
SHRP 2 Capacity Project C21A

Pilot Test of the Ecological Approaches to Environmental Protection Developed in Capacity Research Projects C06A and C06B

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DETAILS

0 pages | 8.5 x 11 | PAPERBACK
ISBN 978-0-309-43399-0 | DOI 10.17226/22493

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SHRP 2
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Colorado State University

TRANSPORTATION RESEARCH BOARD
Washington, D.C.
2013
www.TRB.org

ACKNOWLEDGMENT

This work was sponsored by the Federal Highway Administration in cooperation with the American Association of State Highway and Transportation Officials. It was conducted in the second Strategic Highway Research Program, which is administered by the Transportation Research Board of the National Academies.

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CHAPTER 1
Overview and Context

Awareness of the need for more effective, streamlined, and integrated planning of transportation improvements has permeated all levels of government, and has become a top priority to advance the level of sophistication and integration for transportation planning. For example, the Federal Highways Administration (FHWA) has committed to the use of collaborative approaches to transportation planning, and has established environmental streamlining and stewardship as a major strategic direction for the agency. These approaches are now being recognized for their effectiveness and impact on reduced costs, fewer delays, and better environmental outcomes.

Modernized, integrated concepts of transportation planning are the focus of research being supported through the Strategic Highways Research Programs. A significant advancement in this field is the development of the Integrated Ecological Framework (referred to hereafter as "IEF" or "Framework") that has resulted from the SHRP 2 CO6 projects. Given the progressive approaches that have been embraced and implemented by the Colorado Department of Transportation (CDOT), such as the Shortgrass Prairie Initiative, the framework has a strong potential to further advance efforts to insert proactive natural resource conservation into the transportation planning process. At this stage in the evolution of these practices, a process has been developed that holds great promise for improving ecosystem and species recovery and watershed restoration, but it has yet to be adequately tested. This approach represents a major paradigm shift for transportation planning, and before it is (or should be) embraced by the planning community it requires testing, followed, if necessary, by refinements and adjustments. Thus, the framework, while leading towards better answers and better results, leaves planners with many crucial questions at this juncture.

The questions that the research team (also referred to as "the team") set out to address in this project are:

- How can these practices be integrated into current transportation planning?
- How can these practices lead to a better range of outcomes and mitigation options?
- How can areas be identified that represent the optimal priorities for conservation and mitigation?
- Can species models and improved wetland map resources lead to better conservation outcomes?
- How might credit markets be employed to achieve conservation objectives?
- What perceptions of natural resource values, credit markets, mitigation opportunities, and ecosystem services are held by travelers within project areas?
- And finally, what is the operational feasibility of this process?

According to the results of C06 research, three main barriers to successful environmental outcomes of transportation projects include lack of resources, lack of data, and resistance to change. CO6 identified three recommended solutions: 1) integrated planning (incorporating transportation, land use, and conservation in practical and effective ways), 2) making data available to support project and planning needs, and 3) the identification of priority conservation areas where opportunities for avoidance, preservation, and restoration can be seized. In this project, the research team addressed all three of these needs, as well as the questions highlighted above.

Context

C06 Integrated Ecological Framework and TCAPP Website

The C06 Framework referred to throughout this document consists of nine steps that, taken together, are designed to achieve a partner-driven vision for regional conservation in the context of infrastructure development (Table 1.1).

Table 1.1. The Nine Steps of the Integrated Ecological Framework

Step	Purpose
Step 1: Build and Strengthen Collaborative Partnerships, Vision	Build support among a group of stakeholders to achieve a statewide or regional planning process that integrates conservation and transportation planning.
Step 2: Characterize Resource Status. Integrate Conservation, Natural Resource, Watershed, and Species Recovery and State Wildlife Action Plans	Develop an overall conservation strategy that integrates conservation priorities, data, and plans, with input from and adoption by all conservation and natural resource stakeholders identified in Step 1 that addresses all species, all habitats, and all relevant environmental issues.
Step 3: Create Regional Ecosystem Framework (Conservation Strategy + Transportation Plan)	Integrate the conservation and restoration strategy (data and plans) prepared in Step 2 with transportation and land-use data and plans (LRTP, STIP, and TIP) to create the Regional Ecosystem Framework (REF).
Step 4: Assess Land Use and Transportation Effects on resource conservation objectives identified in the REF	Identify preferred alternatives that meet both transportation and conservation goals by analyzing transportation and/or other land-use scenarios in relation to resource conservation objectives and priorities utilizing the REF and models of priority resources.
Step 5: Establish and Prioritize Ecological Actions	Establish mitigation and conservation priorities and rank action opportunities using assessment results from Steps 3 and 4.
Step 6: Develop Crediting Strategy	Develop a consistent strategy and metrics to measure ecological impacts, restoration benefits, and long-term performance – with the goal of having the analyses be in the same language throughout the life of the project.

Step	Purpose
Step 7: Develop Programmatic Consultation, Biological Opinion or Permit	Develop MOUs, agreements, programmatic 404 permits or ESA Section 7 consultations for transportation projects in a way that documents the goals and priorities identified in Step 6 and the parameters for achieving these goals.
Step 8: Implement Agreements and Deliver Conservation and Transportation Projects	Design transportation projects in accordance with ecological objectives and goals identified in previous steps (i.e., keeping planning decisions linked to project decisions), incorporating as appropriate programmatic agreements, performance measures, and ecological metric tools to improve the project.
Step 9: Update Regional Integrated Plan/Ecosystem Framework	Update the effects assessment to determine if resource goal achievement is still on track. If goal achievement gaps are found, reassess priorities for mitigation, conservation, and restoration in light of new disturbances that may impact the practicality/utility of proceeding with previous priorities. Identify new priorities if warranted.

Transportation for Communities- Advancing Projects through Partnerships (TCAPP) is a product of SHRP 2 C01, designed to deliver a collaborative decision-making framework through a website, which is still under active development. The key feature of this website is the Decision Guide, which provides information needed to support "how to" decisions as part of a collaborative decision-making process. See www.transportationforcommunities.com for additional information.

Study Area

Over the course of the past year, the research team tested Steps 2 through 6 in the framework within the western portion of CDOT Region 1 (Figure 1.1). Region 1 follows the I-70 corridor from Summit County in the west to the Kansas border in the east. This part of Colorado includes many of the State's most heavily traveled roadways, areas of rapid development[1], and popular destinations for recreation. It also contains numerous critical and irreplaceable wetland resources, federally listed threatened and endangered species, other at-risk species[2], and key wildlife corridors. It contains many areas that have been identified as having high conservation values (The Nature Conservancy, Colorado Parks and Wildlife, Colorado Natural Heritage Program (CNHP), Keep it Colorado, and others), and is at the same time subject to tremendous

[1] According to CDOT's current Statewide Transportation Plan, Park County's population is expected to increase 482% by the year 2030 [www.coloradodot.info/programs/statewide-planning/long-range-transportation-plans.html].

[2] For the purposes of this report, "at risk" is defined as species with NatureServe conservation status ranks of G1-G3, S1, state listed species, and Sensitive Species identified by the U.S. Forest Service and/or the Bureau of Land Management. See Appendix A for details.

stress from rapid growth and significant impacts from development. Thus, in many ways it represents an ideal proving ground for the methods developed in CO6A and CO6B.

The research team identified a priority pilot study area within Region 1that is significant in terms of at-risk species, the need for improved data resources, and opportunities for exploring innovative approaches to mitigation. Two HUC-8 watershed boundaries form this pilot study area (Figure 1.1), and serve as the basis for developing a Regional Ecological Framework.

The study area includes a variety of mountainous and flat terrain, sparsely populated rural areas, national forests, dispersed residential developments, agriculture (ranchland and hay meadows), and urban centers (Figure 1.2). It includes the towns of Morrison, Bailey, Fairplay, and Hartsel, among others. Public lands account for the majority of the study area with 60% of the total acreage. Of that, the U.S. Forest Service owns 47%, the Bureau of Land Management owns 4%, and the State Land Board owns 3%. State parks, county parks, and school districts make up less than 2% of the study area (Figure 1.3).

Figure 1.1. Location of study area within Colorado.

This pilot focused on the area surrounding U.S. Highway 285 through the South Platte River Canyon of Jefferson County, and into a large inter-mountain park known as South Park in Park County. State Highway 9 and U.S. Highway 24 also traverse South Park. Highway 285 is one of very few major alternatives to Interstate 70 for metro-Denver residents to access the Rocky Mountains. As such, it is used extensively by tourists and recreationists, especially on weekends and during the vacation season. In addition, there is considerable residential development in the Jefferson County and the northeastern portion of Park County, so this portion of 285 is heavily used by commuters.

South Park, home to two Wilderness Areas, many hiking trails, and gold medal fishing streams, is very popular as a tourist destination, as well as for second home development. It is a National Heritage Area, designated for significant natural, cultural, and historic resources. This area also still supports large cattle ranching operations, and inhabitants are fiercely protective of their rural lifestyle.

Between 1989 and 2003, Highway 285 was upgraded from a two-lane to a four-lane highway from Turkey Creek Canyon (milepost 248) to Foxton Road (milepost 235). As part of this work, interchanges and intersection improvements were made at numerous locations. An Environmental Assessment (EA) for the next stretch of the corridor was completed in 2005. This EA calls for extending the four-lane expansion to the top of Crow Hill (milepost 226), just north of the town of Bailey (milepost 222). Also included in this EA are plans for seven interchanges, curve straightening, and intersection improvements in the Foxton Road to Bailey Corridor. Work on these improvements started in 2006. In addition, as part of its ongoing safety assessment program, CDOT has identified the need to construct passing lanes throughout South Park, south of the town of Bailey. At the time this was written, passing lane construction is scheduled to begin during the summer of 2012. There are no current plans to widen the highway into South Park, though this may be re-visited in the future. Meanwhile, the majority of transportation improvement projects currently planned and scheduled for the study area fall under NEPA's Categorical Exclusion. Given the significant natural and cultural resources, the popularity of the travel corridor, and the potential for significant future growth, this area would be an excellent place to consider a programmatic advance-mitigation project modeled after CDOT's award-winning Shortgrass Prairie Initiative (described below).

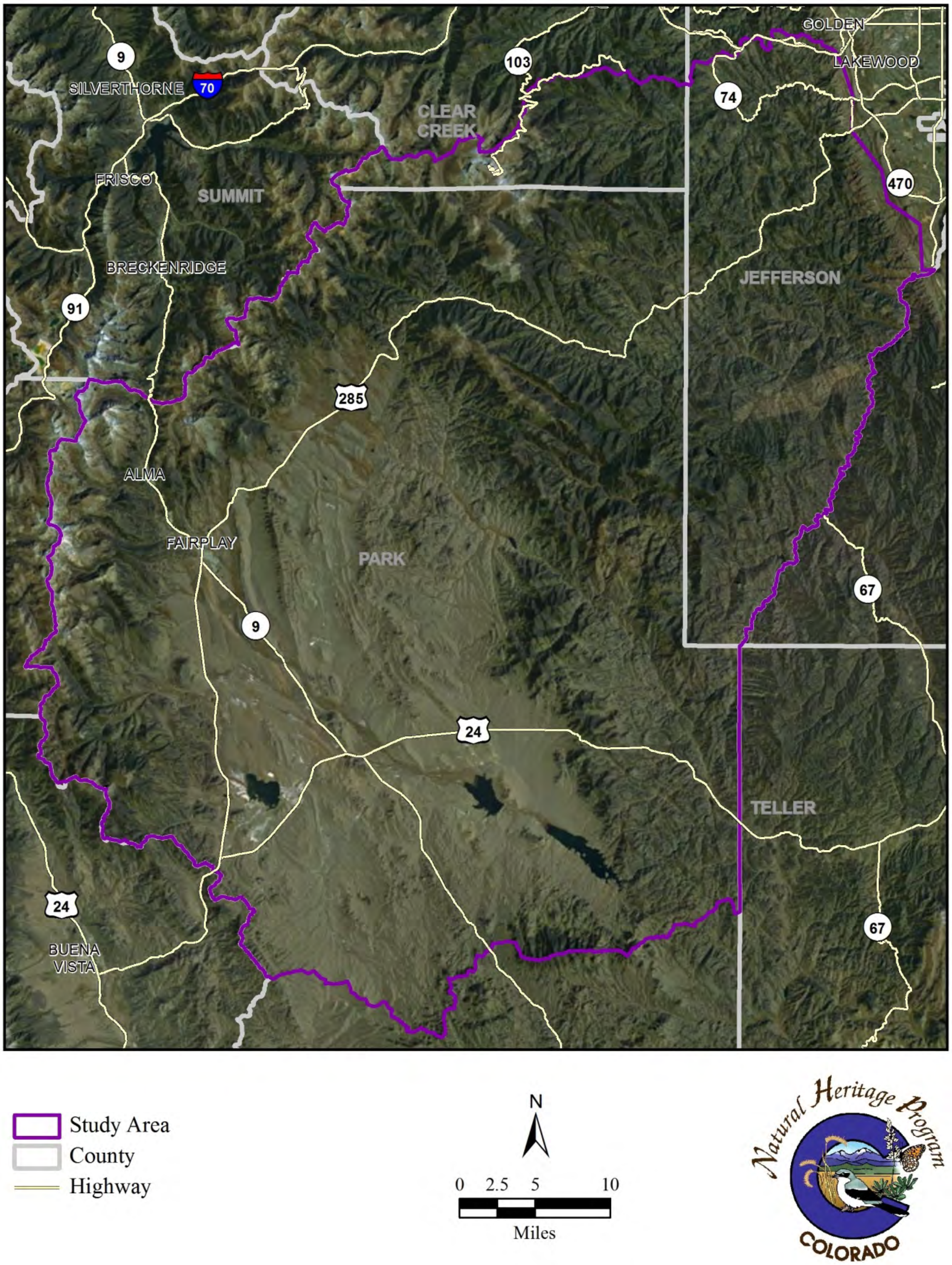

Figure 1.2. Satellite imagery of study area.

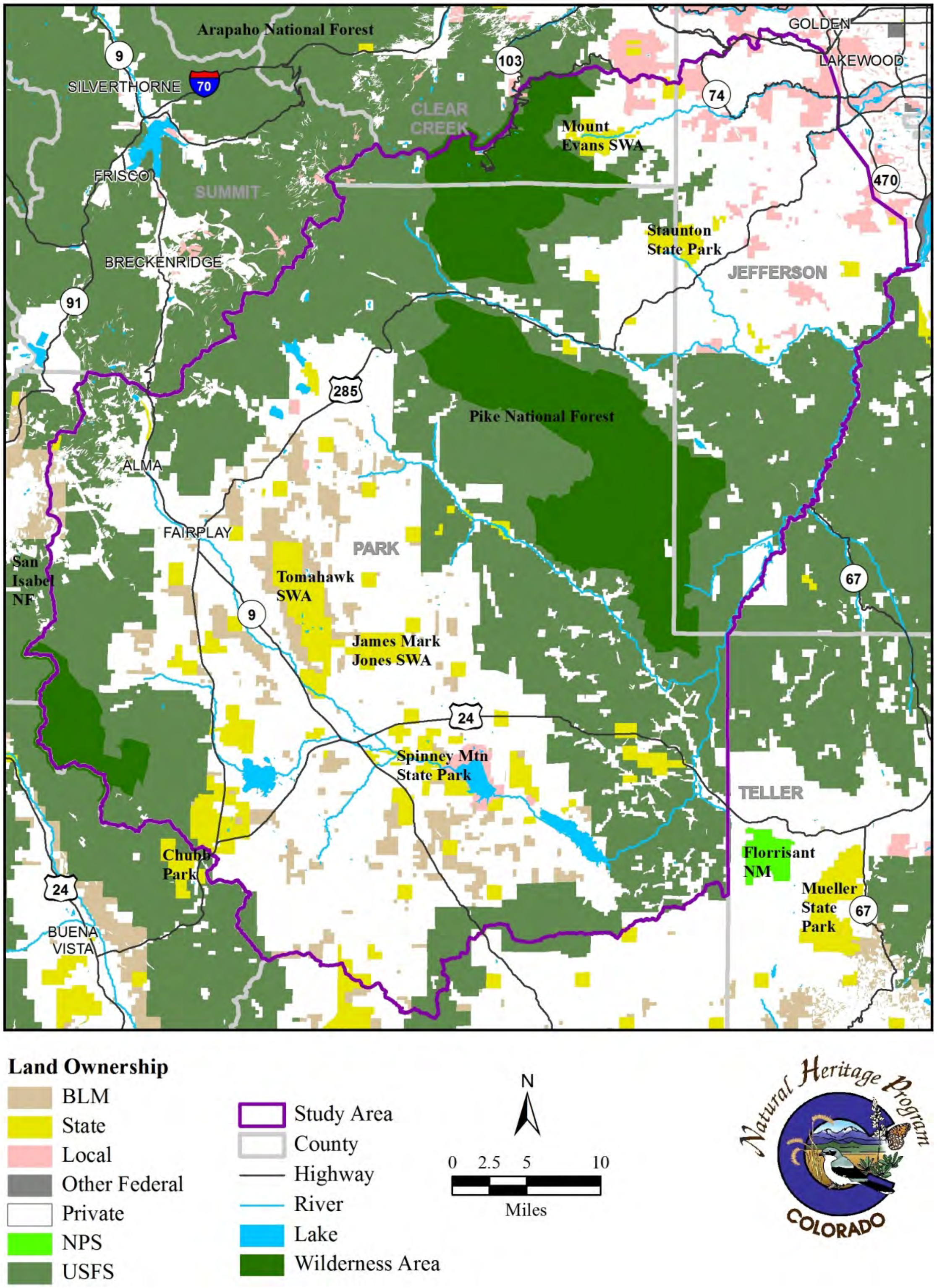

Figure 1.3. Land ownership in study area.

Current CDOT Planning Process[3]

The current transportation planning process in Colorado includes the development of long-range multimodal Regional Transportation Plans (RTPs) in CDOT's 15 transportation planning regions, a long-range multimodal Statewide Transportation Plan that sets the vision for transportation in the state, and a Statewide Transportation Improvement Program (STIP) that identifies short-term project needs and priorities. Development of a 20-year Statewide Transportation Plan begins at the local level with business people, residents and local officials in the Transportation Planning Regions. In brief, the regions develop RTPs, which are then integrated into the Statewide Transportation Plan. The Statewide Transportation Plan is corridor-based, including approximately 350 corridors statewide. Corridor visions include strategies aimed at meeting each corridor's unique transportation needs. The Statewide Transportation Plan is implemented by programming priority projects into the short-term, six-year STIP. All federally funded and regionally significant projects are identified in the STIP, and must be consistent with the corridor visions identified in the Statewide Transportation Plan. STIP projects are selected in cooperation with local officials in RTPs based on a set of criteria developed to solve or improve a particular congestion, safety, or system quality need on the transportation system. Once a STIP project has been selected for funding and construction, project planning and development (including public scoping and NEPA analysis) is begun.

As Colorado's state transportation planning process is currently implemented, environmental considerations are not included directly in regional planning, though they are increasingly considered in corridor planning. Usually, though, resource staff (e.g., biologists) are not involved until the project development phase. That is, Regional Transportation Plans, the Statewide Transportation Plan, and the STIP (steps that precede project planning) have all been created in the absence of direct environmental analyses. This situation appears to be largely due to lack of staff resources. CDOT staff in long-range planning expressed interest in addressing environmental concerns, but identified absence of resource specialists on the planning staff, as well as difficulty in acquiring and maintaining large datasets, as roadblocks. These statements apply very generally to typical transportation planning within CDOT. There are notable exceptions, especially within the realm of regional corridor analyses and related improvement projects, such as the 2002 US 285 Foxton Road to Bailey Corridor study. That project made successful use of a "context sensitive solutions" process that was closely aligned with the major steps in the IEF, but is not considered standard practice according to staff who contributed to this project.

Past and Planned Efforts Similar to the IEF

Shortgrass Prairie Initiative

In 2000, CDOT and a suite of partners that included the U.S. Fish and Wildlife Service, Federal Highway Administration, The Nature Conservancy, Venner Consulting, and the Colorado

[3] This information is summarized from www.coloradodot.info/programs.

Natural Heritage Program, produced a programmatic biological assessment and conservation strategy for the Central Shortgrass Prairie ecoregion of Colorado. At the time, there were several prairie species proposed for federal listing, which would have greatly complicated CDOT's ability to complete its work. The basic premise was to calculate estimated impacts to declining prairie species (including those proposed for listing and many others) from highway improvement projects on the exiting road network. Those impacts were then offset via a set of conservation easements that protected specific high quality prairie habitats. Easement acreage was based on the acres of habitat presumably impacted. "Presumed habitat" was mapped based on existing data (e.g., known occurrences, vegetation, elevation, distance to water) and then fine-tuned by expert review. The impact analysis was a simple GIS overlay process based on some very conservative assumptions on CDOT's part: 1) that all habitat acres were occupied, and 2) that all acres within the impact zone (i.e., the right-of-way) would be destroyed. In 2012, The Nature Conservancy and the Natural Heritage Program are still actively monitoring the easements. This project was widely hailed as a significant success story. Yet, it has not been replicated by CDOT in other regions. Reasons for this are unknown, but may be related to the fact that other regions have not experienced the unique set of circumstances from which this project arose – specifically, a number of species using the same habitats all being reviewed for federal listing at the same time. It should be noted, however, that several of the individuals who really supported this project and drove it through have since retired, moved to different locations, or left the agencies.

STEP-UP

In 2005, CDOT undertook the Strategic Transportation, Environmental and Planning Process for Urbanizing Places (STEP-UP) project, piloted with the North Front Range Metropolitan Planning Organization. The planning process developed under STEP-UP was very similar to the IEF in its focus on regional-scale environmental analysis, data development, and inter-agency collaboration. The STEP-UP process was designed around, and intended to rely heavily upon, development of a widely available statewide, comprehensive environmental database. Ultimately, this emphasis on creating and maintaining the database was the primary reason why STEP-UP did not become part of CDOT's standard operating procedure. The failure does not seem to be related so much to inability to acquire data, or lack of interest in the data. Rather, the problem was the absence of any agency or consortium of agencies willing/able to invest in, and assume responsibility for, the necessary housing, updating, and maintenance of the database. Additionally, as part of STEP-UP, CDOT collaborated with the University of Denver to develop a rigorous and repeatable method for conducting cumulative effects analyses. In the end, the results of that work were so complex and difficult for CDOT staff to understand that the entire idea was scrapped.

Two current efforts are under way that have goals in common with the IEF. CDOT's Statewide Planning office provided the following descriptions of two current projects they are sponsoring: 1) PEL (FHWA's Planning and Environmental Linkages" program) and Long-range

Planning, and 2) Integrating Land Use and Transportation Planning study (Tracey MacDonald, personal communication).

PEL and Long-Range Planning

CDOT's long-range planning staff recently initiated a study to develop a step-by-step methodology to better incorporate FHWA's PEL into the long-range transportation planning process. Once funding becomes available, a pilot study will be conducted to test the methodology. In developing the methodology, the study will consider the following:

- What other states have done in terms of incorporating PEL into the transportation planning process;
- Data needs;
- Stakeholder involvement and collaboration;
- State and federal planning factors;
- Consultation and mitigation requirements;
- Development of corridor needs statements to supplement the corridor visioning process; and
- Outline for pilot study framework (pilot is outside the scope of this initial effort).

Integrating Land Use and Transportation Planning Study

The purpose of this study is to develop a framework for a potential future pilot project in a non-urban area of the state for scenario planning. This will investigate the transportation effects of various land-use decisions. The project would utilize an affordable model (such as CommunityViz) for small town or rural area scenario planning that CDOT can first test and then provide as a tool to interested municipalities.

Principal objectives of the pilot and subsequent integrated land-use and transportation planning efforts include:

- Support land-use planning that reduces the need for costly roadway and infrastructure investments and provides other community benefits
- Foster improved understanding and coordination between CDOT and local communities around state highway mobility and access issues
- Promote federal, state and local sustainability and livability goals through partnerships
- Develop tools and processes to assist ongoing local community planning that better integrates land use, transportation and economic development.

The pilot will likely take place in spring/summer 2012. The pilot will be evaluated for effectiveness and potential for statewide application.

Colorado Watershed Approach to Wetland Mitigation

In 2008, U.S. Environmental Protection Agency (EPA) and U.S. Army Corps of Engineers (USACOE) issued the Joint Agency Final Rule on Compensatory Mitigation (40 CFR 230; referred to as the “2008 Rule”), which codified the use of a watershed approach to wetland mitigation. Though now mandated by the 2008 Rule, the watershed approach was not defined in detail and the process for applying the watershed approach was left to the states and USACOE Districts. Shortly after the rule was issued, EPA convened a multi-agency study team to develop guidance on applying the watershed approach to wetland mitigation in Colorado. The team was composed of staff from EPA Office of Research and Development, EPA Region 8 Wetlands Program, USACOE Omaha District, CDOT, CNHP, and Colorado State University (CSU) researcher Dr. Brad Johnson. This team developed a brief guidance document, or training syllabus, that effectively defined a practically applicable framework for the watershed approach. The document was formally transmitted from EPA Headquarters to the USACOE Denver regulatory Office in July 2011. Through a subsequent EPA Wetland Program Development Grant, CSU and CNHP are currently testing the principles outlined in the syllabus and creating a more detailed manual called the *Colorado Watershed Approach to Mitigation Planning and Permit Review*. Both the syllabus and the manual are based on a framework that lays out the mitigation process as a series of steps in which information is obtained in response to critical questions and then applied to the decision-making process. The most critical piece of information needed to carry out the watershed approach is an accounting for the extent, distribution, and types of wetlands within the watershed, also known as a “wetland landscape profile.” The most reliable data source for creating a wetland profile is U.S. Fish and Wildlife Service’s National Wetland Inventory mapping, which unfortunately is not available digitally in many parts of Colorado, but is being developed by CNHP with funding from multiple partners. Along with a current wetland profile for a given watershed, specific goals for improving the profile are defined (such as long-range watershed conservation plans) and mitigation decisions are made based on an evaluation of how the potential impact and compensatory mitigation project will affect the wetland profile. Whereas in the past, priority was given to mitigation projects that were “on-site and in-kind”, the watershed approach allows for mitigation projects and mitigation banks that are off-site and out-of-kind, if they improve the overall extent and distribution of wetlands within the watershed.

C21A Research Approach

This research was designed to test select elements of Framework Steps 2-6. The objectives of this project were to:

1. Evaluate the operational feasibility of implementing these Framework Steps;
2. Deliver a set of products that can be used to support landscape-scale analysis of priority natural resources and mitigation options; and
3. Provide value-added data that Region 1 personnel can put to immediate use in project evaluations and other work.

This work was organized around three major components:

1. Collaboration with CDOT staff and resource agency partners,
2. Data development and technical analyses, and
3. Assessment of TCAPP and the IEF from an operational implementation standpoint.

Collaboration consisted of a project kick-off meeting, a series of one-on-one phone calls, several online and in-person product review meetings, and a series of closing interviews to solicit feedback on the utility of the products and opportunities for implementing the IEF within CDOT.

Data development and technical analyses included:

- Development of potential habitat models for target species;
- Mapping of wetlands;
- Development of a conservation value summary for the study area;
- Analysis of existing impacts through development of a Landscape Integrity model;
- Identification of potential mitigation sites and strategies using a Marxan computer model; and
- Exploration into the potential for banking and market crediting strategies within the study area.

The assessment of TCAPP and the IEF includes research team observations related to the costs and benefits of the methods tested, as well as CDOT and agency partner input via the interviews mentioned above. Methods and results for each component of the work are presented in the following sections of this report.

