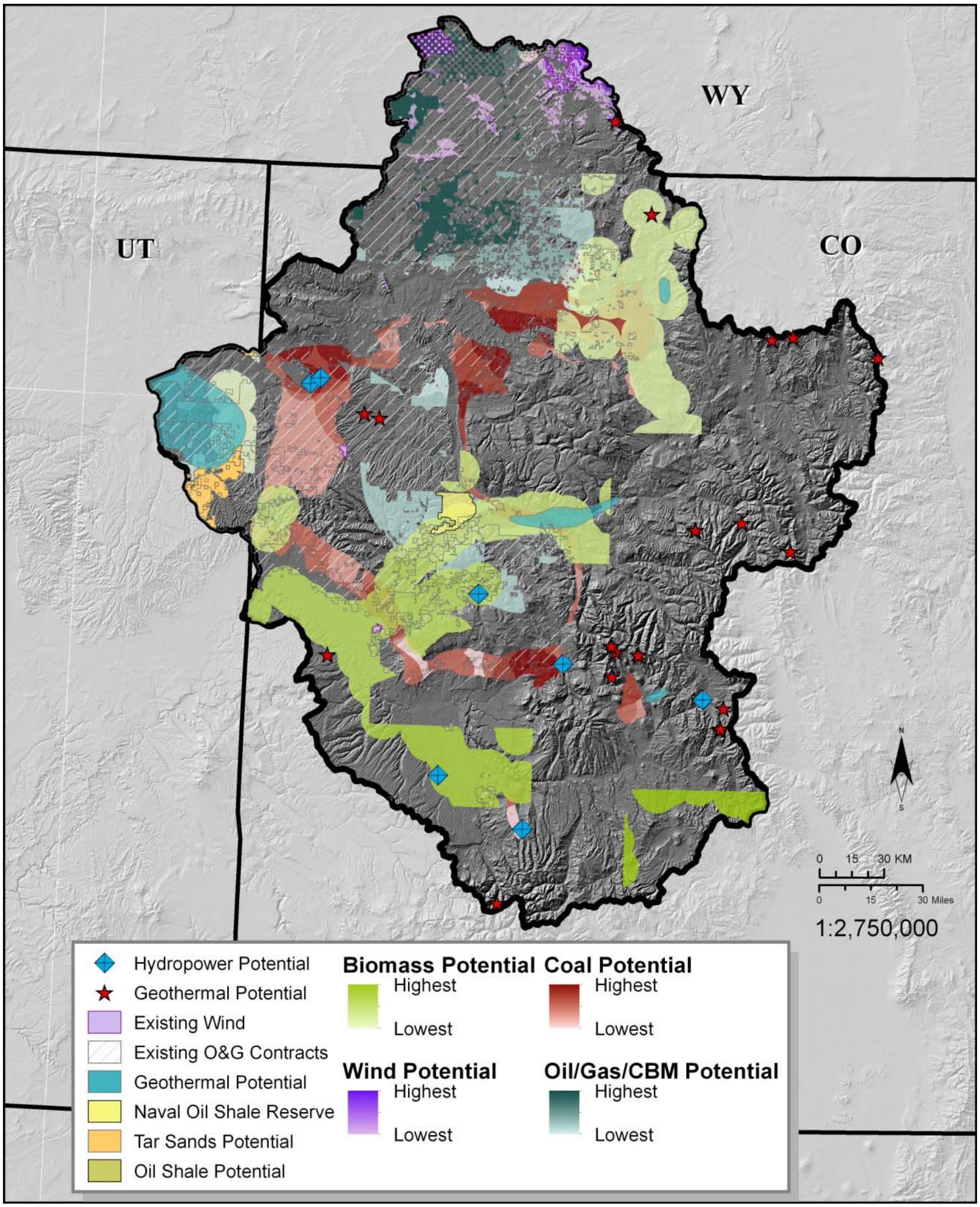
Moderate Conservation Scenario

Under Moderate Conservation (Figure 40), citizens of Colorado follow the lead of voters in 2004, who overrode politicians’ reluctance to set minimum renewable requirements by passing Amendment 37 and subsequently raised by legislation with public and industrial support. Continued widespread support from public, political, and industry sectors exists for raising the bar on renewable energy standards and increases to 40% for investor-owned utilities are codified.

A commitment is made to decreasing carbon emissions, and the necessity of moving away from fossil sources is seen as inevitable. Alternative energy sources begin to replace traditional forms and, through judicious use, fossil fuel sources are expected to support the transition. Continued export of coal helps stabilize regional social and economic structure and maintains international trade. In this storyline, economic recession has reduced consumer purchasing power and availability of goods, thereby reducing overall energy demand, and left people fiscally wary and concerned about continued availability of scarce resources.

Economic activity around new and developing energy production is predicted to create local manufacturing, industry, and jobs, which has a multiplying effect that eventually provides economic resilience and employment to smaller communities. This new economy must stay flexible and adaptive as resources, research, and development open new possibilities. Municipal energy companies and new investments stress locally available resources, which creates a spatially and economically diverse energy infrastructure.

Figure 40. Energy Development Scenario - Moderate Conservation



Alternative Futures

Three alternative futures have been developed by combining energy scenarios with habitat conservation scenarios. In this section, the futures are described and mapped in further detail. In the following chapter they will be evaluated using assessment models from criteria developed in the early Function and Structure stage of the work.

The first alternative future starts with the Moderate Conservation scenario for energy combined with the Management scenario for habitat. This selection of these two storylines provides a middle-of-the road view of one possible future. In the second future, the Protection scenario for habitat was paired with a Business-as-Usual energy development to compare an aggressive stance on habitat as a defense against the development of extractive industries. Finally, if a Buildout scenario for energy resources is the chosen direction, it will be a future with a focus on extraction taking priority over concerns for habitat. Therefore, restoration of small parcels of land will likely be the strategy necessary for wildlife habitat, and the Restoration scenario has been selected for this third alternative future.

Maps are created by an overlay process with GIS mapping. Figure 41 shows the application of geospatial selection and the implementation of the overlay process. As an initial step, the energy layers are combined to form the energy scenario. Areas for the selected habitat preservation scenario are added, and regions where overlap occurs are identified as conflicting areas. The resulting map represents the alternative future, and the geospatial data is then used in the assessment models to evaluate impacts. Figure 42 illustrates the process.

Figure 41. Selection and Overlay Process

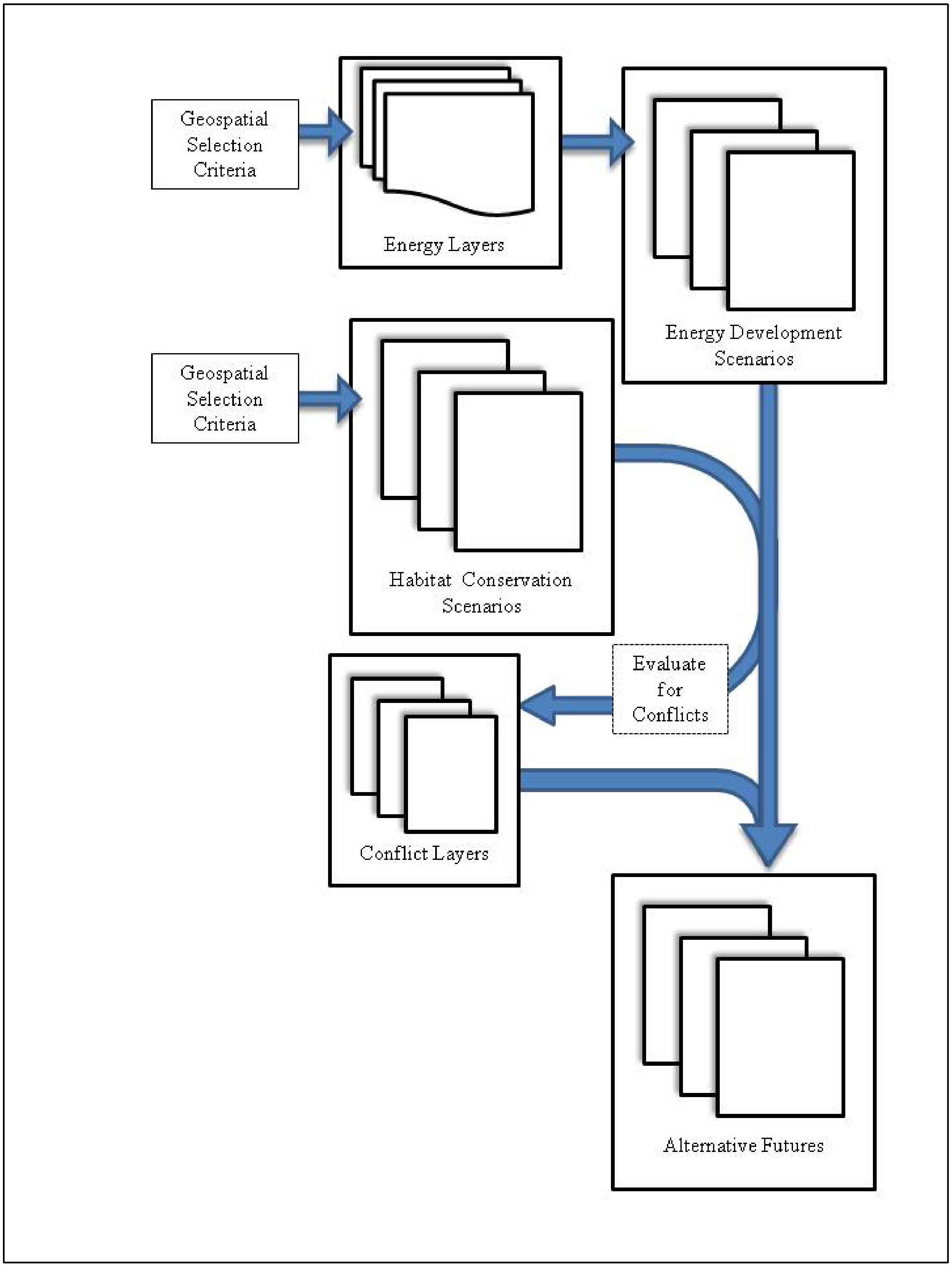
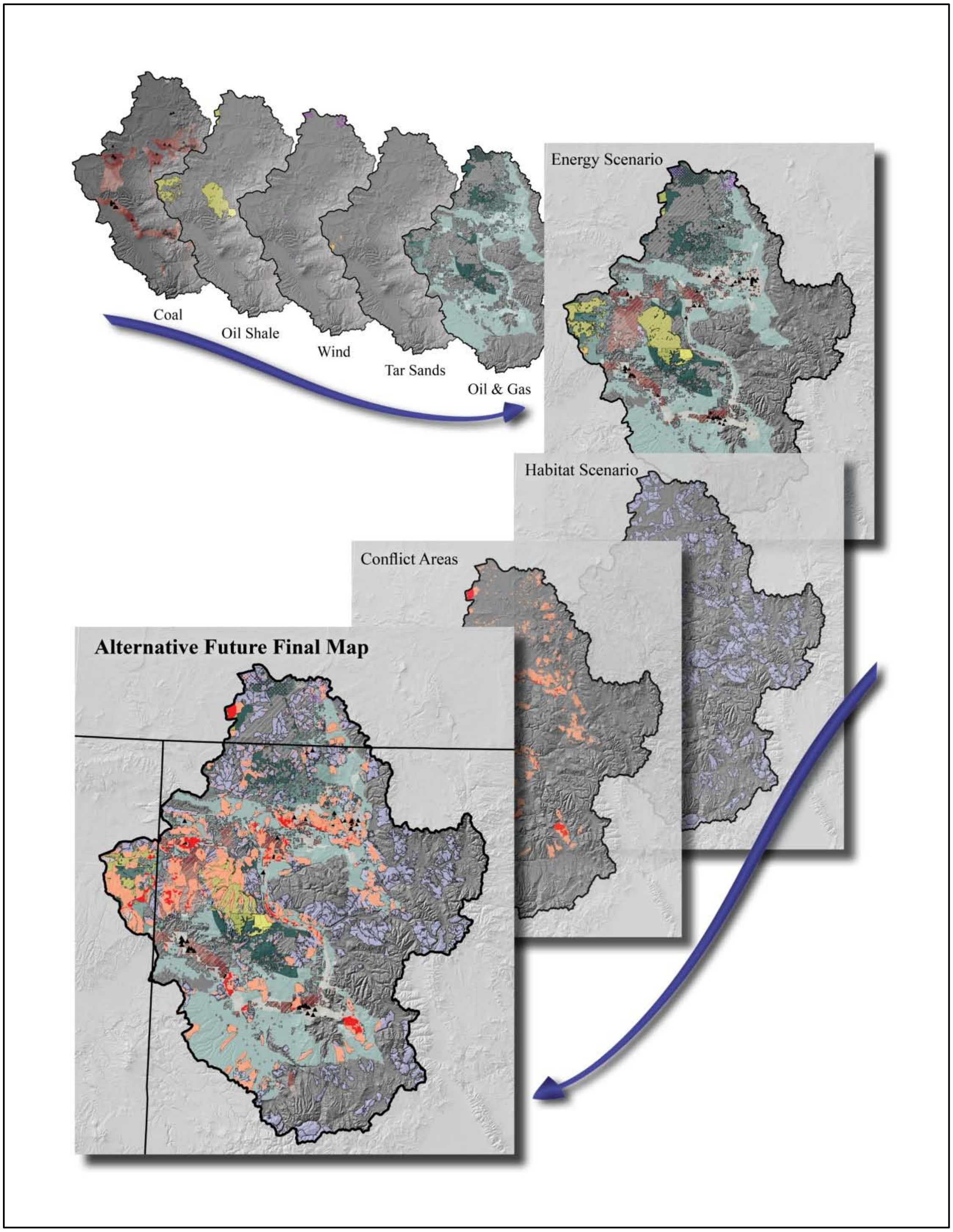


Figure 42. Example of Overlay Process for Alternative Futures



The following Figures 43, 44, and 45 show the composite mapping of these futures, and Figures 46, 47, and 48 highlight the areas of conflict between the land use projections. These are considered to be the areas of primary threat to habitat from anticipated energy development. Any energy resource, whether traditional or alternative, requires roads for access and maintenance, and carries the possibility of habitat disturbance or alteration. For this reason, all energy is considered to pose some degree of threat to the integrity of the habitat scenarios.

In the Alternative Futures maps (Figures 43, 44, and 45), individual energy sources are represented as they correspond to the projected need for each scenario. In these Alternative Futures maps, colors and symbols represent different energy sources. In the maps that follow, energy scenarios are symbolized monochromatically for purposes of simplifying the representation.

Figure 43. Alternative Future 1
Moderate Conservation Energy/Manage Wildlife Habitat

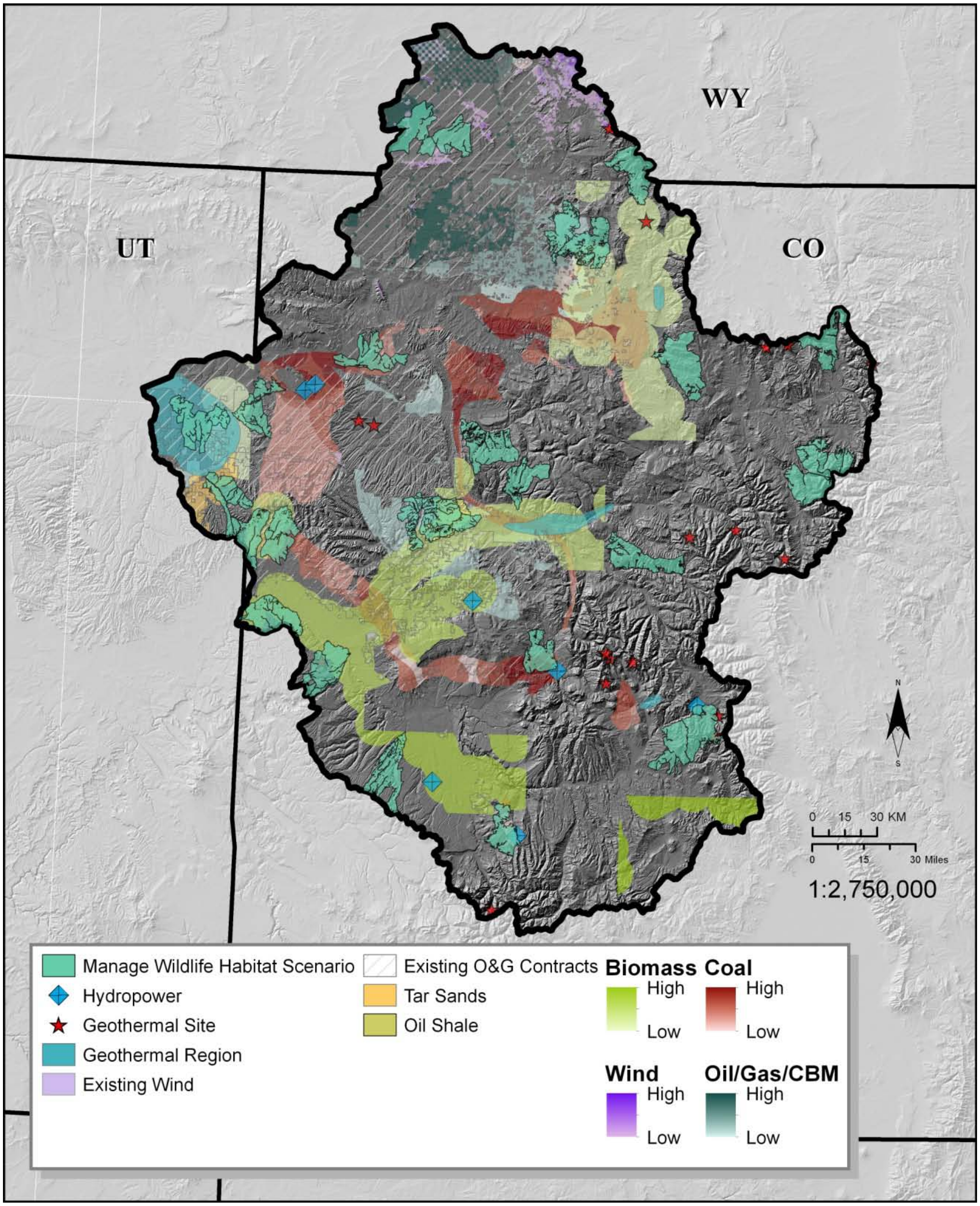


Figure 44. Alternative Future 2
Business-as-Usual Energy/Protect Wildlife Habitat

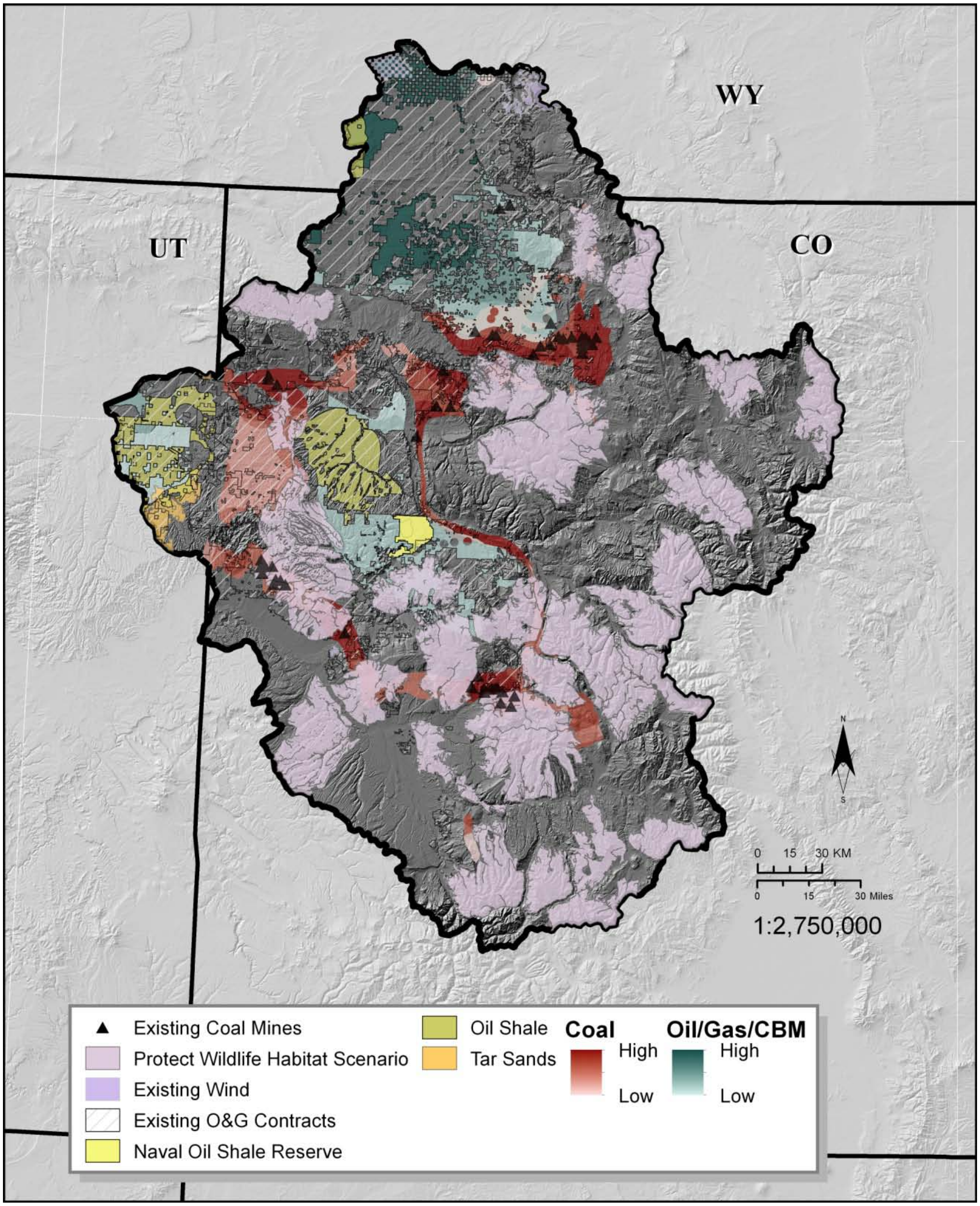


Figure 45. Alternative Future 3
Buildout Energy/Restore Wildlife Habitat

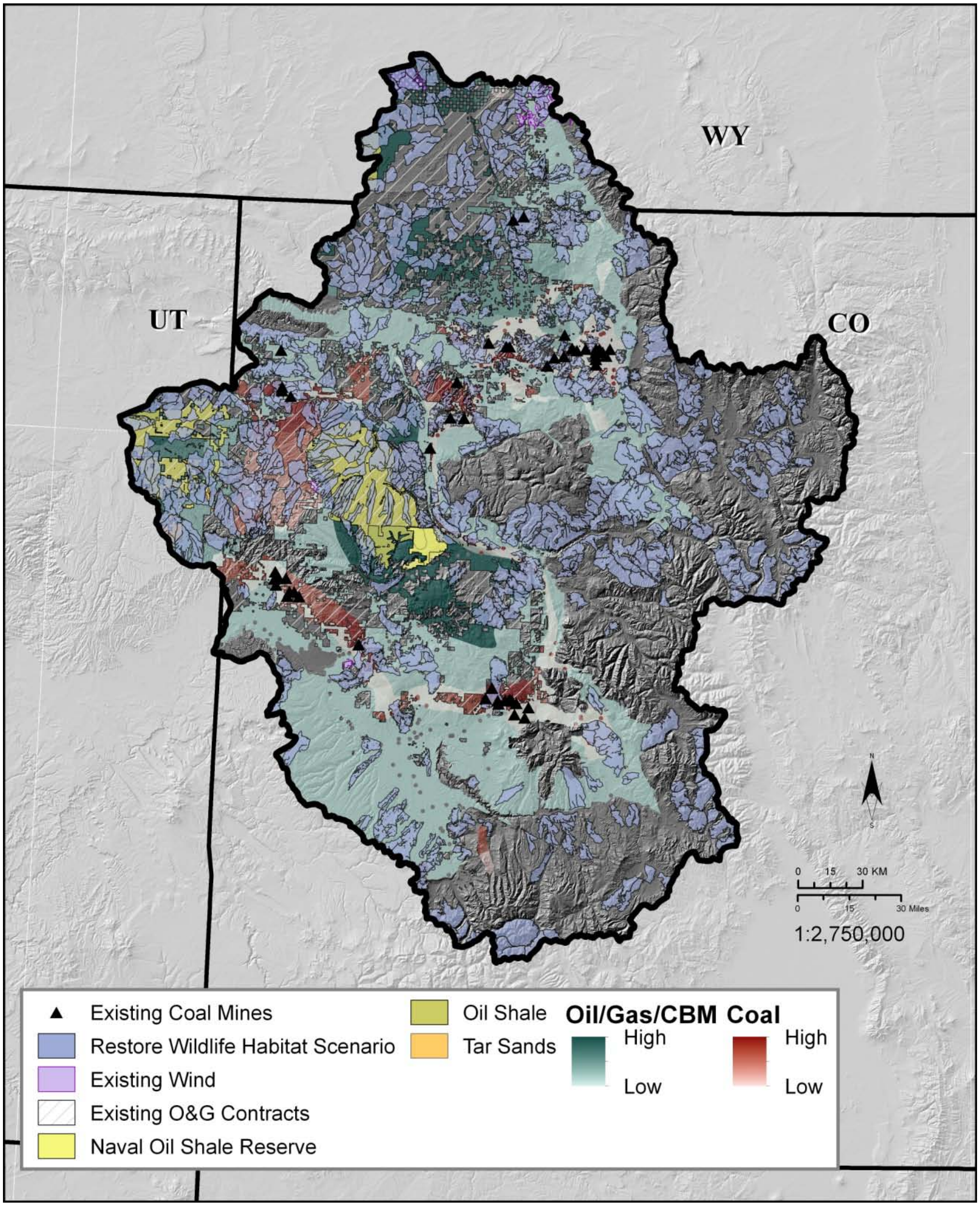


Figure 46. Alternative Future 1
Moderate Conservation Energy/Manage Wildlife Habitat with Conflicts