Partner Involvement

Partners in this effort included CDOT staff and representatives of relevant state and federal resource agencies, including the Federal Highway Administration, the U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, the Pike-San Isabel National Forest, and Colorado Parks and Wildlife. A project kick-off meeting was held on June 21, 2011 to introduce the project to partners, and to solicit preliminary feedback on approach and methods. During this discussion, a number of issues became clear:

1. The research team needed to be engaging CDOT's long-range planners in addition to Region 1 project-level staff.
2. Project-level CDOT staff were not necessarily thinking about non-regulatory environmental impacts (e.g., non-listed species) and cross-boundary analysis.
3. Region 1 appeared to be relying more on advance consultations with resource agencies (e.g., USFWS) than on broad resource-based (e.g., species, ecosystems) planning using current GIS data.
4. Some CDOT personnel did not immediately recognize the difference between current planning processes and the proposed framework.

To address these issues, the team conducted a series of calls with CDOT staff to document how planning within Region 1 currently occurs, where confusion and misunderstanding(s) exist among partners in the current planning process, and where value-added opportunities within the framework lie. Two previous efforts on the part of CDOT to improve their incorporation of environmental issues into the planning process were identified. One of these efforts (STEP-UP, summarized above) was process-based, and included several planning steps similar to the C06 Framework. The other (2007 Statewide Environmental Forum) was primarily data-driven – in effect, a very rapid and coarse-scale data exchange between CDOT planning regions and resource agencies modeled after "speed dating." This Forum was considered very useful at the time, but has not been repeated or updated. The STEP-UP process never really gained traction, and has not been fully implemented in its pilot Metropolitan Planning Organization or adopted into wider use. The primary reasons for this appear to be issues revolving around data, and issues revolving around process (see discussion in Chapter 3 of this report).

Research Team Structure and Partner Collaboration

Dave Anderson (CNHP), Catherine Keske-Hoag (CSU), and Joshua Goldstein (CSU) were the principle investigators responsible for research. Jeff Peterson (CDOT) was responsible for inter- and intra-agency coordination. Lee Grunau (CNHP) was responsible for project management. Specific research components were:

1. Regional Ecological Framework, including species distribution mapping, conservation area priorities, high impact areas, and potential mitigation sites (leads: Lee Grunau, CNHP conservation planner, and Michelle Fink, CNHP landscape ecologist);
2. Wetland mapping (lead: Joanna Lemly, CNHP wetland ecologist);
3. Ecosystem services and crediting opportunities (leads: Drs. Josh Goldstein and Catherine Keske-Hoag); and
4. IEF assessment and critique (lead: Dr. Catherine Keske-Hoag).

CDOT staff from state headquarters, Region 1, and long-range planning participated in conference calls to provide background on current planning processes, meetings to review draft results from the technical analyses, and interviews to assess the IEF process. They also provided an assessment of the TCAPP website. Agency partners attended the project kick-off meeting, reviewed methods and draft results of technical analyses, and participated in interviews to assess the IEF process.

CHAPTER 2
Technical Analyses

IEF Step 2: Characterization of Resources

Resource characterization focused on collecting and summarizing available spatial data pertaining to natural resources in the study area. In addition to compiling base data, the team identified species of interest in the area, produced models of suitable habitat, mapped wetlands, and investigated the potential to integrate these data with information about other classes of resources.

Base Data

Before beginning data analysis, the team assembled all readily available GIS data for the study area. Data categories included:

- Transportation (roads and road-related data, airports, railroads, etc.);
- Political, census, and administrative boundaries, ownership and management (including conservation easements, where available) and land use;
- Physical environment: elevation models and their derivatives, hydrology, geology, soils, climate;
- Biological components: species and plant community occurrences, wildlife habitat and use information, vegetation; and
- Resource extraction (e.g., oil and gas, mining, logging, renewable energy).

The team was able to address an important data gap in the study area by incorporating a wetland mapping component in the project. Additionally, many of these datasets served as inputs for analyses discussed below. Data that were not readily available in a spatially referenced format included long-range transportation planning, county and regional zoning/planning information, county assessors' records, locations of cultural/historic resources, and interpreted socio-economic information.

Data Collection

An impressive amount of GIS data is available for Colorado as a whole, and for the study area in particular. However, the resolution and accuracy of the data vary widely. Also, several important categories of data for the study area were not readily available in a format that could be easily integrated into the spatial analyses. Many partners have expressed the desire to use data in a spatially referenced format, and there were a number of types of data that users would like to see that have never been made available. Potential datasets that were mentioned in partner discussions include:

- Historical land use and condition, including pre-development vegetation types, grazing history, logging or mining history, water diversion structures and hydrological modification through time, historic roads and trails, and similar data;
- Detailed, frequently updated parcel ownership and assessed land value, such as is maintained by county assessor's offices, in a unified format;
- Some kind of spatial representation of recreational or cultural values in an area, but not tied to exact point locations; and
- Cumulative tracking of impacts and mitigation across all agencies and other land management entities, especially on a regional or watershed basis (for instance, water quality information in a watershed context).

It seems worthwhile to invest in actual GIS data development as well as investigating methods for the spatial display of data that are difficult to incorporate into a GIS format. However, many of the desired datasets would require a substantial commitment to ongoing maintenance and updating. Some would also require an almost unconceivable level of cooperation between federal, state, and local agencies.

Target Species

The initial list of species of conservation concern in the study area (referred to hereafter as “target species”) was compiled from CNHP’s BIOTICS (Biodiversity Tracking and Conservation System) database. BIOTICS houses, among other data, information on documented occurrences of species that are considered vulnerable in Colorado at rangewide and statewide scales (see Appendix A for additional details). The list was initially revised to eliminate species lacking sufficient documentation to produce satisfactory modeling results, and species that are essentially peripheral to the study area. After review by project partners and CNHP scientists, several big game species and U.S. Forest Service Sensitive Species not tracked by CNHP were added. Due to time constraints imposed by data processing requirements, five species suggested by project partners were not included. The final list included 59 plants, 30 tracked animal species, and 6 additional large, common animal species, for a total of 95 target species (Table 2.1). Of these 95 species, 11 (10 animals and 1 plant) are either state or federally listed as threatened or endangered, including candidate designations.

Table 2.1. Target Species That Were the Focus of GIS Analysis

Scientific Name	Common Name	Global Status Rank[a]	State Status Rank[a]	Federal Listing Status[b]	State Listing[c]	Federal Agency Sensitive[d]
			AMPHIBIANS			
Bufo boreas boreas	**Western Toad - Southern Rocky Mountains population**	**G4T1Q**	**S1**		**SE**	
Rana pipiens	**Northern Leopard Frog**	**G5**	**S3**		**SC**	**BLM / USFS**
			BIRDS			
Accipiter gentilis	Northern Goshawk	G5	S3B			BLM/ USFS
Aegolius funereus	Boreal Owl	G5	S2			USFS
Aquila chrysaetos	Golden Eagle	G5	S3			
Athene cunicularia	**Burrowing Owl**	**G4**	**S4B**		**ST**	**BLM/ USFS**
Buteo regalis	Ferruginous Hawk	G4	S3B,S4N			BLM/ USFS
Catharus fuscescens	Veery	G5	S3B			
Charadrius montanus	Mountain Plover	G2	S2B			BLM/ USFS
Empidonax trailii	Willow Flycatcher	G5	S4			
Falco mexicanus	Prairie Falcon	G5	S4B,S4N			
Falco peregrinus anatum	American Peregrine Falcon	G4T4	S2B			USFS
Haliaeetus leucocephalus	Bald Eagle	G5	S1B,S3N			USFS
Lagopus leucurus	White-tailed Ptarmigan	G5	S4			USFS
Melanerpes lewis	Lewis's Woodpecker	G4	S4			USFS
Pelecanus erythrorhynchos	American White Pelican	G3	S1B			BLM
Seiurus aurocapilla	Ovenbird	G5	S2B			
Strix occidentalis lucida	**Mexican Spotted Owl**	**G3T3**	**S1B, SUN**	**LT**		
			FISH			
Onchorhynchus clarkii stomias	**Greenback Cutthroat Trout**	**G4T2T3**	**S2**	**LT**	**ST**	
Phoxinus eos	Northern Redbelly Dace	G5	S1			USFS
			INSECTS			
Callophrys mossii schryveri	Schryver's Elfin	G4T3	S2S3			
Celastrina humulus	Hops Azure	G2G3	S2			
Cicindela nebraskana	Prairie Long-lipped Tiger Beetle	G4	S1?			

Scientific Name	**Common Name**	**Global Status Rank[a]**	**State Status Rank[a]**	**Federal Listing Status[b]**	**State Listing[c]**	**Federal Agency Sensitive[d]**
Erynnis martialis	Mottled Duskywing	G3	S2S3			
Hesperia leonardus montana	**Pawnee Montane Skipper**	**G4T1**	**S1**	**LT**		
MAMMALS						
Cynomys gunnisoni	**Gunnison's prairie dog**	**G5**	**S5**	**PS:C**		**BLM/ USFS**
Gulo gulo	**Wolverine**	**G4**	**S1**	**C**		**USFS**
Lynx canadensis	**Lynx**	**G5**	**S1**	**LT**	**SE**	
Sorex nanus	Dwarf Shrew	G4	S2			
Thomomys talpoides macrotis	Northern pocket gopher *macrotis* subspecies	G5T1	S1			
Zapus hudsonius preblei	**Preble's Meadow Jumping Mouse**	**G5T2**	**S1**	**LT**		
PLANTS						
Aquilegia saximontana	Rocky Mountain Columbine	G3	S3			
Arabidopsis salsuginea	Saltwater Cress	G4G5	S1			
Armeria maritima ssp. sibirica	Sea Pink	G5T5	S1			USFS
Astragalus molybdenus	Molybdenum Milkvetch	G3	S2			
Astragalus sparsiflorus	Front Range Milkvetch	G3?	S3?			
Braya glabella ssp. glabella	Smooth Rockcress	G5TNR	S1			USFS
Braya humilis	Low Braya	G5	S2			
Carex limosa	Mud Sedge	G5	S2			
Carex livida	Livid Sedge	G5	S1			USFS
Carex oreocharis	Grassy Slope Sedge	G3	S1			
Carex scirpoidea	Bulrush Sedge	G5	S2			
Carex tenuiflora	Sparse-flower Sedge	G5	S1			
Carex viridula	Little Green Sedge	G5	S1			
Castilleja puberula	Downy Indian-paintbrush	G2G3	S2S3			
Crepis nana	Dwarf Alpine Hawk's-beard	G5	S2			
Cypripedium parviflorum	American Yellow Lady's-slipper	G5	S2			USFS
Draba borealis	Boreal Whitlow-grass	G4	S2			
Draba crassa	Thick-leaf Whitlow-grass	G3G4	S3			
Draba exunguiculata	Clawless Draba	G2	S2			USFS
Draba fladnizensis	White Arctic Whitlow-grass	G4	S2S3			
Draba globosa	Rockcress Draba	G3	S1			
Draba grayana	Gray's Peak Whitlow-	G2	S2			USFS

Scientific Name	**Common Name**	**Global Status Rank[a]**	**State Status Rank[a]**	**Federal Listing Status[b]**	**State Listing[c]**	**Federal Agency Sensitive[d]**
	grass					
Draba oligosperma	Few-seed Whitlow-grass	G5	S2			
Draba porsildii	Porsild's Whitlow-grass	G3G4	S1			
Draba streptobrachia	Colorado Divide Whitlow-grass	G3	S3			
Eriophorum altaicum var. neogaeum	Altai Cotton-grass	G4?T3T4	S3			USFS
Eriophorum gracile	Slender Cotton-grass	G5	S2			USFS
Eutrema penlandii	**Penland's Alpine Fen Mustard**	**G1G2**	**S1S2**	**LT**		
Ipomopsis globularis	Globe Gilia	G2	S2			USFS
Kobresia simpliciuscula	Simple Kobresia	G5	S2			USFS
Machaeranthera coloradoensis	Colorado Tansy-aster	G3	S3			USFS
Malaxis brachypoda	White Adder's-mouth	G4Q	S1			USFS
Mentzelia speciosa	Jeweled Blazingstar	G3?	S3?			
Mimulus gemmiparus	Weber's Monkeyflower	G1	S1			USFS
Oligoneuron album	Prairie Goldenrod	G5	S2S3			
Packera pauciflora	Few-flower Ragwort	G4G5	S1S2			BLM
Parnassia kotzebuei	Kotzebue's Grass-of-Parnassus	G5	S2			USFS
Phippsia algida	Ice Grass	G5	S2			
Physaria alpina	Avery Peak Twinpod	G2	S2			
Potentilla ambigens	Southern Rocky Mountain Cinquefoil	G3	S1S2			
Potentilla rupincola	Rocky Mountain Cinquefoil	G2	S2			USFS
Primula egaliksensis	Greenland Primrose	G4	S2			USFS
Ptilagrostis porteri	Porter's Feathergrass	G2	S2			USFS
Ranunculus karelinii	Arctic Buttercup	G4G5	S2			USFS
Ribes americanum	Wild Black Currant	G5	S2			
Rubus arcticus ssp. acaulis	Nagoonberry	G5T5	S1			USFS
Salix candida	Hoary Willow	G5	S2			USFS
Salix lanata ssp. calcicola	Lanate Willow	G4G5T4	S1			
Salix myrtillifolia	Myrtle-leaf Willow	G5	S1			USFS
Salix serissima	Autumn Willow	G4	S1			USFS
Saussurea weberi	Weber's Saw-wort	G2G3	S2			
Saxifraga foliolosa	Leafy Saxifrage	G4	S1			
Sisyrinchium demissum	Stiff Blue-eyed-grass	G5	S2			
Sisyrinchium pallidum	Pale Blue-eye-grass	G2G3	S2			BLM

Scientific Name	Common Name	Global Status Rank[a]	State Status Rank[a]	Federal Listing Status[b]	State Listing[c]	Federal Agency Sensitive[d]
Sphagnum girgensohnii	Girgensohn's Peatmoss	G5	S1			
Telesonix jamesii	Jame's False Saxifrage	G2	S2			
Townsendia rothrockii	Rothrock's Townsend-daisy	G2G3	S2S3			
Trichophorum pumilum	Rolland's Leafless-bulrush	G5	S2			BLM
Viola pedatifida	Prairie Violet	G5	S2			
BIG GAME						
Ovis canadensis	Bighorn Sheep	G4	S4			
Ursus americanus	Black Bear	G5	S5			
Cervus canadensis	**Elk**	**G5**	**S5**			
Odocoileus hemionus	**Mule Deer**	**G5**	**S4**			
Puma concolor	Mountain lion	G5	S4			

Note: Species highlighted in bold have regulatory status, or, in the case of big game, are considered particular safety hazards for vehicle collision.
[a] Global/State Status: 5 = demonstrably secure; 4 = secure; 3 = vulnerable; 2 = imperiled; 1 = critically imperiled; T = subspecies; B = breeding; N = non-breeding.
[b] Federal listing: C = candidate; LT = listed threatened; LE = listed endangered; PS = partial status.
[c] State listing: SC = species of special concern; ST = state threatened; SE = state endangered.
[d] Federal sensitivity: BLM = Bureau of Land Management; USFS = U.S. Forest Service.

IEF Step 2: Species Distribution Modeling

Species distribution modeling is one of many tools available to assist land managers in the complex process of evaluating and prioritizing different land-use scenarios. Developing a predictive model of the distribution of a particular species can involve several different techniques, and be reported under a variety of names. All such models, however, are based on the ecological principle that the presence of a species on the landscape is controlled by a variety of biotic and abiotic factors, in the context of biogeographic and evolutionary history. Because complete and accurate knowledge of these factors and history is rarely, if ever available, the only option is to predict or seek to discover suitable habitat by using characteristics of known occurrences of the species in question.

The modeling process is further constrained by inability to measure habitat characteristics accurately on a continuous spatial scale. As a result, modeling factors are usually an approximation of the environmental factors that control species distribution, using available data that is probably only a surrogate for the actual controlling factors. In the context of this study, species distribution modeling is a process that uses a sample of a real distribution (known locations or occurrences) to build a model (estimate) of suitable environmental conditions (and, by implication, unsuitable conditions), and map that model across a study area.

It is important to regard these models as hypotheses intended to be field tested, and not as definitive maps of suitable habitat. A variety of life-history and biogeographic factors may preclude the presence of the target element in areas of predicted suitable habitat. Likewise, errors or lack of precision in modeling assumptions, input data, or procedures may incorrectly predict suitable habitat where none exists. In addition, users should be aware that the true resolution of these distribution models is only as fine as the coarsest layer of input data. It is not appropriate to base land management decisions of 1-1000 m scale entirely on this analysis without additional field verification.

Methods

In order to more accurately reflect the ecological factors that determine species distributions, the team decided to model target species on a statewide basis rather than restrict the model to the study area. Maximum entropy (MaxEnt) was selected for the modeling procedure (Phillips et al. 2004, 2006) because it can generate a large number of species models quickly, and because it can use presence-only data. This procedure has been widely used in species distribution modeling and performs well in comparison with other methods (Elith et al. 2011).

The MaxEnt procedure is based on the concept of information entropy, which can be regarded as a measure of the information contained in a set of propositions (e.g., that species A occurs at only at elevations between 8,000 and 9,000 ft) in the context of some known data (e.g., the elevation at actual known locations of species A). The most informative distribution would occur when one of the propositions was known to be true (i.e., species A is absolutely known to not be found at other elevations). The least informative distribution would occur when there is no reason to favor any one of the propositions over the others (e.g., no real evidence exists that species A is not found at all elevations).

In modeling species distributions with MaxEnt, the team deliberately chose to use the distribution with the maximum entropy allowed by the information, that is, the most uninformative distribution possible given what is actually known. To choose a distribution with lower entropy would be to assume information one does not possess; to choose one with a higher entropy would violate the constraints of the information one does possess. Thus the maximum entropy distribution is the most reasonable choice.

As with most inductive modeling, raster data that represent environmental conditions, i.e., elevation, precipitation, soil type, and so forth are used. Included data can represent any environmental conditions that seem biologically meaningful for the target species, and which are available for the study area. These data are combined with mapped point locations where the species is known to occur, and the values of each environmental parameter for each point location are identified and used as input data for the MaxEnt modeling procedure. Ideally, species distribution models are parameterized with environmental data that are known to be highly predictive of conditions determining the ability of a species to persist. Unfortunately, for many species, even basic life-history information that could guide input selection are lacking. Even when extremely detailed information about important micro-habitat factors is available, these factors are generally not mapped or otherwise spatially represented at a scale that is equivalent to that experienced by the organism. Consequently, models represent a best-guess scenario in which data are known to be incomplete and of insufficiently fine resolution.

However, even simple potential habitat or range models seem to have utility as part of a preponderance-of-evidence approach to investigating the spatial patterns of biodiversity. Furthermore, these models serve as a coarse-filter surrogate for the ecosystem component of the study area, since there were enough species included to cover the majority of habitats in the area. The MaxEnt program estimates a distribution that is consistent with the known occurrence data, and produces a probability surface map that more-or-less represents areas of potentially suitable habitat.

Not all species on the final target list had adequate known location data (either CNHP Element Occurrences [EOs] or CNHP Observations) for modeling in MaxEnt. Furthermore, after review several MaxEnt models were deemed to be too poorly fitting and were discarded. For nine plant species, the distribution of the species was understood to be well represented by the EOs mapped for it, and those EOs were used as the literal species distribution. Otherwise deductive models, constructed by simple overlay and intersection of environmental variable ranges believed to be suitable for the target species, were used. These were either CNHP created or pre-existing deductive SWReGAP Vertebrate Habitat Models (New Mexico Cooperative Fish and Wildlife Research Unit 2005). For large game animals, Colorado Parks and Wildlife (CPW) Species Activity Maps representing important use areas for the species were used. These maps are derived from observations by field personnel, and represent the area of the known range of a species that encompasses a particular seasonal or annual use by that species. See Table 2.2 for a breakdown of how many models were created and where other sources were used.

Table 2.2. Species Model Source

Number of Species	Taxonomic Group	Represented By	Created By
50	Plants	MaxEnt Model	CNHP
9	Plants	EOs only	CNHP
19	Animals	MaxEnt Model	CNHP
4	Animals	Deductive Model	CNHP
6	Animals	Deductive Model	SWReGAP
1	Animal	Survey Map	ERT 1986, modified by CNHP
1	Animal	EOs only	CNHP
5	Animals	Activity Map	CPW

Life-history information is more readily available for animal species, so the team was able to identify modeling factors through a literature search for most species (Table 2.3). Plants were grouped into four habitat types (alpine, cliff, wetland, or general), and use a habitat-specific suite of environmental factors (Table 2.4). A list of which plants were grouped into each category and more detail on source data used in modeling may be found in Appendix B.

Table 2.3. Environmental Variables Used in Animal Models

Environmental Inputs	Units	Source	Used

Environmental Inputs	Units	Source	Used
Annual Growing Degree Days (average air temp above 0 °C)	degree-days	Daymet - Climatological summaries for the conterminous United States 1980-1997 www.daymet.org/ (1km)	boreal toad
Aspect	relative levels of northness and eastness	Derived from USGS 30m Digital Elevation Model (DEM) for Colorado. 2006.	Schryver's elfin, hops azure, mottled dusky wing
Depth to Bedrock	cm	Pennsylvania State University Conterminous United States Multi-Layer Soil Characteristics Data Set for Regional Climate and Hydrology Modeling. 1998. (Derived from NRCS STATSGO)	Mountain Plover, Gunnison's prairie dog, N. pocket gopher ssp macrotis
Distance to Prairie Dogs	m	Derived from CNHP BIOTICS and CPW survey data.	Burrowing Owl
Distance to Water	m	Derived from USGS High Resolution National Hydrography Dataset. 2010.	All models
Distance to Wetlands	m	Derived from USGS High Resolution National Hydrography Dataset. 2010.	Bald Eagle, northern leopard frog, Veery, Willow Flycatcher, Schryver's elfin, hops azure, wolverine, Preble's meadow jumping mouse
Elevation	m	USGS 30m Digital Elevation Model (DEM) for Colorado. 2006.	All models
Landform	categorical	USGS National GAP Analysis Program. Ten Class DEM Derived Landform for the Southwest United States. 2004.	All models
Local Relief	m	Derived from USGS 30m Digital Elevation Model (DEM) for Colorado. 2006.	Schryver's elfin, hops azure, mottled dusky wing
Relative Forest Cover	unitless	Derived from USGS LANDFIRE Forest Canopy Cover. 2010.	Boreal Owl, Mexican Spotted Owl, wolverine
Slope	degrees	Derived from USGS 30m Digital Elevation Model (DEM) for Colorado. 2006.	Burrowing Owl, American Peregrine Falcon, greenback cutthroat trout, northern redbelly dace, Gunnison's prairie dog, wolverine

Environmental Inputs	Units	Source	Used
Soil pH	pH	Pennsylvania State University Conterminous United States Multi-Layer Soil Characteristics Data Set for Regional Climate and Hydrology Modeling. 1998. (Derived from NRCS STATSGO)	Burrowing Owl, Mountain Plover, Schryver's elfin, hops azure, mottled dusky wing, Gunnison's prairie dog, N. pocket gopher ssp macrotis
Soil Texture	categorical	Pennsylvania State University Conterminous United States Multi-Layer Soil Characteristics Data Set for Regional Climate and Hydrology Modeling. 1998. (Derived from NRCS STATSGO)	Burrowing Owl, Mountain Plover, Schryver's elfin, hops azure, mottled dusky wing, Gunnison's prairie dog, N. pocket gopher ssp macrotis
Summer Precipitation (June, July, August)	cm	Daymet - Climatological summaries for the conterminous United States 1980-1997 www.daymet.org/ (1km)	boreal toad
Vegetation type	categorical	USGS National GAP Analysis Program. Provisional Digital Land Cover Map for the Southwestern United States. 2004.	All models

Table 2.4. Environmental Variables Used in Plant Models

Environmental Inputs	Units	Source	Alpine	Cliff	Wetland	General
Annual Growing Degree Days (average air temp above 0 °C)	degree-days	Daymet - Climatological summaries for the conterminous United States 1980-1997 www.daymet.org/ (1km)			X	X
Annual Precipitation	cm	Daymet - Climatological summaries for the conterminous United States 1980-1997 www.daymet.org/ (1km)	X		X	
Annual Precipitation Frequency (days in a year with any precipitation)	proportion	Daymet - Climatological summaries for the conterminous United States 1980-1997 www.daymet.org/ (1km)			X	X
April Minimum Temperature	°C	Daymet - Climatological summaries for the conterminous United States 1980-1997 www.daymet.org/ (1km)		X	X	X
Aspect	relative levels of northness and eastness	Derived from USGS 30m Digital Elevation Model (DEM) for Colorado. 2006.	X	X		X
Depth to Bedrock	cm	Pennsylvania State University Conterminous United States Multi-Layer Soil Characteristics Data Set for Regional Climate and Hydrology Modeling. 1998. (Derived from NRCS STATSGO)	X			X
Elevation	m	USGS 30m Digital Elevation Model (DEM) for Colorado. 2006.	X	X	X	X
Distance to Water	m	Derived from USGS High Resolution National Hydrography Dataset. 2010.				X
Distance to Wetlands	m	Derived from USGS High Resolution National Hydrography Dataset. 2010.				X
Geology	categorical	USGS National GAP Analysis Program. 1:500,000 Scale Geology for the Southwestern U.S. 2004.	X	X		X
Landform	categorical	USGS National GAP Analysis Program. Ten Class DEM Derived Landform for the Southwest United States. 2004.		X		
Local Relief	m	Derived from USGS 30m Digital Elevation Model (DEM) for Colorado. 2006.		X		
May Minimum Temperature	°C	Daymet - Climatological summaries for the conterminous United States 1980-1997 www.daymet.org/ (1km)	X	X	X	X
Number of Frost Days (days in a year with air temp < 0 °C)	number of days	Daymet - Climatological summaries for the conterminous United States 1980-1997 www.daymet.org/ (1km)	X			

Environmental Inputs	Units	Source	Alpine	Cliff	Wetland	General
Slope	degrees	Derived from USGS 30m Digital Elevation Model (DEM) for Colorado. 2006.	X	X	X	
Soil pH	pH	Pennsylvania State University Conterminous United States Multi-Layer Soil Characteristics Data Set for Regional Climate and Hydrology Modeling. 1998. (Derived from NRCS STATSGO)	X		X	
Soil Texture	categorical	Pennsylvania State University Conterminous United States Multi-Layer Soil Characteristics Data Set for Regional Climate and Hydrology Modeling. 1998. (Derived from NRCS STATSGO)	X			
Spring Precipitation (March, April, May)	cm	Daymet - Climatological summaries for the conterminous United States 1980-1997 www.daymet.org/ (1km)		X		X
Spring Snow Depth (March, April, May – not averaged but used separately)	mm	National Operational Hydrologic Remote Sensing Center Snow Data Assimilation System (SNODAS) Data Products at NSIDC for 2004 – 2011.	X			
Summer Precipitation (June, July, August)	cm	Daymet - Climatological summaries for the conterminous United States 1980-1997 www.daymet.org/ (1km)		X		X
Vegetation type	categorical	USGS National GAP Analysis Program. Provisional Digital Land Cover Map for the Southwestern United States. 2004.	X	X		X

The draft models were reviewed by biologists from CNHP, the U.S. Forest Service, U.S. Fish and Wildlife Service, Colorado Parks and Wildlife, and CDOT. Models were then revised according to feedback received, usually by removing portions of range by using a mask such as watershed or ecoregion boundaries, or by increasing the threshold cut-off value to more accurately reflect the known distribution of the species. For further information and thumbnail maps of each model, see Appendix C.

Results

The use of MaxEnt software allowed production of a large number of species distribution models in a relatively short period of time. Although the grouping of plant species into habitat types facilitated quick modeling, this approach was not completely successful for all groups. Models for plant species with generalist or cliff-type habitat requirements were not as plausible as those for alpine and wetland habitat types. For generalist species, overall lack of knowledge about what environmental factors determine species distribution is the likely cause of poorer models. For the cliff habitats, the verticality of the habitat generally means that important micro-habitat factors cannot be depicted at the scale used in the modeling (e.g., a cliff face of 25,000 square meters may be reduced to an area of 1,800 square meters by the flattening effect of the digital mapping). In some cases, the lack of precise occurrence mapping also inflated the predicted habitat area, since adjacent habitats types that were not actually suitable were included in the modeled environment. This indicates that it would be better to choose presence threshold values using the most precisely mapped occurrence polygons, selecting a value that gives a good representation of habitat presence for these locations, and that is also more-or-less present for the majority of other known locations. For example, in the case of *Aquilegia saximontana* (in the cliff habitat group), about 20% of the occurrences were mapped with lower precision, with the result that the initial model greatly overestimated the extent of suitable habitat. The model was revised by choosing a cut-off presence probability that included all of the best documented occurrences, as well as a majority of the other occurrences. Although this technique omitted some suitable habitat, it appeared to be a satisfactory trade-off to obtain a realistic estimate of the species' range.

Animal models were generally more successful because more information on habitat requirements from published research was available. The use of species distribution modeling allowed incorporation of habitat information for numerous target species into the ecosystem framework and work around some of the typical limitations of incomplete survey data. Thumbnail maps and summaries of the final statewide models for 69 target species are presented in Appendix C. Figure 1.4 shows a zoomed in display of the study area component of the boreal toad model. Figure 1.5 shows the "before" distribution that would have been available for planning purposes if the model had not been developed. As with all decisions involving planning and data, trade-offs are inevitable. The model covers much more area, and certainly has errors of commission and omission. But, it also provides a more robust picture of how potential habitat is distributed.

As is usual in this type of project, the greatest time constraints involve decision making and feedback from partners, stakeholders, and subject-matter experts. Although many people were willing to participate, varying levels of availability and technical expertise with GIS delayed the process. However, under current data limitations there is no substitute for the review and validation of computer-generated models by biologists personally familiar with the species and study area in question.

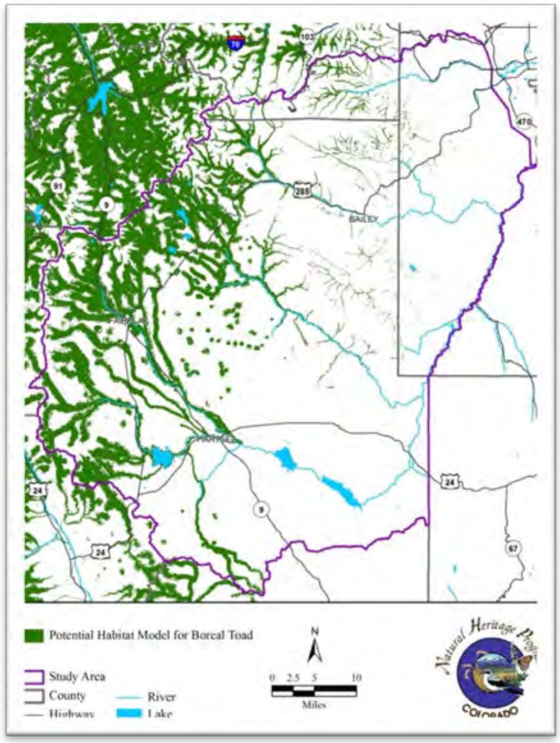

Figure 1.4. MaxEnt model for boreal toad.

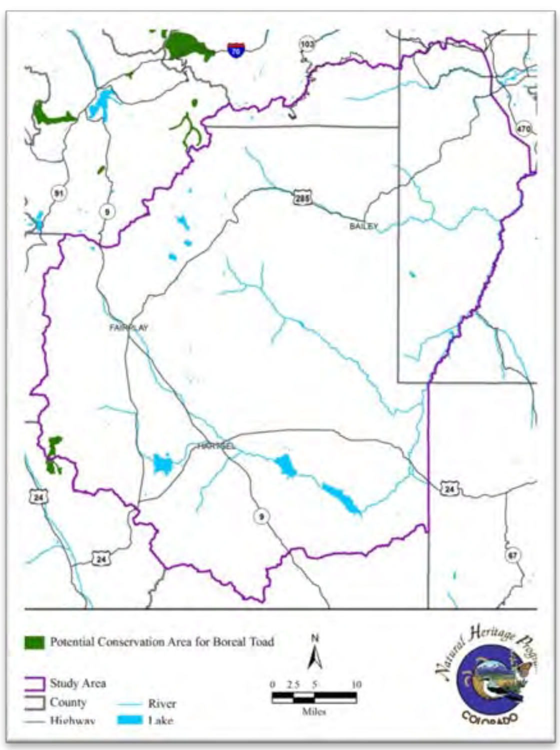

Figure 1.5. Distribution layer for boreal toad before modeling.

IEF Step 2: Wetland Mapping

Colorado's wetlands were mapped by USFWS's National Wetlands Inventory (NWI) program in the late 1970s and early 1980s. Though the maps exist, they were created as paper maps and most are not available as digital data. In today's electronic era, paper maps are not as useful as digital data because acreages cannot be calculated and analyses cannot be conducted from the data. In addition, the paper maps are lower resolution than most modern datasets and are often out of date. To produce a more accurate and current estimate of wetland extent and distribution, NWI mapping for the project study area was updated through photo interpretation of 2009 aerial imagery. All updated mapping was prepared as GIS shapefiles for the 55 USGS 7.5-minute quadrangles (quads) that comprised the target study are (Table 2.5; Figure 1.6). Final spatial data layers and metadata associated with this work will be delivered to USFWS for incorporation into the National NWI dataset, which is publically available for download through the NWI Wetlands Mapper: www.fws.gov/wetlands/Data/Mapper.html.

Table 2.5. USGS 7.5-Minute Quads with Updated NWI Wetland Mapping Generated From This Project

Quad Names in Alphabetical Order			
Agate Mountain	Eagle Rock	Idaho Springs	Observatory Rock
Alma	Elevenmile Canyon	Indian Hills	Pine
Antero Reservoir	Elkhorn	Jefferson	Platte Canyon
Antero Reservoir NE	Evergreen	Jones Hill	Shawnee
Bailey	Fairplay East	Lake George	South Peak
Boreas Pass	Fairplay West	Marmot Peak	Spinney
Castle Rock Gulch	Farnum Peak	McCurdy Mountain	Squaw Pass
Cheeseman Lake	Garo	Meridian Hill	Sulphur
Climax	Glentivar	Milligan Lakes	Tarryall
Como	Green Mountain	Montezuma	Thirtynine Mile Mountain
Conifer	Guffey NW	Morrison	Topaz Mountain
Deckers	Hacket Mountain	Mount Evans	Windy Peak
Dicks Peak	Harris Peak	Mount Logan	Witcher Mountain
Divide	Hartsel	Mount Sherman	

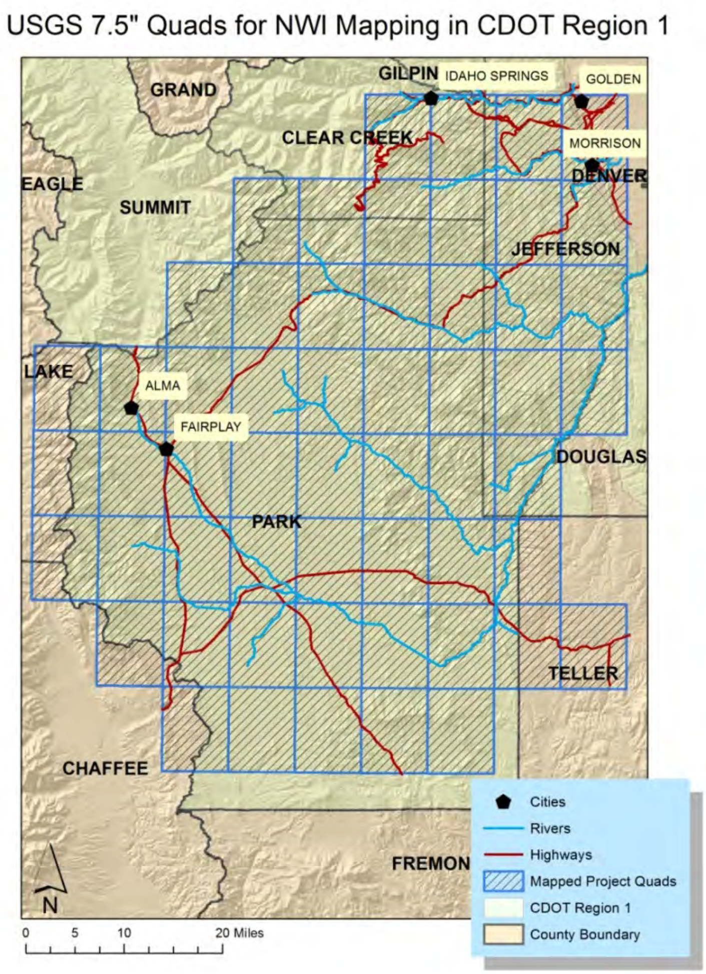

Figure 1.6. Study area with updated NWI wetland mapping for identified USGS 7.5-minute quads.

Methods

Methods used to update wetland NWI mapping based on new photo interpretation followed national standards for wetland mapping (FGDC 2009) and have been successfully used by CNHP for similar projects in Colorado. In addition to the traditional wetland areas mapped by NWI, this project also mapped non-wetland riparian areas following guidance from USFWS (USFWS 2009).

Wetland Mapping Classification Systems

USFWS Wetland Mapping Definition and Classification

There are several definitions of wetlands used by state and federal agencies. For the purpose of this project, CNHP followed the USFWS definition developed for mapping wetlands through the NWI program (Cowardin *et al.* 1979):

"Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have one or more of the following attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year."

In addition to vegetated wetlands, NWI mapping also includes deep water habitats and water bodies. Within the study area, water bodies include lakes greater than 20 acres and all rivers, including the actual river channel and unvegetated sandbars.

The USFWS definition is similar, but not identical to, the definition used by the USACOE and EPA for regulating wetland under Section 404 of the Federal Clean Water Act. Within the USFWS definition, the presence of either hydrophytic vegetation or hydric soils is enough to classify an area as wetland. Under the CWA definition, three wetland criteria (vegetation, soils and hydrology) must be met. The mapped wetlands, therefore, are not intended to portray exact boundaries of jurisdictional or regulated wetlands. Any need to determine jurisdiction wetland boundaries would require an on-the-ground wetland delineation conducted by a trained wetland professional.

Wetland classification codes used for wetland mapping are from NWI's Cowardin classification system (Cowardin *et al.* 1979). See Appendix A for the diagrammatic representation of the classification hierarchy. This hierarchical treatment of wetlands describes wetlands at varying scales of specificity. For the scope of this project and the resolution of data, wetland features have been coded using the first three levels of the hierarchy: system, subsystem, and class. In addition to these levels, site hydrology and modifications were also identified. The result is a four to six character alphanumeric code. Components of the code are described below.

System: The system and subsystem together divide mapped features by aquatic resource types. System represents the first character in the code. Systems present in the study area include:

- R: Riverine = rivers and streams;
- L: Lacustrine = lakes; and
- P: Palustrine = vegetated wetlands, e.g., marshes, swamps, bogs, even if associated with rivers or lakes.

Subsystem: Systems are followed, when appropriate, by a subsystem. In the study area only the Riverine and Lacustrine systems require Subsystem division. Riverine subsystems present in the study area are:

- 2: Lower Perennial = low gradient, slow moving channels
- 3: Upper Perennial = steep, fast moving channels
- 4: Intermittent = channels that do not flow year-round, including man-made ditches

Lacustrine subsystems present in the study area are:

- 1: Limnetic = lake water >2 m deep
- 2: Littoral = lake water <2 m deep

Class: The third portion of the code is the class, which identifies the dominate substrate or vegetation structure present. Class types present in the study area include:

- AB: Aquatic Bed = aquatic rooted or floating vegetation
- EM: Emergent = herbaceous, non-woody vegetation
- SS: Scrub-shrub = low woody vegetation, primarily shrubs but may include low trees
- FO: Forested = tall trees
- UB: Unconsolidated Bottom = unvegetated surfaces with small particle sizes, not associated with river and lake edges
- US: Unconsolidated Shore = unvegetated surfaces with variable small particle sizes, associated with river and lake edges
- SB: Stream Bed = unvegetated surface with variable substrate sizes, within stream channels

Hydrologic regime: Hydrologic regimes describe the duration and timing of flooding. Duration increases from A to H. However, B sites are rarely flooded, but have water at or very near the surface throughout the growing season. For this project, seven hydrologic regimes were identified, including:

- A: temporarily flooded
- B: saturated
- C: seasonally flooded
- F: semi-permanently flooded
- G: intermittently exposed
- H: permanently flooded

Special modifier: Three special modifier codes were used in the study area. The modifiers present information about artificially and naturally modified wetlands. The codes mapped in this study include:

- b: beaver-influenced
- h: diked/impounded
- x: excavated

USFWS Riparian Mapping Definition and Classification

In the years since the original Cowardin classification was introduced in the late 1970s, USFWS realized the need to map riparian areas that may not meet the criteria used for wetland mapping. This need is particularly great in the western U.S. where numerous wildlife species depend on riparian habitats in an otherwise arid landscape. These habitats are moist, can be flooded for short periods of time, and are commonly associated with flowing water. Riparian areas are "wetter" than uplands, but do not meet the flooding, biological composition, or soil criteria to be classified as a wetland. To identify, map, and classify riparian areas across a broad spectrum, USFWS issued guidance in a document titled *A System for Mapping Riparian Areas in the Western United States* (USFWS 2009). The definition of riparian used for mapping is:

> *"Riparian areas are plant communities contiguous to and affected by surface and subsurface hydrologic features of perennial or intermitted lotic and lentic water bodies (rivers, streams, lakes, or drainage ways). Riparian areas have one of both of the following characteristics: 1) distinctively different vegetation species than adjacent areas, and 2) species similar to adjacent areas but exhibiting more vigorous or robust growth forms. Riparian areas are usually transitional between wetland and upland*."

This system is fully integrated into the Cowardin classification scheme and also includes System, Subsystem, and Class. The System is a single unit category of Rp (riparian vegetation). Subsystem defines the water source: 1 (lotic or flowing water associated with rivers) and 2 (lentic or standing water associated with lakes). Class denotes the dominant life form of riparian vegetation: FO (forested), SS (scrub-shrub), and EM (herbaceous). No water regime or modifiers are applied.

Data Creation

Data Inputs: Up-to-date color infra-red and true-color aerial photography was obtained for the 55 priority quads within the study area from the National Agricultural Imagery Program (NAIP). The imagery was flown in 2009 with a horizontal resolution of 1 meter and was delivered as ortho-rectified quarter-quads that fit together seamlessly. Ortho-rectified, 1-m resolution, true-color county mosaic images from 2005 were utilized for a comparison between years. This was critical for the hydrologic regime designation (frequency of flooding/saturation). Seamlessly merged scans of USGS 1:24000 topographic maps, accessed through the ArcGIS Online Map Server, were used for estimates of relief and elevation. Scanned images of the original NWI maps available through the NWI Wetland Mapper were downloaded and used to identify previously mapped wetlands and areas which might require particular scrutiny during the mapping process.

Pre-Mapping Field Survey: Before drawing and attributing new NWI polygons, field visits are used to familiarize mapping specialists with the wetland habitats of the study area, including nuances of the geography and how well the area was represented by the imagery and mapping sources used. Initially, seven quads in the center of the study area were identified to visit. Based on the original 1970-1980s NWI maps and recent imagery, specific wetland areas were identified to visit. Cursory mapping was completed to identify potential wetland areas excluded from early mapping, due perhaps to resolution constraints. Objectives of the pre-mapping survey visits were as follows:

1. Consistent NWI Typing: Several wetland sites in each major class of wetland (PSSC, PEMA, PFOA, PEMB) were visited to identify the components of each type (species and canopy structure). GPS points and pictures were taken for office reference when examining 2005 and 2009 imagery. Information about canopy type, species composition, water level, water source, and anthropogenic modification were noted such that image color, texture, pattern could be associated with a given wetland type. Spatial patterns and location on the landscape were also used to develop a common signature for a given NWI wetland class.

2. Examine Borders and Boundaries: Some GPS points were identified in the office that were mapped as edges of wetlands (border between upland and wetland) and as boundaries between wetland types. These were navigated to in the field and assessed for validity. Dynamics associated with some riverine features and with beaver-influenced wetlands were considered when assessing these sites. Additional border and boundary sites were navigated to while in the field. GPS points taken at these locations were then examined in the office to visually connect image representation of the habitat change on the ground. False boundaries associated with grazing, mowing, and fence lines were also examined in the office and field. Small changes in topography were noted and GPS points related to terraces were used to train visual recognition on the imagery.

3. Visit Previously Unmapped Wetlands: The coarseness of the original NWI mapping was immediately apparent as small patches of different wetland types would be present on the ground but aggregated into a single wetland polygon on the original maps. The dissection of existing polygons into several different wetland patches was noted. Unmapped wet areas were investigated to determine if they met the criteria for a NWI wetland. Some of

these seemed to be missed in the original mapping because of resolution limitation (i.e., the wetlands were too small). Others might have been missed because of poor image quality. This second situation was more common for wetlands with incorrect extents. Some unmapped areas were features that had been developed after the original mapping had been completed. For example, a reservoir was created after the construction of a dam, a pond was excavated on a farm, or beavers entered a new area, altering the hydrology and plant associations.

Wetland Mapping Procedure: CNHP's wetland mapping specialists have experience in a variety of wetland systems in Colorado and across the country. Knowledge of wetland dynamics (flooding, seasonal precipitation patterns, and species composition) comes from years of experience examining aerial photographs and numerous field seasons surveying wetlands. An image is viewed as a snapshot of a landscape feature at one point in time. The mapping technicians are aware that the change in wetland features over the course of a year and between years is critical for providing an accurate description of the wetland's characteristics. The mapping specialists' knowledge of climate, geography, hydrology, land cover, and land use of the region is always instrumental in accurately mapping wetland resources. Striking a balance between field and office time is a necessary component to achieve maximum efficiency and accuracy.

Mapping is completed for each USGS 7.5-minute quad separately, then merged together to form a seamless spatial dataset of wetland and riparian features. Data are created within a file geodatabase, which speeds editing time and table updates and increases file stabilization. Two features classes are created: lines and polygons. The GCS North American 1983 with the NAD Albers 1983 projected geographic coordinate system was used for all newly created data; this is consistent with the existing digitized wetlands in the NWI dataset.

Input data layers are added to the ArcGIS map document with some minor adjustments to the visual representation. The CIR imagery is best displayed with the Red: Band 4, Green: Band 2, and Blue: Band 2. In some instances a 4:1:1 display is more effective. The scale at which the imagery is examined and wetland polygons are created is 1:3,000. This remains consistent across other mapping projects completed and in progress at CNHP.

Using the Editor tools, line features are created for linear wetlands and water bodies and buffered to create polygons. The smallest features delineated are small channels and swales with a width of 4m. Larger and variable width wetlands are traced by hand directly as polygons. Each feature is attributed an NWI wetland code (e.g., PSSC, PUBGb, R3UBF).

Wetlands are identified through their unique and often predictable position on the landscape (Figure 1.7); shape and reference to other terrain features (Figure 1.8); texture (Figure 1.9); and color (Figure 1.10). Cover type (herbaceous, shrubs, or trees) is best determined through texture and shadows. The relative wetness is often tied to the intensity of the color relative to adjacent wetlands and uplands. It is important to identify the date at which the photographs were taken. Spring, mid-summer, early fall, and winter can have very different color signatures and texture (e.g., leaf-on or leaf-off; following or prior to planting or harvest). Comparison between seasons (summer to fall) or between years increases the confidence in classifying the wetness/flood frequency of a wetland.

Additional information about alterations to the wetlands (dams, ditches, etc.) is often related to shape and reference to other landscape features. Other elements such as climate and precipitation patterns, underlying geology, and species composition are not easily identified with imagery and topographic maps, but can be useful when mapping wetland features. This information is obtained from wetland mapping experience, regional knowledge, and field visits.

Figure 1.7. Wetlands oriented along a valley, a typical landscape position where water accumulates and often flows on the surface and through the substrate.

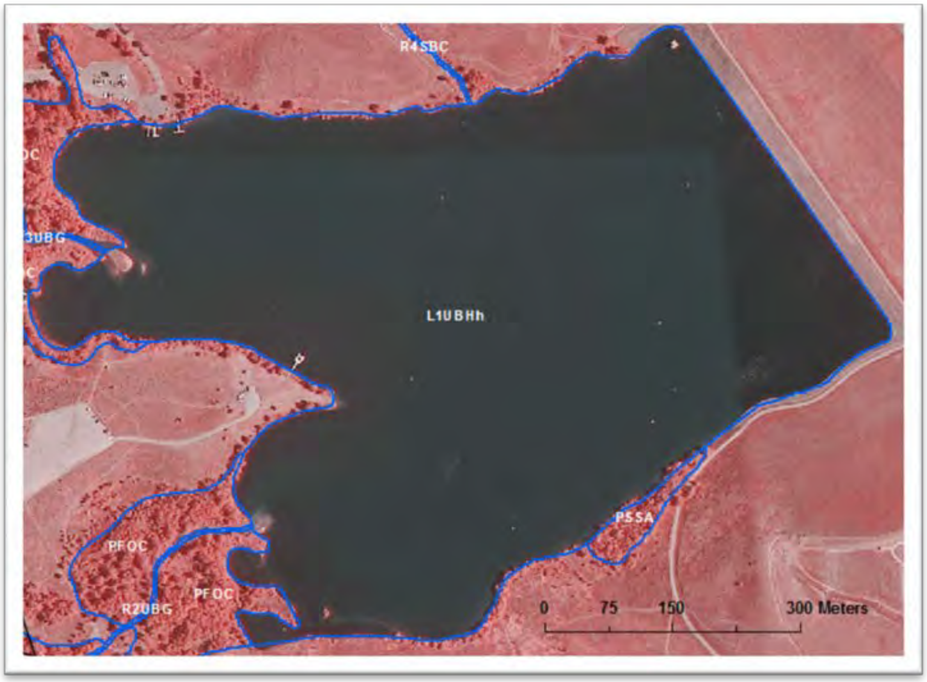

Figure 1.8. Shape used to identify alteration to wetland or water body, seen with a straight line indicating a dam.

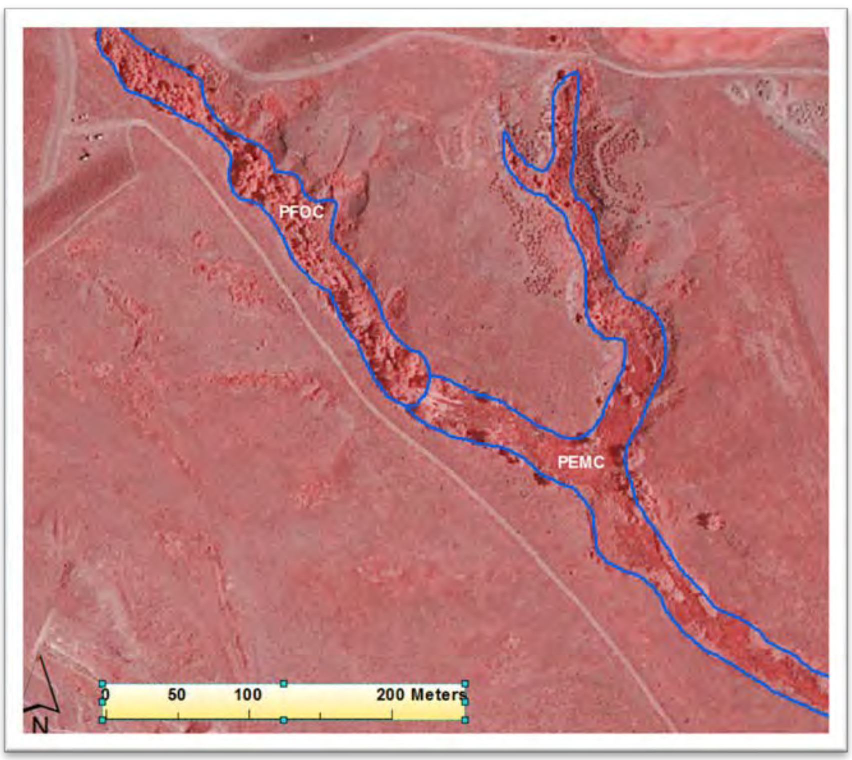

Figure 1.9. Texture used to identify cover type with forests being lumpy with multiple shadows, and herbaceous areas smoother with fewer shadows.

Figure 1.10. Color intensity to determine relative wetness as shown with cattail marshes (PEMF) within a golf course with 2005 true-color imagery on top and 2009 CIR imagery on the bottom.

Mid-Project Field Visits: The fall start date to the mapping and the length of time needed to complete the 55 quads did not permit standard post-mapping ground truthing. Some selected sites, particularly unique saline and riparian features, were visited in late fall, mid-way through mapping. In other wetland mapping projects, post-mapping field visits have been less important to the quality of the mapping than the pre-mapping field visits, suggesting that pre-mapping site visits and the ecologically informed decisions that result are important to high quality NWI data.

During the mapping process, wetlands at higher elevations had a more consistent signature; therefore the focus of mid-project field visits was the lower elevation valley commonly referred to as South Park. Many of the features in South Park were augmented (receiving irrigation water), modified (designed to retain, move, or drain water), or had natural vegetation removed, grazed, or harvested, further complicating accurate delineation and classification. The main focus of the mid-project field visit was to examine saline features (PUSA/PUSC) and sites with dry hydrologic regimes that could either be mapped as wetlands, riparian areas, or neither depending on actual field conditions (PEMA, PSSA, Rp1SS and Rp1FO). Saline features (Figure 1.11) were concentrated in the southwest region of the study area and were associated with several large wetland complexes and reservoirs. Small changes in elevation were observed to differentiate exposed sandy hillsides and saline flats. Small changes in the wetland mapping resulted from this examination, primarily reshaping mapped features.

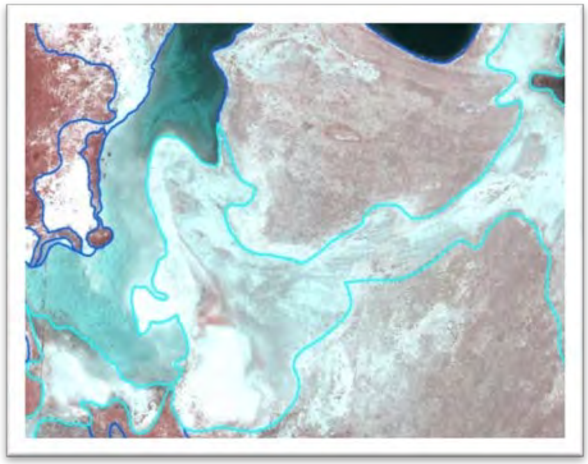

Figure 1.11. A) Saline feature in South Park basin as seen from the ground. B) Saline feature as seen on the CIR imagery (highlighted in light blue).