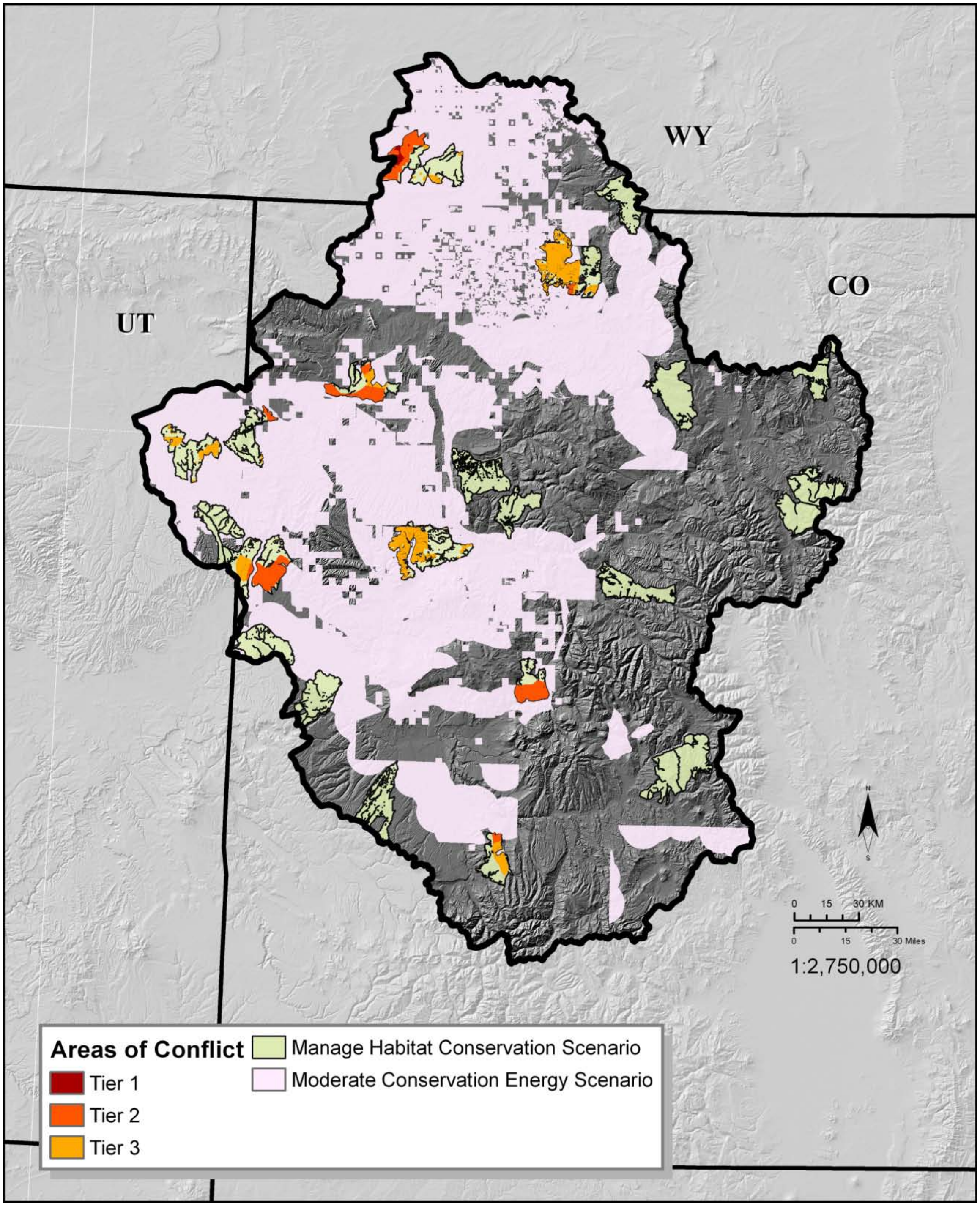


Figure 47. Alternative Future 2
Business-as-Usual Energy/Protect Wildlife Habitat with Conflicts

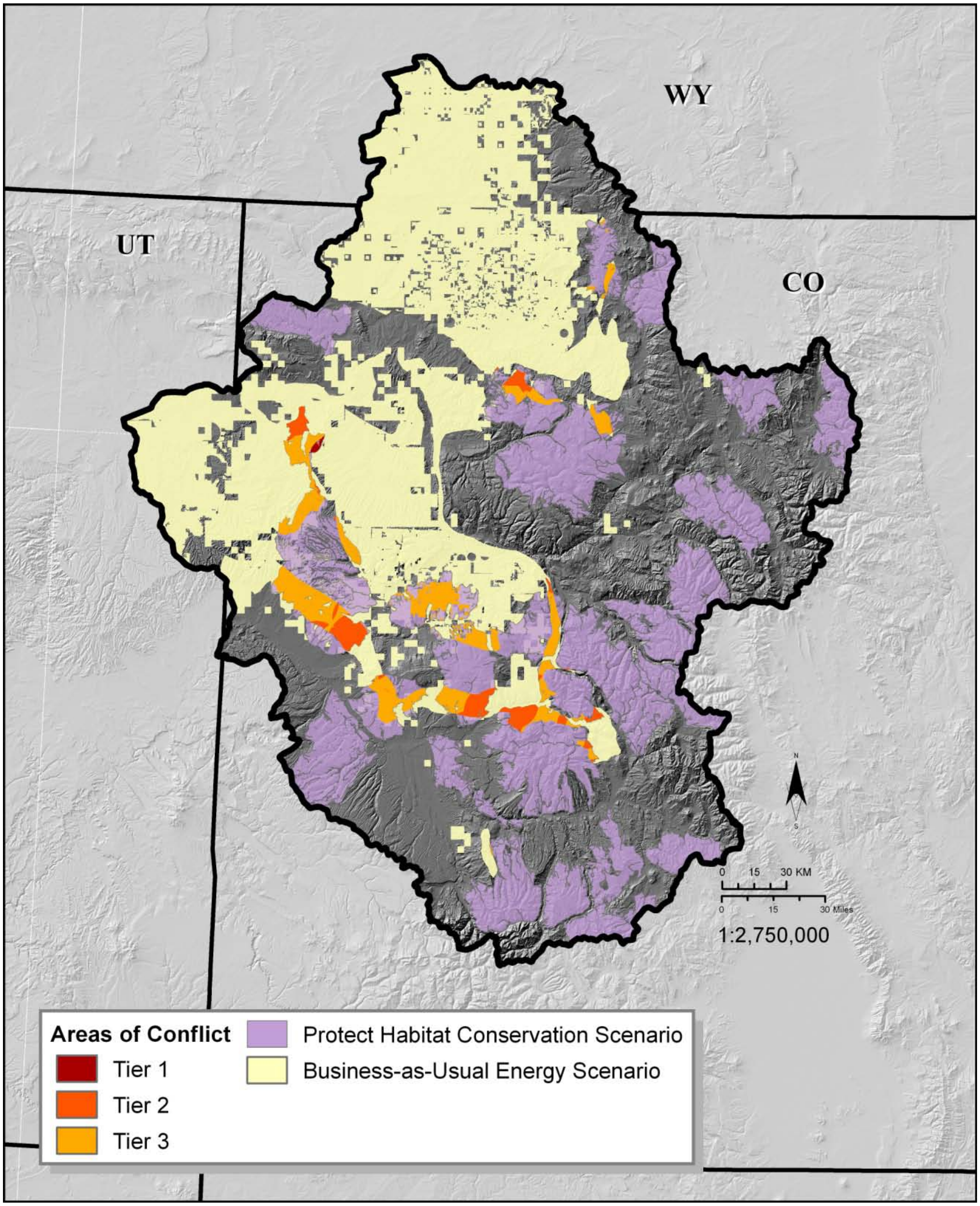
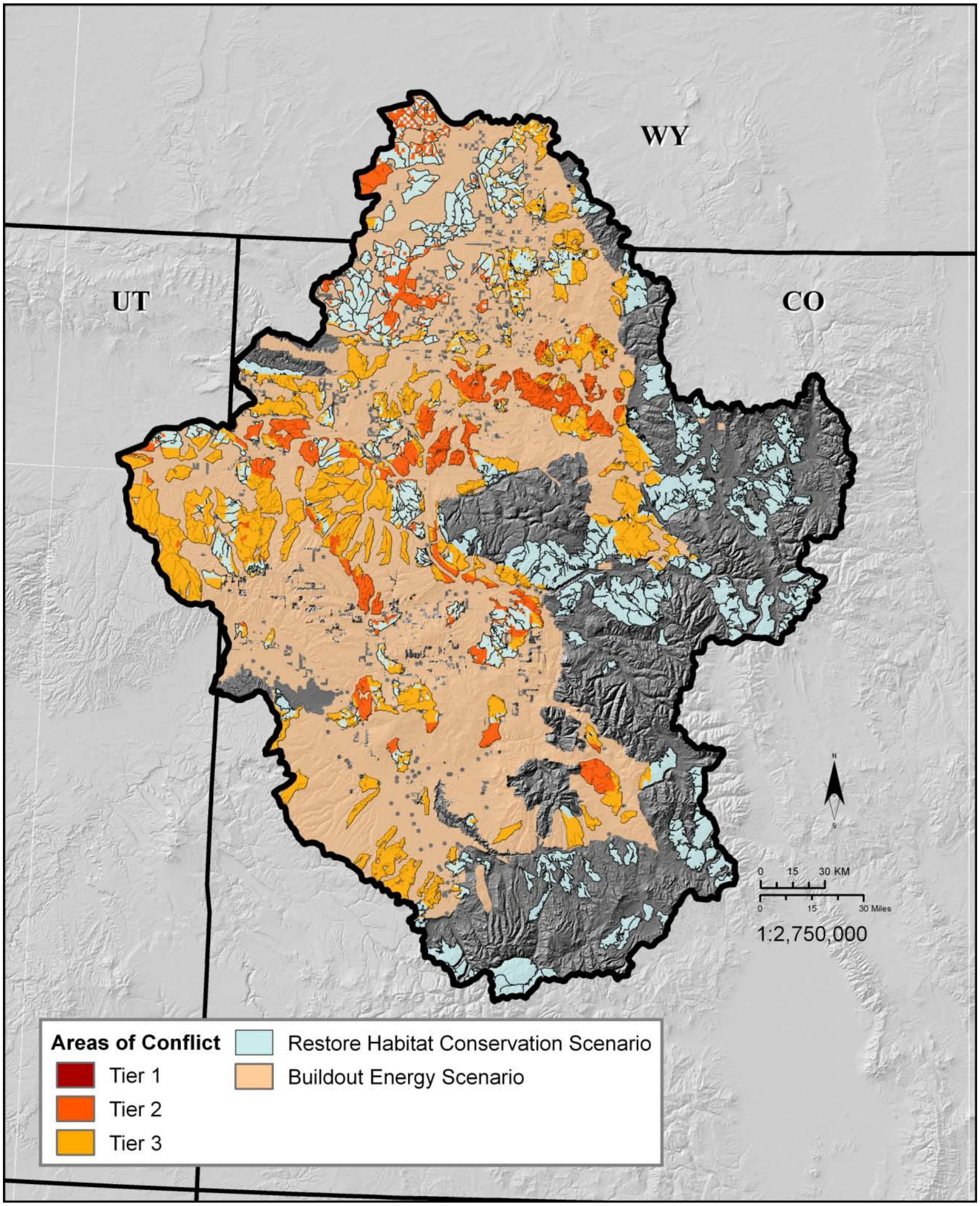


Figure 48. Alternative Future 3
Buildout Energy/Restore Wildlife Habitat with Conflicts



CHAPTER 6

ASSESSMENTS

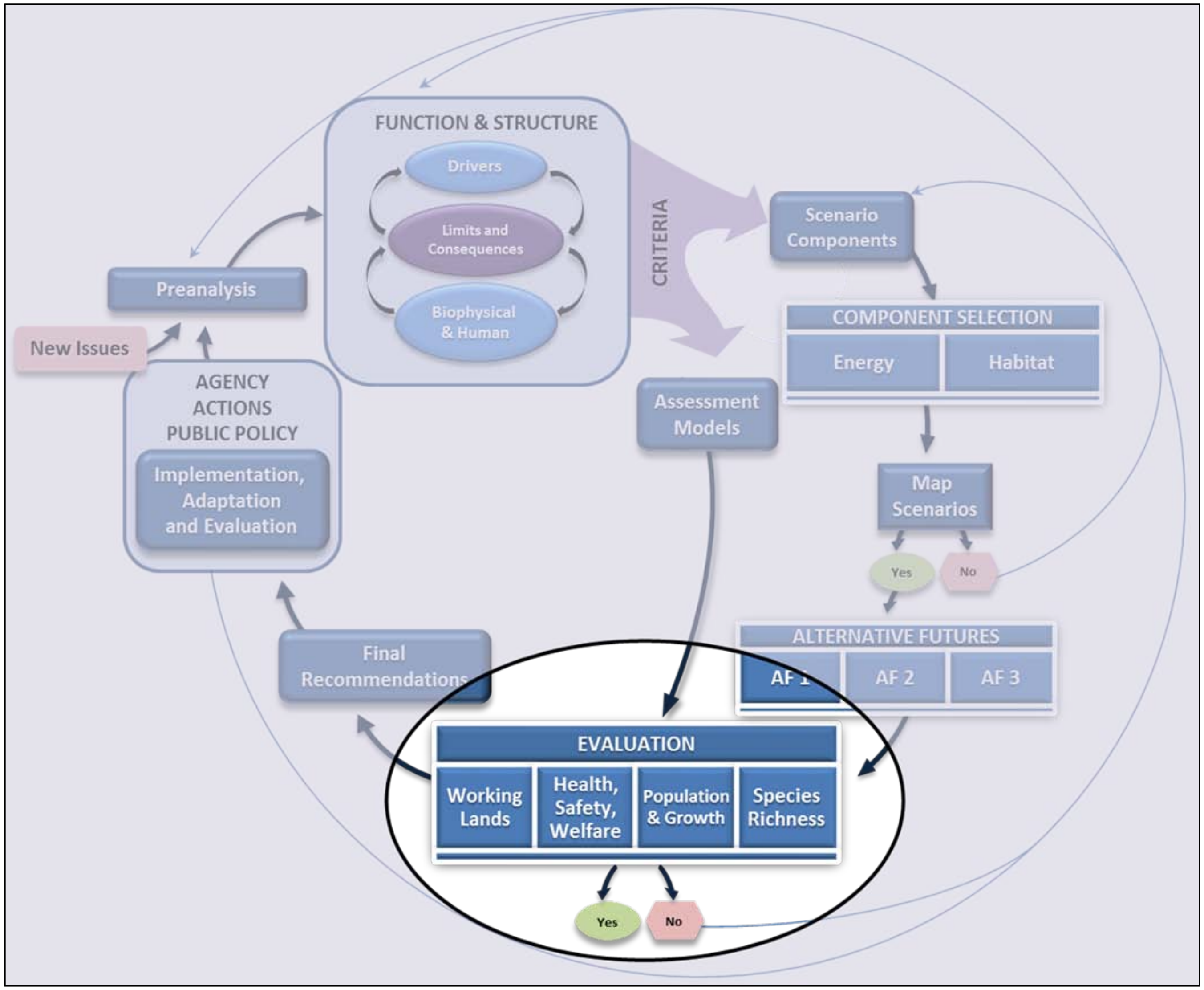
In the assessment stage, models were used to understand the ecological, social, and economic implications of each alternative future. These models allowed evaluation of area available for public health, welfare, safety and growth; degree of species richness conservation; agriculture and rangeland impacts; and potential for compatible uses with farms and rangelands. Conflicts are represented in the tiered format outlined in Chapter 4, with Tiers 1, 2, and 3 representing high, medium, and low levels of anticipated conflict, respectively. The Assessment process is highlighted in Figure 49.

Public Health, Safety, and Welfare and Development Assessment

This assessment model is designed to find suitable areas for human settlement from the standpoint of public health, safety, and welfare concerns. On top of this basic landform and land use suitability, additional criteria for each energy scenario are added to forecast areas likely to be under pressure for urban, suburban, or exurban development as the population in the region grows (shown in Figure 50).

Futures using the Buildout energy scenarios emphasize development near energy extraction and production. This may result in new towns, as well as expansion of existing towns near new mines or energy fields. The Business-as-Usual scenario is based on previous patterns of settlement in the region. These include lower-density development and a continuation of development trends near I-70, especially in Grand, Eagle, Pitkin, and Summit Counties, generally for second homes or recreational properties. Moderate

Figure 49. Process Diagram Highlight - Assessment Process



Conservation scenarios project infill development in areas of existing low and medium density, and concentrate on areas close to existing towns. Table 9 summarizes the criteria and preferences for this model.

Those regions identified as likely to be targeted for development are represented in the following maps (Figures 51, 52, and 53) specific to the three alternative futures. They show areas that may be available for development if habitat conservation restrictions exclude development according to the scenarios in each future. Areas are represented in two tiers, high and moderate probability, on the basis of these assumptions.

Figure 50. Assessment Model
Public Health, Safety, and Welfare, Development Potential

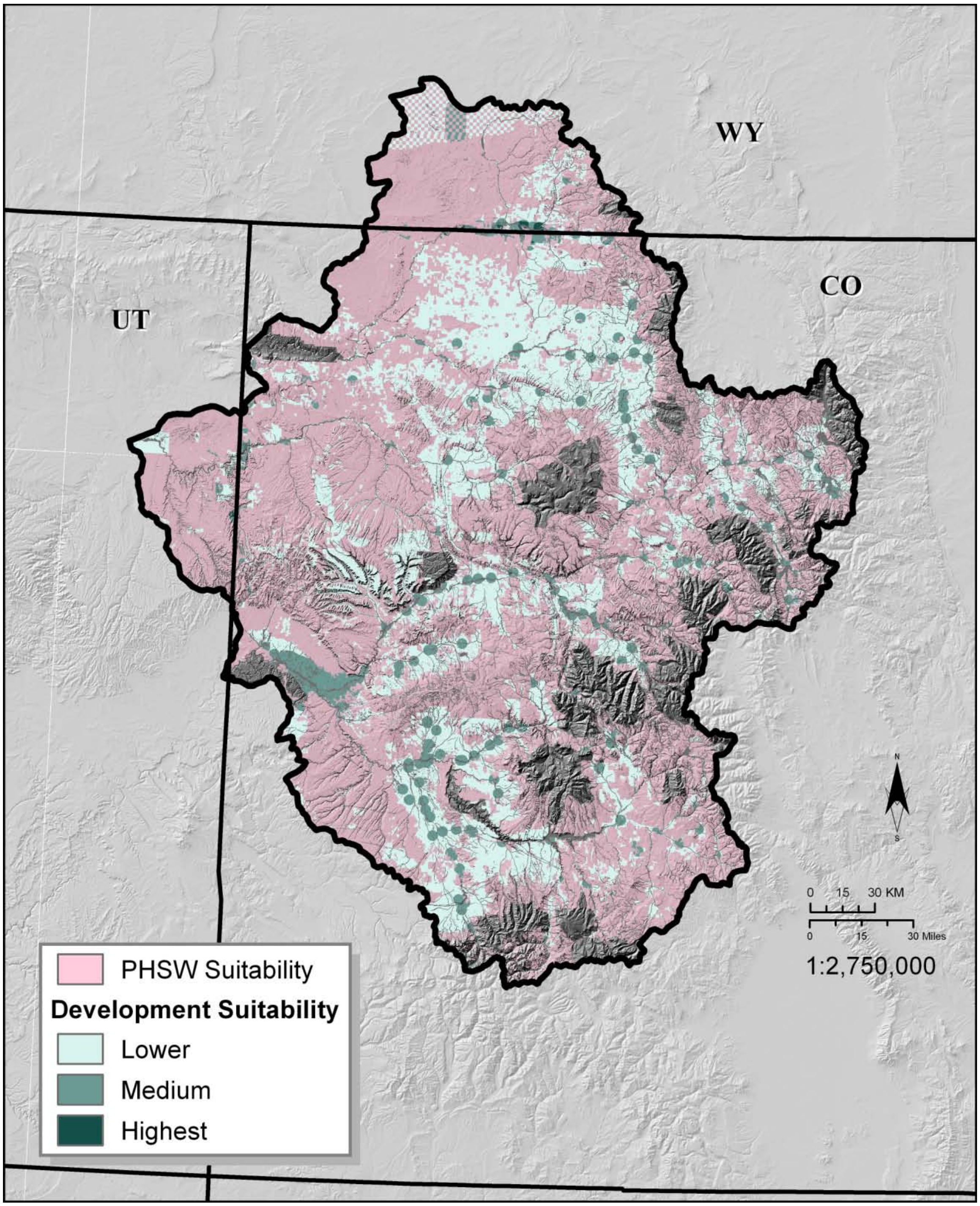


Table 9

Selection Criteria for Public Health, Safety, and Welfare and Development Model

Public Health, Welfare & Safety Criteria
Slope <30%
300 M buffer for perennial streams and rivers
No wetlands
No perennial ice/snow
No barren land
No existing oil and oas leases
General Development Criteria
<5K distance to existing roads
Prefer 15K to towns/urban areas
Private lands
Scenario Priorities
Buildout - near energy development potential
Business-as-Usual - Within 15 K of I-70, Preference for Summit, Grand, Pitkin, Eagle Counties
Moderate Conservation - Within 10K of existing towns, Preference for existing Low and Medium Density

Figure 51. Public Health, Safety, and Welfare/Development Assessment
Alternative Future 1, Moderate Conservation/Manage

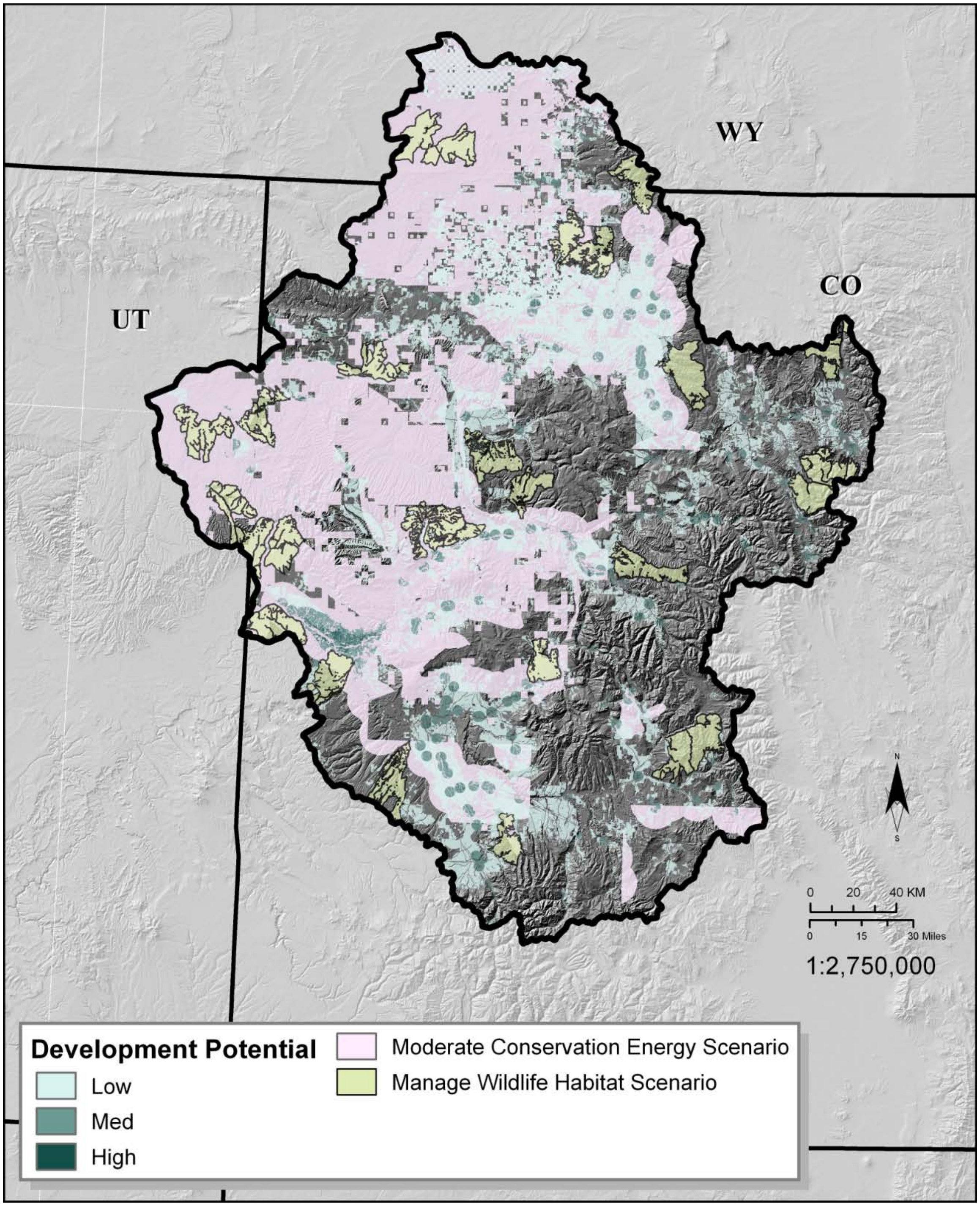


Figure 52. Public Health, Safety and Welfare/Development Assessment
Alternative Future 2, Business-as-Usual/Protect