Riparian and temporarily flooded wetland features (A-water regimes) were widespread. These features were often narrow. Understory species composition and evidence of flowing water and the width of wetland-like characters were discriminating characteristics used to classify riparian features. Observed species composition, soil type, and landscape position were used to make decisions on drier wetland sites (Figure 1.12). Small changes were made to the feature shapes and NWI classifications of these wetlands. Visits were conducted in late fall, and many of the species were desiccated and plant material difficult to identify. Inability to identify known wetland species was not a reason to exclude an area as a wetland, but the presence of such species was used as confirmation.

Figure 1.12. A narrow feature excluded from the riparian mapping based on lack of wetland vegetation and minimum width characteristics.

Quality Assurance/Quality Control (QA/QC): CNHP uses a rigorous QA/QC procedure to ensure the highest possible data quality. The QA/QC process contains the following steps:

1. The wetland data within each quad are visually inspected by a wetland technician other than the data creator. This inspection takes place at the same 1:3,000 resolution in which the data were created, and every wetland polygon is reviewed. This subjective scrutiny can highlight consistent errors in NWI code assignment, wetland extent/shape, and missed areas. Particular attention is also paid to places that wetlands may have been overlooked.
2. A GIS topology rule set that contains the rule “Dataset must not overlap” is run and validated. Everywhere a wetland polygon overlaps another wetland polygon, an error is created. A wetland mapping specialist cycles though each error and resolves them in the appropriate way depending on the circumstances that produced the error.
3. The data are run through the official NWI Wetlands Verification Toolset provided by USFWS (www.fws.gov/wetlands/Data/Tools.html), which identifies the following errors:
    a. Incorrect codes: Codes that are not on the NWI valid codes list are flagged.
    b. Adjacent wetlands: Multi-part features and adjacent polygons with the same wetland code are flagged.
    c. Sliver wetlands: Polygons less than 0.01 acres are flagged.
    d. Lake and pond size: Lakes less than 20 acres or ponds (PAB and PUB) greater than 20 acres are flagged for inspection. There can be valid exceptions to this rule, so each must be reviewed.
    e. Overlapping wetlands.
    f. Sliver uplands: Upland islands (gaps between wetland polygons) that are less than 0.01 acres and probably unintentional are flagged.
4. Error codes are placed into the [QAQC_CODE] field for review. The errors are corrected by the mapping specialist, and then the set is tested again iteratively until all errors that are flagged are exceptions.
5. Randomly selected polygons are reviewed by a mapping specialist with the goal of reviewing 10% of wetlands in every wetland class present in the study area. This review is done to ensure consistency of wetland attributing throughout the project.

Results

Results of Field Visits: The majority of the study area had few changes to land use or land cover since the original NWI maps were created in the 1970-1980s. The northeastern portion experienced more residential development, while much of the southern, western, and northern portions are owned by the USFS and wetlands there remained relatively unchanged. During the office preparation and point selection for pre-mapping field visits, several habitats were noted as particularly confusing. Minor elevation changes in saline and irrigated areas (Figure 1.13) are often a key characteristic used to identify wetland type. Visiting these areas was a priority as they were new to the mapping personnel. Familiarity with the image and landscape signatures of grassy swales (Figure 1.14) and shrubby draws were two other wetland features that also necessitated field visits. Saturated sites (Figure 1.15), riverine features (Figure 1.16), and beaver-influenced wetlands (Figure 1.17) were confirmed across the study area. Field sites were located on public land or along publicly access roads and spread widely across the study area.

Figure 1.13. Irrigated land (PEMC).
Notice the irrigation ditch running across the photograph.

Figure 1.14. Grassy swale (PEMC).

Figure 1.15. Saturated shrub wetland (PSSB).

Figure 1.16. Riverine feature (R3UBH) with PSSC on the banks.

Figure 1.17. Beaver influence riverine feature.

Results of GIS Mapping: Based on photo interpretation of 2009 aerial imagery, wetlands, riparian areas, and water bodies mapped within the study area total 84,987 acres. Of these, 71,401 acres (84%) are wetland features; 200 acres (<1%) are riparian areas; and 13,356 acres (16%) are water bodies, including lakes, rivers, streams, and canals (Table 2.6). Of particular note is the prevalence of herbaceous (Palustrine Emergent) and shrub (Palustrine Scrub-Shrub) wetlands and the limited number of forested wetlands. The regional ecology of the high inter-mountain parks do not generally support forested wetland assemblages like cottonwood gallery forests of the Great Plains or cypress swamps of the Southeastern U.S. A typical scene from the Pike-San Isabel National Forest on the west side of the study area is shown in Figure 1.18, with large areas of saturated shrublands and beaver activity. Figure 1.19 shows a scene typical of the east side of the study area in Jefferson County, with residential and agriculture (pasture) land uses affecting the pattern of wetlands.

Wetland area in each hydrologic regime is shown in Table 2.7. The hydrologic regime describes the amount of time the wetland is "flooded" and ranges from two weeks (temporarily flooded sites) to year-round flooding (permanently flooded sites). The saturated hydrologic regime is unique in that it is ground water controlled and has very little fluctuation seasonally or annually. Riparian areas (Rp1) are generally considered to be drier than the temporarily flooded hydrologic regime. The inundation of these systems may last for a few hours to a few weeks and can be very temporally stochastic.

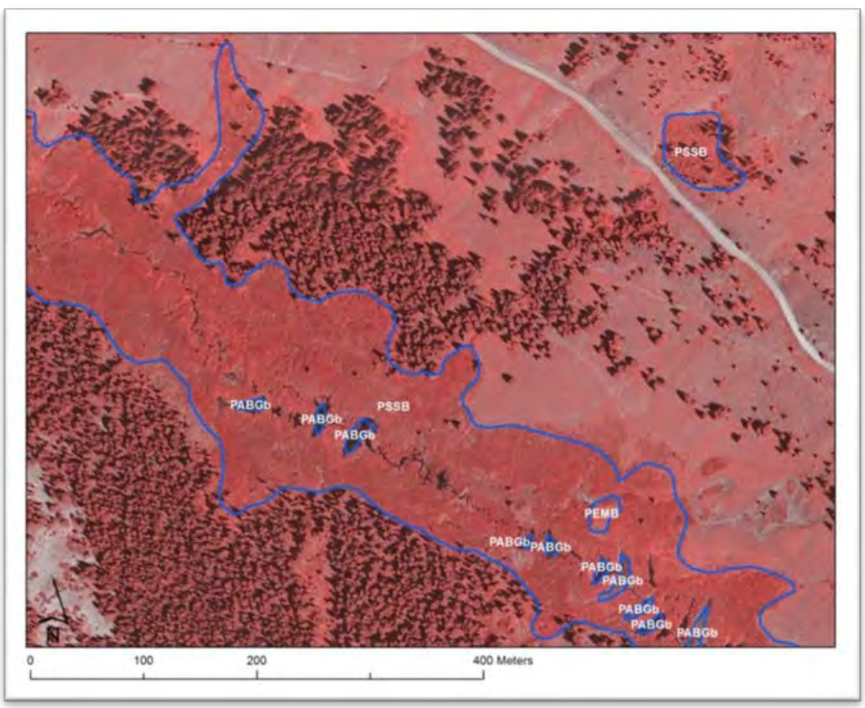

Figure 1.18. Sub-alpine saturated shrub wetland (PSSB) with small beaver ponds (PABGb).

Figure 1.19. Lower montane wetland complex with a shrubby stream corridor (R3UBG, PSSC), excavated ponds (PUBGx). and irrigated pasture (PEMC). Notice the residential and agricultural structures.

Table 2.6. Wetland Acreage in the C21A Study Area by NWI System / Class

NWI Code	NWI System/Class	Wetland Type (Common Name)	All NWI Acres	% Wetlands & Waterbodies	% Wetlands (excl. Lakes & Rivers)
R2/3/4	Riverine	Rivers / Streams / Canals	2,640	3%	NA
L1/2	Lacustrine	Lakes	10,716	13%	NA
PAB	Palustrine Aquatic Bed	Vegetated Ponds	708	1%	1%
PUB	Palustrine Unconsolidated Bottom	Unvegetated Ponds	957	1%	1%
PUS	Palustrine Unconsolidated Shore	Unvegetated Shores and Bare Areas	2,301	3%	3%
PEM	Palustrine Emergent	Herbaceous Wetlands	41,483	49%	58%
PSS	Palustrine Scrub-Shrub	Shrub Wetlands	25,080	30%	35%
PFO	Palustrine Forested	Forested Wetlands	904	1%	1%
Rp1	Lotic Riparian	Riparian	200	< 1% (0.2%)	< 1% (0.3%)
Total Wetlands & Waterbodies			**84,987**	100%	NA
Total Wetlands (Excluding Lakes & Rivers)			**71,431**	NA	100

Table 2.7. Wetland Acreage in the C21A Study Area by NWI Hydrologic Regime

NWI Code	NWI Hydrologic Regime	All NWI Acres	% Wetlands & Waterbodies	% Wetlands (excl. Lakes & Rivers)
A	Temporarily Flooded	18,288	22%	26%
B	Saturated	22,722	27%	32%
C	Seasonally Flooded	29,136	34%	41%
F	Semi-permanently Flooded	534	< 1% (0.6%)	< 1% (0.7%)
G	Intermittently Exposed	2,359	3%	3%
H	Permanently Flooded	11,748	14%	16%
None*	Riparian	200	< 1% (0.2%)	< 1% (0.3%)
Total Wetlands & Waterbodies		**84,987**	100%	NA
Total Wetlands (Excluding Lakes & Rivers)		**71,431**	NA	100%

The Cowardin classification includes certain types of modification to wetlands and waterbodies. Within the study area, the most common human modifications were dammed/impounded (11,841 acres) and excavated (493 acres) wetlands (Table 2.8). Natural beaver modification also affected 5,223 acres of wetlands, mostly in the higher elevations. Human modifiers were documented extensively on ponds, lakes, and intermittently flowing channels, accounting for 31%, 97%, and 28% (respective) of the area mapped within those groups. Though diversion structures and run-of-the-river dams exist on some of the larger rivers and streams, these types of partial impoundments are not mapped as impoundments in the Cowardin methodology. The major river features, therefore, are not mapped as modified, though it is known that hydrologic modifications do exist.

Table 2.8. Wetland Acreage in the C21A Study Area by NWI Modifier

Wetland Type	No modifier		Beaver		Dammed/Impounded		Excavated	
	Acres	% of Class	Acres	% of Class	Acres	% of Class	Acres	% of Class
Rivers / Streams / Canals	2,477	94%	-	< 1%	-	< 1%	163	6%
Lakes	352	3%	-	< 1%	10,326	96%	38	< 1%
Vegetated Ponds	135	19%	330	47%	234	33%	9	1%
Unvegetated Ponds	126	13%	63	7%	526	55%	242	25%
Shores and Bare Areas	2,061	90%	29	1%	192	8%	19	1%
Herbaceous Wetlands	40,678	98%	267	1%	519	1%	18	< 1%
Shrub Wetlands	20,507	82%	4,526	18%	43	< 1%	4	< 1%
Forested Wetlands	896	99%	8	1%	1	< 1%	-	< 1%
Riparian	200	100%	-	< 1%	-	< 1%	-	< 1%
Grand Total	**67,432**		**5,223**		**11,841**		**493**	

Note: For NWI codes associated with each wetland type, see Table 2.6.

The ownership of the lands in the project area is as diverse as the types of ecological communities; Table 2.9 shows the distribution of both land and wetland ownership. Federal agencies cover 51% of the mapped area; three National Forests totaling 47% of the area alone. State-owned land is significantly less, only 4%, comprised mainly of Colorado Parks and Wildlife and State Land Board properties. Private land holdings comprise much of the remaining land at 40%. It is interesting to note that when the total wetland acreage is described by owner (Table 2.9), more wetlands fall on private lands (50% of total wetland acreage) than would be expected by the total land area ownership. Fewer wetland acres under public ownership is not surprising considering the majority of the public land is National Forest, which is fairly mountainous and drier than many of the privately-owned larger valley bottoms.

In addition to the overall summaries presented here, Appendix D summarizes the wetland data by USGS 7.5-minute quad and Appendix E presents several other arrangements of the data. Figures 1.20 and 1.21 compare the wetland data before and after this mapping exercise.

Table 2.9. Wetland Acreage in the C21A Study Area by Grouped Land Owner

Grouped Owner	Total Land Area within Project		Total NWI Acres within Project	
	Total Acres	% of Project Area	Total Acres	% of NWI Acres
Federal Lands	**1,035,902**	**51%**	**22,704**	**27%**
Arapaho-Roosevelt Nat'l Forest	62,291	3%	1,542	2%
Bureau of Land Management	72,560	4%	1,382	2%
Pike-San Isabel National Forest	865,337	43%	18,677	22%
White River National Forest	29,565	1%	907	1%
National Park Service	5,984	< 1%	196	< 1%
State Lands	**90,522**	**4%**	**4,292**	**5%**
Colorado Parks and Wildlife	27,564	1%	2,345	3%
State Land Board	55,157	3%	1,734	2%
State Parks	7,801	< 1%	213	< 1%
Other	**907,812**	**45%**	**57,991**	**68%**
Local Governments	56,921	3%	4,109	5%
Non-Government Organizations	42,388	2%	11,011	13%
Private	808,504	40%	42,871	50%
Grand Total	**2,034,237**	**100%**	**84,987**	**100%**

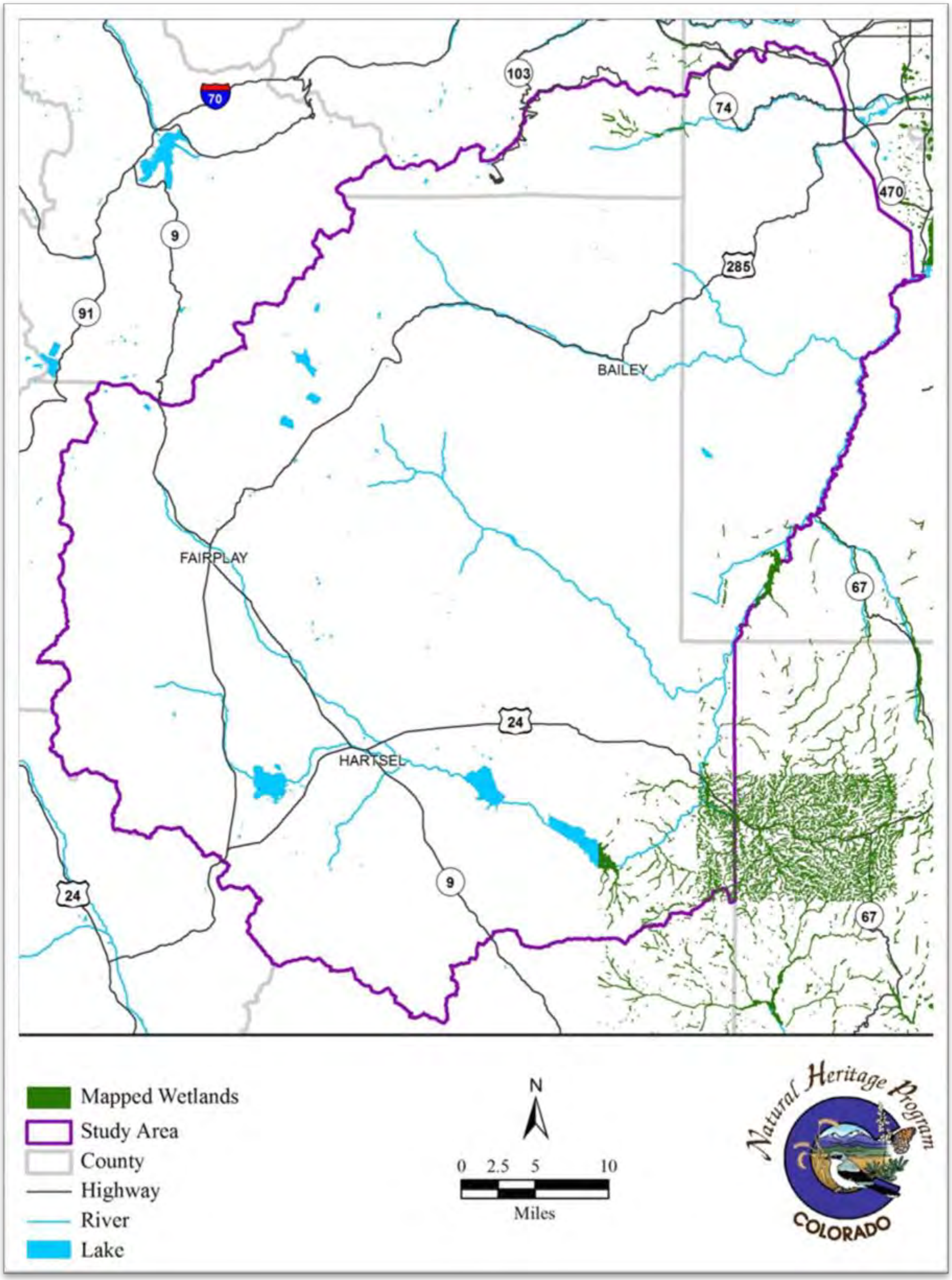

Figure 1.20. Study area wetlands before C21A mapping.

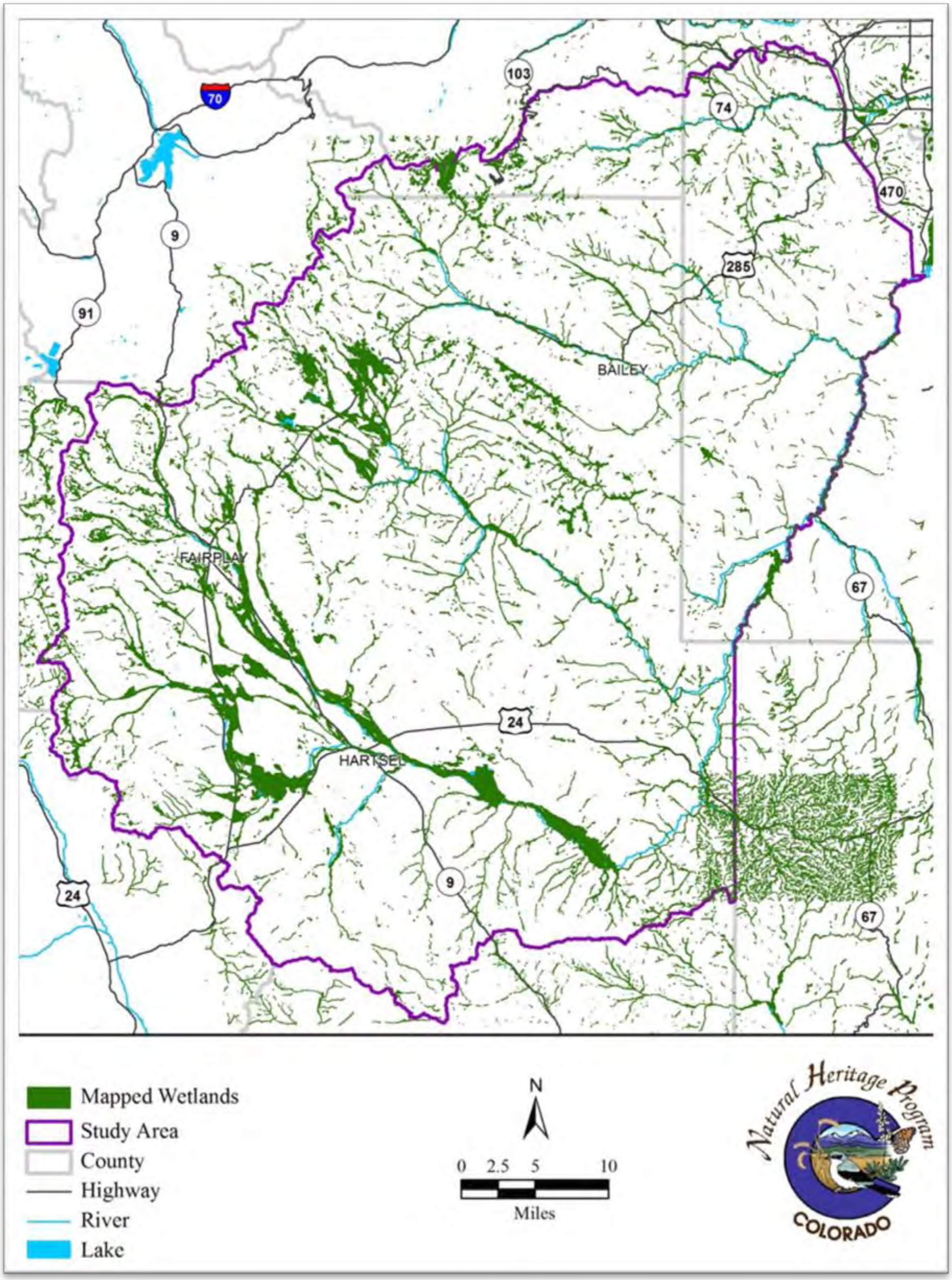

Figure 1.21. Study area wetlands after C21A mapping.

IEF Step 2: Conservation Value Summary

Methods

The first step in creating the Regional Ecosystem Framework step was to construct a biological conservation value summary (CVS) using the species distribution models and wetland map prepared earlier. The purpose of the CVS is to summarize high priority conservation opportunities based on biological resource values. The CVS consisted of a weighted, summed overlay of all target species, plus CNHP Potential Conservation Areas (PCAs) and as much of the wetland mapping as was completed when the CVS was created. The result is a relative measure of prioritized conservation value throughout the study area (Figure 1.22). Species inputs used for the CVS were the same as those discussed in the Marxan optimization analysis section below.

Inputs were weighted to represent their importance to biodiversity conservation. Species were prioritized by NatureServe's conservation status ranks (i.e., G-rank and S-rank; see Appendix A), with globally imperiled species (G1 and G2) weighted highest. All species with state or federal listing status (threatened, endangered, candidate) were also given the highest weight, regardless of G-rank. PCAs were weighted by their Biodiversity Rank (B-Rank; Appendix A). All natural wetlands were given a single weight; man-made wetlands were not included. Because the species models and activity maps represent potential habitat rather than known occurrence, they were given half the weight of CNHP Element Occurrence (EO) inputs of the same G-rank. If both models and CNHP EOs for a species existed within the study area, both inputs were used. Weights for each input ranged from 0.5 to 16, and are listed in Table 2.10.

Table 2.10. Weights for Each Conservation Value Summary Input

EOs		Models		PCAs		Wetlands	
G-Rank[a]	Weight	G-Rank[b]	Weight	B-Rank	Weight	All Types	Weight
1	16	1	8	1	8		12
2	12	2	6	2	6		
3	4	3	2	3	2		
4	2	4	1	4	1		
5	1	5	0.5	5	0.5		

[a] Any species with a state or federal T&E listing (including candidate) were given a full weight of 16 regardless of G-rank.
[b] Any species with a state or federal T&E listing (including candidate) were given a full weight of 8 regardless of G-rank.

Those inputs that were not already in raster form (CPW species activity maps, CNHP EOs and PCAs, and the mapped wetlands) were rasterized and snapped to the same extent and resolution as the CNHP models, with their respective assigned weights as the cell value. All weighted inputs (88 in total) were then summed to create the final CVS.

Results

The conservation value summary (Figure 1.22) indicates that the highest values in the study area are concentrated in alpine areas with limestone substrates and in areas associated with wetlands. Partner response to the CVS was generally positive, and the summary was acknowledged as believably representing the distribution of biological values in the study area. However, the most frequent feedback was the expressed desire to be able to "drill down" or distinguish exactly what species or target habitat(s) contributed to the value of a particular high-scoring area. The CVS dataset itself does not contain this information, and it would be a fairly complex undertaking to make it work as if it did in a seamless and transparent fashion. Furthermore, some sensitive location data that would not be available to all partners was incorporated in the final summary. CDOT and agency biologists at the project planning and permitting level were most interested in the component CVS breakdown, although acknowledging that even this information could not entirely substitute for on-the-ground clearance work. Those who work at wider-scope planning levels were able to see potential applications for the generalized information in their work, for instance, as a means of prioritizing review in corridor planning, or as a means of identifying key environmental hotspots that need attention during long-range planning. In this case, it would be valuable to have the CVS on a statewide basis.

With regard to the concept of integrating data on other resource types and transportation planning, partners indicated that it was not necessarily appropriate to combine cultural values with biological values in this type of summary, although they do somehow need to keep track of such things in the overall planning process. The difficulty of integrating the many disparate types of data that appear in the general planning cloud was acknowledged by all, but no one was able to articulate a solution to the problem.

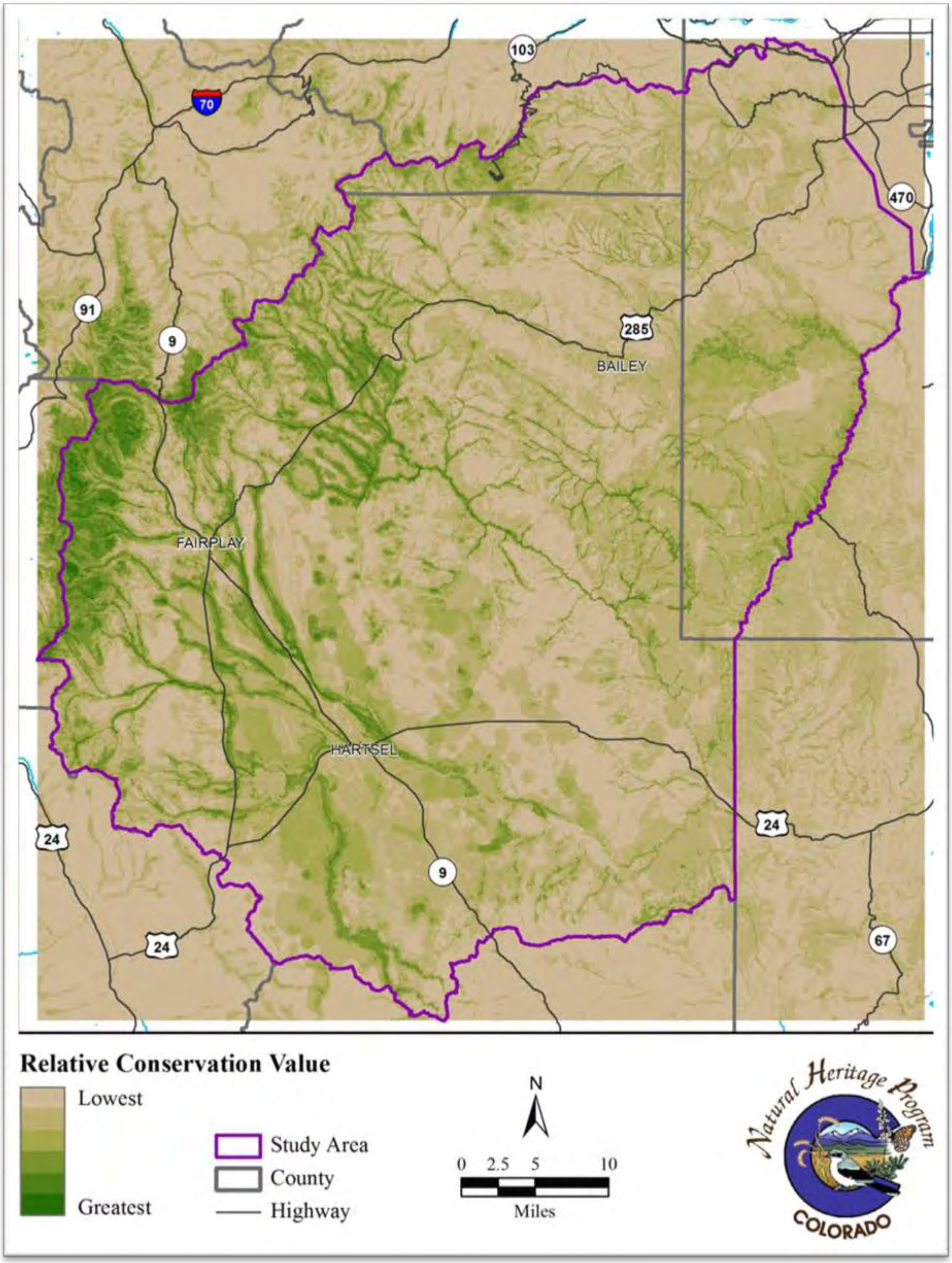

Figure 1.22. Conservation Value Summary.