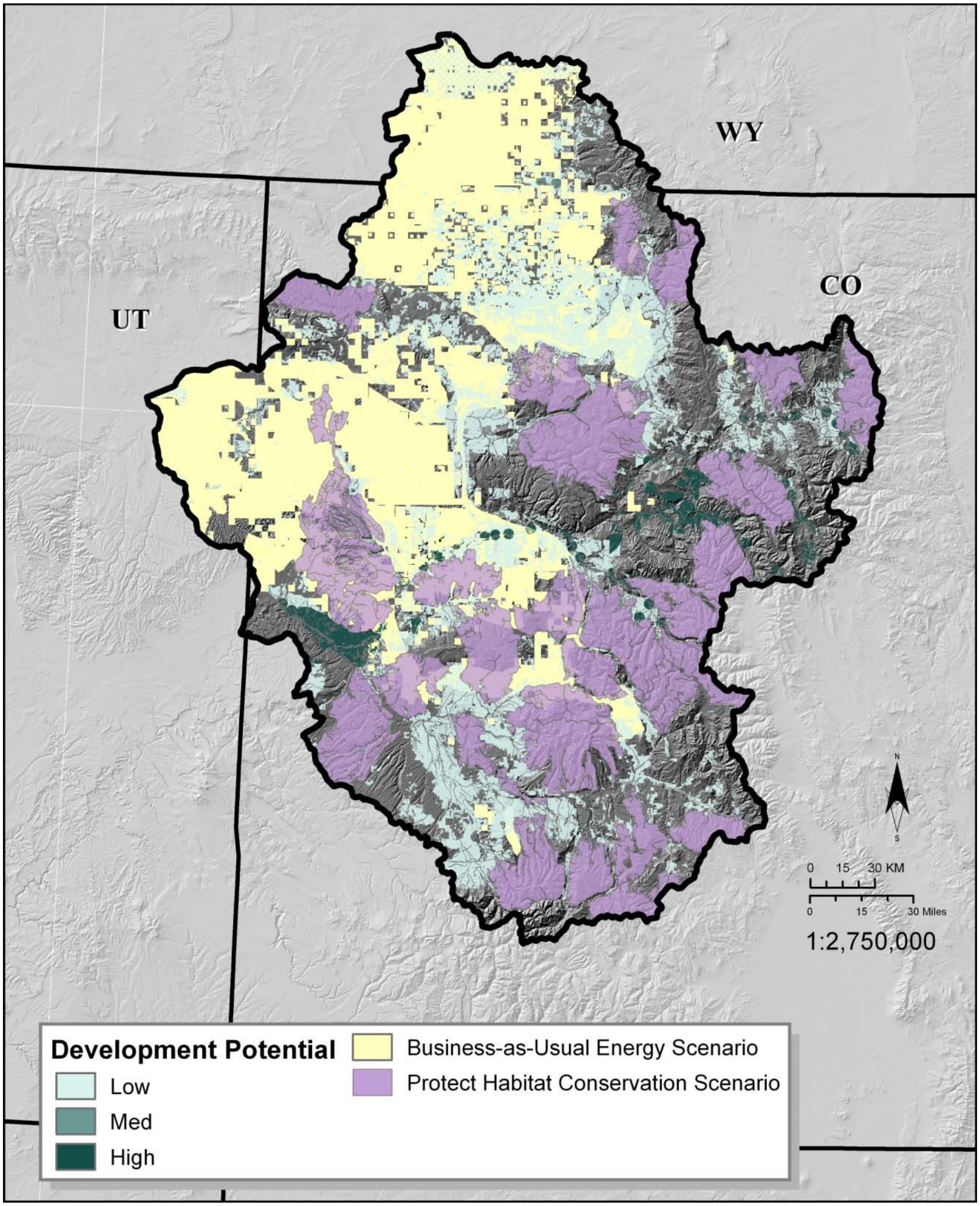
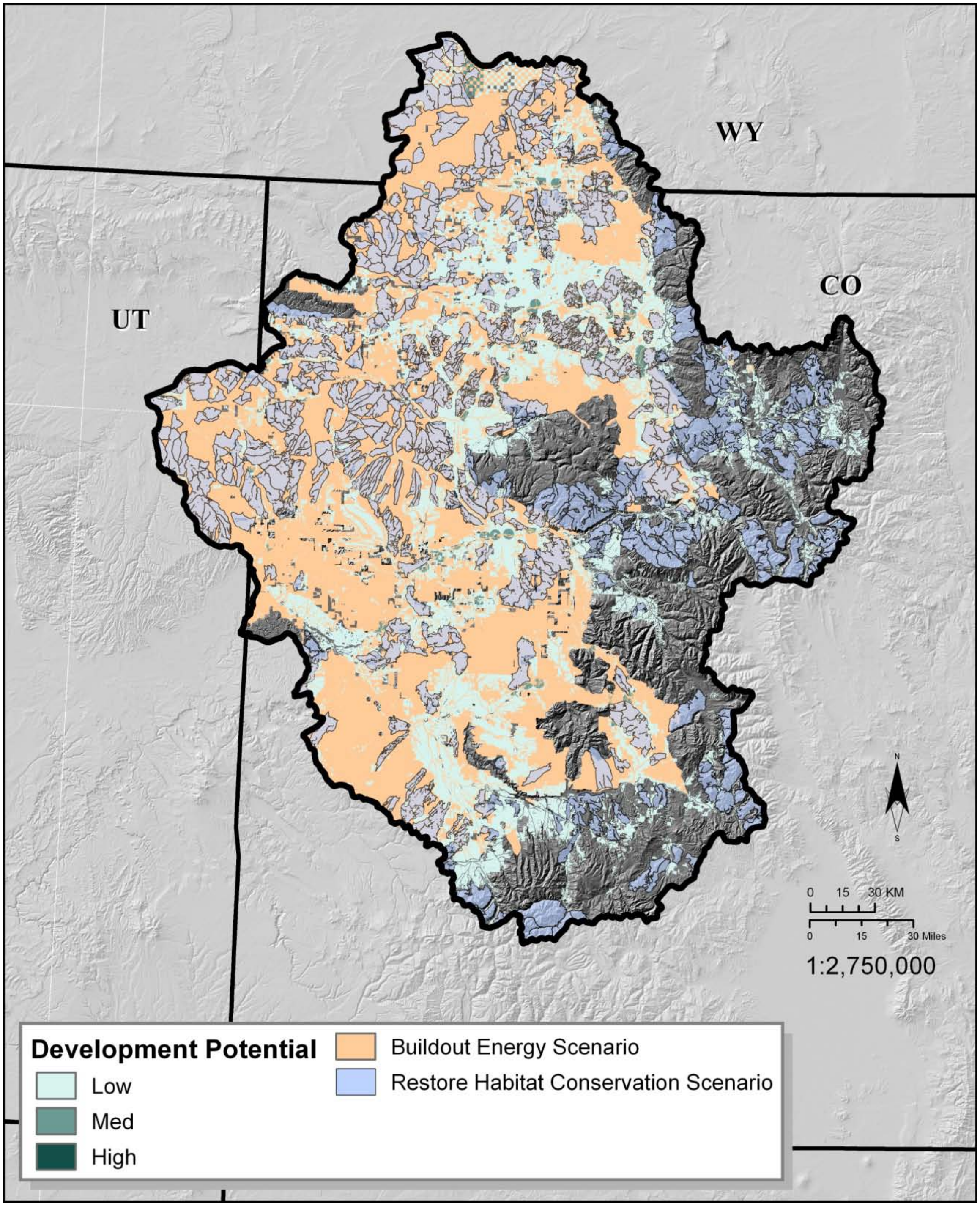


Figure 53. Public Health, Safety and Welfare/Development Assessment
Alternative Future 3, Buildout/Restore



The NLCD 1992-2001 Land Cover Retrofit Change data indicates that the vast majority of land converted to urban uses in the study area during that time was private land. During those nine years, a total of 8.4 square kilometers, or 2,075 acres, became urbanized. This average rate is approximately 231 acres per year. Census figures show that the approximate population of the region grew 34.4% over the period between 1990 and 2000. Based on state level projections for population from 2000 to 2030, population for the region will grow from about 325,600 to 706,100, an increase of 380,500 people. This means that if building patterns continue as they were during that time, land needed to accommodate this expected growth will be roughly equivalent to 117% of the area currently occupied by development. These estimates indicate that 7,830 acres could be converted to urban uses by 2030, based on past trends. The Moderate Conservation scenario includes NLCD areas that have potential for infill development; other scenarios do not. Table 10 shows the area identified by the PHSW and Development assessments that would be available for development under the criteria applied. For all futures, there is more than enough area available for development that would not interfere with selected habitat protection models. Futures 2 and 3 have sufficient availability in the highest suitability category, while Future 1 relies on some medium suitability area to meet demand for land to accommodate expected growth. Actual land use development will, of course, depend on a myriad of factors, such as local zoning, landowner preferences, density, infrastructure availability, and site-specific building considerations.

Table 10

Assessment of Availability of Land for Development

Area Description/Criteria		sq KM	Hectares
Total in Region		8,056.36	805,636.00
Overall Development Criteria		1,909.20	190,920.00
Future 1 - Total Development Available		1,423.96	142,396.00
	High	0.18	18.00
	Medium	38	3,800.00
Future 2 - Total Development Available		1,539.61	153,961.00
	High	39.86	3,986.00
Future 3 - Total Development Available		1,173.98	117,398.00
	High	90.72	9,072.00
Area Est. to Accommodate Development		31.69	3,169.00

Species Richness

The Species Richness assessment model is based upon the species richness data collected in the first year of the project. These data are from GAP projects, and ratings represent potential habitat for numbers of species viable in a spatial distribution (as described in Chapter 3). The Colorado and Utah portions of the study area draw from the South West Regional GAP Analysis Project's (SWReGAP) Animal Habitat Models. Because Wyoming was not part of the SWReGAP, Wyoming GAP Analysis (WYGAP) data were used for the Wyoming lands. Due to a difference in methods, the data differs slightly in the WYGAP and accounts for the artificially abrupt change in species number data at the state line. Species richness information for the entire phase two region was shown earlier in Figure 19. The Species Richness Assessment model makes use of this data to evaluate conservation in the three alternative futures.

This assessment takes place in four parts. The first three maps (Figures 54, 5,5 and 56) display the species richness within the areas for each of the habitat preservation models, Manage, Protect, and Restore. The second set of maps (Figures 57, 58, and 59) shows species richness for the land identified to be in conflict between the habitat and energy models for each of the three alternative futures. Next, Figures 60, 61, and 62 show high and medium species richness categories according to land ownership. This may help direct efforts toward lands that may be more easily protected. A summary of the Species Richness Assessment maps is given in Table 11. Table 12 provides a summary of the area in the region according to highest projected species richness according to ownership. It also lists the percentages of land protected under each of the wildlife habitat scenarios for both federal and state lands, and the total for all ownership types.

Table 11

Species Richness Assessment Map Summary

Figure	Title
54	Potential Species Richness within Manage Habitat Conservation Scenario
55	Potential Species Richness within Protect Habitat Conservation Scenario
56	Potential Species Richness within Restore Habitat Conservation Scenario
57	Species Richness Assessment - Conflict in Alternative Future 1, Moderate Conservation/Manage
58	Species Richness Assessment - Conflict in Alternative Future 2, Business-as-Usual/Protect
59	Species Richness Assessment - Conflict in Alternative Future 3, Buildout/Restore
60	Species Richness Assessment - Ownership of High Value-Habit Lands, Manage Habitat Scenario
61	Species Richness Assessment - Ownership of High Value-Habit Lands, Protect Habitat Scenario
62	Species Richness Assessment - Ownership of High Value-Habit Lands, Restore Habitat Scenario
63	Species Richness Assessment - High Value Habitat not included in Alternative Future 1, Moderate Conservation/Manage
64	Species Richness Assessment - High Value Habitat not included in Alternative Future 2, Business-as-Usual/Protect
65	Species Richness Assessment - High Value Habitat not included in Alternative Future 3, Buildout/Restore

Figure 54. Potential Species Richness within Manage Habitat Conservation Scenario

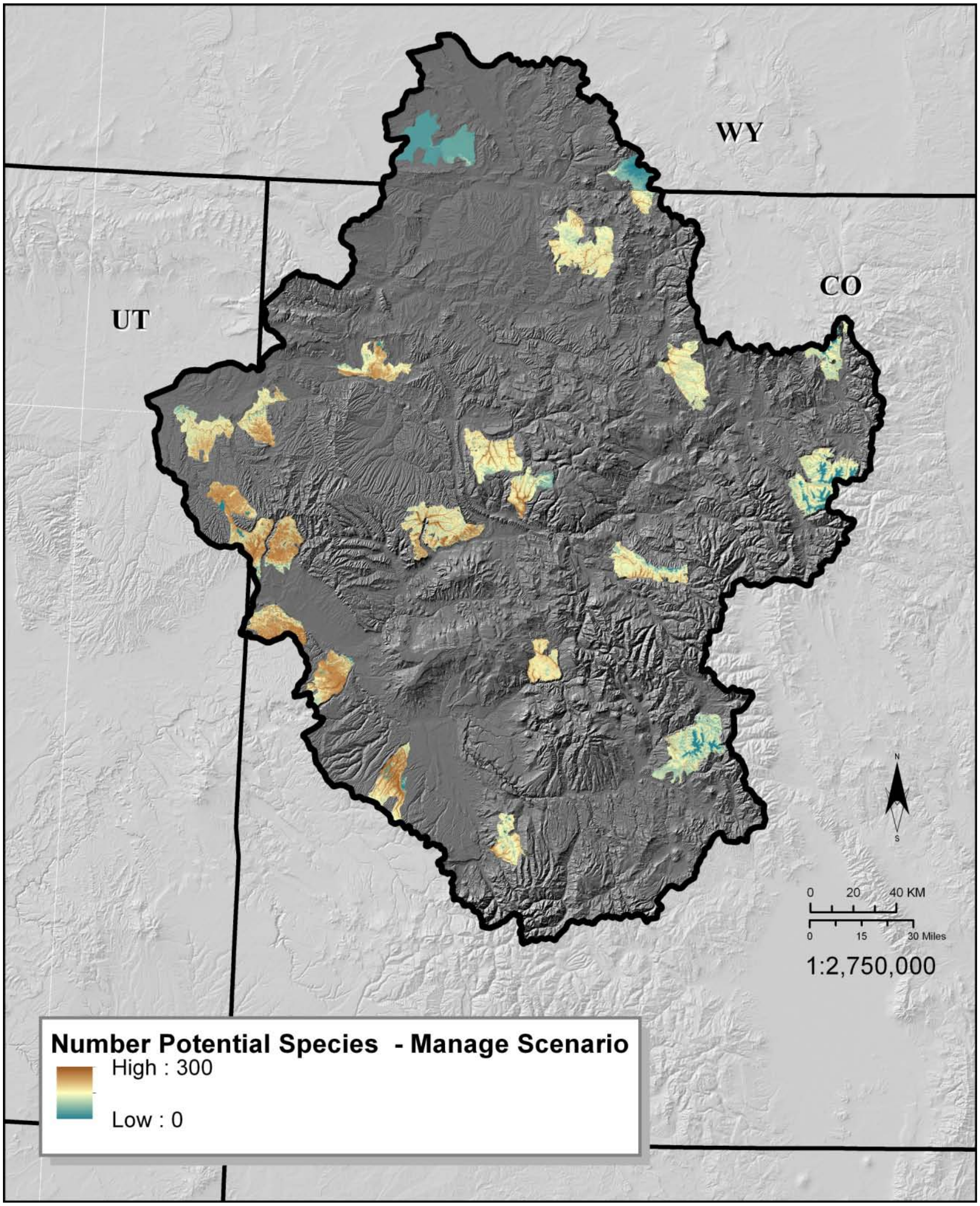


Figure 55. Potential Species Richness within Protect Habitat Conservation Scenario

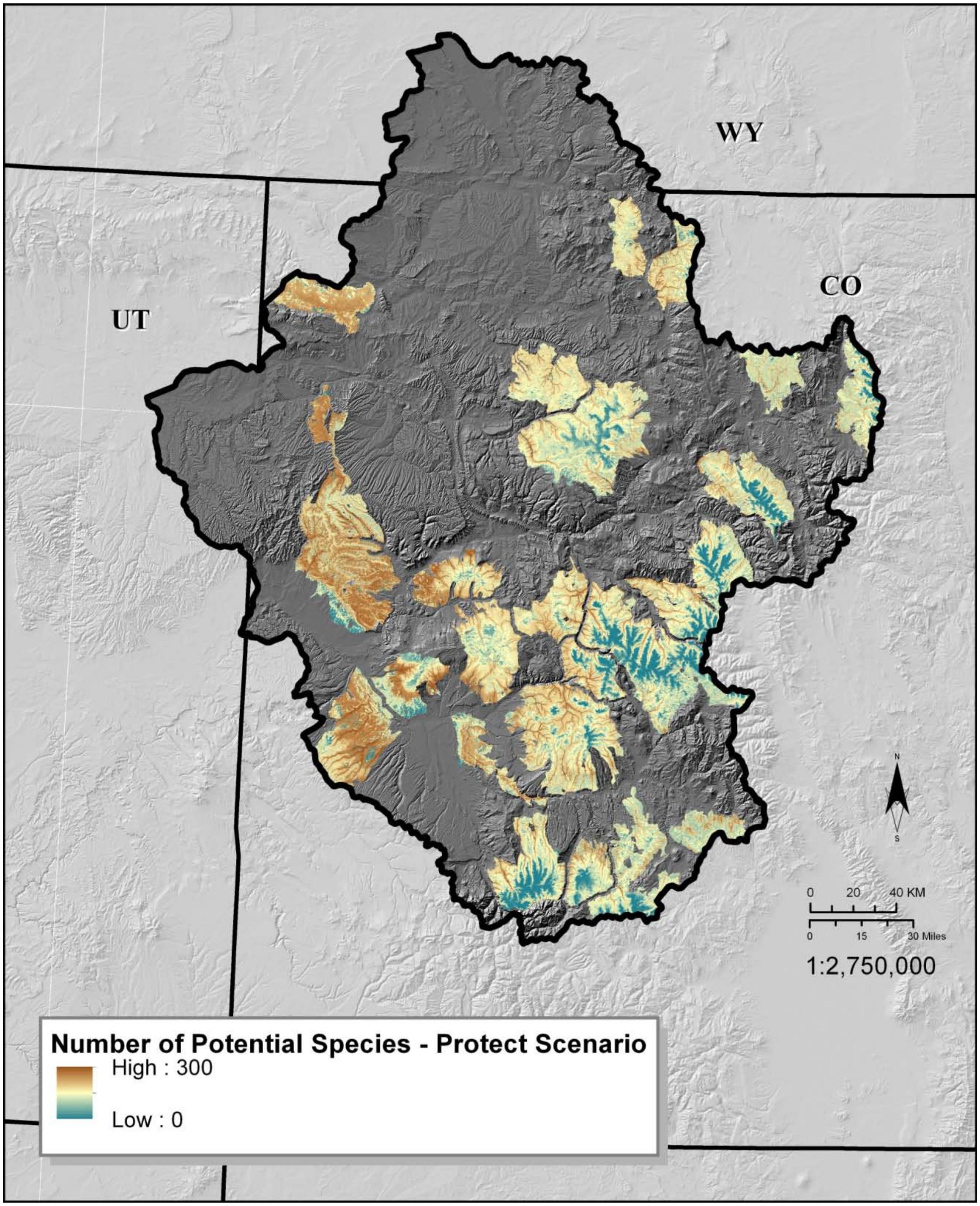


Figure 56. Potential Species Richness within Restore Habitat Conservation Scenario

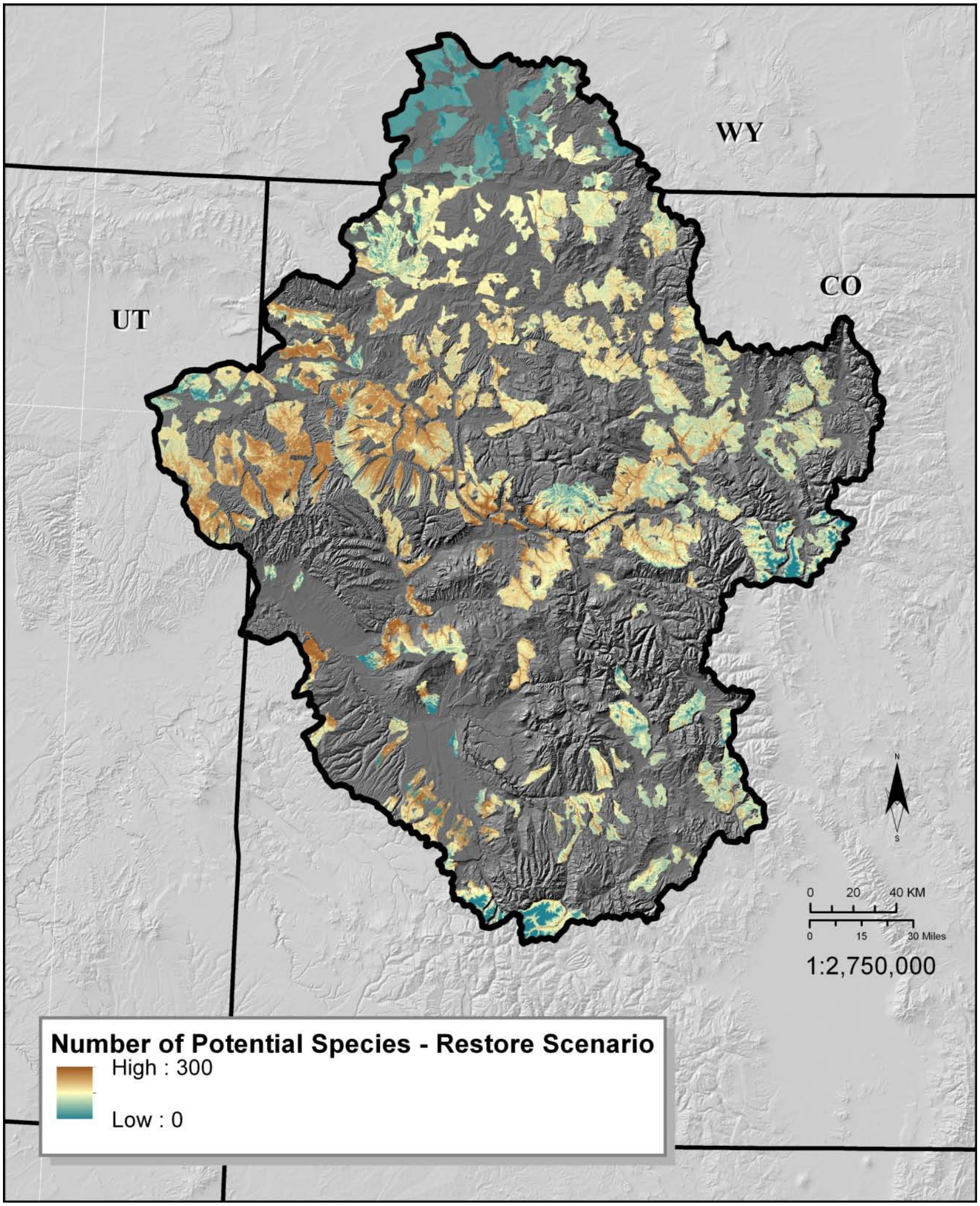


Figure 57. Species Richness Assessment
Conflict in Alternative Future 1, Moderate Conservation/Manage

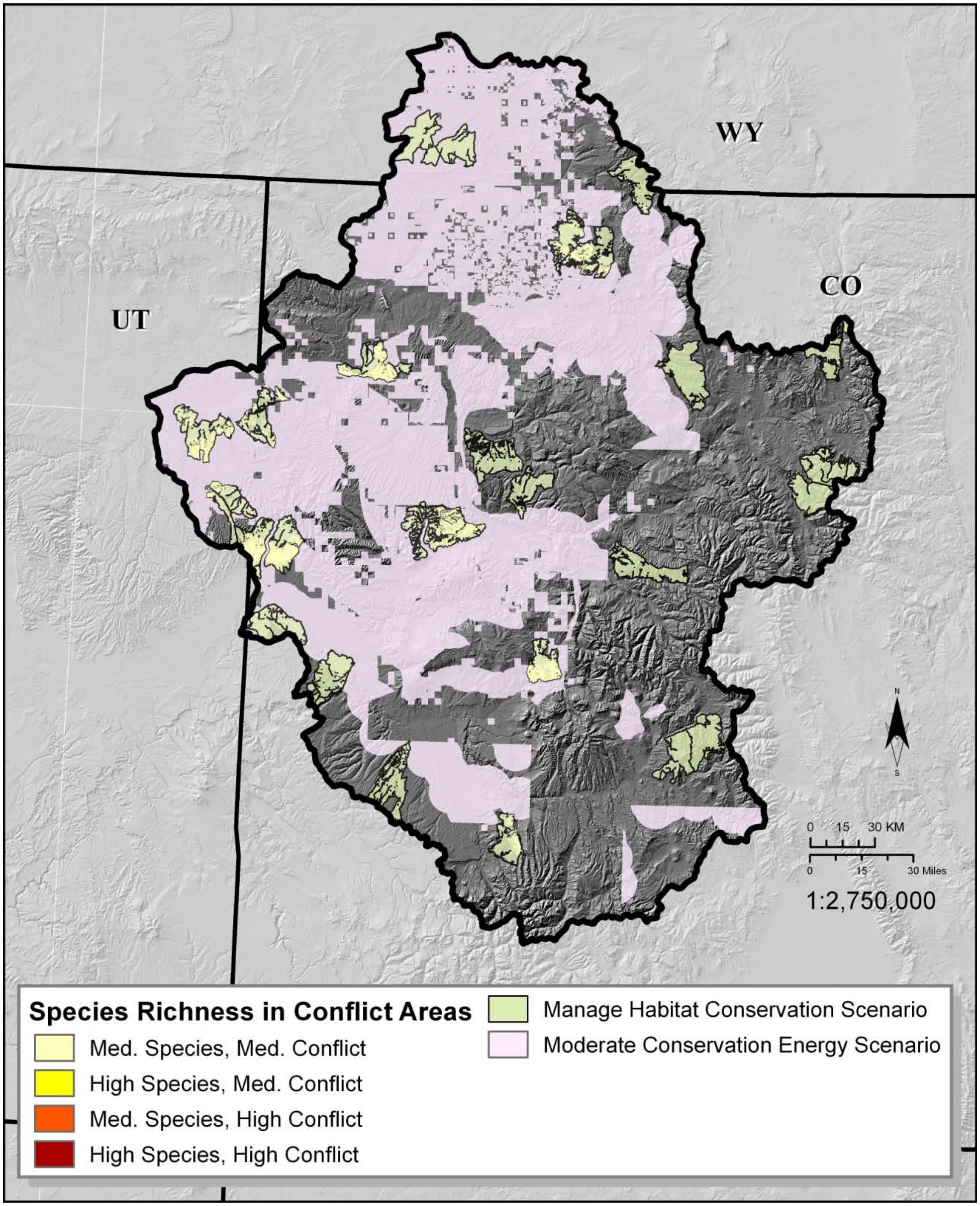


Figure 58. Species Richness Assessment
Conflict in Alternative Future 2, Business-as-Usual/Protect

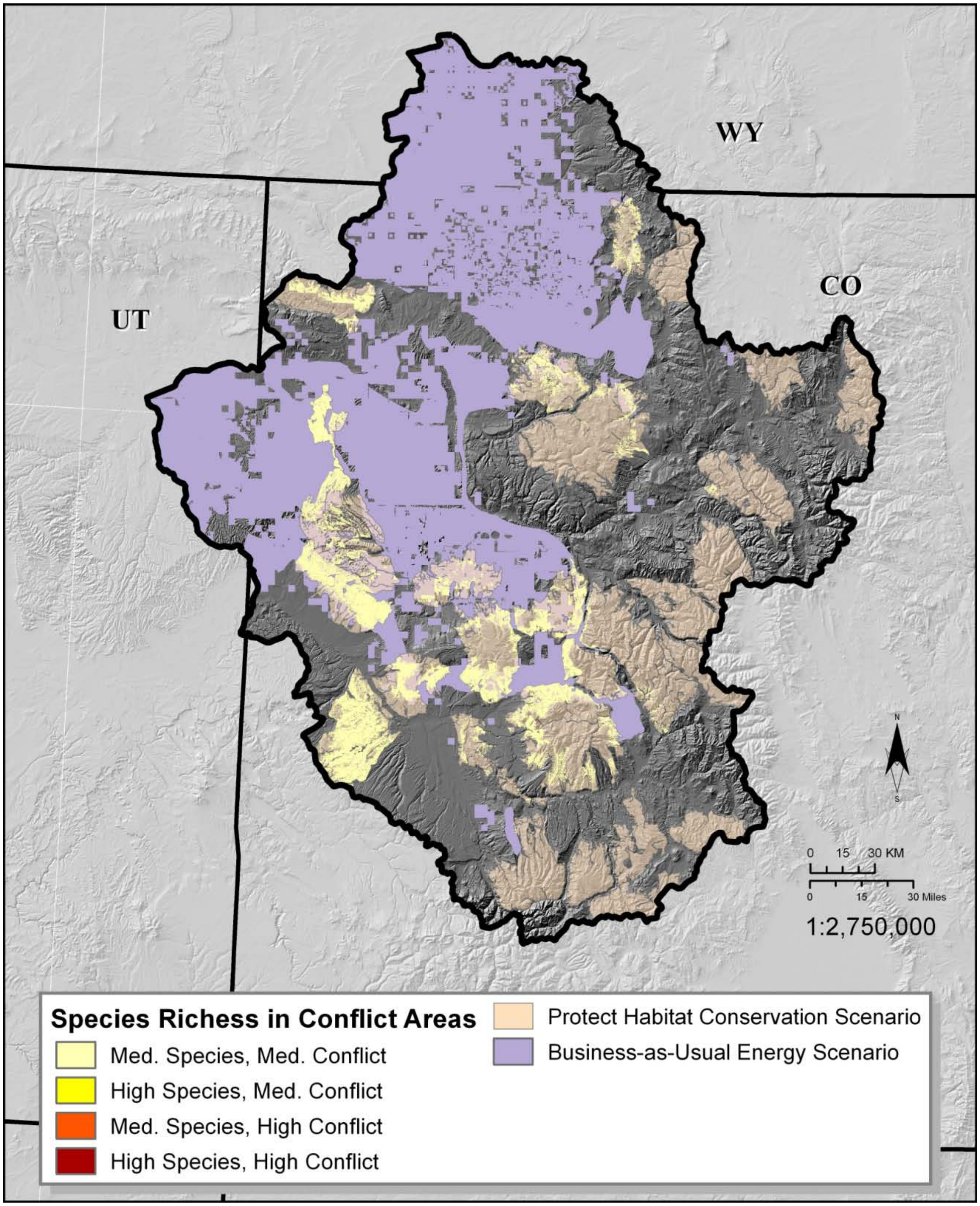


Figure 59. Species Richness Assessment
Conflict in Alternative Future 3, Buildout/Restore

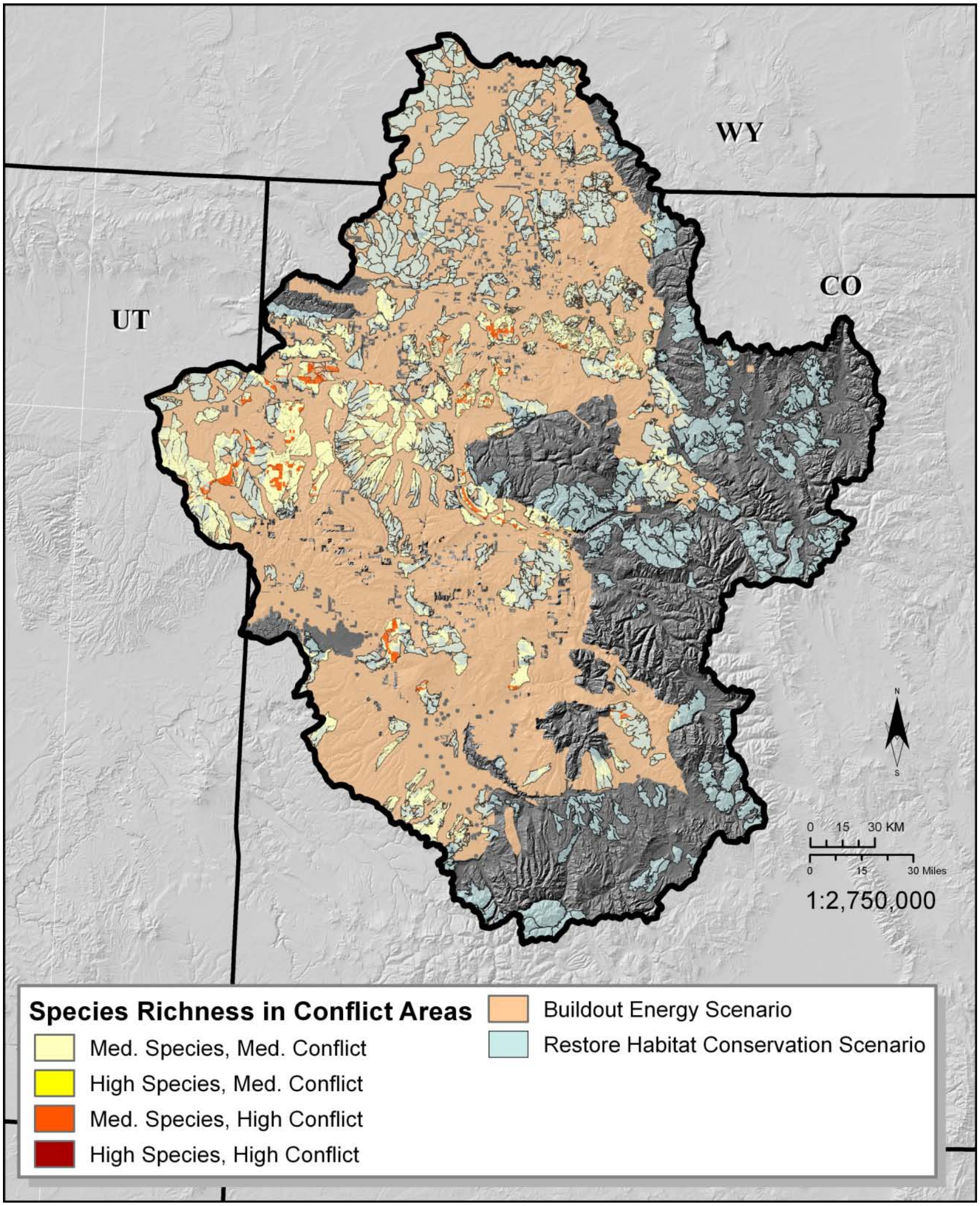


Figure 60. Species Richness Assessment
Ownership of High Value Habit Lands, Manage Habitat Scenario

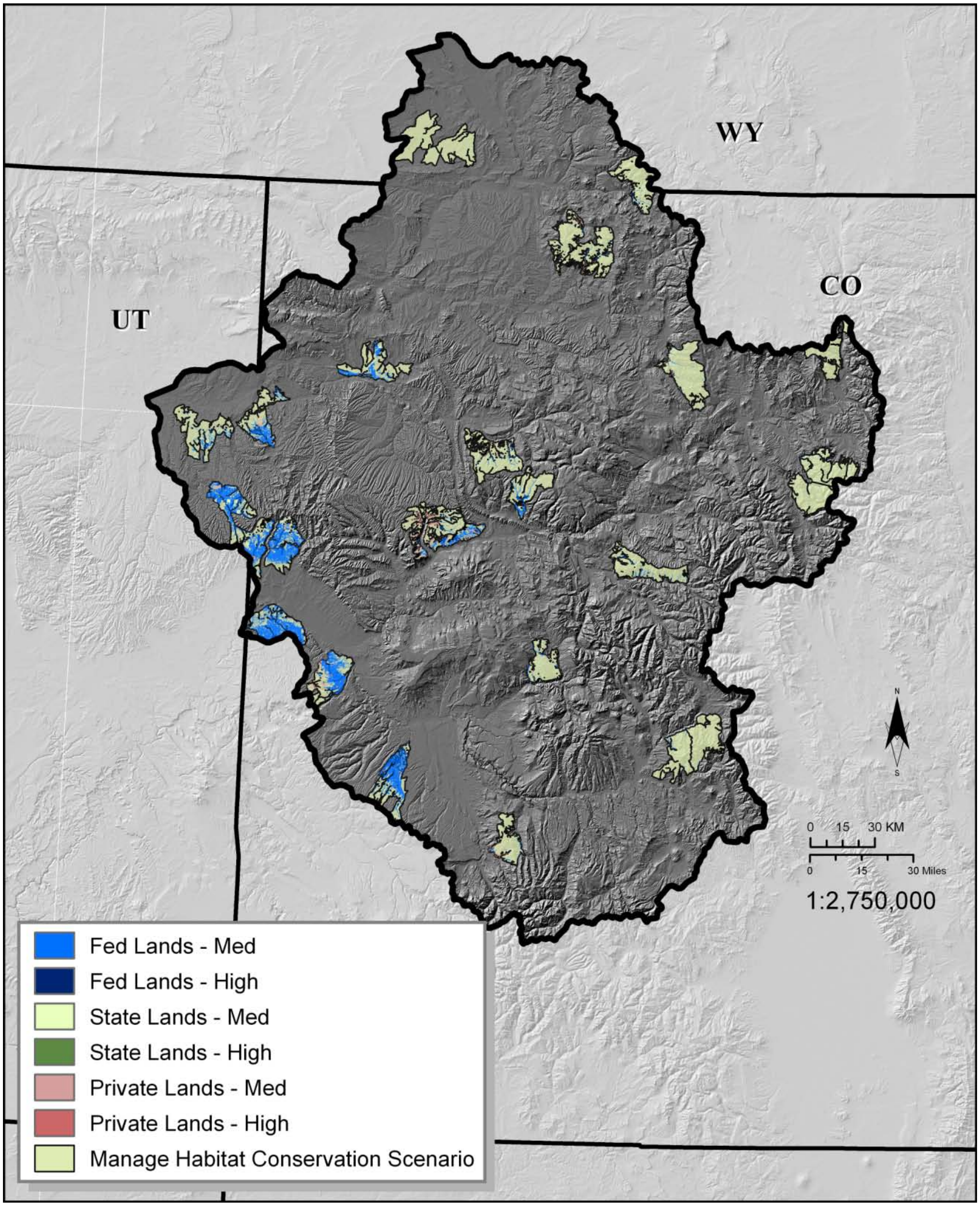


Figure 61. Species Richness Assessment
Ownership of High Value Habit Lands, Protect Habitat Scenario

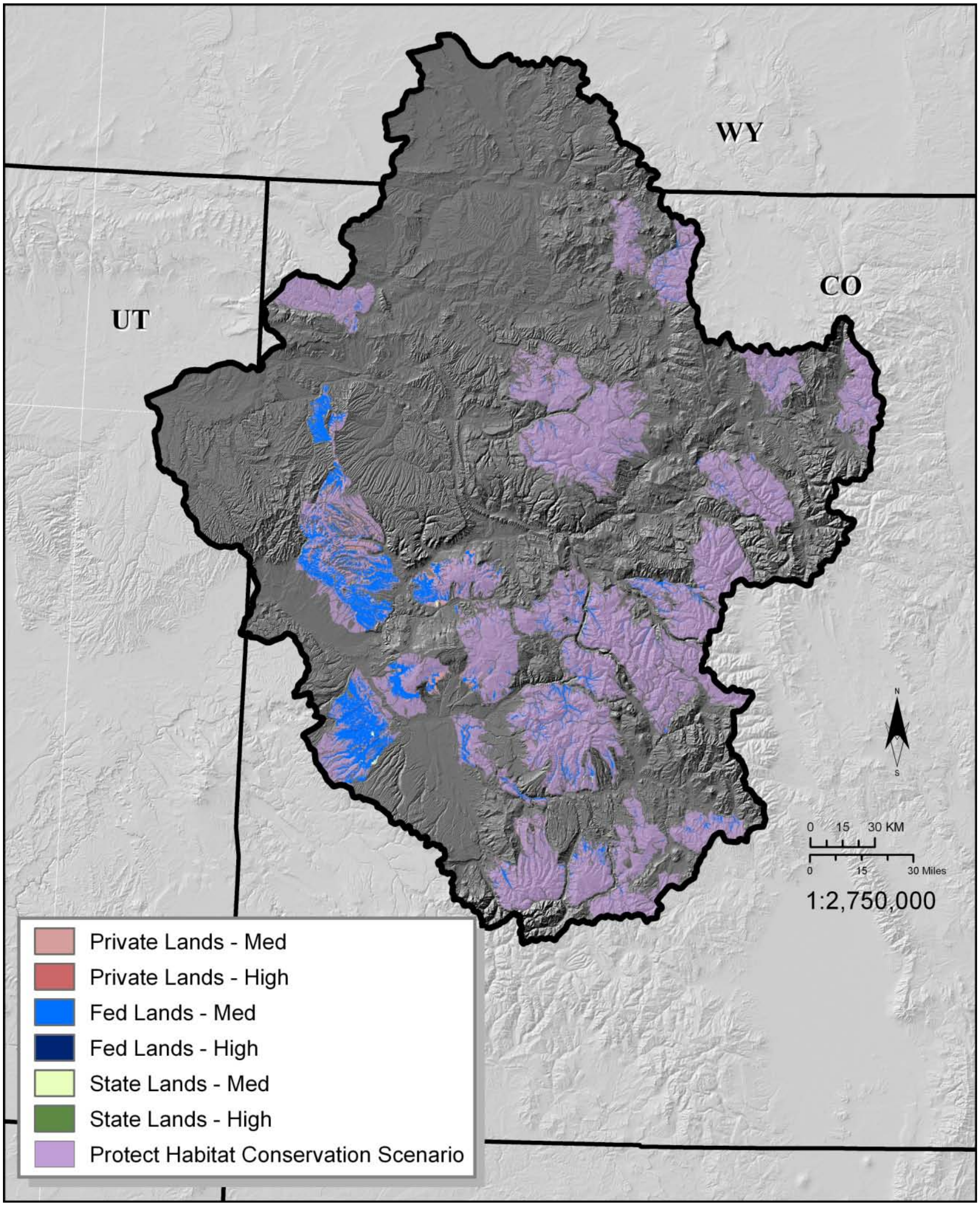


Figure 62. Species Richness Assessment - Ownership of High Value Habit Lands, Restore Habitat Scenario

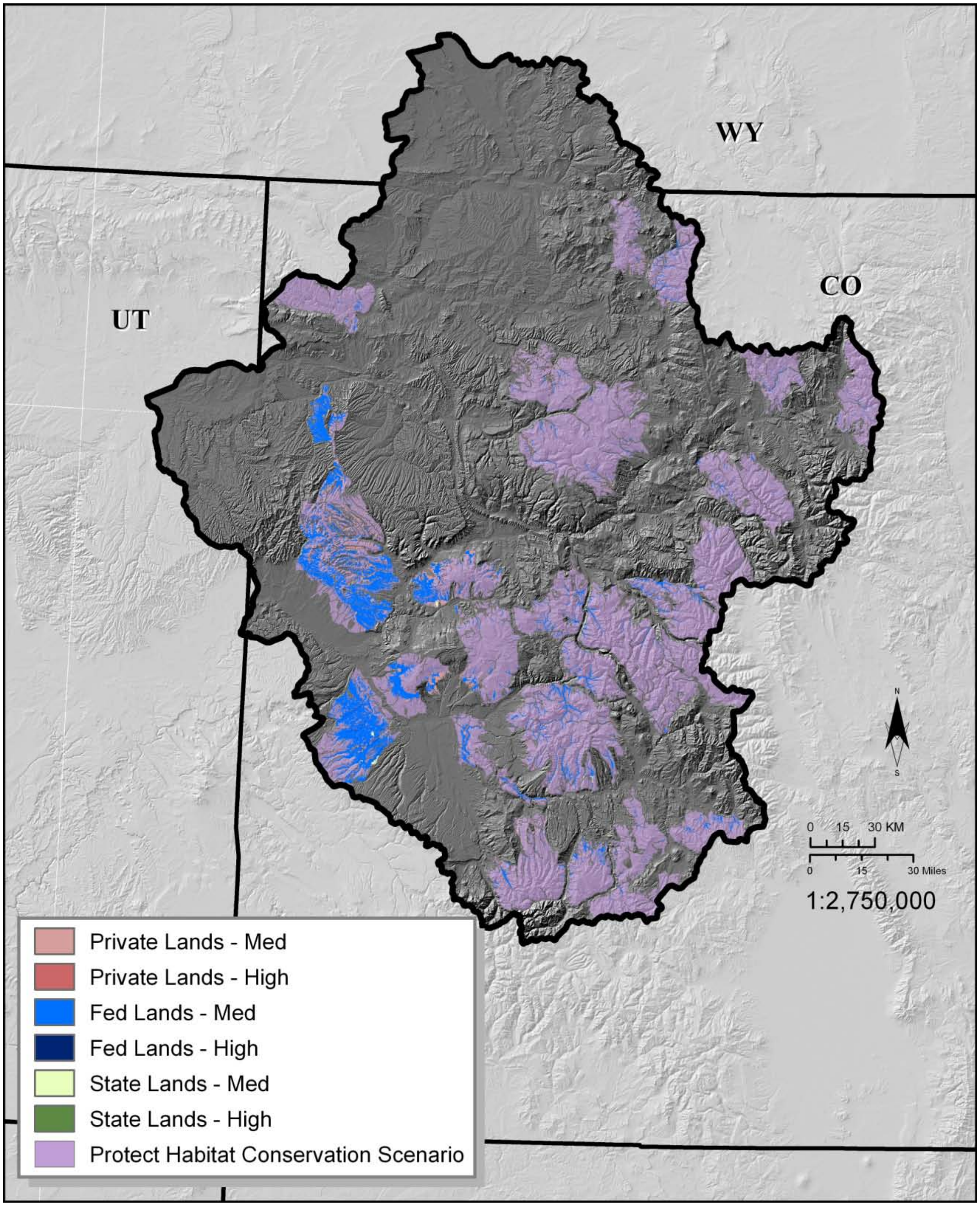


Table 12.

Areas of High Species Richness, Acres and Percent Conserved

		Habitat Scenario		
Ownership Type	**Hectares**	Manage	Protect	Restore
Federal and State	66,238	25,622	51,648	51,810
Other	24,927	3,481	8,709	8,570
Total	91,164	29,103	60,357	60,380
% Federal/State Lands Identified		16%	32%	32%
% Total Lands Identified		11%	23%	23%

Finally, a model was developed to determine areas of valuable habitat potential which are not proposed for protection under the three habitat scenarios. This can help to determine whether important areas of high habitat value are adequately protected and indicate areas that may be important to include in consideration. The ability to preserve areas near high quality habitat, especially if they are likely to be compromised, can be important in providing refuge to species relocating due to human or natural disturbances. Using GIS data, several iterations of filtering were run to generalize areas of highest number of species (120 or more). Land ownership was also added to this model, showing areas of Federal and State lands (excluding National Parks). Private, Bureau of Indian Affairs, and Other classifications that would prove difficult to preserve directly are also displayed because there may be adjacency or contiguousness with other lands providing high value habitat (Figures 63, 64, and 65).