IEF Step 4: Impact Assessment

In order to address step 4 in the framework, the team developed methods to evaluate the impacts of various types of land use (including transportation effects) on resource conservation objectives identified in the conservation value summary. The process proposed and modeled herein involves the construction of a landscape integrity map representing cumulative impacts to the natural landscape resulting from anthropogenic activities. This model also served as one of two alternative cost layer inputs for the optimization analysis discussed under IEF Step 5.

Landscape Integrity Model

The continuing expansion in digital mapping of infrastructure and landuse-landcover through geographic information systems (GIS) provides a wealth of data with which to investigate the spatial distribution of human impacts to the environment and the species and habitats of conservation interest. Spatial data, whether in point, vector, or raster format, require some translation and interpretation in order to reflect the real-world conditions they are intended to represent. Furthermore, the effects of anthropogenic changes to the landscape often extend some distance into the surrounding environment, beyond the actual footprint of disturbance (e.g., Forman and Diblinger 2000, Drewitt and Langston 2006, Houlahan et al. 2006, Nasen 2009, McDonald et al. 2009). The effect generally decreases with increasing distance, conforming to Tobler’s first law of geography: "Everything is related to everything else, but near things are more related than distant things" (Tobler 1970, p.236). Due to the diffusion of disturbance effects, it is important to assess the landscape context of a potential transportation project. Although spatially displayed data are several steps removed from reality, and cannot fully replace on-the-ground evaluation of ecological impacts, GIS can provide powerful tools for spatial modeling of landscape context, including one that is especially useful for analysis at a landscape scale.

Landscape context is an integrated measure of the quality of the ecological processes (e.g., hydrological processes such as flooding, disturbance regimes such as insect outbreaks and fire) that support species and habitats, and the connectivity of those habitats within the surrounding landscape. Ecological processes are often not amenable to direct measurement or modeling, especially over large landscapes. As a surrogate for measuring the quality and connectivity of the landscape, the location and intensity of anthropogenic disturbances was modeled. This method, referred to as a distance-decay model, is based on the broad assumption that anthropogenic disturbances are affecting the quality and connectivity of the landscape-scale ecological processes, and, by extension, having an impact on the species and habitats. A variety of data can be used to develop such models, including roads, residential and commercial development, mines, oil wells, tilled land, power lines, wind turbines, and solar arrays, among others.

As mentioned previously, this analysis assumes a decrease in the effect of disturbance(s) with increasing distance from the point of impact or project footprint. The choice of curve for the distance-decay function is determined by how the disturbance is believed to behave in the real world – i.e., does the effect drop sharply near the source but then fade gradually, or perhaps maintain a noticeable effect for some distance away from the source before decreasing, or is the rate of decrease constant? The landscape integrity model incorporated a family of sigmoid (s-shaped) decay curves as shown below, representing effects that remain strong near the source for some distance before decreasing.

$$y = \frac{1}{1 + \exp(\frac{bx}{c} - a)} \times w$$

where
a - shifts curve to right or left
b - determines spread of curve, or slope of the rapidly decreasing part of curve
c - scalar to adjust total distance of interest (=distance in meters divided by 20)
x - distance in meters from threat
w - weight of threat (maximum value)

By adjusting the shift and spread of the curve (*a* and *b*), it can be tailored to specific threats. Different values of *a* and *b* were used to derive four decay curves within a distance of 2,000 meters (Table 2.11, Figure 1.23): abrupt, moderately abrupt, moderate, and gradual. The inflection point of the curve marks the distance where the effect of the threat is reduced by half. These curves are asymptotic at both ends; therefore, the results of the equation must be manually adjusted to equal the maximum weight at zero distance and minimum weight at a distance at which the weight becomes essentially zero ("cut-off distance"). In this case, the cut-off point was at twice the distance to the inflection point.

Table 2.11. Values for Distance-Decay Curves

curve type	*a*	*b*	inflection point	cut-off
abrupt	1	5	100m	250m
moderately abrupt	2.5	2	300m	600m
moderate	5	1	500m	1,250m
gradual	10	0.5	1,000m	2,000m

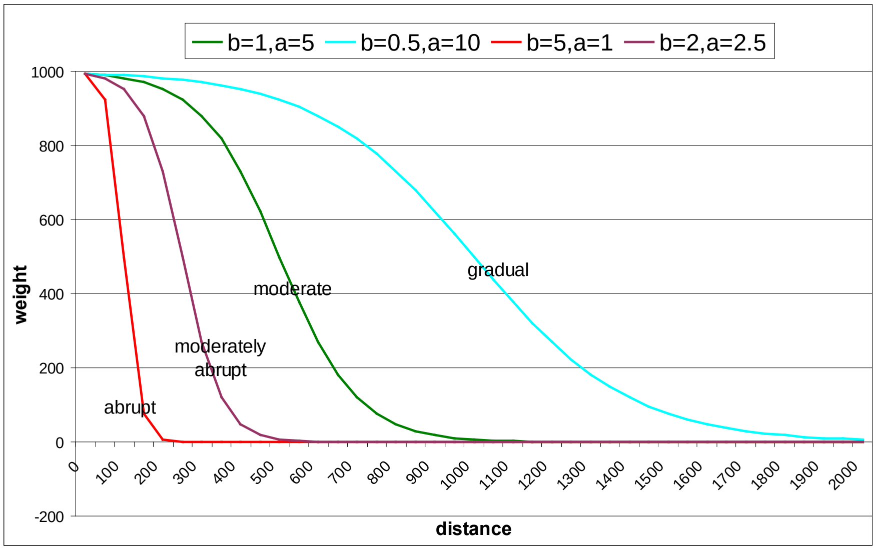

Figure 1.23. As an example, for a total distance of 2,000 meters, different values of a and b produce the following curve types.

This analysis included only anthropogenic disturbances thought to be detrimental to landscape integrity, producing a model that ranges from absence of impact (essentially neutral) to very high impact. If desired, one could also incorporate favorable impacts, and represent a continuum from excellent to poor habitat using similar techniques. This might be most useful in the case of species that are known to favor habitats that have been disturbed in a particular way, for example, mountain plovers and well-grazed pastures.

For this project, the team updated a pre-existing statewide landscape integrity model, and then modified it to more accurately represent real conditions in the study area. Data sets used for the Colorado statewide model are shown in Table 2.12. For the study area model, agriculture was omitted. This decision was due to the fact that cropped land was not a primary land use in the area, and the mapped land cover data were incorrectly identifying wet meadows as agriculture. Data sets were reconciled to a common extent and geographic projection. Each individual layer has its own relevant weight and decay function type. Each disturbance type was assigned a weight or maximum value and one of the four curve types. The selected layers are not mutually exclusive in the threats they represent, but were chosen to complement one another in order to compensate for incomplete or inaccurate source data. The individual threat layers are then additively combined to produce an overall landscape integrity layer.

Table 2.12. Data Sets Used in the Colorado Statewide Landscape Integrity Model

Threat type	Weight	Distance-Decay Function Type	Source
High/med intensity development	500	gradual	SWReGAP high/medium development types

Low intensity development	300	gradual	SWReGAP low intensity development types
Roads primary & secondary	500	moderate	2006 TIGER/Line roads (A1-A3)
Roads - local & rural, 4WD etc.	300	abrupt	2006 TIGER/Line roads (all other roads)
Oil & gas wells - active	400	moderate	Colorado Oil & Gas Commission (2008)
Oil & gas wells - inactive	200	mod-abr	Colorado Oil & Gas Commission (2008)
Gas pipelines	100	abrupt	2006 TIGER\Line utilities
Transmission lines	200	mod-abr	Digital Chart of the World Utilities layer
Surface Mines - active	500	moderate	Colo. Division of Reclamation, Mining, & Safety
Surface Mines - inactive	300	moderate	Colo. Division of Reclamation, Mining, & Safety

All impact data sets were converted to grids with a common cell size (in this case 30 meters) and identical extent. Each impact layer was used to create a distance grid, with a maximum calculated distance that reflected the pre-defined cut-off point for the curve type selected. The distance grid was used to create a distance-decay grid according to the formula given above. Resulting NoData cells were replaced with zeros, to represent the distance beyond which the threat has no further impact. Finally, cells representing the location of the threat itself were replaced with the maximum value for that threat. The individual threat layers were added together to produce a single landscape integrity layer representing the cumulative impact to an area from the included land uses (Figure 1.24).

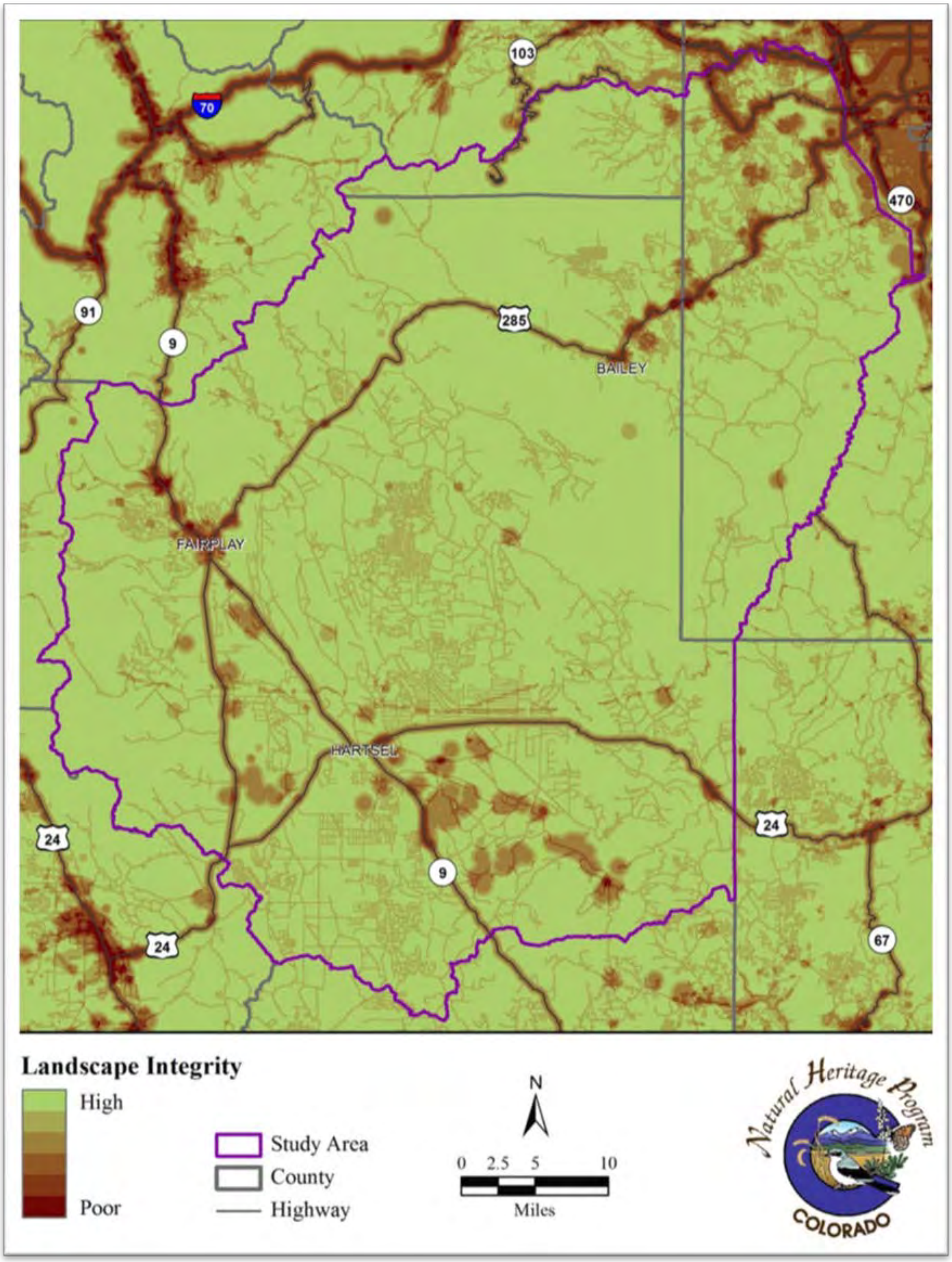

Figure 1.24. Landscape Integrity model.

Draft Methodology for Impact Assessment

The IEF process includes an assessment of the effects of transportation effects on resource conservation objectives. The landscape integrity model evaluates past impacts from anthropogenic sources, including transportation development, and can be adapted to track impacts over time. In the study area, there were no major projects planned with which to test the hypothetical assessment process, so draft methods are presented. The basic methodology is as follows.

Step 1: Spatially locate (i.e., roughly map) the new project and estimate a project-specific effect area using a raster-based distance-decay model, using or modifying the suggested decay curve parameters shown in Table 2.13. This model represents the estimated area of immediate impact for the project in question, but not in a cumulative context.

Step 2: Overlay the impact model with the conservation values data to evaluate the degree of potential conflict between the planned project and the biological and/or cultural values of the area (Figure 1.25). If the proposed project is coincident with a very high conservation value area, investigation into options for relocating or redesigning the project would be warranted. Any revisions should be accomplished in the context of the conservation value summary map so that reoccurring proposal-revision loops are minimized. If the project is modified or relocated, the distance-decay model map should be updated to reflect the revisions.

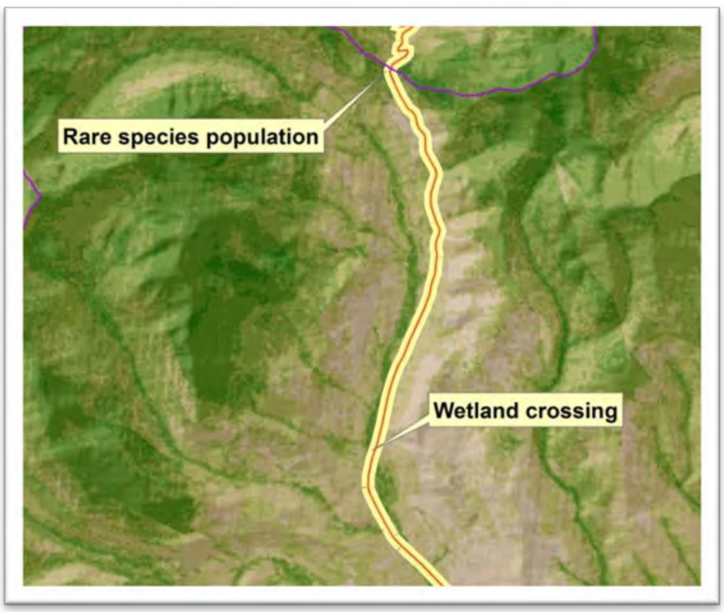

Figure 1.25. Hypothetical example of bike path development along Highway 9 from Fairplay to Hoosier Pass.

Step 3: The project-specific impact model data should be added to existing landscape integrity data. Over time, these types of project impact additions will track cumulative effects. As currently envisioned, the landscape integrity layer has a set maximum value representing an assumed level of disturbance beyond which an area cannot be returned to a natural, functioning ecosystem state without prohibitive investment levels; above this level, additional impact does not really increase the damage done, because it is already beyond recovery. Here again, a threshold of maximum acceptable cumulative impact due to transportation development should be identified, probably on a resource-specific basis. The raster datasets for both the individual project impact and the additive impacts over time may be maintained on a statewide or regional scale, but the datasets must be of equal extents and correctly aligned.

Results

Because there were no projects planned in the study area other than impacts that would take place in already heavily impacted areas (e.g., resurfacing, bridge repair, passing lanes), the proposed methodology has not been tested with a real-world scenario. In a case such as this study, where no spatially explicit plans are forthcoming, the CVS would serve as a way for DOT planners to visualize the regional resource conservation objectives that may be of interest in the future. Although few mapped conservation values are subject to regulatory requirements, the public-relations value of avoiding these types of conflicts may be important enough to warrant consideration. The entire process of impact analysis would benefit from the development of thresholds to guide the decision-making process, perhaps including a conflict matrix with action points or a decision tree.

IEF Step 5: Establish and prioritize ecological actions

In consultation with CDOT, the team reviewed three potential methods for conducting this analysis. These include 1) the CDOT Shortgrass Prairie Initiative approach, 2) an alternative scenario analysis based on STIP project areas, and 3) a conservation network optimization model. The Shortgrass Prairie Initiative analysis was a simple overlay of species habitats and highway right-of-ways, and a calculation of acres of habitat lost by species, and by habitat type. It identified regional-scale impact areas, but did not specifically identify a network of priority conservation or mitigation areas. The scenario-based analysis, where the impacts of different projects would be analyzed, was judged by CDOT to be a less desirable approach given the uncertainty of STIP project implementation and the difficulty in developing realistic project scenarios. The conservation network optimization model analyzes conservation and land-use data inputs through many iterations to identify highest quality (i.e., least impacted) and lowest cost (e.g., financial, restoration effort, or other) options that will meet conservation/mitigation goals. This approach was the most appealing method from CDOT's perspective because it addresses cost and identifies specific areas of conservation value. The team judged the optimization model to be the most robust analysis, with the greatest potential for meeting project goals; therefore, the software tool Marxan (version 2.43) was chosen to create a conservation network optimization model.

Marxan is a decision-support software program for conservation planning and reserve system design (Ball et al. 2009). It helps planners identify geographic areas to protect and manage to achieve specific conservation goals for species and ecological systems. It does this by maximizing cost-benefit ratios to identify an optimal arrangement of conservation areas that allows planners to achieve stated goals at minimum cost. Conservation goals define how much (acreage or number of occurrences) of each target must be retained in order to sustain healthy populations into the future. How "cost" is defined depends on the project objectives and available data. Cost can be actual financial value of land, or some indication of the relative condition of conservation lands (based on the assumption that less pristine habitats require more dollar/manpower resources to restore and maintain). Actual real estate value is highly variable and fluctuates rapidly. Furthermore, these values are rarely readily available in a GIS format at a landscape scale. Often, therefore, cost is measured as a more abstract indicator, such as the landscape integrity layer discussed previously, which serves as a proxy for the desirability and practicality of implementing a conservation project in a particular area.

In order to run a Marxan analysis, the study area must first be divided into "planning units" that will ultimately be selected as either within or outside of the optimal conservation solution. For best results, planning units should be of equivalent size and small enough to allow reasonable resolution and flexibility in creating the solution, but large enough to contain practical amounts of conservation targets and not take excessive computing time and resources (Ardron et al. 2010). Ideally, the analysis unit would be meaningful in real terms. The original intention was to use Public Land Survey System (PLSS) quarter sections to provide appropriate resolution and have the advantage of coinciding with many real property boundaries. However, because of the mountainous terrain occurring within the study area and the way in which PLSS sections were originally laid out in the Western U.S., there are numerous quarter sections that are at least four times smaller than the average 160 acre size, which would result in biased planning unit selections (Ardron et al. 2010). Therefore, an ad hoc grid of 150 acre hexagons was generated and used instead. This approach has the added benefit of obscuring specific landowners' property boundaries – a significant concern in some conservation planning exercises. The study area contains 10,561 hexagons. To maintain a consistent size, hexagons were not clipped at the study area boundary, but were instead allowed to slightly under- or over-shoot the precise boundary as necessary.

Costs

As previously discussed, Marxan requires that each planning unit be assigned a "cost," the additive total of which Marxan attempts to minimize in the final solution. Because actual land values and other literal dollar amounts such as restoration or management costs are very difficult to estimate and apply over large project areas, some indicator of ecological integrity is frequently used as a cost surrogate in Marxan (Ardron et al. 2010). However, after discussion with CDOT, the team decided to try applying some relative measure of actual land value. So, for testing purposes, two separate cost layers were used: the Landscape Integrity model discussed previously (Figure 1.26), and a Land Value cost developed for the project area (Figure 1.27).

Land Value

The increasing availability and use of GIS in land-use management and recording means that many county assessor's offices are developing spatially referenced databases of parcel ownership and assessed value. Unfortunately, there is not yet a uniformly adopted standard for such data. Furthermore, the continually shifting nature of real estate values means that revisions to the data are ongoing. Ideally, a land value dataset would be compiled from the parcel-specific information maintained by county assessor's offices in the study area.

In the study area, this was not feasible under project schedule constraints. Ownership and assessed value of property, although legally characterized as public information, is treated as sensitive data and county offices are generally unwilling to release complete GIS datasets of mapped parcels, even without values attached. Acquiring these data would involve lengthy negotiation, and potentially significant cost. Information that is available online is cumbersome to access (query by parcel ID, cadastral metes-and-bounds, etc.) and difficult to attach to publicly available ownership datasets. Thus, the team used a surrogate for actual assessed property value to represent this alternative. A test in which assessed property values were compiled per section for three townships in the center of the study area spanning both developed and undeveloped lands showed that private property values were highly correlated with road density on private lands ($R^2 = 0.72$, $p > 0.001$). The team also assumed that property in public ownership or with a conservation easement already in place would not need to be purchased for conservation, but management of such lands may vary in its focus on natural resources conservation versus other uses such as resource extraction and recreation. The intent for which public lands are managed should therefore also contribute to their relative land value. To combine these two disparate concepts (road density as surrogate of land value on private lands and management intent on public lands or private lands with easements) into a single land value cost layer, the team started with The Nature Conservancy's (TNC) Conservation Management Status Measure for the state of Colorado (TNC 2008), which is in turn derived from the Colorado Ownership, Management and Protection (COMaP) layer version 6 (Wilcox et al. 2007). TNC assigned scores from 0 (Poor) to 10 (Very Good) as to the intent, tenure, and management systems in place to protect biodiversity on all mapped land parcels within Colorado (Table 2.13). CNHP had previously rolled these individual scores up into a single conservation status score (again ranging 0–10) for assessing Colorado’s biodiversity status (Rondeau et al. 2011).

For the current project, CNHP used these pre-existing conservation status scores for all mapped land parcels within the study area. Privately-owned lands without conservation easements are not individually mapped and were by default given a score of 0. Road densities were calculated for these areas, using a 20 m resolution and a 1 km search radius. Results, in kilometers of road per square kilometer, were then summed within each planning unit containing private land without conservation easements. Area-weighted summed values were then compared against the assessed property values per section to derive a cut-off value that distinguished potentially high-value private lands from average-value private lands. High-value private lands retained a conservation status score of 0, whereas average-value private lands were given a score of 2. Two was chosen in this case because it is higher than "Poor" but less than "Fair" (“fair” would imply some actual protection status, and this is still private unprotected). Area-weighted conservation status scores were then calculated for each planning unit, so that a planning unit containing more than one type of land was given a hybrid score representing its overall conservation status. These scores were then inverted to represent relative cost to acquire and/or manage for conservation and then transformed to a scale of 0 (no cost) to approximately 1,000 (high cost) for each planning unit, to bring it into the same order of magnitude as the Landscape Integrity cost layer.

Table 2.13. Scores Used to Represent Degree of Biodiversity Protection

Very Good	10
Good	7
Fair	4
Unknown	2
Poor	0

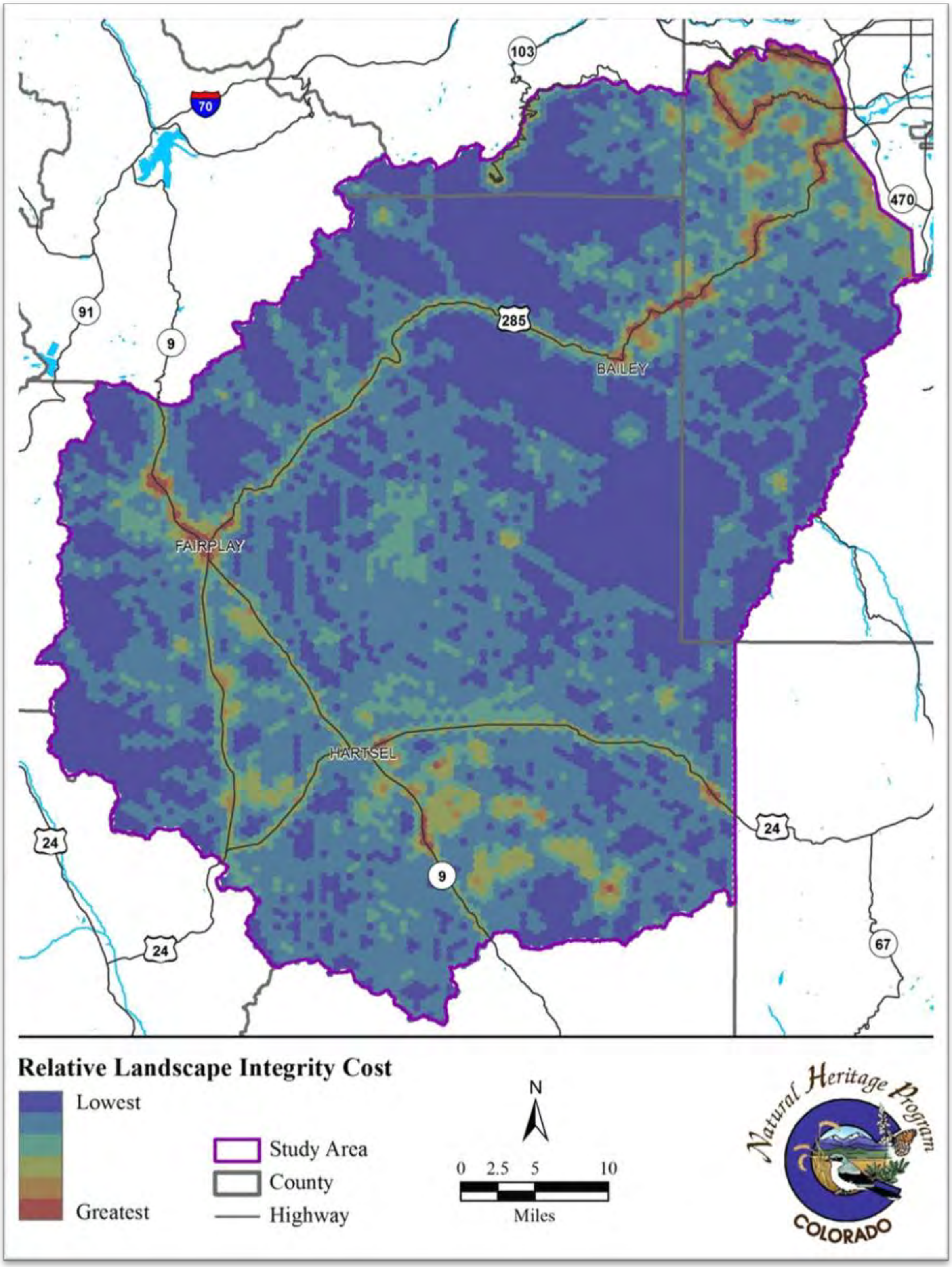

Figure 1.26. Landscape Integrity as "cost" input for Marxan analysis.

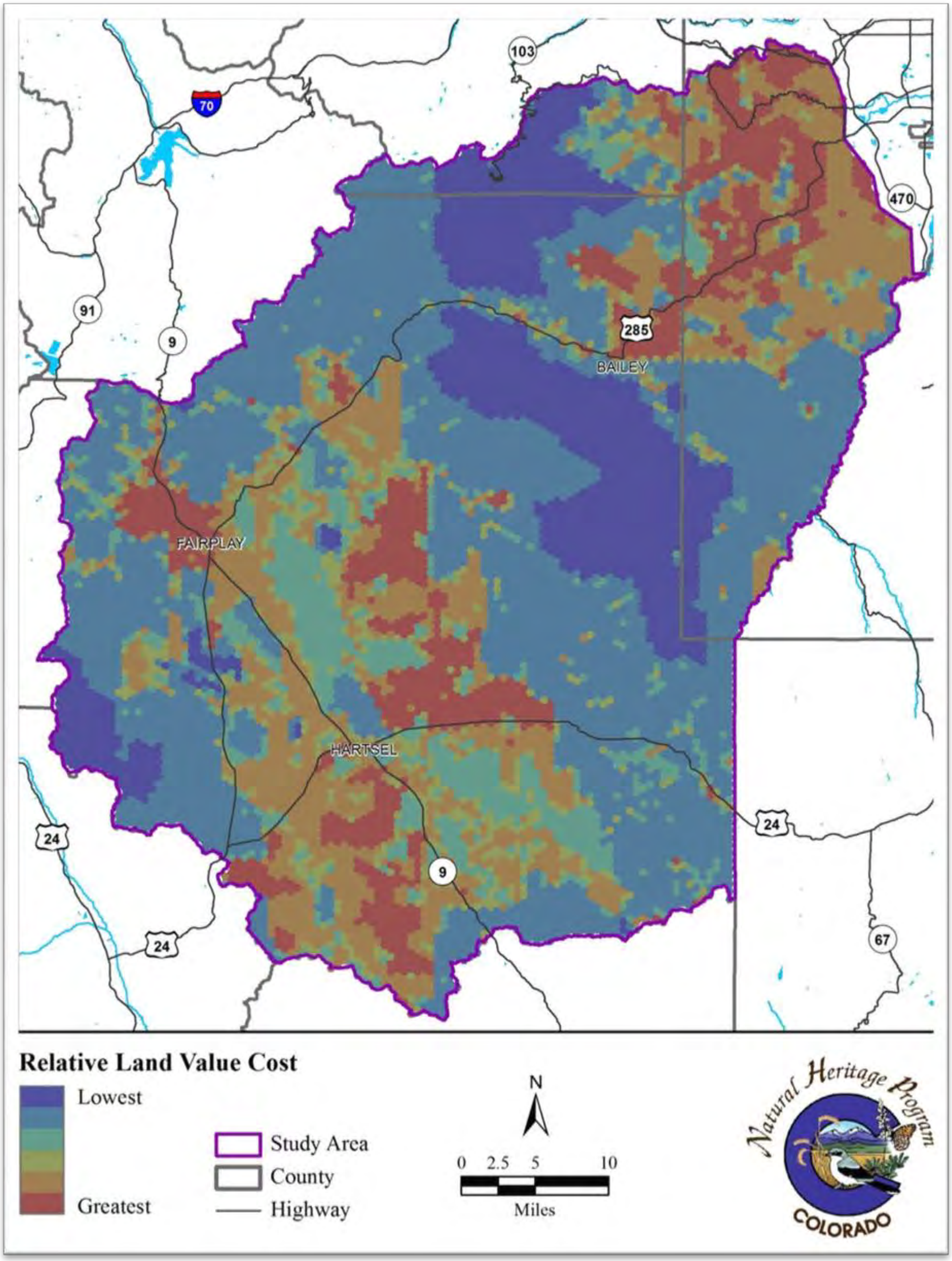

Figure 1.27. Land Value model as "cost" input for Marxan analysis.

Analysis Targets and Conservation Goals

Target species were represented by CNHP EOs and all species distribution models and activity maps listed in Table 2.2. Because wetland mapping was being completed simultaneously with this analysis, the updated wetland map was not available in time to include here. However, the analysis includes a number of wetland-specific plant species models that provide more-or-less equivalent coverage of this important habitat. Species distribution models and species activity map data were represented as acres in each planning unit. Models for mid- to large-size animal species were modified to remove habitat patches deemed generally too small to be viable (defined as patches of three 30 meter cells, or 1/3 acre, or less). Because EOs are considered discrete known occurrences and a conservation goal cannot be met by conserving only part of an occurrence, EOs were represented as the proportion of each EO in each planning unit, regardless of EO size. Large EOs spanned multiple planning units, whereas smaller EOs could be fully contained within a single unit.

Each conservation target must be assigned a goal – how much of the species' potential habitat or known occurrences within the study area should be retained in the final solution. Two separate goal schemas were created for this project: "High-Risk" and "Low-Risk." A High-Risk goal would require that fewer acres or occurrences of the species would be retained, and thus that the risk of losing the species would be higher. Conversely, Low-Risk indicates that more acres or occurrences are conserved, and therefore the risk of not adequately conserving the species or habitat is assumed to be low. Note that these risk levels are based on best professional judgment of local and regional experts, and have not been empirically tested or otherwise validated.

A set of goal scheme rules were created based on NatureServe's conservation status ranks (Table 2.14). These initial goals and their resulting Marxan solutions were then reviewed and modified iteratively as necessary for each species and input type. Modeled inputs in particular seemed likely to be over-representing suitable habitat and high goals resulted in almost the entire study area being identified as required for conservation. Because 1) field-truthing of the habitat models to determine their validity was outside the scope of the project, and 2) a selection of all or nearly all of the study area does not provide useful guidance for prioritization and decision support, model goals were lowered from their initial schema. This adjustment, however, does not address the possibility that more area really is required for adequate conservation of species. As with most goal-setting attempts in conservation biology, the process is a complex, iterative exercise that relies on expert opinion as well as data. The eventual decision was that if both CNHP EOs and modeled potential habitat were available for a species within the study area, both inputs were used, and model goals were further reduced based on the mobility of the species in question. Final goals used are presented in Table 2.15.

Table 2.14. Goal Scheme Rules for Marxan Analysis

Initial Goal Scheme Rules for Targets & PCAs (high-risk | low-risk):
G1-G2 at 100% | 100% (90% if acreage)
G3+ S1 at 100% | 100% (90% if acreage)
G3+ S2 at 75% | 100% (90% if acreage)
G3+ S3 at 50% | 75%
G4+ S4 at 33% | 66%
G5 S5 at 10% | 50%
B1 & B2 PCAs at 75% | 90%
B3 - B5 PCAs at 33% | 50%
These initial goals were then modified to result in whole number of occurrences (i.e., targets with less than 2 occurrences will always have a goal of 100%; 2 occurrences will either be 50% or 100%; 3 occurrences will be either 33%, 66%, or 100%).

Table 2.15. Final Species Goals for Marxan Analysis ***Scientific Name***	**Common Name**	**Data Source**	**Amount in Area[a]**	**Low-Risk Goal**	**High-Risk Goal**
AMPHIBIANS					
Bufo boreas **pop. 1**	**Western Toad - Southern Rocky Mountains population**	Model	245,740	40%	20%
		EOs	2.6	100%	100%
Rana pipiens	**Northern Leopard Frog**	Model	11,120	90%	75%
BIRDS					
Accipiter gentilis	Northern Goshawk	Model	861,580	66%	33%
Aegolius funereus	Boreal Owl	Model	251,450	60%	30%
		EOs	0.8	100%	100%
Aquila chrysaetos	Golden Eagle	Model	1,303,070	66%	33%
Athene cunicularia	**Burrowing Owl**	Model	114,180	75%	50%
Buteo regalis	Ferruginous Hawk	Model	3,280	60%	30%
		EOs	1.0	100%	100%
Catharus fuscescens	Veery	Model	202,900	75%	50%
Charadrius montanus	Mountain Plover	Model	494,500	60%	30%
		EOs	13.9	100%	100%
Empidonax trailii	Willow Flycatcher	Model	64,750	66%	33%
Falco mexicanus	Prairie Falcon	Model	62,040	66%	33%
Falco peregrinus anatum	American Peregrine Falcon	Model	127,680	60%	30%
		EOs	2.0	100%	100%
Haliaeetus leucocephalus	Bald Eagle	Model	33,300	60%	30%
		EOs	1.8	100%	100%

Table 2.15. Final Species Goals for Marxan Analysis ***Scientific Name***	**Common Name**	**Data Source**	**Amount in Area**[a]	**Low-Risk Goal**	**High-Risk Goal**
Lagopus leucurus	White-tailed Ptarmigan	Model	216,270	75%	50%
Melanerpes lewis	Lewis's Woodpecker	Model	178,760	75%	50%
Pelecanus erythrorhynchos	American White Pelican	Model	111,050	60%	30%
		EOs	1.0	100%	100%
Seiurus aurocapilla	Ovenbird	Model	132,880	90%	100%
Strix occidentalis lucida	**Mexican Spotted Owl**	Model	269,610	75%	75%
FISH					
Onchorhynchus clarkii stomias	**Greenback Cutthroat Trout**	Model	40,680[b]	90%	90%
Phoxinus eos	Northern Redbelly Dace	Model[c]	2,490 ‡	90%	90%
INSECTS					
Callophrys mossii schryveri	Schryver's Elfin	Model	43,490	20%	10%
		EOs	1.3	100%	77%
Celastrina humulus	Hops Azure	Model	23,070	20%	10%
		EOs	1.0	100%	100%
Cicindela nebraskana	Prairie Long-lipped Tiger Beetle	EOs	1.0	100%	100%
Erynnis martialis	Mottled Duskywing	Model	58,070	20%	10%
		EOs	2.9	100%	69%
Hesperia leonardus Montana	**Pawnee Montane Skipper**	Model	14,690	20%	10%
		EOs	2.0	100%	100%
MAMMALS					
Cynomys gunnisoni	**Gunnison's prairie dog**	Model	147,470	66%	33%
Gulo gulo	**Wolverine**	Model	318,210	60%	30%
		EOs	1.6	100%	100%
Lynx canadensis	**Lynx**	Model	262,940	90%	90%
Sorex nanus	Dwarf Shrew	Model	1,191,790	20%	10%
		EOs	1.0	100%	100%
Thomomys talpoides macrotis	Northern pocket gopher *macrotis* subspecies	Model	130	90%	90%
Zapus hudsonius preblei	**Preble's Meadow Jumping Mouse**	Model	7,250	90%	90%
PLANTS					
Aquilegia saximontana	Rocky Mountain Columbine	Model	220,030	20%	10%
		EOs	6.0	83%	50%
Arabidopsis salsuginea	Saltwater Cress	Model	79,890	20%	10%
		EOs	3.0	100%	100%

Table 2.15. Final Species Goals for Marxan Analysis ***Scientific Name***	**Common Name**	**Data Source**	**Amount in Area[a]**	**Low-Risk Goal**	**High-Risk Goal**
Armeria maritima ssp. Sibirica	Sea Pink	Model	9,460	20%	10%
		EOs	0.3	100%	100%
Astragalus molybdenus	Molybdenum Milkvetch	Model	46,040	20%	10%
		EOs	4.9	100%	82%
Astragalus sparsiflorus	Front Range Milkvetch	Model	73,770	20%	10%
		EOs	3.0	66%	33%
Braya glabella ssp. glabella	Smooth Rockcress	Model	10,810	20%	10%
		EOs	1.0	100%	100%
Braya humilis	Low Braya	Model	14,915	20%	10%
		EOs	5.8	100%	69%
Carex limosa	Mud Sedge	Model	32,430	20%	10%
		EOs	2.0	100%	50%
Carex livida	Livid Sedge	Model	34,540	20%	10%
		EOs	4.0	100%	100%
Carex oreocharis	Grassy Slope Sedge	Model	201,260	20%	10%
		EOs	2.0	100%	50%
Carex scirpoidea	Bulrush Sedge	Model	283,970	20%	10%
		EOs	12.0	100%	75%
Carex tenuiflora	Sparse-flower Sedge	EOs	1.0	100%	100%
Carex viridula	Little Green Sedge	Model	104,350	20%	10%
		EOs	1.0	100%	100%
Castilleja puberula	Downy Indian-paintbrush	Model	28,600	20%	10%
		EOs	1.0	100%	100%
Crepis nana	Dwarf Alpine Hawk's-beard	Model	25,440	20%	10%
		EOs	2.0	100%	50%
Cypripedium parviflorum	American Yellow Lady's-slipper	Model	146,890	20%	10%
		EOs	2.0	100%	100%
Draba borealis	Boreal Whitlow-grass	Model	33,910	20%	10%
		EOs	0.04	100%	100%
Draba crassa	Thick-leaf Whitlow-grass	Model	72,780	20%	10%
		EOs	2.8	71%	36%
Draba exunguiculata	Clawless Draba	Model	24,180	20%	10%
		EOs	4.6	100%	100%
Draba fladnizensis	White Arctic Whitlow-grass	Model	78,550	20%	10%
		EOs	3.4	100%	88%

Table 2.15. Final Species Goals for Marxan Analysis ***Scientific Name***	**Common Name**	**Data Source**	**Amount in Area[a]**	**Low-Risk Goal**	**High-Risk Goal**
Draba globosa	Rockcress Draba	Model	5,320	20%	10%
		EOs	1.0	100%	100%
Draba grayana	Gray's Peak Whitlow-grass	Model	45,490	20%	10%
		EOs	2.0	100%	100%
Draba oligosperma	Few-seed Whitlow-grass	Model	14,540	20%	10%
		EOs	3.0	100%	75%
Draba porsildii	Porsild's Whitlow-grass	Model	40,930	20%	10%
		EOs	0.04	100%	100%
Draba streptobrachia	Colorado Divide Whitlow-grass	Model	19,510	20%	10%
		EOs	2.0	100%	50%
Eriophorum altaicum var. neogaeum	Altai Cotton-grass	Model	53,130	20%	10%
		EOs	1.0	100%	100%
Eriophorum gracile	Slender Cotton-grass	Model	72,390	20%	10%
		EOs	4.0	100%	100%
Eutrema penlandii	**Penland's Alpine Fen Mustard**	Model	49,210	20%	10%
		EOs	9.4	100%	100%
Ipomopsis globularis	Globe Gilia	Model	107,090	20%	10%
		EOs	6.3	100%	100%
Kobresia simpliciuscula	Simple Kobresia	EOs	1.0	100%	100%
Machaeranthera coloradoensis	Colorado Tansy-aster	Model	191,830	20%	10%
		EOs	5.0	100%	80%
Malaxis brachypoda	White Adder's-mouth	EOs	1.0	100%	100%
Mentzelia speciosa	Jeweled Blazingstar	Model	247,540	20%	10%
		EOs	2.0	100%	50%
Mimulus gemmiparus	Weber's Monkeyflower	Model	60,080	20%	10%
		EOs	4.0	100%	100%
Oligoneuron album	Prairie Goldenrod	Model	5,280	20%	10%
		EOs	1.0	100%	100%
Packera pauciflora	Few-flower Ragwort	Model	37,320	20%	10%
		EOs	11.0	100%	100%
Parnassia kotzebuei	Kotzebue's Grass-of-Parnassus	Model	30,990	90%	90%
Phippsia algida	Ice Grass	EOs	2.0	100%	50%
Physaria alpina	Avery Peak Twinpod	Model	25,870	20%	10%

Table 2.15. Final Species Goals for Marxan Analysis ***Scientific Name***	**Common Name**	**Data Source**	**Amount in Area[a]**	**Low-Risk Goal**	**High-Risk Goal**
		EOs	3.0	100%	100%
Potentilla ambigens	Southern Rocky Mountain Cinquefoil	Model	119,570	20%	10%
		EOs	1.0	100%	100%
Potentilla rupincola	Rocky Mountain Cinquefoil	Model	322,410	20%	10%
		EOs	1.0	100%	100%
Primula egaliksensis	Greenland Primrose	Model	73,690	20%	10%
		EOs	16.0	100%	100%
Ptilagrostis porteri	Porter's Feathergrass	Model	260,860	20%	10%
		EOs	19.0	100%	100%
Ranunculus karelinii	Arctic Buttercup	Model	9,430	20%	10%
		EOs	3.0	100%	100%
Ribes americanum	Wild Black Currant	Model	36,140	90%	75%
Rubus arcticus ssp. acaulis	Nagoonberry	EOs	1.0	100%	100%
Salix candida	Hoary Willow	Model	268,210	20%	10%
		EOs	13.0	100%	100%
Salix lanata ssp. calcicola	Lanate Willow	EOs	1.0	100%	100%
Salix myrtillifolia	Myrtle-leaf Willow	EOs	5.0	100%	100%
Salix serissima	Autumn Willow	Model	39,810	90%	90%
Saussurea weberi	Weber's Saw-wort	Model	68,040	20%	10%
		EOs	9.6	100%	100%
Saxifraga foliolosa	Leafy Saxifrage	EOs	1.0	100%	100%
Sisyrinchium demissum	Stiff Blue-eyed-grass	EOs	1.0	100%	100%
Sisyrinchium pallidum	Pale Blue-eye-grass	Model	406,540	20%	10%
		EOs	24.0	100%	100%
Sphagnum girgensohnii	Girgensohn's Peatmoss	Model	25,040	20%	10%
		EOs	1.0	100%	100%
Telesonix jamesii	Jame's False Saxifrage	Model	259,420	20%	10%
		EOs	3.0	100%	100%
Townsendia rothrockii	Rothrock's Townsend-daisy	Model	45,010	20%	10%
		EOs	1.0	100%	100%
Trichophorum pumilum	Rolland's Leafless-bulrush	Model	139,330	20%	10%
		EOs	12.0	100%	100%
Viola pedatifida	Prairie Violet	Model	27,300	90%	75%
BIG GAME					
Ovis canadensis	Bighorn Sheep	SAM[d]	70,360	66%	33%

Table 2.15. Final Species Goals for Marxan Analysis ***Scientific Name***	**Common Name**	**Data Source**	**Amount in Area**[a]	**Low-Risk Goal**	**High-Risk Goal**
Ursus americanus	Black Bear	SAM[d]	248,210	50%	10%
Cervus canadensis	**Elk**	SAM[d]	243,000	50%	10%
Odocoileus hemionus	**Mule Deer**	SAM[d]	575,170	66%	33%
Puma concolor	Mountain lion	SAM[d]	479,120	66%	33%

Notes: Regulatory and safety concern species are in bold.
EO = CNHP Element Occurrence

[a] Amount in area is in acres for models and number of occurrences for EOs. Acreages have been rounded to the nearest 10 for display. Fractional EOs indicates that the occurrence continues outside the project area.

[b] Acres of potential habitat is not precisely applicable to aquatic species, but acres can be calculated from the models, so were treated the same as other model inputs.

[c] This is a model of historic/restoration habitat only. This species does not currently occur in the study area.

[d] SAM = Species Activity Maps as developed by the Colorado Parks and Wildlife. These are treated the same as the potential habitat models.

In addition to using the full species list, the team also ran a Marxan solution on a subset of this list that represents only regulated species (state and federally listed and candidate species) and those species deemed to be a highway safety concern by CDOT (deer, elk) (bolded in Table 2.15). Because CDOT and other agencies are only required to avoid or mitigate for these species, some participants were interested in this more limited analysis. The same conservation goals were used for both lists.

A total of eight solutions were created, using the various alternate inputs for goal-sets (high-risk and low-risk), cost schema (landscape integrity and land value), and species list (full list and regulatory species only) (Table 2.16, Figures 1.28-1.35). Each solution represents the "best" (lowest overall score) out of the 1,000 runs.

Table 2.16. Input Combinations Resulting in Eight Separate Marxan Solutions

Goal Set	Cost Schema	Target List
Low-Risk	Land Value	Full
Low-Risk	Land Value	Regulatory/Safety
Low-Risk	Landscape Integrity	Full
Low-Risk	Landscape Integrity	Regulatory/Safety
High-Risk	Land Value	Full
High-Risk	Land Value	Regulatory/Safety
High-Risk	Landscape Integrity	Full
High-Risk	Landscape Integrity	Regulatory/Safety

Results

A summary of each of the eight Marxan solutions created is presented in Table 2.17. Marxan was parameterized such that if a solution came within meeting 95% of a goal, that goal was considered effectively met. All eight solutions met all goals. Some species goals were significantly exceeded, because Marxan attempts to meet all goals for all species, which can potentially select more area than is needed for any one species. A way to determine which subset of species may be largely driving the final solution is to examine which goals were met at no more than 100% with at least 1,000 planning units. This was one technique used to iteratively adjust goals to create a more informative set of solutions.

Table 2.17. Summary of the Eight Marxan Solutions

Goal Set	Cost Schema	Target List	Total Percent of Goals Met
Low-Risk	Land Value	Full	99.7%
Low-Risk	Land Value	Regulatory/Safety	99.8%
Low-Risk	Landscape Integrity	Full	97.8%
Low-Risk	Landscape Integrity	Regulatory/Safety	99.8%
High-Risk	Land Value	Full	97.1%
High-Risk	Land Value	Regulatory/Safety	99.8%
High-Risk	Landscape Integrity	Full	97.8%
High-Risk	Landscape Integrity	Regulatory/Safety	100%

The planning units selected for each solution are shown in Figures 1.28–1.35. To help focus attention on which parts of the solution represent mitigation and restoration opportunities, each planning unit was assigned one of four conservation strategy labels, depending on the majority land owner and mean landscape integrity within each unit (Table 2.18). The land planning unit was considered to have protected status if the percent of land within the unit that was privately owned and not in a conservation easement was less than 50%. Likewise, the ecological integrity of a planning unit was considered good if the mean Landscape Integrity value for the unit was less than 500. This is, of course, an approximation of the true strategy for any particular parcel of land due to the relatively coarse resolution of the 150 acre hexagons used as planning units.

Table 2.18. Conservation Strategy Assigned to Planning Units in Each Marxan Solution

Strategy	Land Status	Ecological Integrity
Effectively Conserved	Protected	Good
Protection Strategy	Unprotected	Good
Management Strategy	Protected	Poor
Protection & Mgmt Strategy	Unprotected	Poor

The conservation strategies assigned to planning units can be interpreted as follows:

- Areas that are **Effectively Conserved** do not require further action; they are already in acceptable condition and sufficiently protected. Note that these areas are contributing to regional conservation goals, but would not be areas where mitigation requirements could be met (i.e., they are not threatened and do not require restoration).

- Areas requiring a **Protection Strategy** are believed to be in good condition, and would require only some form of legal protection from land-use conversion to preserve their ecological value. These areas are obvious candidates for conservation easements or similar mitigation efforts.
- Areas requiring a **Management Strategy** have protection in place to prevent conversion, but their current condition is poor. These areas are likely to provide restoration sites that could contribute to mitigation needs.
- Units in need of both **Protection and Management Strategy** represent places where both restoration and protection are needed, and could be used to meet mitigation needs. These areas may, at first glance, seem to be the least desirable places in which to focus conservation efforts. However, they are necessary to achieve conservation goals and may offer the greatest gain in terms of meeting mitigation requirements.

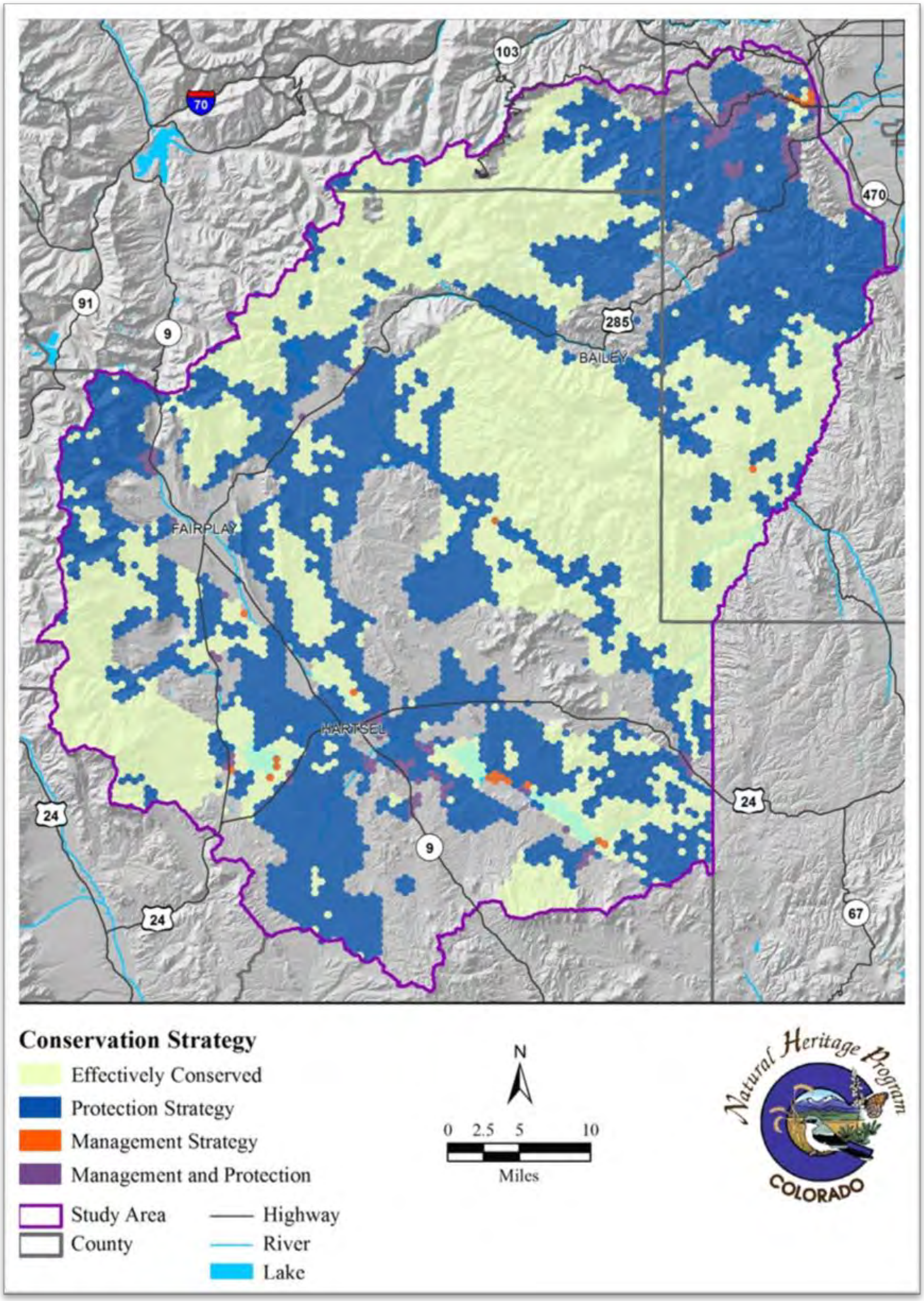

Figure 1.28. Marxan solution for low-risk goal set, landscape integrity cost layer, and full target list.