Figure 63. Species Richness Assessment - High Value Habitat not included in Alternative Future 1, Moderate Conservation/Manage

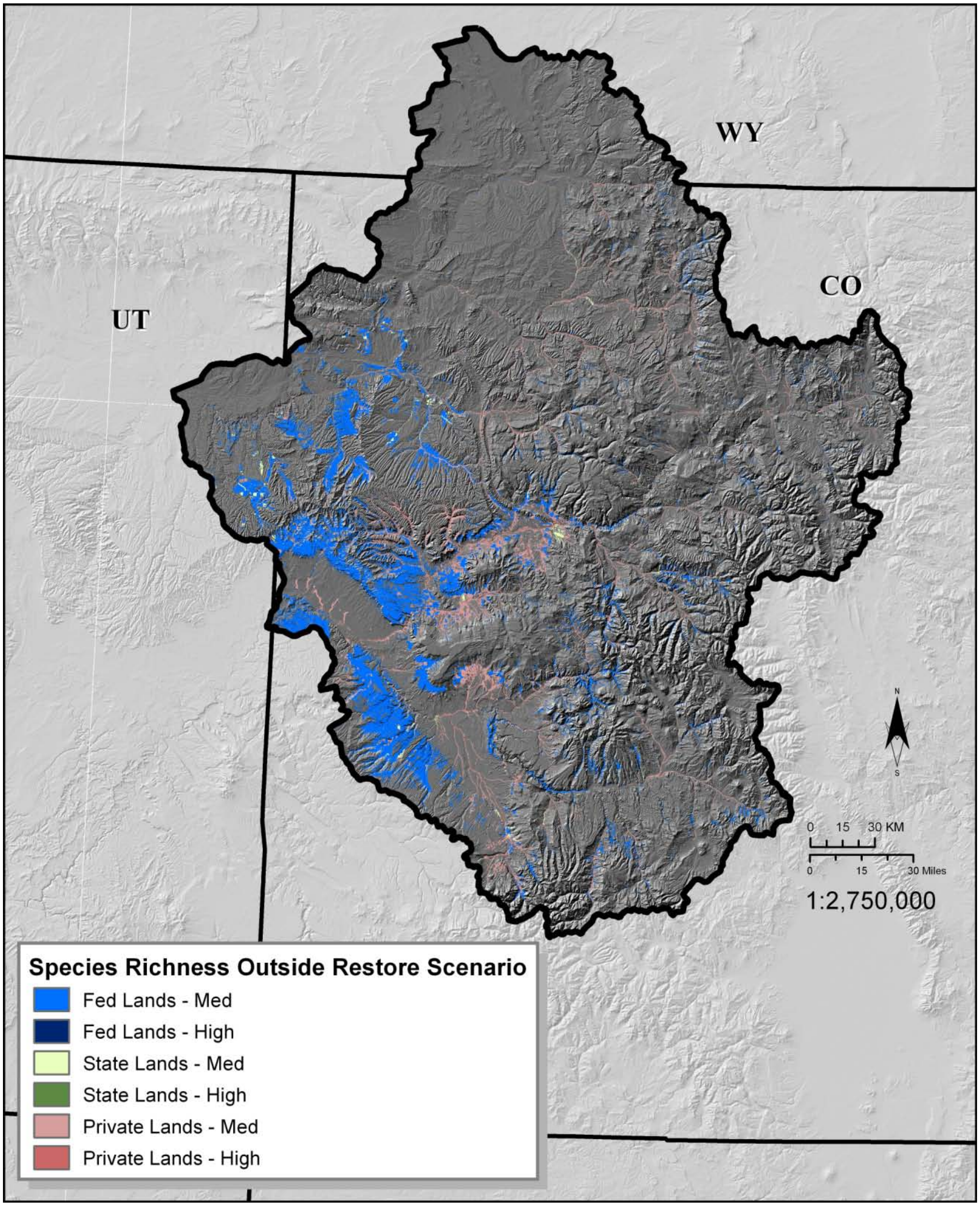


Figure 64. Species Richness Assessment - High Value Habitat not included in Alternative Future 2, Business-as-Usual/Protect

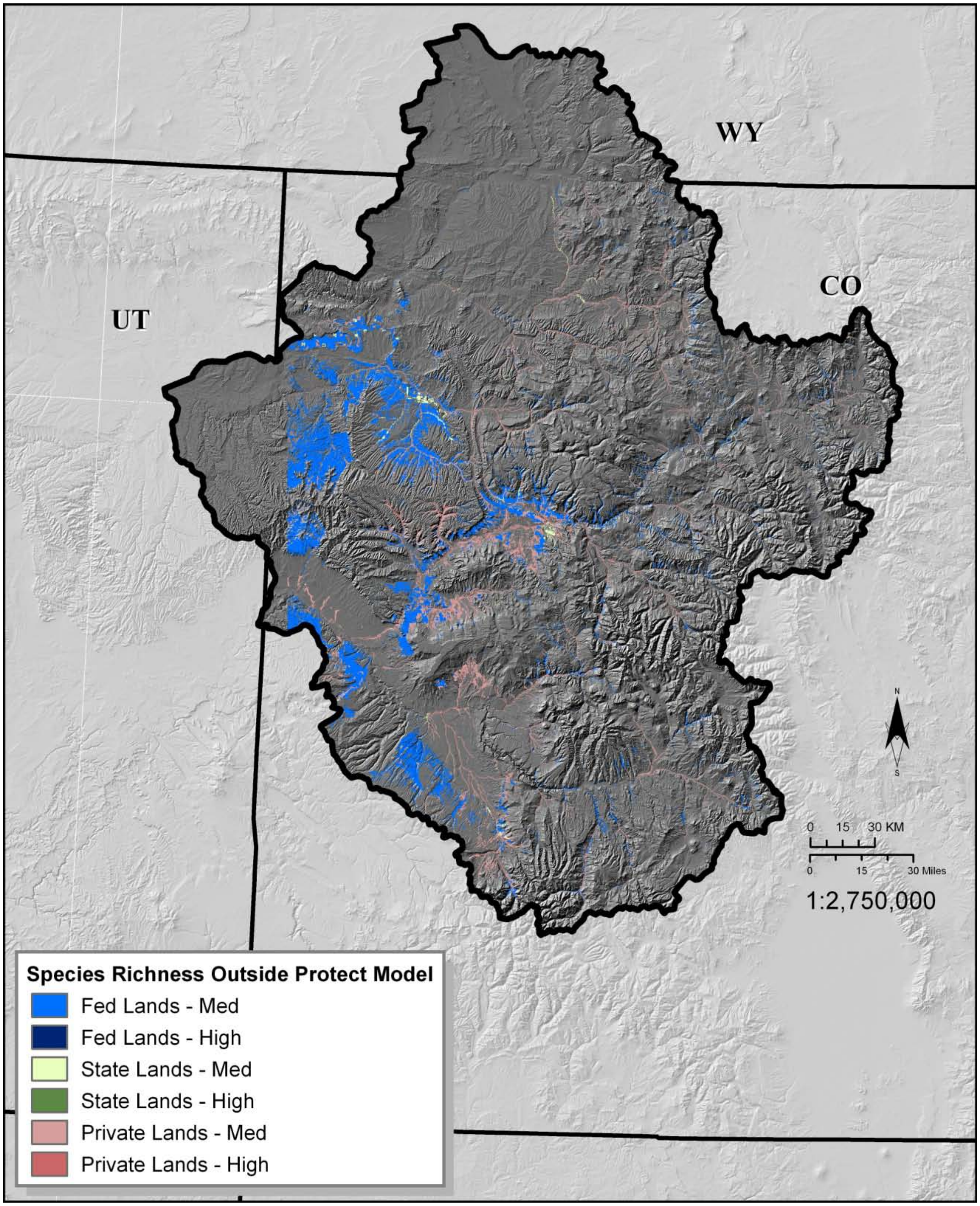
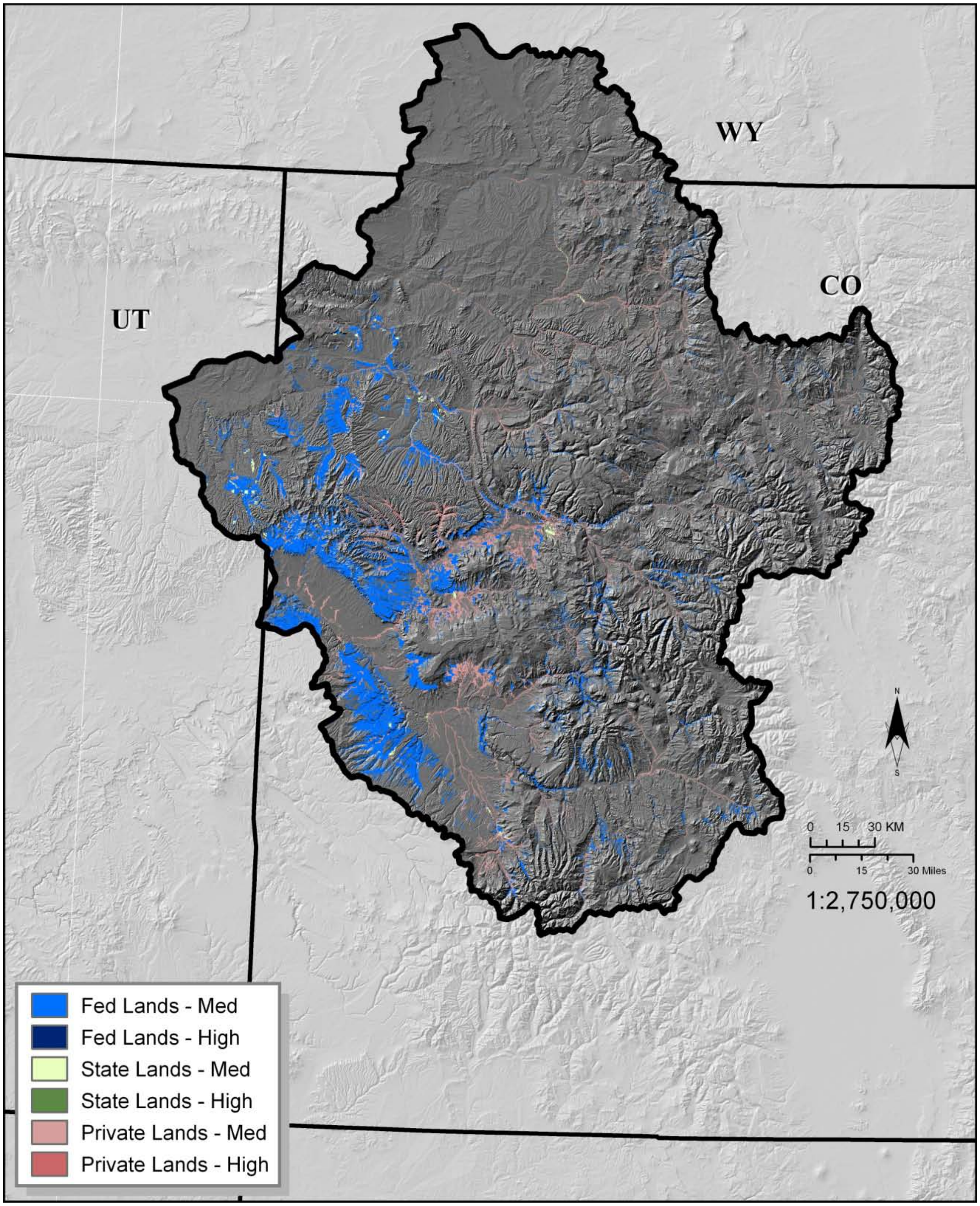


Figure 65. Species Richness Assessment - High Value Habitat not included in Alternative Future 3, Buildout/Restore



Agriculture and Rangeland Assessment

Data from the U.S. Department of Agriculture's National Agriculture Statistics Service (NASS) was used to develop the working lands assessment model. Data for 2008 cropland was mapped and selected for farmland specific data. In 2008, the study region supported roughly 220 square kilometers, or 54,334 acres, of agricultural land. The Bureau of Land Management and the U.S. Forest Service lease a combined 14,608,594 acres of allotments to grazing of cattle and sheep.

For the purpose of this assessment, wind, biomass, and geothermal energy generation were considered compatible uses. Wind energy has potential to create additional income for farmers through land leases, and has minimal impact on land use, allowing farming and ranching to continue. Geothermal energy could likewise provide income for landowners, and space requirements for geothermal generation are relatively small. Energy generation from biomass fuel stocks can take advantage of farm waste and byproducts. Hydroelectric generation in the scenarios is based on retrofit of existing dams, and therefore is considered to have neither negative nor positive impacts on agricultural activities.

Extraction and use of coal, oil, gas, tar sands, and oil shale are classified as incompatible uses. Because of the high likelihood of continued and expanding coal mining and oil and gas drilling, these activities were assigned impact values in the assessment model based on highest (1), medium (2) and lowest (3) tiers of potential conflict in each of the energy scenarios. Assessment of the Buildout scenario, due to the likelihood of development of this resource in the storyline, also weights oil shale development as a higher risk for agricultural activities.

Competing water use from energy, municipal, or industrial use has potential to disrupt agricultural practices. Sale of water rights may be appealing if demand creates a high price for water shares, especially if other factors make farming less profitable. Loss or sale of irrigation water rights could result in a change to less water intensive crops, fallowing of fields, or sale of land for exurban development.

Both compatible and incompatible energy development were assessed for agricultural and grazing uses in each of the three alternative futures. Because the results of some assessments are in small patches, the areas are negligible. Specifically, the Buildout and Business-as-Usual scenarios show only a few acres of lands compatible with wind energy in areas of Wyoming. In general terms, the areas of greatest threat or benefit to agriculture are in Colorado near the cities of Grand Junction and Craig.

The Agriculture and Rangeland assessment maps show the areas which could conceivably be impacted by different energy development scenarios (Figures 66 through 71). They are intended to show tiered areas of higher and lower threat or potential for impact, and energy development that is compatible with agriculture and ranching. Table 13 lists the acreage for each of the scenarios shown in the assessment maps. The areas identified are locations with the likelihood to be impacted by one or more incompatible uses or activities; however, it is very improbable that the entirety of the areas shown any assessment would be displaced for development.

Figure 66. Agricultural Assessment - Alternative Future 1, Moderate Conservation/Manage

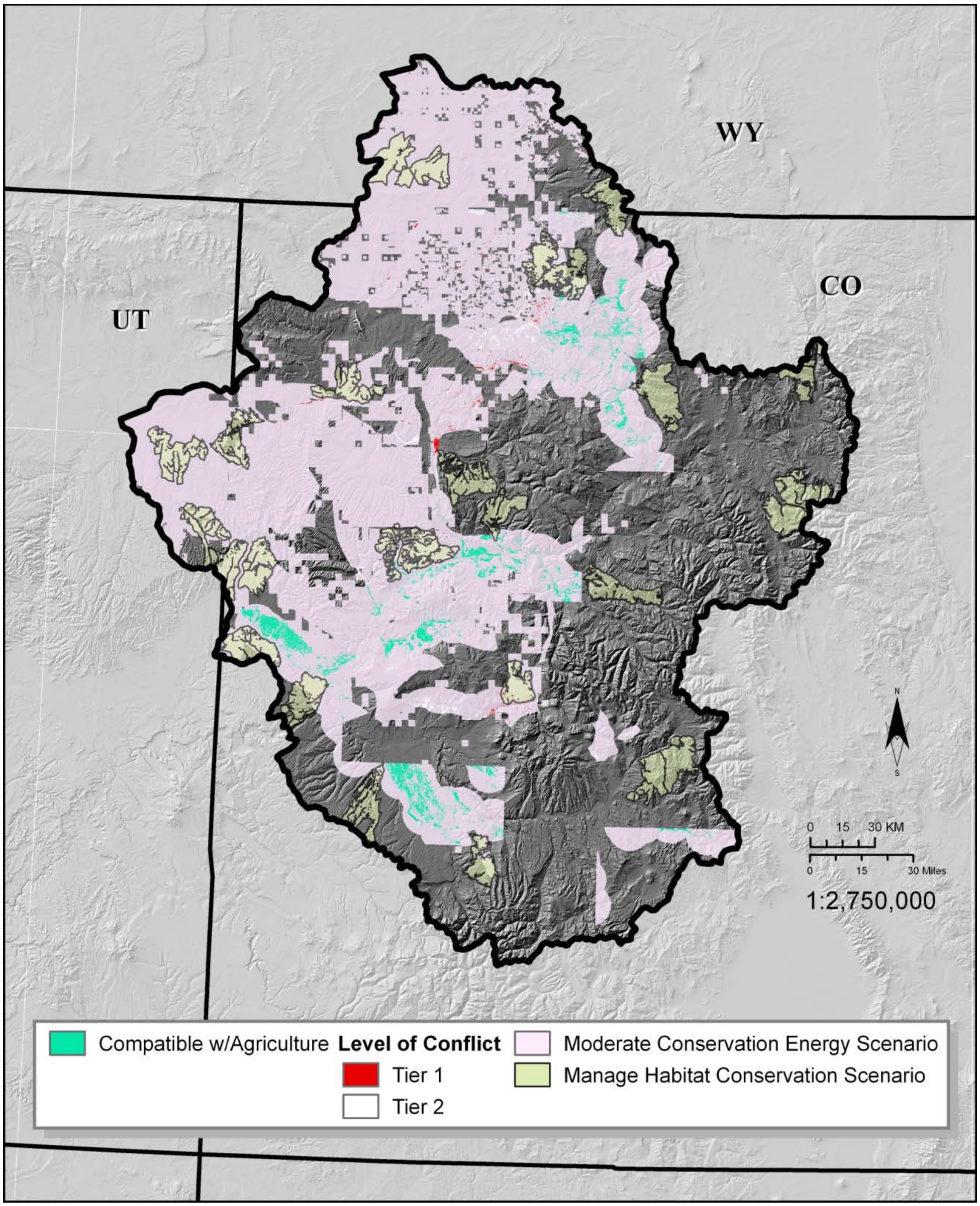


Figure 67. Agricultural Assessment - Alternative Future 2, Business-as-Usual/Protect

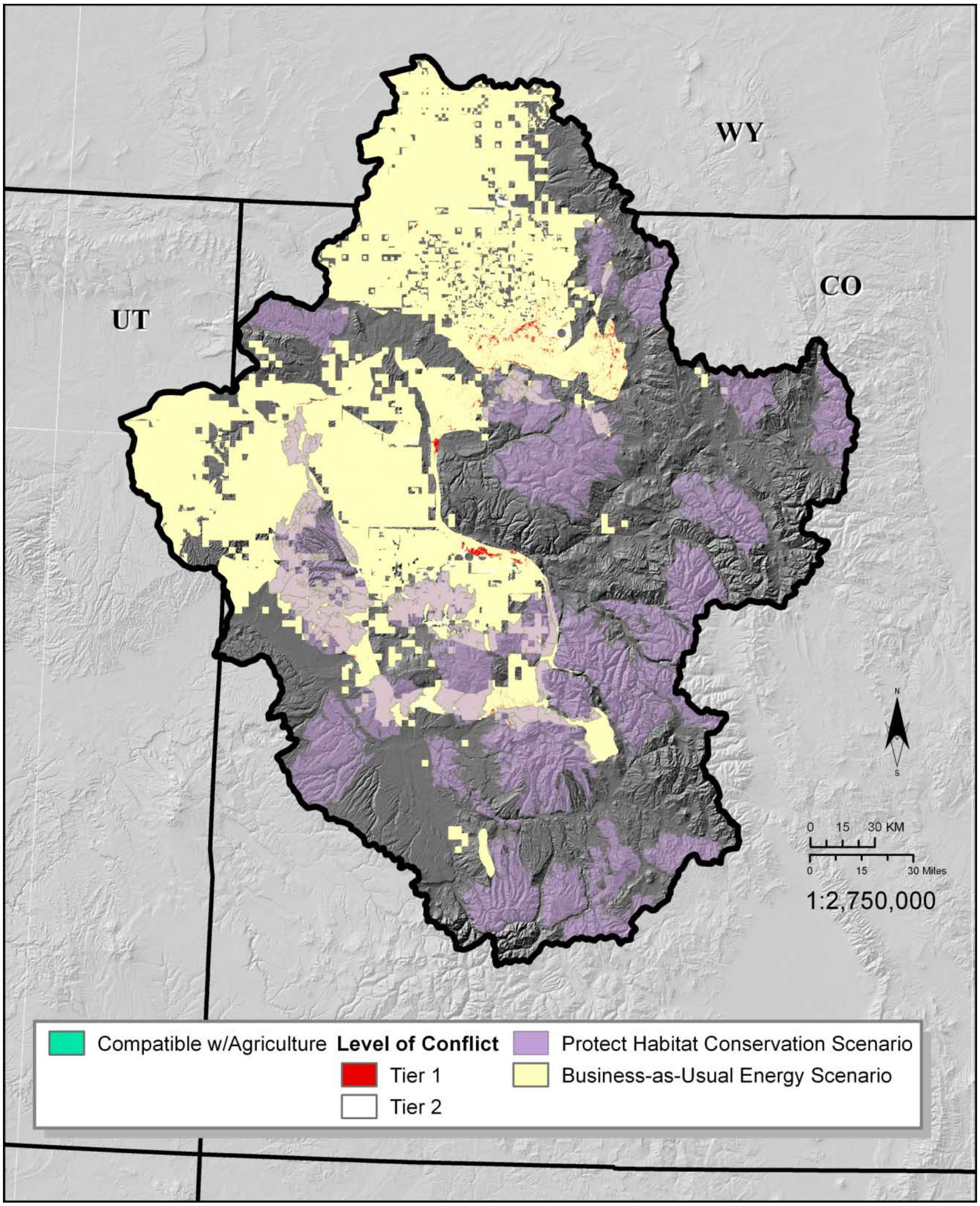


Figure 68. Agricultural Assessment - Alternative Future 3, Buildout/Restore

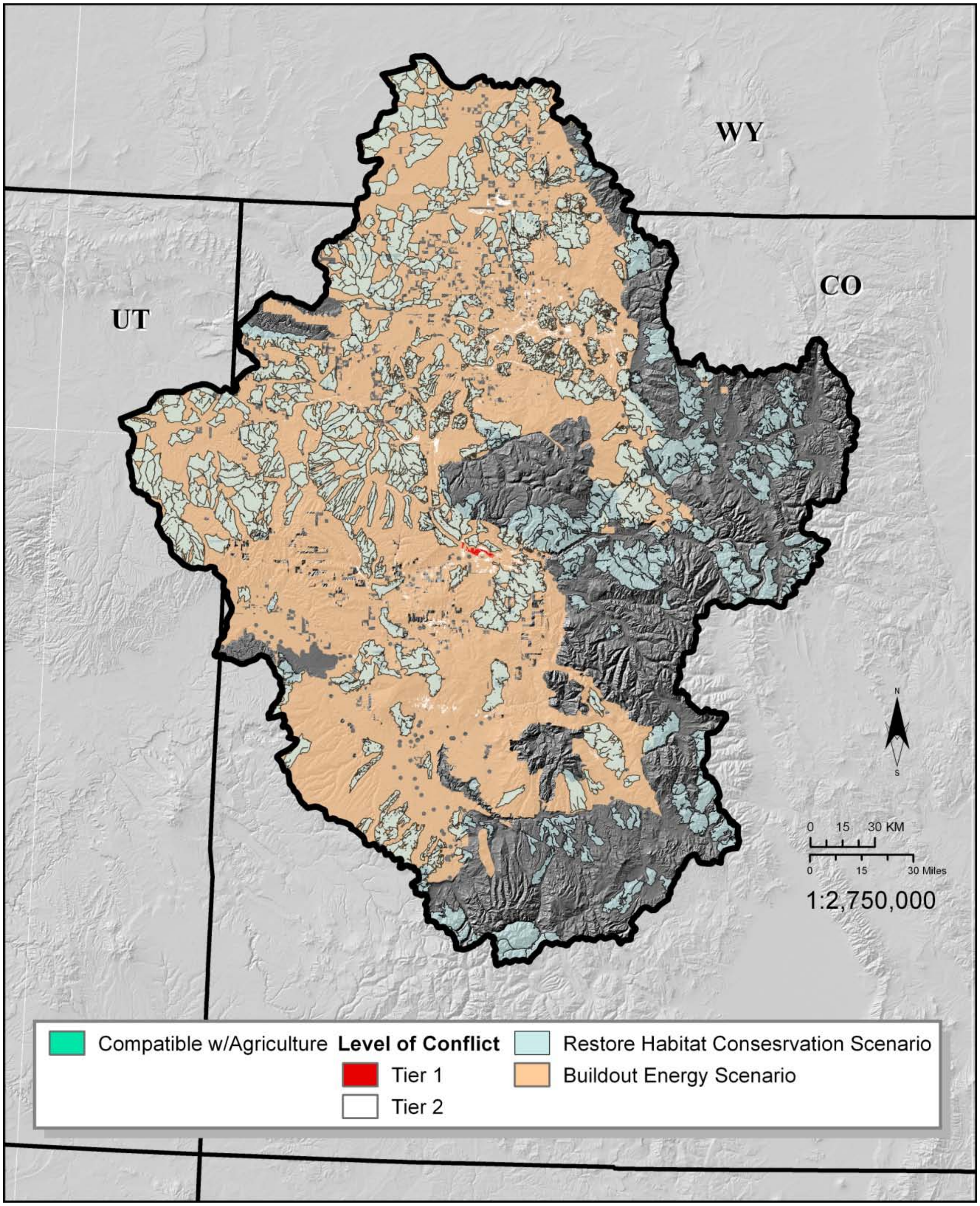


Figure 69. Rangeland Assessment - Alternative Future 1, Moderate Conservation/Manage