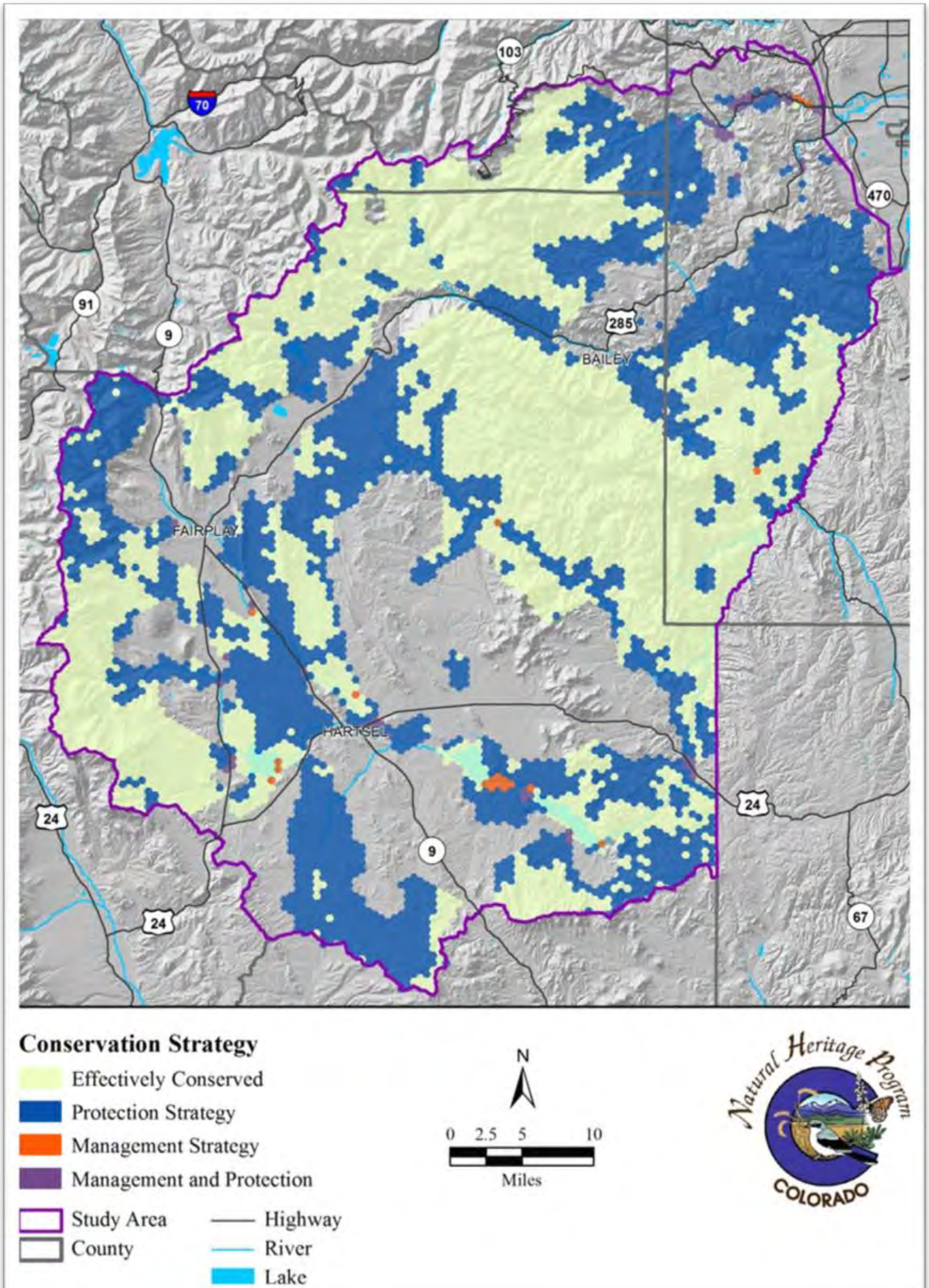

Figure 1.29. Marxan solution for low-risk goal set, landscape integrity cost layer, and regulatory species only.

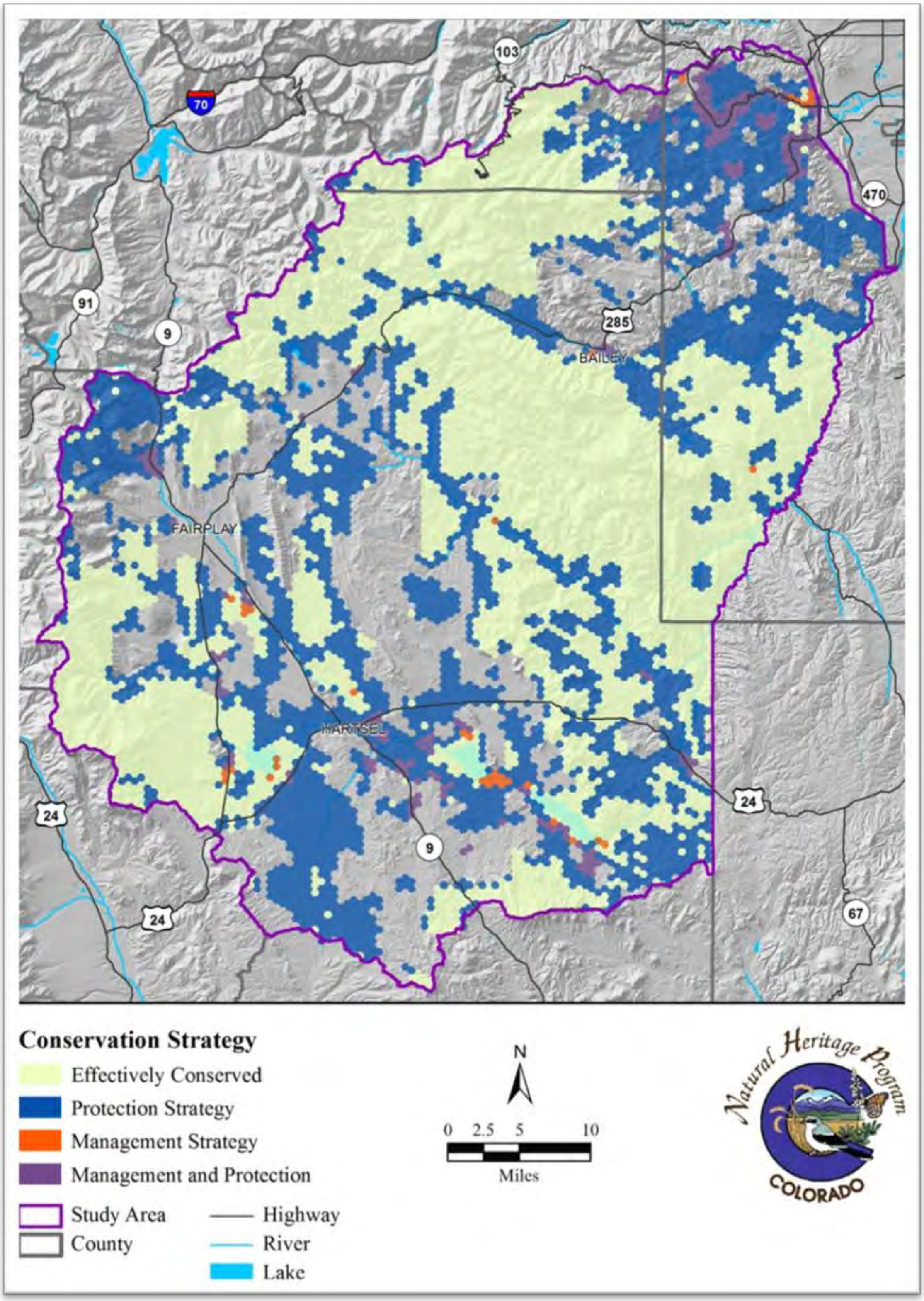

Figure 1.30. Marxan solution for low-risk goal set, land value cost layer, and full target list.

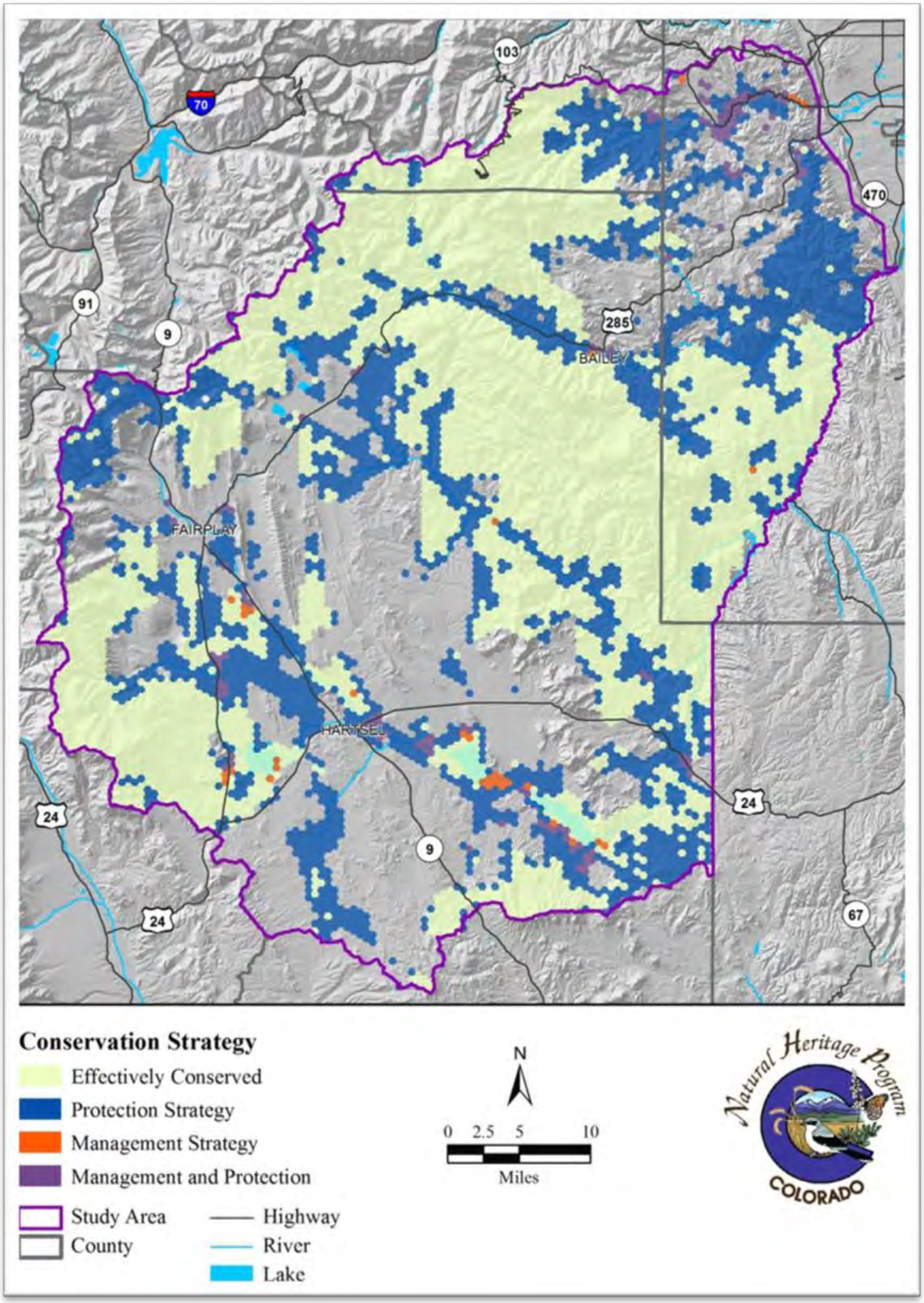

Figure 1.31. Marxan solution for low-risk goal set, land value cost layer, and regulatory species only.

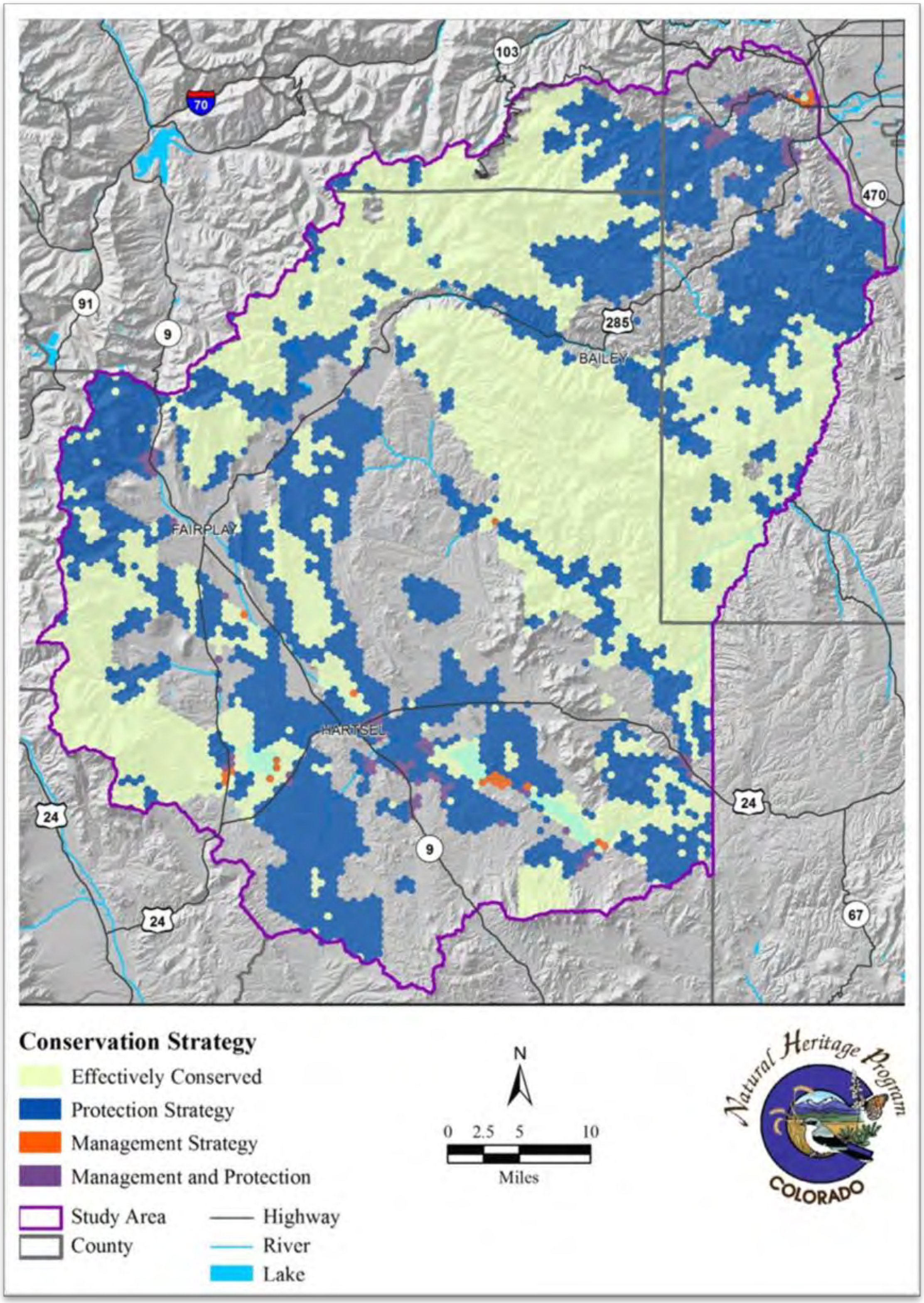

Figure 1.32. Marxan solution for high-risk goal set, landscape integrity cost layer, and full target list.

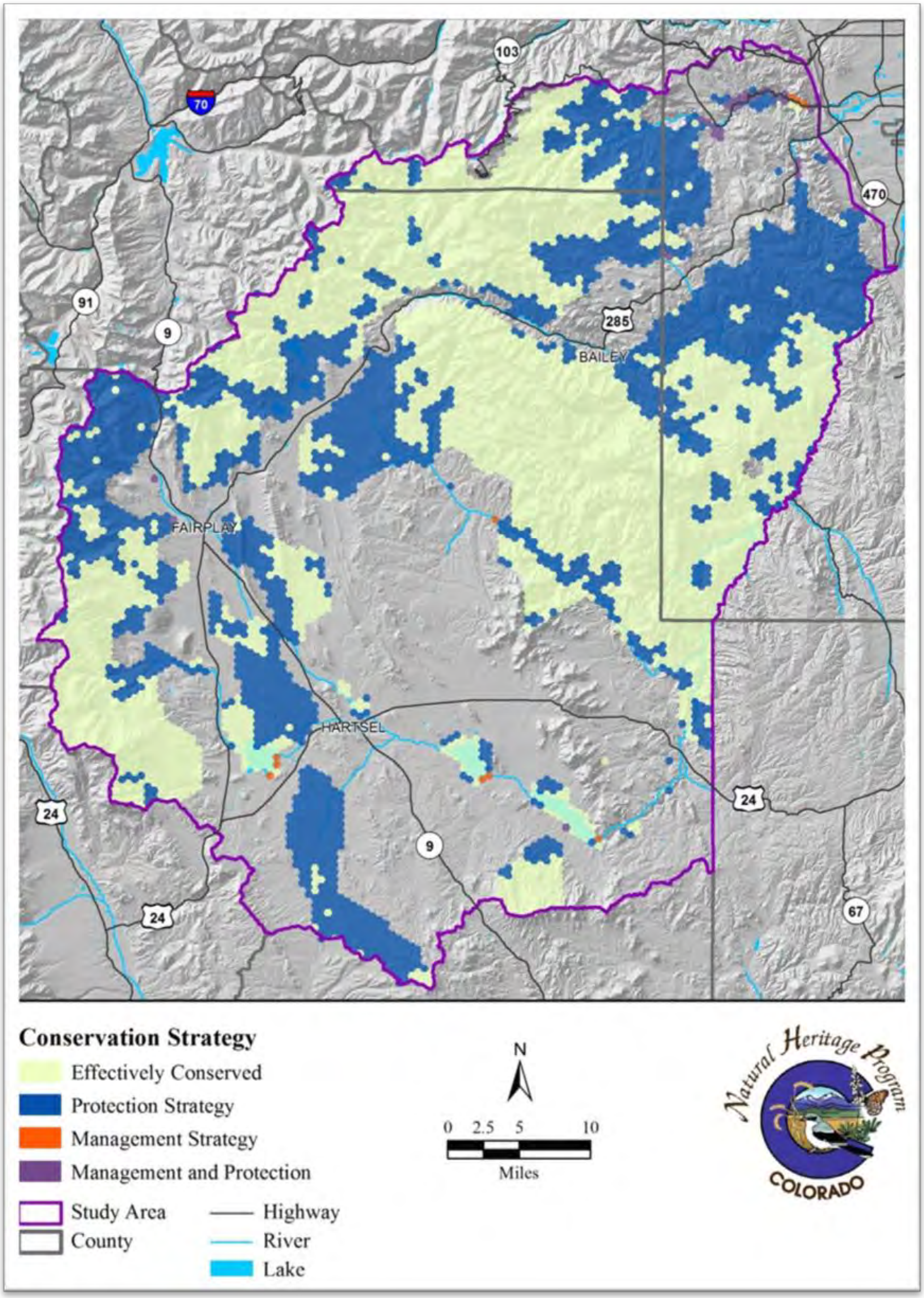

Figure 1.33. Marxan solution for high-risk goal set, landscape integrity cost layer, and regulatory species only.

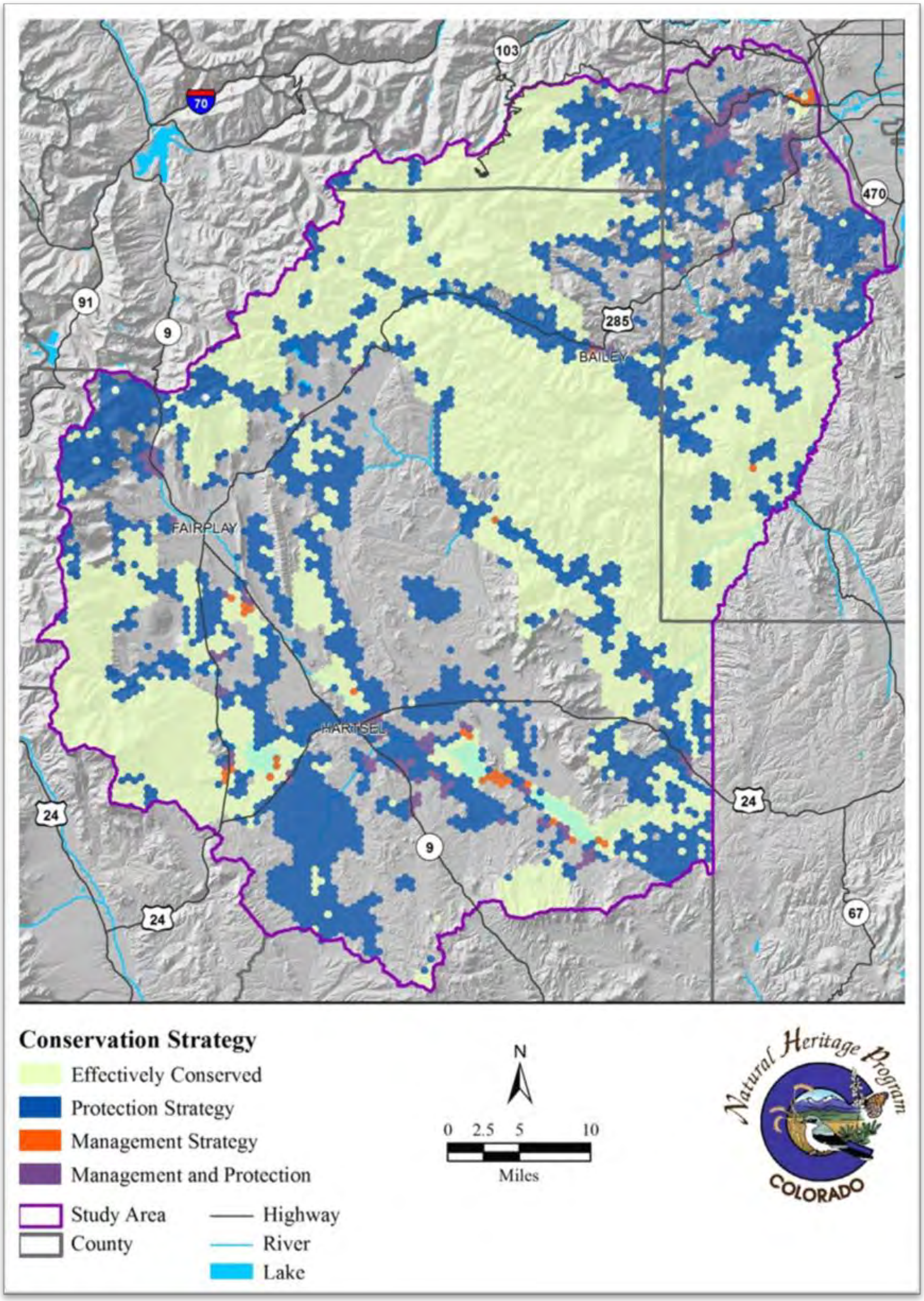

Figure 1.34. Marxan solution for high-risk goal set, land value cost layer, and full target list.

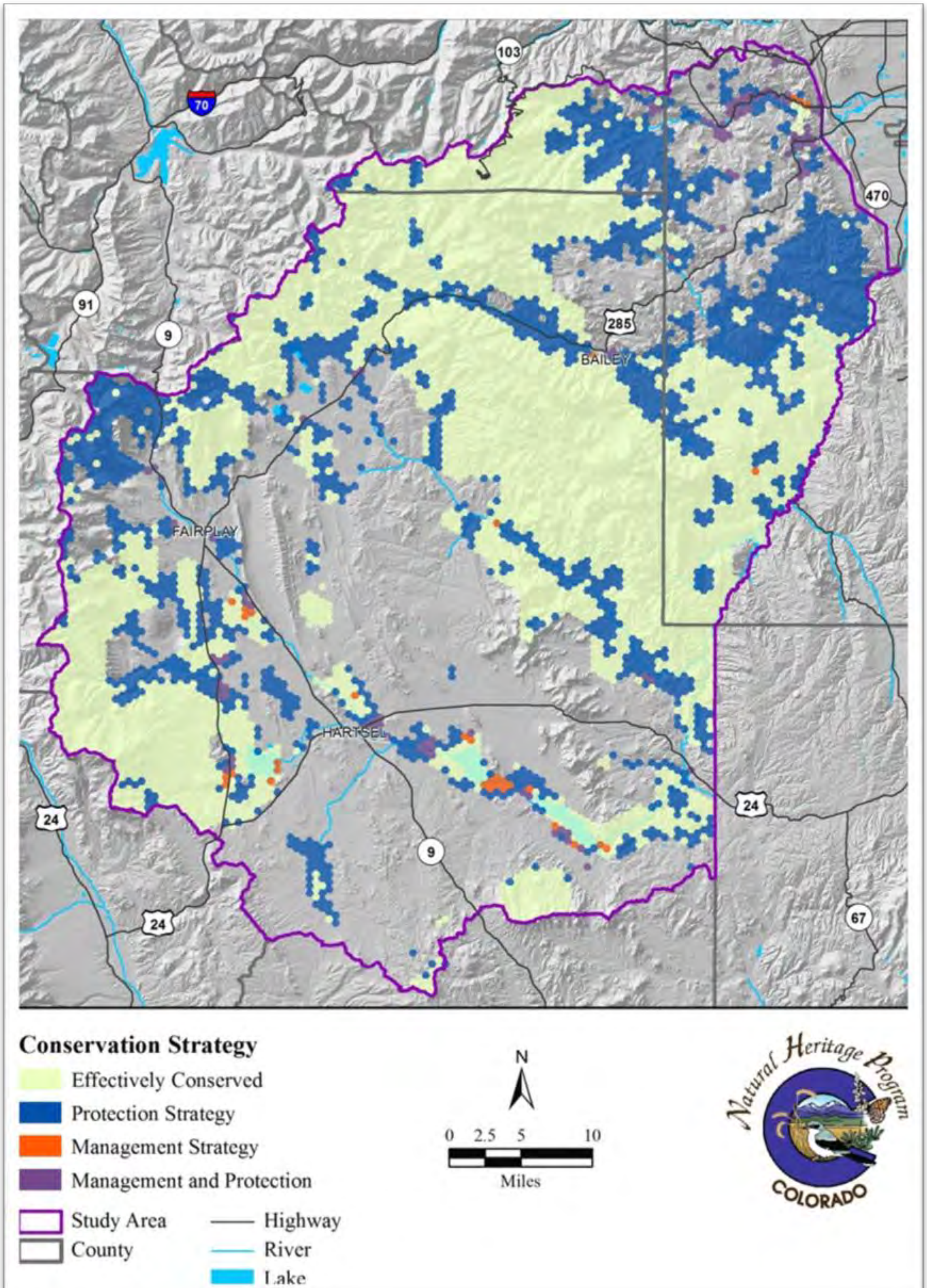

Figure 1.35. Marxan solution for high-risk goal set, land value cost layer, and regulatory species only.

IEF Step 6: Develop Crediting Strategy

Ecosystem Services

Ecosystem services are the benefits that people derive from nature that support and fulfill human life (Millennium Ecosystem Assessment 2005). These benefits are many and include, for example: landscapes and wildlife, which provide opportunities for recreation, hunting, and eco-tourism; insects that pollinate crops to provide food and nutrition; and trees that sequester and store carbon helping to stabilize the climate. More broadly, the full suite of ecosystem services can be grouped into four categories, as defined by the Millennium Ecosystem Assessment (2005): (1) *provisioning services* (also referred to by others as ecosystem goods) such as food, water, and timber; (2) *regulating services* such as processes by which forests and other ecosystems help to regulate the climate or purify water that passes through them; (3) *cultural services* such as recreational and educational activities, and the aesthetic and spiritual fulfillment of connecting with nature; (4) *supporting services* which are needed to support the production of services in the preceding three categories. Examples include nutrient cycling, soil formation, and net primary production. Of these four categories, economic markets have developed most robustly for provisioning services and some cultural services (e.g., recreation), but are largely lacking for the remaining services.