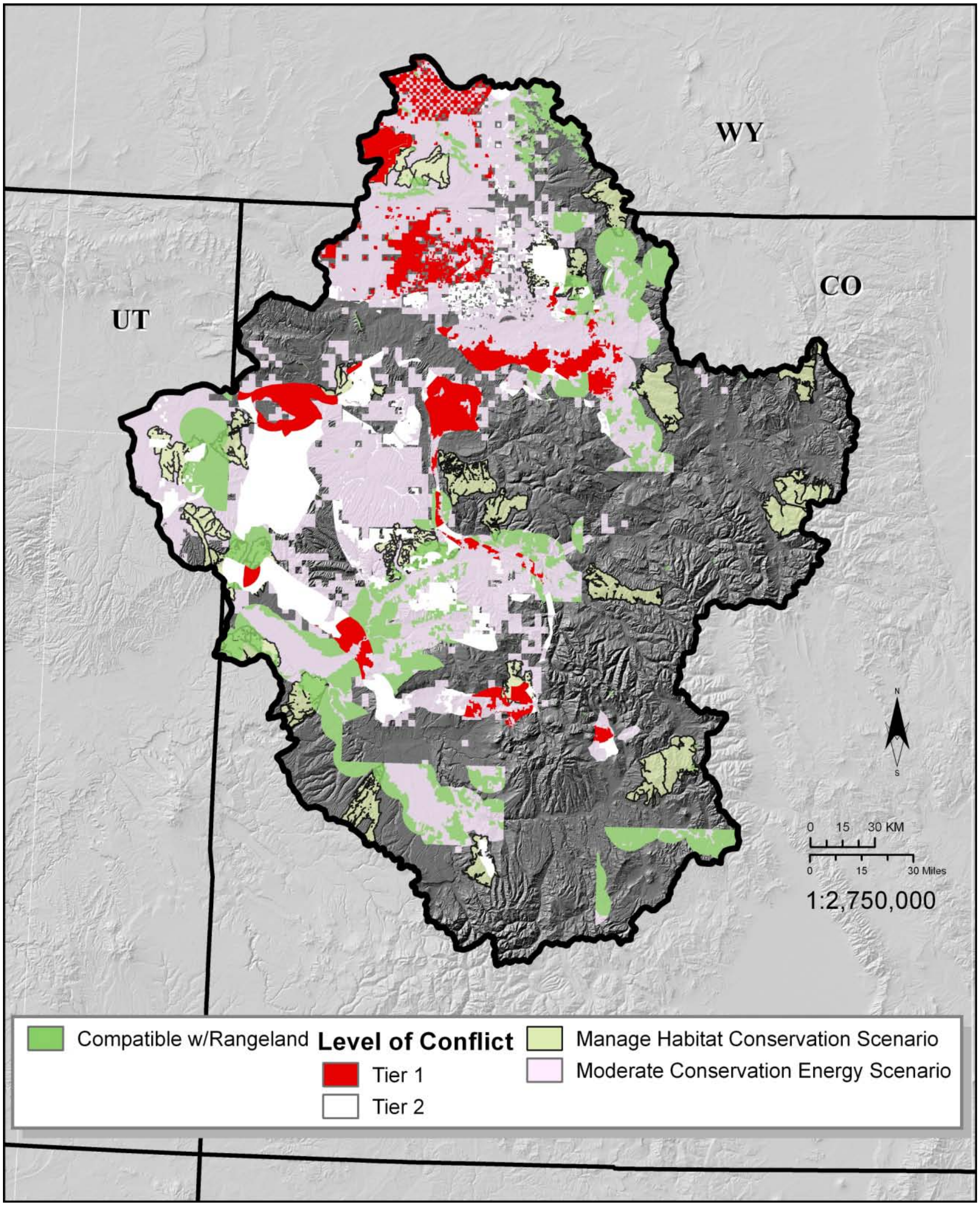


Figure 70. Rangeland Assessment - Alternative Future 2, Business-as-Usual/Protect

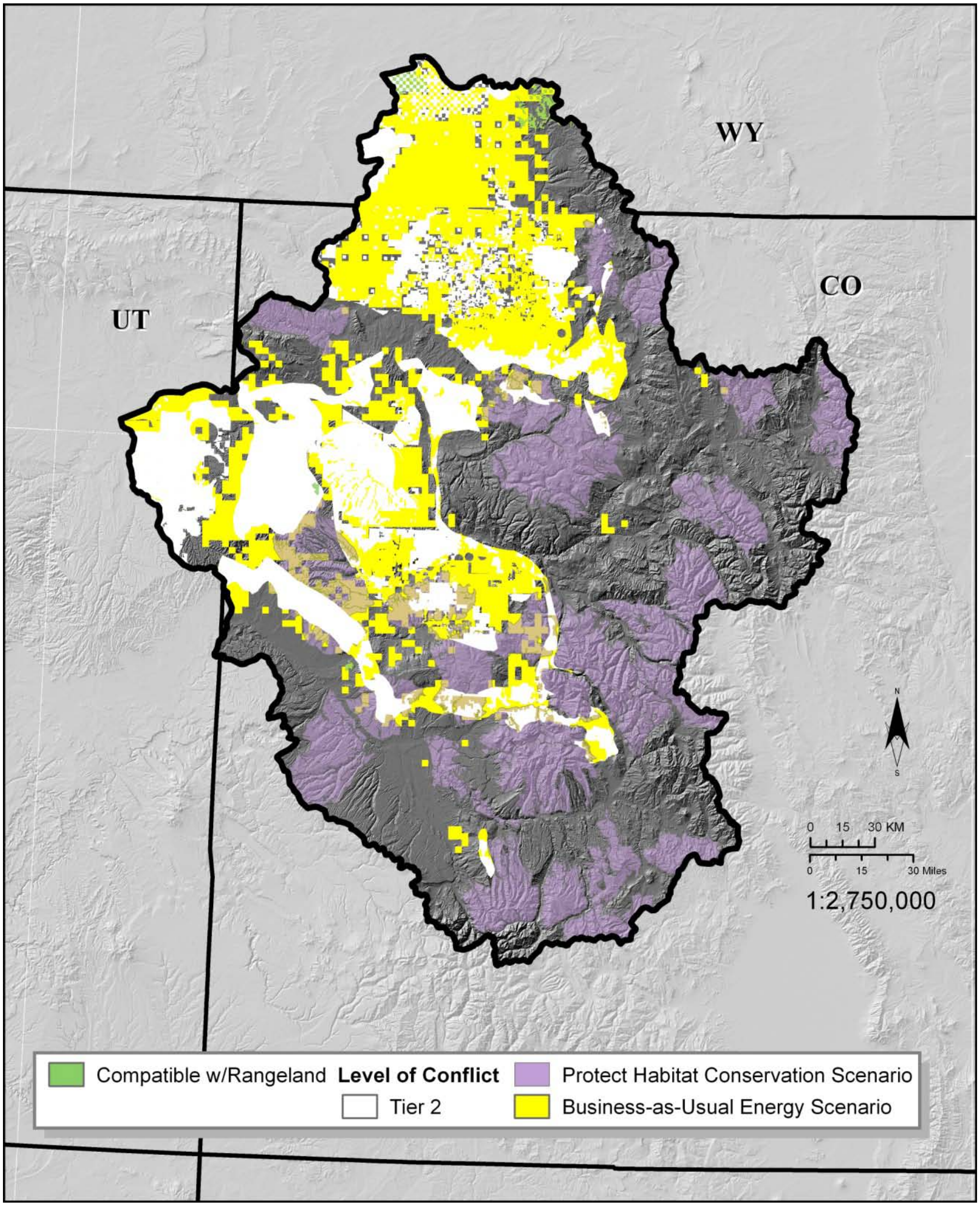


Figure 71. Rangeland Assessment - Alternative Future 3, Buildout/Restore

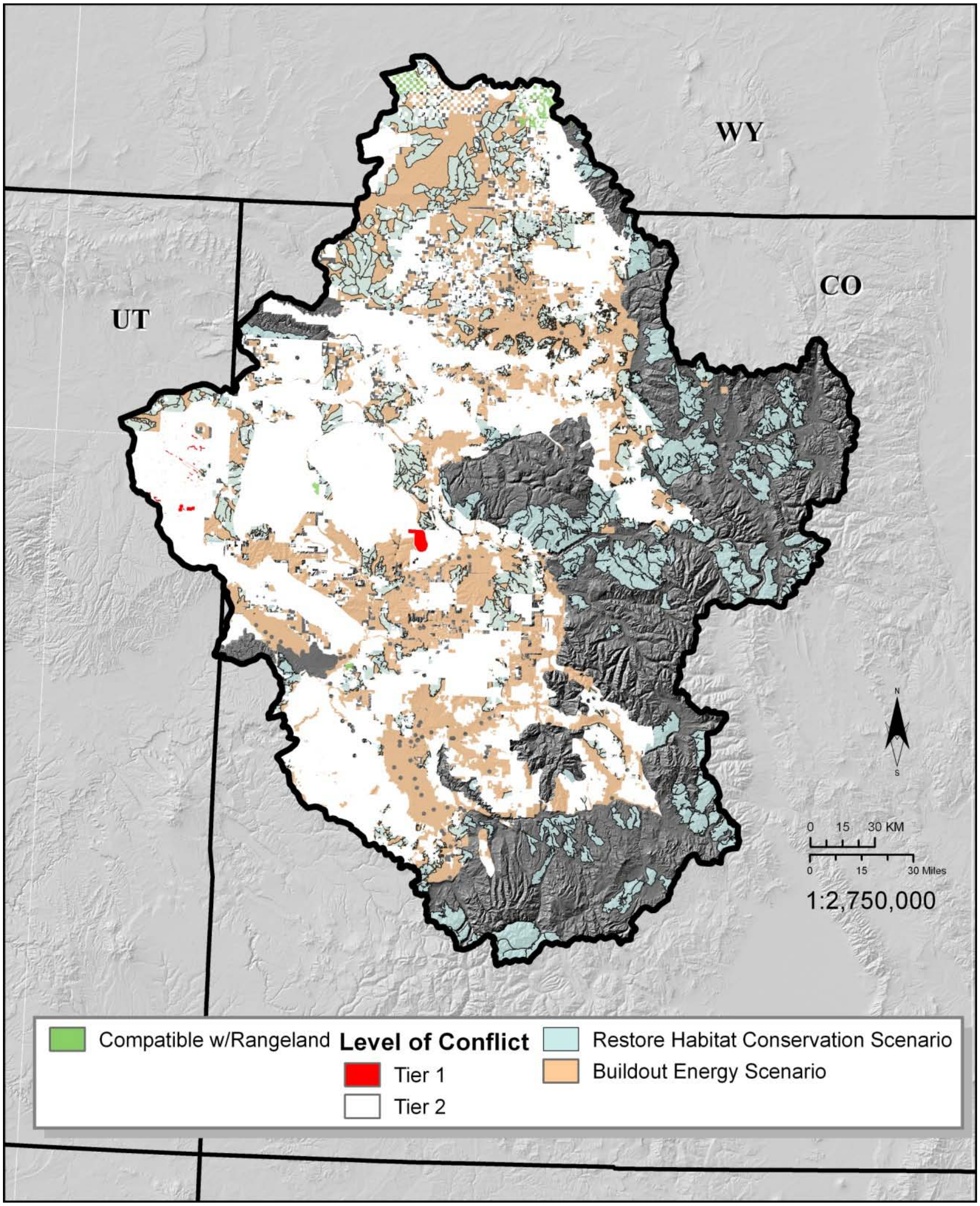


Table 13

Acreage Summary for Farmland and Rangeland Assessments

	Farmland	Rangeland
Alternative Future 1	Acres	Acres
Conflicting	3839.3	98820.2
High Conflict	1234.3	42535.3
Moderate Conflict	2605.0	56284.9
Compatible	9714.1	90759.7
Alternative Future 2		
Conflicting	4728.8	137172.2
High Conflict	1769.7	0.0
Moderate Conflict	2959.1	137172.2
Compatible	1.6	2404.2
Alternative Future 3		
Conflicting	16393.4	290971.0
High Conflict	2071.6	867.6
Moderate Conflict	14321.8	290103.8
Compatible	1.6	2404.2

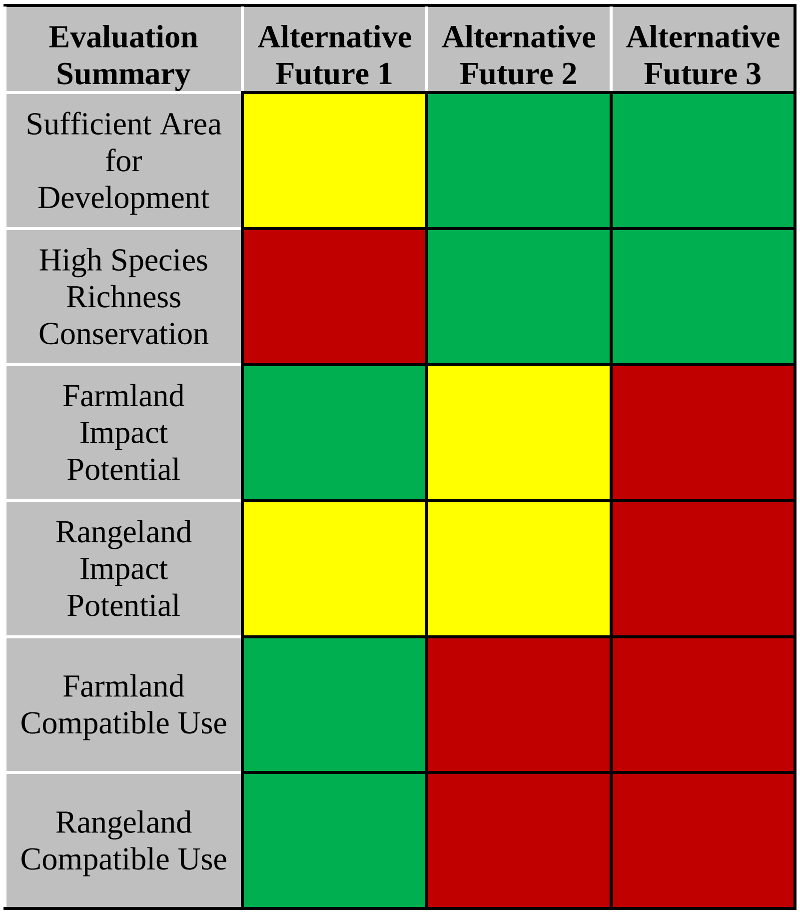
CHAPTER 7

CONCLUSIONS

The landscape covered by this phase of the Upper Colorado Ecosystem Study, the Yampa-White, Gunnison, and Colorado Headwaters basins, faces a highly variable future. Conservation of wildlife requires habitat to sustain native biodiversity. Human prosperity likewise depends on those things we term ecosystem services, and the ability to protect the public health, safety, and welfare. There will undoubtedly be a great demand for energy from the region, but the locations from which it is extracted and in what forms may change from current practices. Population is certain to grow, and those new residents will demand housing, development, and recreation. Where and how that growth is accommodated have yet to be determined. Meanwhile, all of these changes will have impacts and effects on wildlife and habitat.

Figure 72 is a summary of relative overall performance for each future against each of the assessment models. The color code represents a favorable (green), moderate (yellow) or unfavorable (red) outcome for each future in terms of six categories determined by analysis of the models and maps. This evaluation is of the three futures in relationship to *each other*. Other futures that have not yet been modeled or described may perform much better, or could fare far worse, than these three.

Figure 72. Tiered Summary of Alternative Futures Assessments



Green represents favorable outcomes for the assessment of the alternative future. Yellow indicates a moderate outcome, and red symbolize unfavorable outcomes.

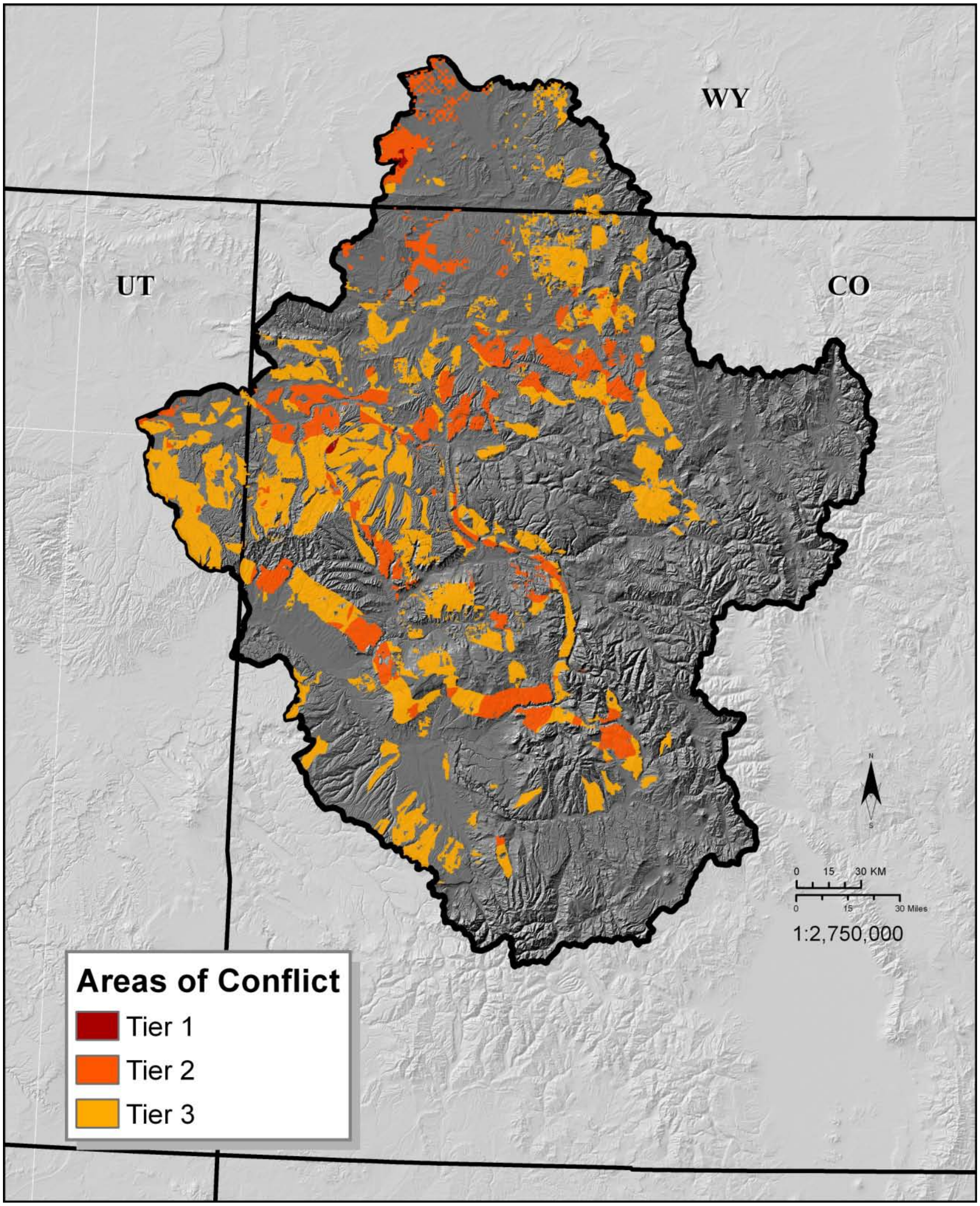
The intent of this work is not to predict the future, but to find and test the sensitivities of the landscape that supports humans and wildlife. By trying out different approaches, we can test the responses across different interacting systems, the human and the biophysical. As noted in the introduction, the purpose of a study such as this is to help avoid the pitfalls, conflicts, and irreversible missteps that can be found through modeling. Unanticipated outcomes undoubtedly still exist. The purpose of making projections about the future is to allow the creation of a more desirable future than the one predicted by the model. In a sense, the planner wants these futures to *not* come about as written.

The areas of conflict in any alternative future will be important considerations. They can identify areas at greatest potential risk for land use conversion, development, or other habitat loss. They also can indicate areas that may prove especially difficult to set aside for conservation due to high desirability and demand for other purposes. Another approach to the application of this information comes through understanding which areas have high likelihood for human activity, whereby we can anticipate habitat disturbances and fragmentation. Neighboring areas may therefore be unsuitable as wildlife refuges.

As a generalization, Figure 73 shows the combined areas of conflict for all three Alternative Futures in one map. These conflict areas are the regions of overlap between the habitat and energy scenarios in the futures identified. Taken as a whole, they can help to form a condensed picture of the risk to habitat found in these futures.

Habitat able to support a high number and diversity of species is a second key concern. Areas within each of the Management, Protection, and Restoration habitat conservation scenarios that hold the highest species richness should be further evaluated.

Figure 73. Combined Conflict Layers, All Habitat Scenarios



For the preferred habitat conservation approach, species richness on proximal non-federal lands should also be evaluated. Conservation of areas adjacent to prime habitat on private lands may help species adapt, or could provide refugia in the case of habitat destruction on those private lands. Figure 74 illustrates the combined areas of medium and high species richness within the three habitat models.

The most robust and perhaps the most feasible courses of action will be those identified as appropriate responses to multiple scenarios, or those meeting several of these prioritization criteria. Because of the close spatial relationship between the lands identified by these models, evaluation of their adjacency can help to provide connectivity in the landscape. Overlap in 5 kilometer buffers was mapped for the habitat conservation scenarios (Figure 75) and for the National Parks lands and Wilderness areas (Figure 76). These were combined with the conflict and species rich data shown in Figures 73 and 74 to form a generalization of focus areas for the entire region and to take into account the proximity of the three habitat scenarios. Figure 77 illustrates the overlay process used to develop the map of final recommendations shown in Figure 78.

Although at a smaller scale than the Phase I study, this analysis still is subject to the limitations of a large-scale investigation. Principles of ecology and systems theory stress the importance of multiple scales of analysis. This work should be considered a starting point for more detailed evaluations of habitat targets and objectives for conservation decisions. Data at this scale can be useful for narrowing the scope within a broad landscape for further investigation; at the same time, it is not possible to capture smaller-scale information, such as individual species prioritization, that may be relevant

Figure 74. High and Medium Potential Species Richness,
Combined for all Habitat Scenarios

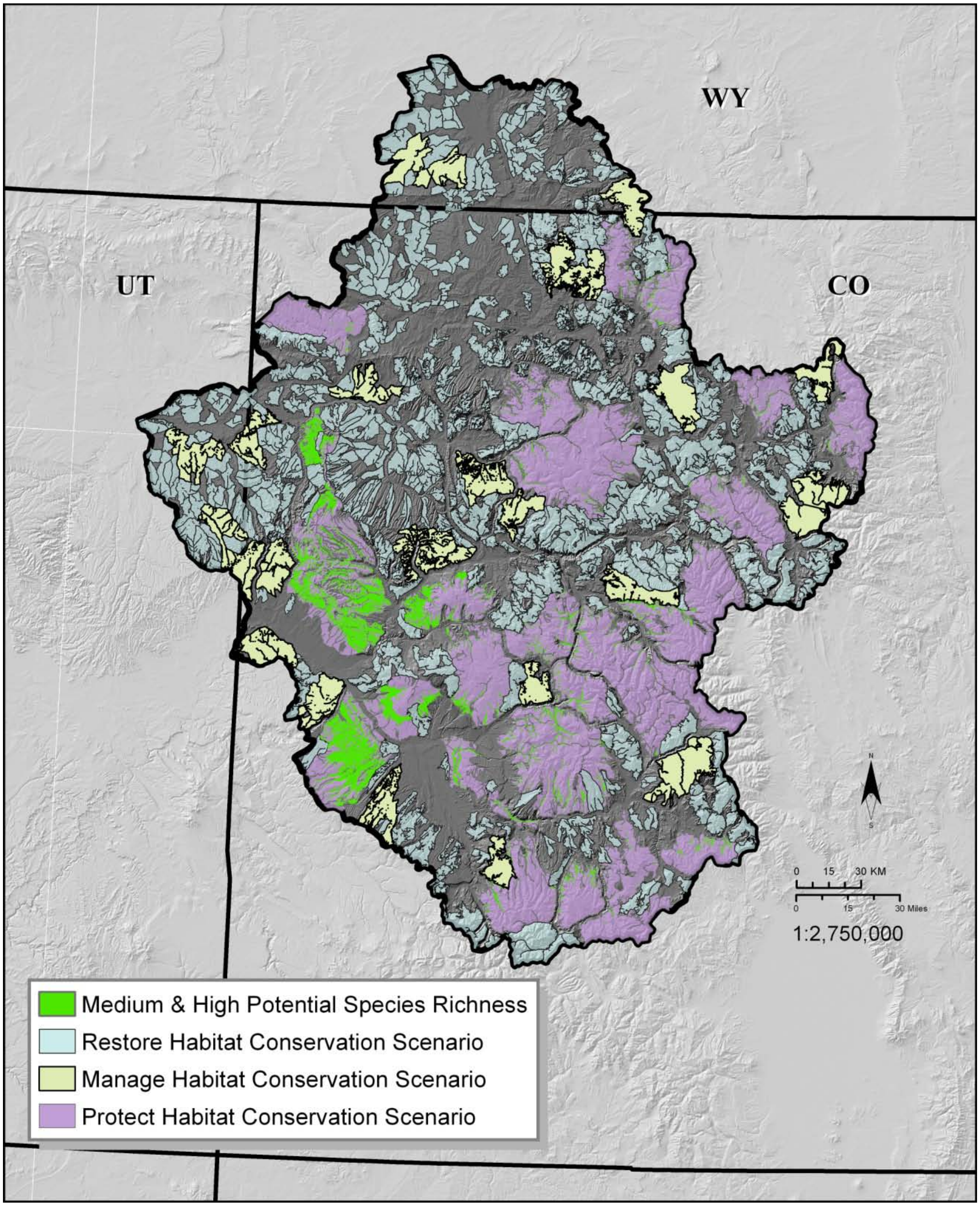


Figure 75. Overlap in Five Kilometer Buffers around Habitat Conservation Scenarios

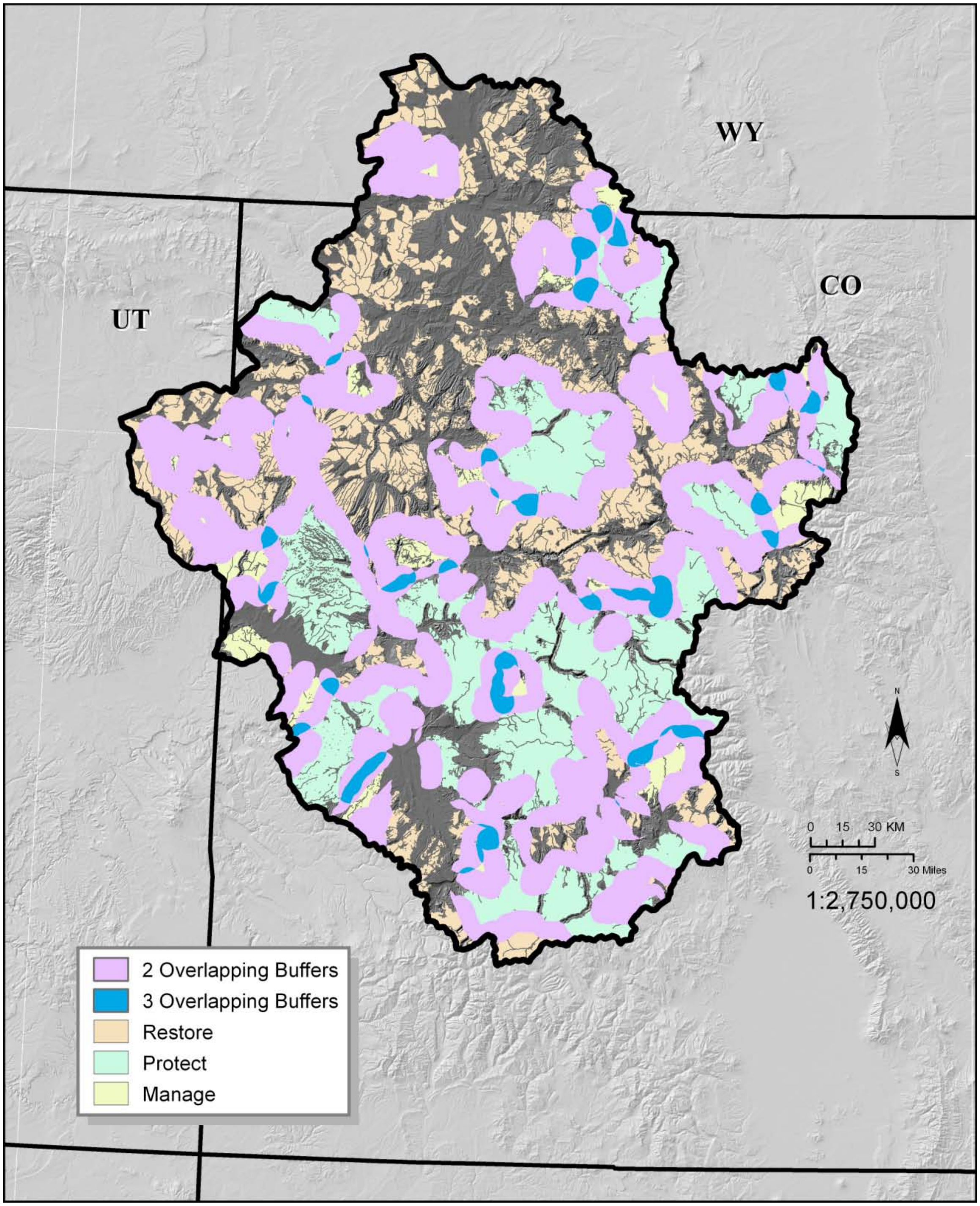


Figure 76. Overlap in Five Kilometer Buffers around National Park Lands and Wilderness Areas

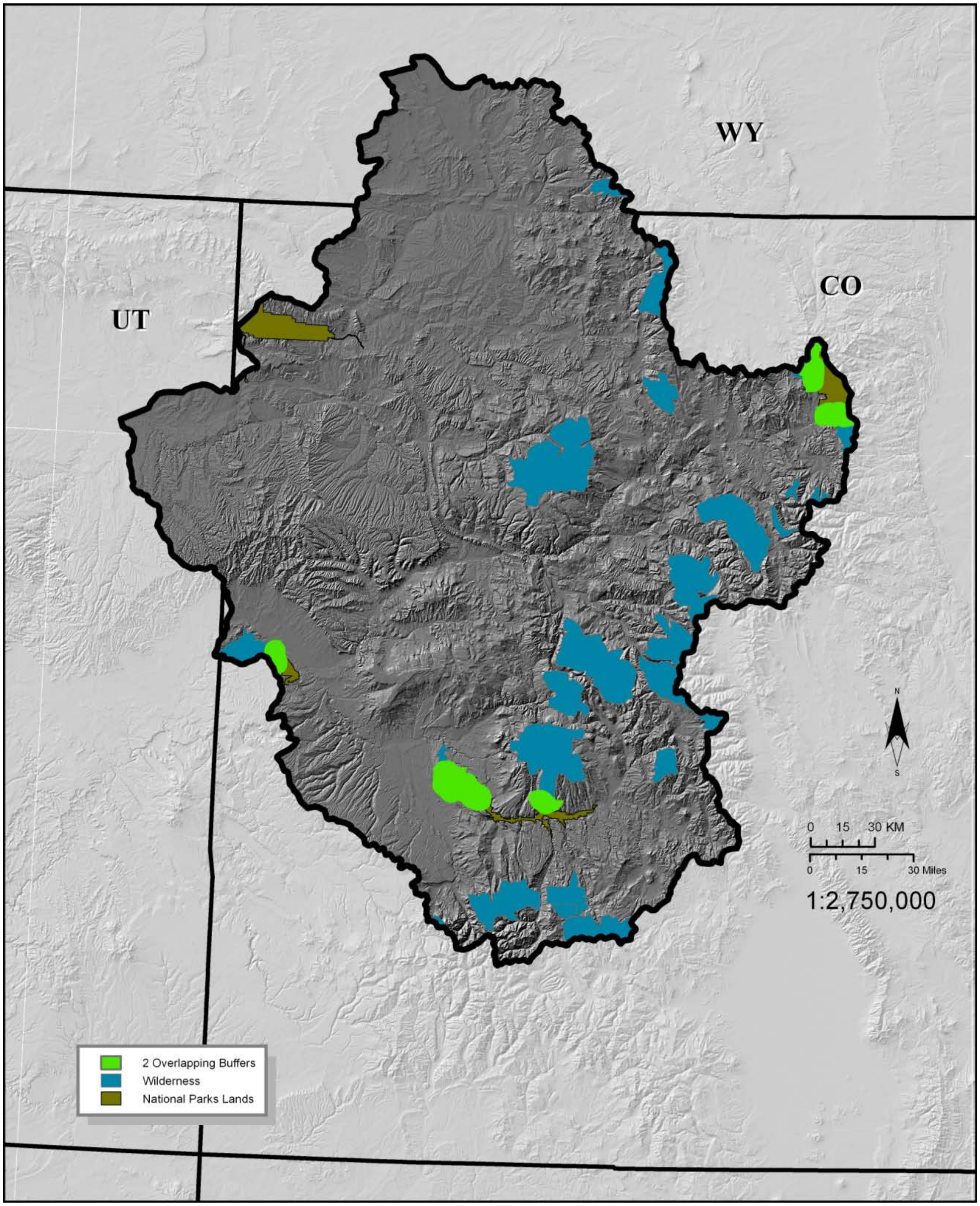


Figure 77. Overlay for Final Recommendation Map

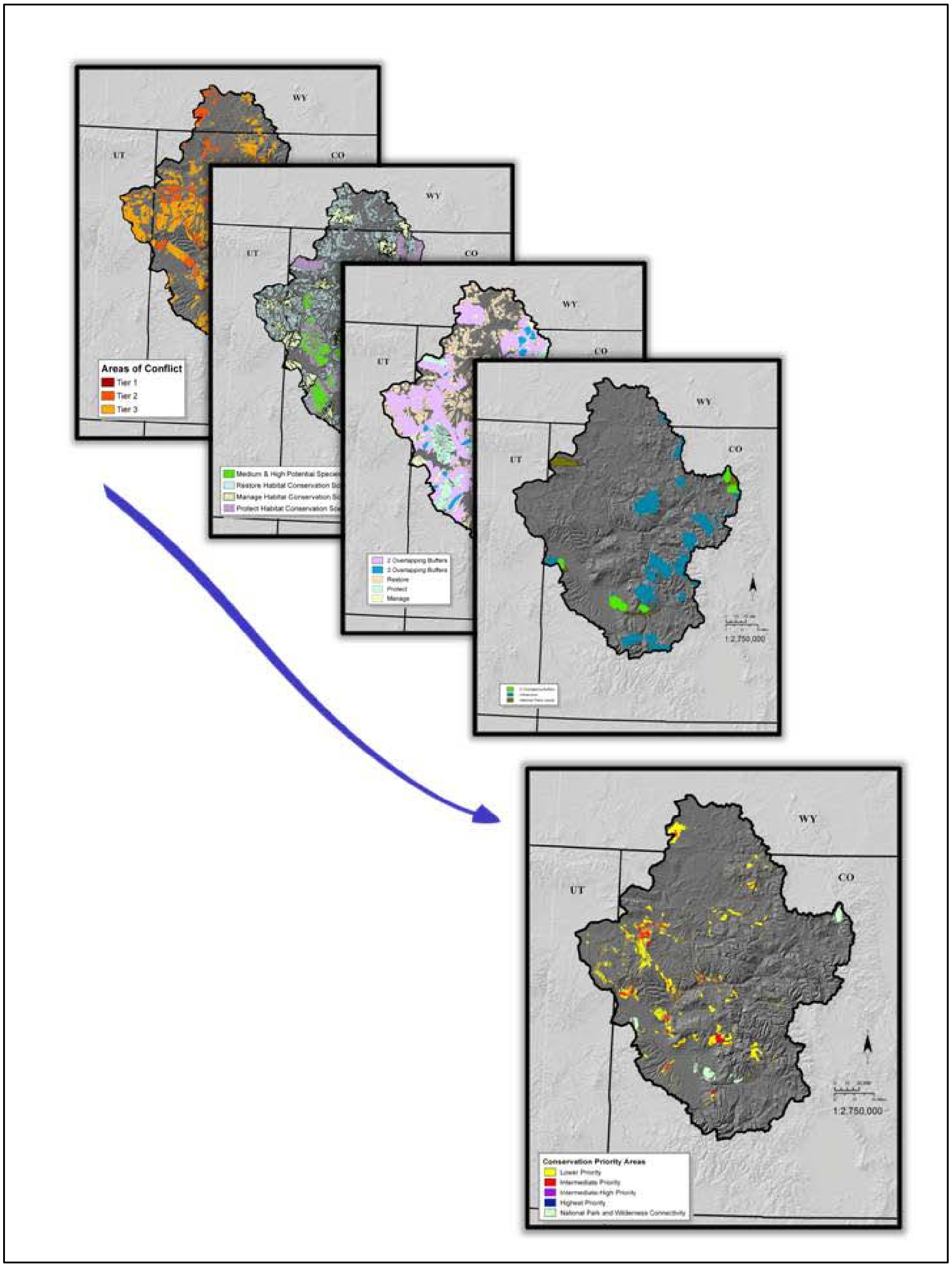
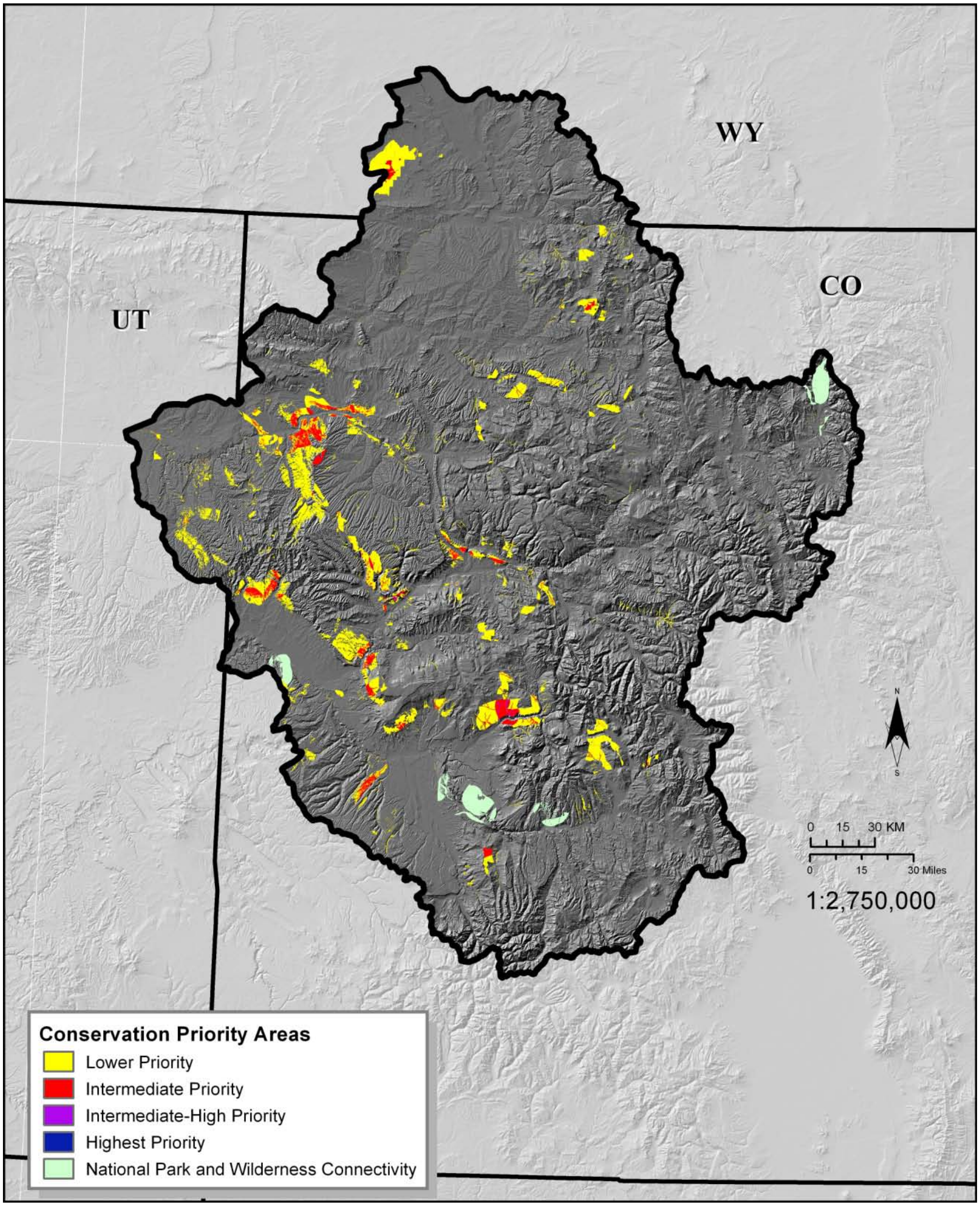


Figure 78. Areas of Final Recommendation for Conservation Efforts



to refuge prioritization. As a modeled system, it can only be a guiding tool. Firsthand, on-the-ground knowledge of the landscape and wildlife are important factors to management decisions and implementation of these results. Localized expertise should be used in refining the general or species-specific selection criteria and for determining important geographic qualities and habitat needs.

There are also limitations to the data used as model inputs. Data is static, but the biophysical and human worlds are constantly changing. New census data would allow, and perhaps require, re-evaluation and re-conception of the scenarios, futures, and assessments. Assumptions and predictions for the scenarios and models are fallible variables in the process. The species richness data is based on habitat, and until comprehensive actual species location is available, habitat is the proxy available for work such as this.

Climate change will lead us into uncharted territory. We can expect warmer global temperatures. Our understanding of regional or local impacts is limited, but we can be fairly certain that the future climate will not be like the present. We do not yet know how species – including ours – will respond to the changes. As more predictive regional climate models become available, predictive data could be an asset to studies such as this.

Beyond simply identifying target areas for conservation, alternative futures evaluations can also provide information about undesirable outcomes and conflicts. Forecasting the trajectory of policies or actions in the near future can help correct course for better long-term outcomes. Studies such as this can offer suggestions as to what *can* be done to reach desirable futures, but what *will* be done is another matter. This work is an attempt to help inform those actions.

> "If we don't save the living environment, then saving the physical environment won't do us much good in the long run."
>
> *-E.O. Wilson (2010)*

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APPENDICES

APPENDX A. GEOGRAPHIC INFORMATION SYSTEMS DATA SOURCES

Geographic Information Systems Data Sources

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Utah: RS/GIS Laboratory, College of Natural Resources, UMC 5275, Utah State University, Logan, UT 84322-5275, Principal Investigators: Doug Ramsey, John Lowry, Landcover Analysts: Jessica Kirby, Lisa Langs, Gerald Manis.

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APPENDIX B. CASE STUDIES

Case Studies

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APPENDIX C. LIST OF CONSULTANTS AND ADVISERS

Consultants and Advisers

Table C.1

List of Consultants and Advisers

Name	Institution	Topic
Justin Brashares	UC Berkeley, Environmental Science, Policy and Management	Wildlife Conservation and Development Patterns, Land Use Conflict
Mark Brunson	Utah State University, Environment and Society	Rangeland and Development, Land Use Conflict
Fee Busby	Utah State University, Wildland Resources	Anticipating Future Directions, Wildlife Habitat
Thomas Edwards	Utah State University, Wildland Resources	Storyline Development, Buildout Scenarios, Agricultural Land Abandonment, Land Use Conversion
Gaylord Gardner	Bingham Engineering	Dam Retrofitting for Hydropower
Karin Kettenring	Utah State University, Watershed Science	Wetland Networks
James MacMahon	Utah State University, Ecology Center	Ecological Context, Succession, Climate Change
Nancy Mesner	Utah State University, Watershed Science	Water Quality and Quantity
Christopher Monz	Utah State University, Environment and Society	Trends in Recreation and Management
Benamin Phillips	Radian Bioenergy	Biofuels, Syngas and Local-Scale Power Generation
Allan Shearer	Rutgers University, Landscape Architecture	Security Aspects of Planning, Systems Theory, Land Use Conflict
Scott Shine	City of Montrose, Colorado	Public Health, Welfare and Safety, Cultural Aspects of Planning, Development
Carl Steinitz	Harvard University, Landscape Architecture	Visual Quality Assessment, Land Use Conflict
Sean Stevens	Newfield Exploration Company	Oil and Gas Drilling and Industrial Operations
Joseph Tainter	Utah State University, Environment and Society	Defining Sustainability

APPENDIX D. LIST OF SPECIES INCLUDED IN POTENTIAL SPECIES RICHNESS MODEL

List of Species Included in Species Richness Model

Table D.1

Names of Species in Species Richness Model

SPECIES NAME	COMMON NAME
Accipitercooperii	Cooper’s Hawk
Accipitergentilis	Northern Goshawk
Accipiterstriatus	Sharp-Shinned Hawk
Actitismacularia	Spotted Sandpiper
Aechmophorusclarkii	Clark's Grebe
Aechmophorusoccidentalis	Western Grebe
Aegoliusacadicus	Northern Saw-Whet Owl
Aegoliusfunereus	Boreal Owl
Aeronautessaxatalis	White-Throated Swift
Agelaiusphoeniceus	Red-Winged Blackbird
Aixsponsa	Wood Duck
Alcesalces	Moose
Alectorischukar	Chukar
Ambystomatigrinum	Tiger Salamander
Ammodramusbairdii	Baird's Sparrow
Ammodramussavannarum	Grasshopper Sparrow

Table D.1

Names of Species in Species Richness Model (continued)

SPECIES NAME	COMMON NAME
Amphispizabelli	Sage Sparrow
Anasacuta	Northern Pintail
Anasamericana	American Wigeon
Anasclypeata	Northern Shoveler
Anascrecca	Green-Winged Teal
Anascyanoptera	Cinnamon Teal
Anasdiscors	Blue-Winged Teal
Anasplatyrhynchos	Mallard
Anasstrepera	Gadwall
Anseralbifrons	Greater White-Fronted Goose
Anthusspragueii	Sprague's Pipit
Antilocapraamericana	Pronghorn
Antrozouspallidus	Pallid Bat
Aquilachrysaetos	Golden Eagle
Archilochusalexandri	Black-Chinned Hummingbird
Ardeaherodias	Great Blue Heron
Asioflammeus	Short-Eared Owl
Asiootus	Long-Eared Owl
Athenecunicularia	Burrowing Owl

Table D.1

Names of Species in Species Richness Model (continued)

SPECIES NAME	COMMON NAME
Aythyaaffinis	Lesser Scaup
Aythyaamericana	Redhead
Aythyacollaris	Ring-Necked Duck
Bartramialongicauda	Upland Sandpiper
Bassariscusastutus	Ringtail
Bombycillacedrorum	Cedar Waxwing
Bombycillagarrulus	Bohemian Waxwing
Bonasaumbellus	Ruffed Grouse
Botauruslentiginosus	American Bittern
Brachylagusidahoensis	Pygmy Rabbit
Brantacanadensis	Canada Goose
Bubovirginianus	Great Horned Owl
Bubulcusibis	Cattle Egret
Bucephalaalbeola	Bufflehead
Bucephalaclangula	Common Goldeneye
Bucephalaislandica	Barrow's Goldeneye
Bufoboreas	Western Toad
Bufocognatus	Great Plains Toad
Bufowoodhousii	Woodhouse's Toad
Buteojamaicensis	Red-Tailed Hawk

Table D.1

Names of Species in Species Richness Model (continued)

SPECIES NAME	COMMON NAME
Buteolagopus	Rough-Legged Hawk
Buteoplatypterus	Broad-Winged Hawk
Buteoregalis	Ferruginous Hawk
Buteoswainsoni	Swainson's Hawk
Calamospizamelanocorys	Lark Bunting
Calcariuslapponicus	Lapland Longspur
Calcariusmccownii	Mccown's Longspur
Calcariusornatus	Chestnut-Collared Longspur
Calidrisalba	Sanderling
Calidrisbairdii	Baird's Sandpiper
Calidrishimantopus	Stilt Sandpiper
Calidrismauri	Western Sandpiper
Calidrismelanotos	Pectoral Sandpiper
Calidrisminutilla	Least Sandpiper
Calidrispusilla	Semipalmated Sandpiper
Canislatrans	Coyote
Canislupus	Gray Wolf
Carduelisflammea	Common Redpoll
Carduelispinus	Pine Siskin
Carduelispsaltria	Lesser Goldfinch

Table D.1

Names of Species in Species Richness Model (continued)

SPECIES NAME	COMMON NAME
Carduelistristis	American Goldfinch
Carpodacuscassinii	Cassin's Finch
Carpodacusmexicanus	House Finch
Carpodacuspurpureus	Purple Finch
Castorcanadensis	Beaver
Cathartesaura	Turkey Vulture
Catharusfuscescens	Veery
Catharusguttatus	Hermit Thrush
Catharusustulatus	Swainson's Thrush
Catherpesmexicanus	Canyon Wren
Catoptrophorussemipalmatus	Willet
Centrocercusurophasianus	Greater Sage-Grouse
Certhiaamericana	Brown Creeper
Cervuselaphus	Wapiti
Cerylealcyon	Belted Kingfisher
Chaeturapelagica	Chimney Swift
Charadriusalexandrinus	Snowy Plover
Charadriusmelodus	Piping Plover
Charadriusmontanus	Mountain Plover
Charadriussemipalmatus	Semipalmated Plover

Table D.1

Names of Species in Species Richness Model (continued)

SPECIES NAME	COMMON NAME
Charadriusvociferus	Killdeer
Chencaerulescens	Snow Goose
Chlidoniasniger	Black Tern
Chondestesgrammacus	Lark Sparrow
Chordeilesminor	Common Nighthawk
Cinclusmexicanus	American Dipper
Circuscyaneus	Northern Harrier
Cistothoruspalustris	Marsh Wren
Clethrionomysgapperi	Southern Red-Backed Vole
Cnemidophorussexlineatus	Six-Lined Racerunner
Coccothraustesvespertinus	Evening Grosbeak
Coccyzusamericanus	Yellow-Billed Cuckoo
Coccyzuserythropthalmus	Black-Billed Cuckoo
Colaptesauratus	Northern Flicker
Colinusvirginianus	Northern Bobwhite
Contopussordidulus	Western Wood-Pewee
Corvuscorax	Common Raven
Cyanocittacristata	Blue Jay
Cyanocittastelleri	Steller's Jay
Cygnusbuccinator	Trumpeter Swan

Table D.1

Names of Species in Species Richness Model (continued)

SPECIES NAME	COMMON NAME
Cygnuscolumbianus	Tundra Swan
Cynomysleucurus	White-Tailed Prairiedog
Dendroicacoronata	Yellow-Rumped Warbler
Dendroicapetechia	Yellow Warbler
Dendroicastriata	Blackpoll Warbler
Dendroicatownsendi	Townsend's Warbler
Dipodomysordii	Ord's Kangaroo Rat
Dolichonyxoryzivorus	Bobolink
Dumetellacarolinensis	Gray Catbird
Egrettathula	Snowy Egret
Empidonaxhammondii	Hammond's Flycatcher
Empidonaxoberholseri	Dusky Flycatcher
Empidonaxoccidentalis	Cordilleran Flycatcher
Empidonaxtraillii	Willow Flycatcher
Empidonaxwrightii	Gray Flycatcher
Eremophilaalpestris	Horned Lark
Erethizondorsatum	Porcupine
Eudermamaculatum	Spotted Bat
Euphaguscyanocephalus	Brewer’s Blackbird
Falcocolumbarius	Merlin

Table D.1

Names of Species in Species Richness Model (continued)

SPECIES NAME	COMMON NAME
Falcomexicanus	Prairie Falcon
Falcoperegrinus	Peregrine Falcon
Falcosparverius	American Kestrel
Fulicaamericana	American Coot
Gallinagogallinago	Common Snipe
Gaviaimmer	Common Loon
Geomysbursarius	Plains Pocket Gopher
Geothlypistrichas	Common Yellowthroat
Glaucidiumgnoma	Northern Pygmy-Owl
Glaucomyssabrinus	Northern Flying Squirrel
Grusamericana	Whooping Crane
Gruscanadensis	Sandhill Crane
Guiracacaerulea	Blue Grosbeak
Gulogulo	Wolverine
Gymnorhinuscyanocephalus	Pinyon Jay
Haliaeetusleucocephalus	Bald Eagle
Himantopusmexicanus	Black-Necked Stilt
Icteriavirens	Yellow-Breasted Chat
Icterusgalbula	Baltimore Oriole
Icterusparisorum	scott's oriole

Table D.1

Names of Species in Species Richness Model (continued)

SPECIES NAME	COMMON NAME
Icterusspurius	Orchard Oriole
Juncohyemalis	Dark-Eyed Junco
Lagopusleucurus	White-Tailed Ptarmigan
Laniusexcubitor	Northern Shrike
Laniusludovicianus	Loggerhead Shrike
Larusargentatus	Herring Gull
Laruscalifornicus	California Gull
Larusdelawarensis	Ring-Billed Gull
Larusphiladelphia	Bonaparte's Gull
Laruspipixcan	Franklin's Gull
Lasionycterisnoctivagans	Silver-Haired Bat
Lasiurusborealis	Eastern Red Bat
Lasiuruscinereus	Hoary Bat
Lemmiscuscurtatus	Sagebrush Vole
Lepusamericanus	Snowshoe Hare
Lepuscalifornicus	Black-Tailed Jackrabbit
Lepustownsendii	White-Tailed Jackrabbit
Limnodromusscolopaceus	Long-Billed Dowitcher
Limosafedoa	Marbled Godwit
Lophodytescucullatus	Hooded Merganser

Table D.1

Names of Species in Species Richness Model (continued)

SPECIES NAME	COMMON NAME
Loxiacurvirostra	Red Crossbill
Loxialeucoptera	White-Winged Crossbill
Lynxcanadensis	Lynx
Lynxrufus	Bobcat
Marmotaflaviventris	Yellow-Bellied Marmot
Martesamericana	Marten
Martespennanti	Fisher
Melanerpeserythrocephalus	Red-Headed Woodpecker
Melanerpeslewis	Lewis's Woodpecker
Melanittafusca	White-Winged Scoter
Melanittaperspicillata	Surf Scoter
Meleagrisgallopavo	Wild Turkey
Melospizalincolnii	Lincoln's Sparrow
Melospizamelodia	Song Sparrow
Mephitismephitis	Striped Skunk
Mergusmerganser	Common Merganser
Mergusserrator	Red-Breasted Merganser
Microtuslongicaudus	Long-Tailed Vole
Microtusmontanus	Montane Vole
Microtusochrogaster	Prairie Vole

Table D.1

Names of Species in Species Richness Model (continued)

SPECIES NAME	COMMON NAME
Microtuspennsylvanicus	Meadow Vole
Microtusrichardsoni	Water Vole
Mimuspolyglottos	Northern Mockingbird
Mniotiltavaria	Black-And-White Warbler
Molothrusater	Brown-Headed Cowbird
Mustelaerminea	Ermine
Mustelafrenata	Long-Tailed Weasel
Mustelanigripes	Black-Footed Ferret
Mustelavison	Mink
Myadestestownsendi	Townsend's Solitaire
Myiarchuscinerascens	Ash-Throated Flycatcher
Myotiscalifornicus	California Myotis
Myotisciliolabrum	Western Small-Footed Myotis
Myotisevotis	Long-Eared Myotis
Myotislucifugus	Little Brown Bat
Myotisthysanodes	Fringed Myotis
Myotisvolans	Long-Legged Myotis
Myotisyumanensis	Yuma Myotis
Neotomacinerea	Bushy-Tailed Wood Rat

Table D.1

Names of Species in Species Richness Model (continued)

SPECIES NAME	COMMON NAME
Nucifragacolumbiana	Clark's Nutcracker
Numeniusamericanus	Long-Billed Curlew
Numeniusphaeopus	Whimbrel
Nycticoraxnycticorax	Black-Crowned Night-Heron
Ochotonaprinceps	American Pika
Odocoileushemionus	Mule Deer
Odocoileusvirginianus	White-Tailed Deer
Ondatrazibethicus	Muskrat
Onychomysleucogaster	Northern Grasshoppe Rmouse
Oporornistolmiei	Macgillivray's Warbler
Oreamnosamericanus	Mountain Goat
Oreoscoptesmontanus	Sage Thrasher
Otusasio	Eastern Screech-Owl
Otusflammeolus	Flammulated Owl
Otuskennicottii	Western Screech-Owl
Oviscanadensis	Bighorn Sheep
Oxyurajamaicensis	Ruddy Duck
Pandionhaliaetus	Osprey
Passerculussandwichensis	Savannah Sparrow
Passerellailiaca	fox sparrow

Table D.1

Names of Species in Species Richness Model (continued)

SPECIES NAME	COMMON NAME
Passerinaamoena	Lazuli Bunting
Passerinacyanea	Indigo Bunting
Pelecanuserythrorhynchos	American White Pelican
Perdixperdix	Gray Partridge
Perisoreuscanadensis	Gray Jay
Perognathusfasciatus	Olive-Backed Pocket Mouse
Perognathusflavescens	Pains Pocket Mouse
Perognathusflavus	Silky Pocket Mouse
Perognathusparvus	Great Basin Pocket Mouse
Peromyscuscrinitus	Canyon Mouse
Peromyscusleucopus	White-Footed Mouse
Peromyscusmaniculatus	Deer Mouse
Peromyscustruei	Pinon Mouse
Phalacrocoraxauritus	Double-Crested Cormorant
Phalaenoptilusnuttallii	Common Poorwill
Phalaropuslobatus	Red-Necked Phalarope
Phalaropustricolor	Wilson's Phalarope
Phasianuscolchicus	Ring-Necked Pheasant
Phenacomysintermedius	Heather Vole
Pheucticusludovicianus	Rose-Breasted Grosbeak

Table D.1

Names of Species in Species Richness Model (continued)

SPECIES NAME	COMMON NAME
Pheucticusmelanocephalus	Black-Headed Grosbeak
Picoidespubescens	Downy Woodpecker
Picoidestridactylus	Three-Toed Woodpecker
Picoidesvillosus	Hairy Woodpecker
Pinicolaenucleator	Pine Grosbeak
Pipilochlorurus	Green-Tailed Towhee
Pirangaludoviciana	Western Tanager
Pirangarubra	Summer Tanager
Plectrophenaxnivalis	Snow Bunting
Plegadischihi	White-Faced Ibis
Pluvialisdominica	American Golden-Plover
Pluvialissquatarola	Black-Bellied Plover
Podicepsauritus	Horned Grebe
Podicepsgrisegena	Red-Necked Grebe
Podicepsnigricollis	Eared Grebe
Podilymbuspodiceps	Pied-Billed Grebe
Polioptilacaerulea	Blue-Gray Gnatcatcher
Pooecetesgramineus	Vesper Sparrow
Porzanacarolina	Sora

Table D.1

Names of Species in Species Richness Model (continued)

SPECIES NAME	COMMON NAME
Procyonlotor	Raccoon
Psaltriparusminimus	Bushtit
Quiscalusquiscula	Common Grackle
Ralluslimicola	Virginia Rail
Ranacatesbeiana	Bullfrog
Ranapipiens	Northern Leopard Frog
Ranasylvatica	Wood Frog
Recurvirostraamericana	American Avocet
Reguluscalendula	Ruby-Crowned Kinglet
Regulussatrapa	Golden-Crowned Kinglet
Reithrodontomysmegalotis	Western Harvest Mouse
Reithrodontomysmontanus	Plains Harvest Mouse
Ripariariparia	Bank Swallow
Salpinctesobsoletus	Rock Wren
Sayornisphoebe	Eastern Phoebe
Sayornissaya	Say’s Phoebe
Scalopusaquaticus	Eastern Mole
Sciurusaberti	Abert's Squirrel
Sciurusniger	Fox Squirrel
Seiurusaurocapillus	Ovenbird

Table D.1

Names of Species in Species Richness Model (continued)

SPECIES NAME	COMMON NAME
Seiurusnoveboracensis	Northern Water Thrush
Selasphorusplatycercus	Broad-Tailed Hummingbird
Selasphorusrufus	Rufous Hummingbird
Setophagaruticilla	American Redstart
Sialiacurrucoides	Mountain Bluebird
Sialiasialis	Eastern Bluebird
Sittacanadensis	Red-Breasted Nuthatch
Sittacarolinensis	White-Breasted Nuthatch
Sittapygmaea	Pygmy Nuthatch
Sorexcinereus	Masked Shrew
Sorexhoyi	Pygmy Shrew
Sorexmerriami	Merriam's Shrew
Sorexmonticolus	Montane Shrew
Sorexnanus	Dwarf Shrew
Sorexpalustris	Northern Water Shrew
Sorexpreblei	Preble's Shrew
Sorexvagrans	Vagrant Shrew
Spermophilusarmatus	Uinta Ground Squirrel
Spermophiluselegans	Wyoming Ground Squirrel
Spermophiluslateralis	Golden-Mantled Ground Squirrel

Table D.1

Names of Species in Species Richness Model (continued)

SPECIES NAME	COMMON NAME
Spermophilusspilosoma	Spotted Ground Squirrel
Spermophilustridecemlineatus	Thirteen-Lined Ground Squirrel
Sphyrapicusnuchalis	Red-Naped Sapsucker
Sphyrapicusthyroideus	Williamson's Sapsucker
Spilogalegracilis	Western Spotted Skunk
Spilogaleputorius	Eastern Spotted Skunk
Spizaamericana	Dickcissel
Spizellaarborea	American Tree Sparrow
Spizellapallida	Clay-Colored Sparrow
Spizellapasserina	Chipping Sparrow
Spizellapusilla	Field Sparrow
Stelgidopteryxserripennis	Northern Rough-Winged Swallow
Stellulacalliope	Calliope Hummingbird
Sternacaspia	Caspian Tern
Sternaforsteri	Forster's Tern
Sternahirundo	Common Tern
Strixoccidentalis	Spotted Owl
Sturnellaneglecta	Western Meadowlark
Sylvilagusaudubonii	Desert Cottontail
Sylvilagusfloridanus	Eastern Cottontail

Table D.1

Names of Species in Species Richness Model (continued)

SPECIES NAME	COMMON NAME
Sylvilagusnuttallii	Mountain Cottontail
Tachycinetabicolor	Tree Swallow
Tachycinetathalassina	Violet-Green Swallow
Tadaridabrasiliensis	Brazilian Free-Tailed Bat
Tamiasamoenus	Yellow-Pine Chipmunk
Tamiasdorsalis	Cliff Chipmunk
Tamiasminimus	Least Chipmunk
Tamiasumbrinus	Uinta Chipmunk
Tamiasciurushudsonicus	Red Squirrel
Taxideataxus	Badger
Thomomysidahoensis	Idaho Pocket Gopher
Thomomystalpoides	Northern Pocket Gopher
Thryomanesbewickii	Bewick's Wren
Toxostomarufum	Brown Thrasher
Tringaflavipes	Lesser Yellowlegs
Tringamelanoleuca	Greater Yellowlegs
Troglodytesaedon	House Wren
Turdusmigratorius	American Robin
Tympanuchusphasianelluscolumbianus	Sharp-Tailed Grouse-Columbian

Table D.1

Names of Species in Species Richness Model (continued)

SPECIES NAME	COMMON NAME
Tympanuchusphasianellusjamesi	Sharp-Tailed Grouse-Plains
Tyrannustyrannus	Eastern Kingbird
Tyrannusverticalis	Western Kingbird
Tyrannusvociferans	Cassin's Kingbird
Tytoalba	Common Barn-Owl
Urocyoncinereoargenteus	Gray Fox
Ursusamericanus	American Black Bear
Ursusarctos	Brown Bear
Vermivoracelata	Orange-Crowned Warbler
Vermivoraperegrina	Tennessee Warbler
Vermivoraruficapilla	Nashville Warbler
Vermivoravirginiae	Virginia’s Warbler
Vireogilvus	Warbling Vireo
Vireoolivaceus	Red-Eyed Vireo
Vulpesvelox	Swift Fox
Vulpesvulpes	Red Fox
Wilsoniapusilla	Wilson's Warbler
Xanthocephalusxanthocephalus	Yellow-Headed Blackbird
Zapushudsonius	Meadow Jumping Mouse
Zapusprinceps	Western Jumping Mouse

Table D.1

Names of Species in Species Richness Model (continued)

SPECIES NAME	COMMON NAME
Zenaidamacroura	Mourning Dove
Zonotrichialeucophrys	White-Crowned Sparrow
Zonotrichiaquerula	Harris's Sparrow

APPENDIX E. THREATENED AND ENDANGERED SPECIES, AND SPECIES OF CONCERN

Threatened and Endangered Species, and Species of Concern

Table E.1

Names of Federal and State Listed Species in the Region

COMMON NAME	SCIENTIFIC NAME	STATUS*
	AMPHIBIANS	
Boreal Toad	Bufo boreas boreas	SE
Northern Cricket Frog	Acris crepitans	SC
Great Plains Narrowmouth Toad	Gastrophryne olivacea	SC
Northern Leopard Frog	Rana pipiens	SC
Wood Frog	Rana sylvatica	SC
Plains Leopard Frog	Rana blairi	SC
Couch's Spadefoot	Scaphiopus couchii	SC
	BIRDS	
Whooping Crane	Grus americana	FE, SE
Least Tern	Sterna antillarum	FE, SE
Southwestern Willow Flycatcher	Empidonax traillii extimus	FE, SE
Plains Sharp-Tailed Grouse	Tympanuchus phasianellus jamesii	SE
Piping Plover	Charadrius melodus circumcinctus	FT, ST
Bald Eagle	Haliaeetus leucocephalus	ST
Mexican Spotted Owl	Strix occidentalis lucida	FT, ST
Burrowing Owl	Athene cunicularia	ST
Lesser Prairie-Chicken	Tympanuchus pallidicinctus	ST
Western Yellow-Billed Cuckoo	Coccyzus americanus	SC
Greater Sandhill Crane	Grus canadensis tabida	SC
Ferruginous Hawk	Buteo regalis	SC
Gunnison Sage-Grouse	Centrocercus minimus	SC
American Peregrine Falcon	Falco peregrinus anatum	SC
Greater Sage Grouse	Centrocercus urophasianus	SC
Western Snowy Plover	Charadrius alexandrinus	SC
Mountain Plover	Charadrius montanus	SC
Long-Billed Curlew	Numenius americanus	SC
Columbian Sharp-Tailed Grouse	Tympanuchus phasianellus columbianus	SC
	FISH	
Bonytail	Gila elegans	FE, SE
Razorback Sucker	Xyrauchen texanus	FE, SE
Humpback Chub	Gila cypha	FE, ST
Colorado Pikeminnow	Ptychocheilus lucius	FE, ST
Greenback Cutthroat Trout	Oncorhynchus clarki stomias	FT, ST
Rio Grande Sucker	Catostomus plebeius	SE
Lake Chub	Couesius plumbeus	SE
Plains Minnow	Hybognathus placitus	SE
Suckermouth Minnow	Phenacobius mirabilis	SE
Northern Redbelly Dace	Phoxinus eos	SE
Southern Redbelly Dace	Phoxinus erythrogaster	SE
Brassy Minnow	Hybognathus hankinsoni	ST
Common Shiner	Luxilus cornutus	ST

Table E.1

Names of Federal and State Listed Species in the Region (continued)

COMMON NAME	SCIENTIFIC NAME	STATUS*
Arkansas Darter	Etheostoma cragini	ST
Mountain Sucker	Catostomus playtrhynchus	SC
Plains Orangethroat Darter	Etheostoma spectabile	SC
Iowa Darter	Etheostoma exile	SC
Rio Grande Chub	Gila Pandora	SC
Colorado Roundtail Chub	Gila robusta	SC
Stonecat	Noturus flavus	SC
Colorado River Cutthroat Trout	Oncorhynchus clarki pleuriticus	SC
Rio Grande Cutthroat Trout	Oncorhynchus clarki virginalis	SC
Flathead Chub	Platygobio gracilus	SC
	MAMMALS	
Gray Wolf	Canis lupus	FE, SE
Black-Footed Ferret	Mustela nigripes	FE, SE
Grizzly Bear	Ursus arctos	FT, SE
Preble's Meadow Jumping Mouse	Zapus hudsonius preblei	FT, ST
Lynx	Lynx canadensis	FT, SE
Wolverine	Gulo gulo	SE
River Otter	Lontra canadensis	ST
Kit Fox	Vulpes macrotis	SE
Townsend's Big-Eared Bat	Corynorhinus townsendii pallescens	SC
Black-Tailed Prairie Dog	Cynomys ludovicianus	SC
Botta's Pocket Gopher	Thomomy bottae rubidus	SC
Northern Pocket Gopher	Thomomys talpoides macrotis	SC
Swift fox	Vulpes velox	SC
	REPTILES	
Triploid Checkered Whiptail	Cnemidophorus neotesselatus	SC
Midget Faded Rattlesnake	Crotalus viridis concolor	SC
Longnose Leopard Lizard	Gambelia wislizenii	SC
Yellow Mud Turtle	Kinosternon flavescens	SC
Common King Snake	Lampropeltis getula	SC
Texas Blind Snake	Leptotyphlops dulcis	SC
Texas Horned Lizard	Phrynosoma cornutum	SC
Roundtail Horned Lizard	Phrynosoma modestum	SC
Massasauga	Sistrurus catenatus	SC
Common Garter Snake	Thamnophis sirtalis	SC
	MOLLUSKS	
Rocky Mountain Capshell	Acroloxus coloradensis	SC
Cylindrical Papershell	Anodontoides ferussacianus	SC

*Status Codes:

FE = Federally Endangered

FT = Federally Threatened

SE = State Endangered

ST = State Threatened

SC = State Special Concern (not a statutory category) Last Updated: 10/15/2007

APPENDIX F. SELECTED SPECIES IN THE THREATENED AND ENDANGERED POTENTIAL SPECIES RICHNESS MODEL

Selected Species in the Threatened And Endangered Potential Species Richness Model

Table F.1

Names of selected species in Threatened and Endangered Species Richness Model

COMMON NAME	SCIENTIFIC NAME	STATUS*
	AMPHIBIANS	
Boreal Toad	Bufo boreas boreas	SE
Northern Leopard Frog	Rana pipiens	SC
Wood Frog	Rana sylvatica	SC
	BIRDS	
Least Tern	Sterna antillarum	FE, SE
Southwestern Willow Flycatcher	Empidonax traillii extimus	FE, SE
Bald Eagle	Haliaeetus leucocephalus	ST
Mexican Spotted Owl	Strix occidentalis lucida	FT, ST
Burrowing Owl	Athene cunicularia	ST
Western Yellow-Billed Cuckoo	Coccyzus americanus	SC
Greater Sandhill Crane	Grus canadensis tabida	SC
Ferruginous Hawk	Buteo regalis	SC
American Peregrine Falcon	Falco peregrinus anatum	SC
Greater Sage Grouse	Centrocercus urophasianus	SC
Mountain Plover	Charadrius montanus	SC
Long-Billed Curlew	Numenius americanus	SC
Columbian Sharp-Tailed Grouse	Tympanuchus phasianellus columbianus	SC
	FISH	
Razorback Sucker	Xyrauchen texanus	FE, SE
Humpback Chub	Gila cypha	FE, ST
Colorado Pikeminnow	Ptychocheilus lucius	FE, ST
	MAMMALS	
Black-Footed Ferret	Mustela nigripes	FE, SE
Lynx	Lynx canadensis	FT, SE
Wolverine	Gulo gulo	SE
River Otter	Lontra canadensis	ST
Kit Fox	Vulpes macrotis	SE
Botta's Pocket Gopher	Thomomy bottae rubidus	SC
Northern Pocket Gopher	Thomomys talpoides macrotis	SC
Swift fox	Vulpes velox	SC

APPENDIX G: MODEL CRITERIA FOR ENERGY DEVELOPMENT SCENARIOS

Energy Development Scenario Criteria

Table G.1

Details of development criteria for energy scenario models

Energy Source / Criteria	Buildout	Business-as-Usual	Moderate Conservation
Coal			
Model location preferences for new mines:			
	150% of current mean distance:	120% of current mean distance:	100% of current mean distance:
Meters to towns	13,304	10,643	8,869
Meters to roads	24,293	19,434	16,195
Meters to rail	9,404	7,523	6,269
Meters to power grid	15,554	12,443	10,369
Meters to other mines	17,000	17,000	15,000
Wilderness & National Park Buffer	None	3Km	3Km
Coal mine replacement rate	100%	100%	100%
Antipater need	50% new	25% new	No New
Criteria weighting	75% location, 25% coal type	75% location, 25% coal type	75% location, 25% coal type
Oil and Gas			
Gas Density, Million CF/Square Mile	Any Amount	> 710	>1245
Liquid Density, MBbls/Square Mile	Any Amount	> 36	>56
Less Coal Scenarios for Oil *			
Wilderness & National Park Buffer	None	1Km	3Km
Oil Shale			
Preferences	All	Selected	Exploration only
Land Ownership	All	Public Lands	Oil Shale Reserve
Less Coal and Gas scenarios*	No Coal overlap*	No Coal overlap*	No Coal overlap*
Wilderness & National Park Buffer	None	1 Km	3 Km
Populated Places Buffer	1 Km	2 Km	5 Km
Tar Sands			
Preferences	All	Selected	None
Public Lands	All	Public Lands	
Less Coal, Gas and Oil Shale scenarios*	No Coal overlap*	No Coal overlap*	
NPS Buffer	None	1 Km	
Wilderness Buffer	None	1 Km	
Populated Places Buffer	1 Km	2 Km	

*Prioritization is given first to coal, then oil and gas, and lastly oil shale. Where resources overlap, they are modeled for the higher priority source. For this reason, the Buildout Scenario yields smaller area than Business-as-Usual.

Table G.1

Details of development criteria for energy scenario models (continued)

Energy Source / Criteria	Buildout	Business-as-Usual	Moderate Conservation
Geothermal			
Graded wells	None	None	Grade A sites
Areas w/large scale potential			All
Distance to towns			10 K
Hydro			
Preferences	None	None	Identified in Federal Study for retrofit or improvement
Biomass			
Preferences	None	None	Selected
Distance from populated places			10 Km
Tonnes of fuelstock/year			>10373 (Top 30%)
Wind			
Preferences	Existing only	Existing only	Category 4 and up
Slope			Slope <50%
Elevation			< 3,048 meters