Transportation projects are increasingly incorporating ecosystem services into planning efforts, particularly in the context of “progressive” approaches to mitigation that seek to maximize ecological and economic net benefits at landscape and watershed scales (Cambridge Systematics 2011). In order to develop a crediting strategy for conservation targets and address Framework Step 6, the team first conducted an ecosystem services assessment to descriptively answer the following three questions: (1) Which ecosystem services of interest are most likely to be impacted, positively or negatively, by transportation projects? (2) Do wetland mitigation banks, conservation banks, or other markets already exist for ecosystem services likely to be affected? (3) In cases where markets for affected ecosystem services do not exist, what approaches are available from projects in other regions that could inform the development of markets to serve the needs of CDOT Region 1? These questions are answered in the sub-headings below.

Ecosystem Services Impacted by Transportation Projects

In consultation with CDOT personnel, the team decided to apply the IEF steps in the context of current and projected future projects, but not to one specific project. As such, the general types of ecosystem services that would be impacted by projects in this region were identified, though an individual project may only impact a subset of these services.

Four information sources were used to identify ecosystem services that may be impacted by transportation projects in this region: (1) expert input from CDOT personnel and other agency personnel (e.g., US Forest Service, US Fish and Wildlife Service); (2) listening sessions at stakeholder meetings conducted by the South Park National Heritage Program May 18 through

20, 2011; (3) a literature review of documents related to the study region and ecological data compiled by the Colorado Natural Heritage Program; and (4) a field trip to the study region on August 25, 2011, to "ground truth" information obtained from the previous two sources.

The three highest priority concerns for CDOT in this study region are wetlands, water quality, and species, specifically state or federally listed species (e.g., threatened and endangered species, candidate species, U.S. Forest Service sensitive species). In each case, federal regulation – the Clean Water Act for wetlands and water quality and the Endangered Species Act for species – is the major driver for focusing on these concerns for evaluating ecosystem-service impacts and the need for mitigation activities. The study region is rich with wetlands, as discussed in the "Wetland Mapping" section above. In addition, negative impacts to water quality (which may arise from modifications to wetlands, but could occur from other impacts) could lead to impairments of downstream water bodies (natural and human-built) that may be regulated directly by the Clean Water Act, or even if not regulated, may raise concerns by local communities or stakeholders farther downstream (e.g., municipalities along the Front Range). There are also multiple listed species that would be considered, as discussed in the "Characterization of Resources" section above. For species, impacts directly to the species are of concern, as are habitat and wildlife movement corridors.

In addition to the regulatory driven concerns described above, there are other ecosystem services that are important to the region and which could be impacted by transportation projects. However, their consideration in project planning and implementation would be at the discretion of project participants, since there is no legal requirement. The western part of the study region is nationally designated as the South Park National Heritage Area. The region is renowned for its mining, ranching, pioneering, and Native American culture and history. Historic structures such as the Como Round House and the Paris Mill reflect two of several historical preservation efforts presently under way. The region's National Heritage Area and "Preserve America Community" designations reflect the community's focus on ranching, recreation, and mining. All of these are examples of cultural ecosystem services. The May 18 through 20, 2011 focus groups reviewed stakeholder importance of these and other cultural ecosystem services. Data collected about cultural ecosystem services during the National Heritage Program stakeholder meetings were compared to transportation projects being prioritized by CDOT during the June 2011 CDOT stakeholder meeting. During this time, it was determined that no cultural ecosystem services, aside from alterations to scenic views, would be directly affected by pending CDOT projects. In general, landscape aesthetics and scenic values could be affected by transportation projects due to alteration of viewsheds (e.g., more vehicle traffic due to a road widening; new signage or other infrastructure installed). Notably, these aesthetic values are important to local communities and to tourists who come to appreciate the beautiful landscapes.

Transportation projects could also impact the ecosystem service of carbon sequestration and storage (a *regulating* ecosystem service) through habitat loss or degradation resulting in a net release of carbon dioxide (and possibly other greenhouse gases). If the project "footprint" for staging and conducting the work is relatively small, then impacts to carbon will also likely be minor. Consultation with CDOT confirmed that impacts to carbon are not currently a primary consideration in transportation projects, though ongoing state, national, and international policy discussions on climate change should be monitored to see if regulatory requirements change in the future.

Existing Payment Programs and Other Market-based Incentives for Protecting and Restoring Ecosystem Services

Payments for ecosystem services (PES) are a market-based approach in which users (or beneficiaries) of ecosystem services directly compensate providers (meaning landowners) for supplying services. PES creates an economic feedback loop between users and providers where a missing market existed previously. PES combines a positive incentive ("if you improve and protect a resource, you can get paid by others to do so") with a negative incentive ("if you impact a resource, you must or should pay for it"). For example, in the context of wetlands mitigation for a transportation project, the ecosystem-service "user" would be CDOT, who impacts a wetland and therefore needs to address its impacts through the Clean Water Act. If done through a market-based payment for ecosystem services approach, this mitigation could be achieved by purchased credits in a wetlands mitigation bank.

Based upon a global assessment conducted by Forest Trends and the Ecosystem Marketplace (2008), payments for ecosystem services have been most frequently developed in the context of four ecological targets: carbon sequestration, watershed services, biodiversity, and "bundled" services, meaning a combination of two or more ecosystem services or biodiversity targets. There are also three general types or drivers of existing payment programs for ecosystem services: 1) compliance markets, which are created by regulation (e.g., Endangered Species Act, Clean Water Act); 2) voluntary markets, which motivate payments for value- and business-driven reasons; and 3) government-mediated payment programs (e.g., Farm Bill programs), in which public funds are used to pay landowners for protecting or enhancing ecosystem services (Forest Trends and Ecosystem Marketplace 2008).

In the context of transportation projects (generally and in the study region), the two most relevant types of payments for ecosystem services are wetland and stream mitigation banking and conservation banking. Cambridge Systems (2011, p. 1-3) explains these approaches as follows: "Mitigation banks are a mechanism to provide compensation for lost wetland, stream, and endangered species habitats. Private entities or public agencies invest in the purchase of land, undertake mitigation activities (restoration, recreation, enhancement, or preservation), and then sell the credits they earn from their investment to third parties in need of mitigation credits."

To determine if any wetland, stream, or conservation banks exist in the study region, the team consulted the Ecosystem Marketplace's website speciesbanking.com, which is a centralized information clearinghouse on U.S. and global programs and banks for biodiversity offsetting, compensation and offset banking (www.speciesbanking.com/). The website speciesbanking.com listed 13 wetland and stream banks across all of Colorado (see Table 2.19). These numbers include banks that are categorized as active, inactive, pending, or sold out. Of the 13 banks, there are two wetland and stream banks with confirmed service areas applicable to the study region. These banks are the Middle South Platte River Wetland Mitigation Bank and the Mile High Wetland Bank.

Table 2.19. Wetland and Stream Banks in Colorado, Based upon Information Compiled by the Ecosystem Marketplace's speciesbanking.com.[a]

	Bank Name	Date Established	Type	Status	Size (acres)	Eligible bank service area for study region?
1	Chatfield	2004	Wetland	Sold out	Not reported	Not reported
2	Finger Rock Wetland Mitigation Bank	2003	Wetland	Active	255	No
3	Limon Bank		Wetland	Active	14	Not reported
4	Marshall Mitigation Bank	2000	Wetland and stream	Approved-inactive	Not reported	Not applicable (because inactive)
5	Mesa County Wetland Mitigation Bank	2005	Unknown	Active	8	Not reported
6	Middle South Platte River Wetland Mitigation Bank	1999	Wetland	Active	63	Yes (secondary service area)
7	Mile High Wetland Bank	1999	Wetland	Active	30	Yes
8	Riverdale Mitigation Bank	2001	Wetland	Active	14	Not reported
9	Rocky Flats Mitigation Bank	1996	Wetland	Sold out	Not reported	Not applicable (because sold out)
10	Rocky Mountain Institute Wetland Mitigation Bank	2001	Unknown	Active	60	No
11	Spring Water Ranch Wetland Mitigation Bank	2005	Wetland	Active	60	Not reported
12	Warm Springs Wetland Mitigation Bank	2000	Wetland and stream	Active	198	Not reported
13	WetBank-Gunnison	1999	Wetland	Active	109	No

[a] http://global.speciesbanking.com/documents/files/2010_us_bank_dataset.pdf

Colorado has only one existing conservation bank located in Douglas County called the East Plum Creek Conservation Bank.[4] This bank was established by CDOT in 2003 to mitigate

[4] http://us.speciesbanking.com/pages/dynamic/states.page.php?page_id=7297&eod=1

impacts from CDOT projects in Douglas County to the federally listed threatened species Preble's Meadow Jumping Mouse (*Zapus hudsonius preblei*). Its geographic location places it in CDOT Region 1, but the primary service area is the Plum Creek watershed in Douglas County and the secondary service area is limited to select additional areas in Jefferson, Douglas, and Elbert counties.[5] The bank is 25.3 acres in size. Its status is listed as active, though no credits have yet been utilized.[6]

In addition to Ecosystem Marketplace's accounting of mitigation banks, the team also consulted USACOE's Regulatory In-Lieu Fee and Bank Information Tracking System (RIBITS: http://geo.usace.army.mil/ribits/index.html). The RIBITS site lists 12 wetland, stream, or conservation banks, including the East Plum Creek Conservation Bank. Four wetland banks listed by Ecosystem Marketplace were not on the RIBITS site (Chatfield, Limon, Rocky Flats, and Warm Springs). However, the RIBITS site included two additional banks (Animas River and Cramer Creek) not in the Ecosystem Marketplace list. Neither list is fully comprehensive. At least one other wetland mitigation bank occurs within the study region, but was not listed by either site. The Four Mile Creek Mire wetland mitigation bank within South Park was developed by Denver Water for the purpose of offsetting potential future wetland impacts by Denver Water (Johnson Environmental Consulting, LLC, and Denver Water 2007).

Beyond wetland, stream, and conservation banks, additional incentive-based programs are available in the study region to support conservation efforts that protect or restore ecosystem services. However, these are all voluntary programs, meaning that there is no regulatory driver for participation. For the ecosystem service of carbon sequestration and storage, verified carbon offsets may be purchased through a variety of providers selling into the voluntary market space. The Chicago Climate Exchange was a major offset broker for land-based offsets up until its closure at the end of 2010. Since then, the Climate Action Reserve[7] has emerged as a new offset broker. More information on voluntary carbon market opportunities can be obtained through the Ecosystem Marketplace's "Carbon Markets" website.[8]

In cases where land protection is a key goal of mitigation efforts, conservation easements are an important and widely used legal tool. A conservation easement is a legally binding agreement whereby the landowner agrees to protect the land's conservation values and limit development. The land typically remains in private ownership, although conservation easements can be placed on publicly owned lands, as well. Landowners can receive direct payment for a conservation easement from a land trust, known as "selling a conservation easement". Landowners donating an easement to a land trust can receive financial benefits if they are eligible for federal income tax deductions or Colorado state tax credits. In the case of a donated conservation easement, the trust is responsible for ensuring that the conservation values of the land are maintained, but the financial incentives come in the form of tax relief. Colorado's state

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[5] http://environment.transportation.org/pal_database/view_attachment.aspx?fileID=165
[6] http://us.speciesbanking.com/pages/dynamic/banks.page.php?page_id=7210&eod=1.
[7] www.climateactionreserve.org/
[8] www.ecosystemmarketplace.com/pages/dynamic/carbon_market.landing_page.php?section=marketwatch&category_section=carbon

tax credit is also transferable. This means that the landowner may sell the unused portion of the tax credit and receive cash from the tax credit purchaser. While there are market fluctuations, the landowner typically receives approximately $0.80 for selling $1.00 of tax credits. There is typically a brokerage fee, for the tax credit transfer service. The transferable state tax credit provides significant incentive for conservation easements.

Several trusts operate in the study region, and might have an interest in protecting the conservation values through a conservation easement program. Trusts that might be interested in purchased or donated conservation easements in the study region include three local and regional land trusts:

- Continental Divide Land Trust (Frisco, CO)
- Mountain Area Land Trust (Evergreen, CO)
- Palmer Land Trust (Colorado Springs, CO)

Several land trusts protect conservation values statewide and might have an interest in the study region and the identified ecosystem services. These trusts include:

- Colorado Cattleman's Agricultural Land Trust
- Colorado Open Lands
- Colorado Water Trust
- Colorado Wildlife Heritage Foundation
- The Conservation Fund
- Ducks Unlimited, Inc.
- The Nature Conservancy
- Trust for Land Restoration
- Trust for Public Land
- Wilderness Land Trust

Contact information about these respective land trusts can be found on the Colorado Coalition of Land Trusts website: www.cclt.org/cclt/.

Federal programs through the Conservation Title in the Farm Bill are also a possible source to support conservation and mitigation activities. Examples of programs include the Environmental Quality Incentives Program (EQIP), the Conservation Stewardship Program (CSP), the Wildlife Habitat Incentive Program (WHIP), and the Farm and Ranch Lands Protection Program (FRLPP).

Innovative Mitigation Projects That Could Inform Work in This Study Region

As discussed above, mitigation banking for wetlands, streams, and species is already occurring in the state of Colorado, including some activity in the study region. Of particular note, CDOT was involved in developing the East Plum Creek Conservation Bank, which is designed to mitigate impacts to Preble's Meadow Jumping Mouse from transportation projects in Douglas County. Accordingly, CDOT already has initial experience working with these market-based approaches that can advance "progressive" approaches to ecosystem-based mitigation (Cambridge Systematics 2011). CDOT's experience will support and inform the appropriateness of using market-based approaches, such as wetlands mitigation banking and conservation banking, in future projects. The Cambridge Systematics (2011) report provides insightful descriptions of transportation projects across the country using innovative tools and methods to support progressive approaches to mitigation. Because it is concise and well-written, we point the reader to this document rather than summarizing it here.

An emerging opportunity in the conservation banking space is what is being called "pre-compliance banking". Whereas conservation banking focuses specifically on species listed under the Endangered Species Act as threatened or endangered, pre-compliance banking focuses on candidate species that are being considered for listing. The purpose of establishing a pre-compliance mitigation banking system is to motivate investment in restoration and protection activities for candidate species, and to do so in a way that provides those involved in the mitigation activities with assurances that species credits generated and purchased would be recognized if the species gets listed and compliance becomes required. One of the most developed pilot tests of the pre-compliance approach is occurring in the southeastern US, where the American Forest Foundation and World Resources Institute are working with stakeholders (including USFWS, DOT, DOD, and others) to develop a pre-compliance Habitat Crediting System for gopher tortoises in the context of longleaf pine ecosystems (Gartner and Donlan 2011). While there are no pre-compliance markets currently operating in Colorado, this model is being explored as one option (amongst many) for the Greater sage-grouse (*Centrocercus urophasianus*) and the Gunnison sage-grouse (*Centrocercus minimus*), which are currently candidate species. Pre-compliance markets could be a valuable new tool to add to CDOT's options for mitigation activities, for sage grouse and other candidate species.

Crediting Strategy

Ecosystem services crediting programs could advance ecosystem-based mitigation efforts at the scale of an individual transportation project up to planning for larger geographic regions. As discussed above, crediting schemes that relate to wetlands and stream mitigation banking or conservation banking have the strongest drivers due to regulatory requirements established through the Clean Water Act and the Endangered Species Act. Crediting schemes could be developed for other ecosystem services or conservation targets, but in the current setting, wetlands, stream, and conservation banks remain the most near-term opportunities. In pursuing crediting schemes, transportation planners have two main options: first, to utilize existing banks that meet specific mitigation needs; and second, to participate in the development of new crediting programs.

To the degree that CDOT would be able to use existing wetland, stream, or conservation banks, this would streamline the procedural steps for incorporating off-site mitigation activities into transportation planning. There are wetland and stream mitigation banks in operation (as described above) that could potentially provide offsets for transportation projects in CDOT Region 1. That said, additional examination would be needed to determine actual suitability on a project-by-project basis. The East Plum Creek Conservation Bank for Preble's Meadow Jumping Mouse provides an existing conservation bank for projects in its geographic service area limited to parts of Jefferson, Douglas, and Elbert counties. Collectively, existing banks provide important opportunities for CDOT to consider for mitigation. However, the relatively small number of banks, restrictions on their geographic service area, and the fact that only one species is addressed through a conservation bank may limit the practical ability of CDOT to use these opportunities for many projects.

In pursuing new crediting schemes, CDOT is positioned to draw upon its experience with the East Plum Creek Conservation Bank to inform the development of additional conservation banks that would address future mitigation needs. This could involve developing banks for new federally listed species, or if needed, for new geographic service areas for Preble's Meadow Jumping Mouse. Across wetland, stream, and conservation banks, a critical part of any crediting scheme is the rules and metrics that define credits, and that further define the relationship between impacts at the project site and conservation benefit at the mitigation site. A key goal of the USDA Office of Environmental Markets is to develop technical standards for ecosystem markets, and to provide guidance on ways to standardize and improve the integrity of crediting protocols. In April, 2011, a report published by the Willamette Partnership and funded by the USDA Office of Environmental Markets provided guidance on best practices in the design of biodiversity-related metrics (Cochran and Maness 2011). An additional report is being written for water quality related metrics. These reports provide a valuable way to efficiently learn from others' experience and to ensure that new crediting schemes are in line with the standards being advanced more generally within the ecosystem markets arena. In providing this push towards standardization, reports like these also help to identify where region-specific information is critical to arriving at crediting protocols that will be scientifically valid and appropriate for mitigation programs.

Developing new crediting schemes can provide CDOT and other stakeholders with a way to advance ecosystem-based mitigation, yet doing so will likely require substantial time and monetary resources. Identifying who will lead the process and what other stakeholders to involve is also critical. Recognizing these challenges, there may be opportunities for CDOT to partner with or participate in efforts that are already under way in Colorado. These opportunities relate to mitigation banking needs as described above, while also in some cases going beyond direct regulatory requirements. For example, Environmental Defense Fund, the Colorado Department of Natural Resources, Partners for Western Conservation, and other key stakeholders are exploring the development of a habitat crediting system to service mitigation needs primarily related to energy development. The system being developed could provide a larger platform for habitat mitigation across Colorado. Another example is efforts by the U.S. Forest Service to partner with municipal water utilities and other water users to develop partnerships driving investment in watershed stewardship to improve forest health conditions. This is part of a nationwide Forests-to-Faucets effort, of which one of the most high profile projects to date has been a $33 million, 5-year partnership between the USFS and Denver Water. Finally, in the Northern Colorado Front Range, there is an initiative called the Colorado Conservation Exchange that is working with diverse partners to develop payments for ecosystem services, focusing initially on the Big Thompson River and Poudre River watersheds. While geographic areas may not directly overlap with the focus of this project in CDOT Region 1, these and other efforts across the state may provide technical knowledge and experience that could assist with ecosystem-based mitigation for transportation projects.

CHAPTER 3
TCAPP and IEF Assessment

TCAPP

CDOT headquarters environmental and long-range planning staff tested the TCAPP website. Comments reflect the version of TCAPP that was online during the late February to early March, 2012 time frame. Feedback from CDOT suggests that the TCAPP website is potentially a very useful tool for informing stakeholders who do not fully understand the process CDOT uses to get from a concept to constructing a project. They thought that the website would support input at the appropriate level and time during project development, which would, in turn, lead to a more streamlined and efficient process with fewer instances where the process has to regress to an earlier stage because needed information was not provided at the appropriate time.

Though the site contains a considerable amount of information and was somewhat overwhelming at first, they found it to be more user-friendly with some practice. The Partner and Stakeholder Portal and the library were found to be particularly useful. Having the common contact information for the many stakeholders and partners at one location is seen as a big benefit.

However, they also see a challenge in getting people to view and use the website, primarily because there is no obvious way to determine where any given project is in the process at any given time. Until there is some way to find that out, they anticipate that the TCAPP website will be used primarily as a learning tool. Also, there was confusion on when or how this website is envisioned to be used. For example, is each project going to have its own TCAPP site with the stakeholders and documents that pertain only to that project, or is this meant to be more of a clearing house for all of the information from all of the projects? If the latter were the case, there would need to be someone to update the information.

Other specific comments and questions include:

- The steps identified are appropriate, but the term “approve” is confusing. Is this intended to reflect the need to get buy-in from a wide variety of stakeholders and planning partners on each of the steps? Is this to be documented somehow or just that this step needs to have some sort of conclusion to move forward.
- LRP-1 Outcome: What would a documented agreement look like? Who would agree to it?
- LRP-1 Integration Tab: What about transportation considerations in land-use plans? The integration should go both ways. Also, one of the outcomes is a documented agreement on the LRTP process – what exactly is this? Who agrees to it? Can a sample be provided?
- Integration Table: Is “process” the correct term for these six items? Process is also included as an integration type. How were they determined? It might be helpful in the description of each to identify what they include.

- Can timelines be provided for each step? For example, LRP-1, Scope of the LRTP would take six to eight months.
- Good reference links for LRP.
- LRP-3: Consider explaining a bit more what is meant by evaluation criteria, methods, and measures. The outcome gets closer at explaining what these are.
- LRP-7: Are there tools that can be used for the scenarios? People may struggle with how to do scenarios without examples of tools or methods, etc.
- ENV-3 (and elsewhere as applicable): What about Section 4(f)? Purpose and Need, alternatives, etc., must be considered as well as with the Section 404 process. Understanding that the primary focus is on the natural environment, the human environment is also a necessary component and it would be good to let users know about Section 4(f) too.
- ENV-4: The study area needs to include the entire area where an impact may occur and not be limited to the project footprint. It could be very localized or may encompass several states depending upon the project and the resource.
- The environmental review needs to include actual on-the-ground surveys and coordination with the regulatory agencies. This could take a year or more to accomplish. Maybe this could be put in ENV-7 or possibly a new folder between ENV-7 and ENV-8?
- ENV-4: It seems like your project study area would be known sooner. Is this more to do with the study area for resource evaluation?
- While there is a lot of emphasis in partnerships and collaboration, it seems that public and agency involvement is missing from the steps. The LRTP, STIP, and NEPA documents must all go through a public review and comment period. Though not required in corridor planning, it is advisable as well.
- Seems this is developed from the standpoint of the MPO. Is there a way to make it clearer that State DOTs can also benefit from this process? They go through all steps even more so than MPOs, in that they often lead the NEPA process or are major partners with local jurisdictions when federal funds are involved.

Integrated Ecological Framework

The team's overall impression is that the IEF is most appropriate for long-range and corridor planning. The IEF is a well thought out and logical approach to landscape-scale planning for multiple conservation targets and programmatic mitigation. It could be very straightforward to implement within a corridor planning context, and in fact is not all that different from recent CDOT corridor studies. Implementation of the IEF within current long-range planning methods used by CDOT would require staffing adjustments, as well as a shift in approach. At this time, there are no resource specialists (e.g., biologists) in long-range planning. Regional transportation plans are compiled from the bottom up – that is, they are based on local transportation needs and desires, and then evaluated and packaged up the chain. They are not based on comprehensive analysis and vision/strategy development at a landscape scale, nor do they generally contain any environmental considerations, per se. It is not difficult to see how the process evolved to its present state, given the mission of CDOT, which is to provide transportation infrastructure, not to conserve natural resources.

Effecting a transition within CDOT to an IEF-based approach will likely require a sustained and concerted effort aimed at all levels of their hierarchy, including top level managers, mid-level managers, and planners and staff within state headquarters and the regions. Even more than this, however, will be the need for shifting the focus of resource agencies from a project-scale, permit-driven system to a large-scale, collaborative, strategy-driven approach. Within CDOT, mitigation is governed fairly exclusively by regulatory requirements and the preferences of the regulatory agencies. In some cases, the issue may be as straightforward as encouraging agencies to follow their own existing guidance (e.g., to base mitigation on a landscape rather than a project basis – a concept that is supposedly in existing USACOE guidance). However, over past decades all the agencies – including both CDOT and the natural resource regulatory agencies – have evolved bureaucracies and corporate cultures focused specifically on project permitting. Within the realm of natural resource protection and mitigation, organizational structure, standard procedures, staffing, and allocation of resources are all guided by permitting requirements. Fully implementing not only the steps, but also the full spirit, of the IEF may require realigning priorities and resource allocation across agencies.

Also, it would be ideal if the relationship, if any, between the IEF and other agency initiatives was clearer. For example, the Federal Highways Administration's Planning and Environmental Linkages program appears to have a great deal in common with the IEF. It is difficult to determine what relationship, if any, either of these has with the other by looking at the PEL and TCAPP websites. If they are not related and mutually supportive, then they seem to be duplicative. It is difficult for busy transportation professionals to keep track of which programs are currently in favor. The best possible approach would be for the agencies that collaborated on the original Eco-Logical report to coordinate a multi-agency step-down guidance document, possibly based on the IEF, which is promoted and implemented throughout all the agencies and DOTs. It is important that the agencies coordinate to reduce redundancy in these efforts.

Finally, one of the messages from all levels of CDOT is that data are an issue. The team's best interpretation of this discussion can be summarized like so: CDOT wants to be able to do better planning, and they know they need both statewide and local data readily accessible to do so, but they do not have the capacity to obtain, manage, and update said data. Instead, they consult with the regulatory agencies and provide the information the agencies ask for. (Note that this does not seem to be a universally held opinion within CDOT, but it does reflect the attitudes of the staff who contributed to this project.) Meanwhile, input from the agencies obtained during this project can be summarized like this: results of these broad scale analyses are good to know, but at the end of the day, we have to have detailed, site-specific information that we can use to base a permit on. We do not tell project proponents what to provide us, we react to what they provide.

Data Issues

Issues revolving around "lack of data" appear to be more closely related to the lack of resources needed to collect, house, and maintain comprehensive datasets than to an actual lack of existing data per se. On one level, there is definite interest in having access to data (especially GIS data), and general agreement that a set of statewide data layers would be useful in better incorporating environmental considerations into transportation planning. On another level, however, there is the thought that collection and maintenance of these data are "not my job."

In project development, there seems to be a reliance on project-by-project consultation with regulatory agencies rather than programmatic in-house analysis. Note that these consultations tend to take place at the very beginning of the project development process, leading to the conclusion that environment issues are considered early in the process (hence the disconnect between perceptions of "early," depending on which planning process – regional, statewide, or project-level – is being referred to). In considering the potential benefits of applying the IEF, CDOT's regional biologists (whose primary role is project development) generally see the benefit of the IEF, but do not see their role as directly involved in the implementation of it, at least where data development is concerned. In other words, the sentiment was, in a nutshell: "It looks good in concept. In practice, I don't want to – or can't – or shouldn't have to be involved in the heavy lifting of developing the IEF, but I do want to have input on the final answer."

There is no getting around the data issue. It is highly significant from all standpoints, and factors related to development, scale, accessibility, and applicability must be tackled. Evidence of this was present, for instance, at the recent annual meeting of the Landscape Conservation Cooperatives hosted by the U.S. Fish and Wildlife Service. Nearly every session discussed data: how to share it, where to host it, how to maintain/update/manage it – and again, how to share it, and again – how to share it. There are many concurrent efforts to crack this nut ongoing at national and regional scales. Examples include Data Basin, LandScope, LC Map, EBM Tools, California Climate Commons, and the Western Governors Association Critical Habitat Assessment Tools. It seems that the idea of reconvening the Eco-Logical agencies and other interested parties in an attempt to create a national data portal may warrant serious consideration.

Collaboration and Process Issues

Inter-agency collaboration is appreciated and desired by CDOT, the U.S. Fish and Wildlife Service, and the Colorado Parks and Wildlife. This component of the IEF is one that all parties agree should be pursued. For example, one partner in the U.S. Fish and Wildlife Service's Region 6 office would like to see "a grander scheme that everyone can plan around," and that includes not only CDOT, MPOs, and federal agencies, but also state agencies such as the Division of Parks and Wildlife and the State Land Board. The USFWS has project-level liaisons, and has considered additional liaison positions at the planning level. CDOT personnel are interested in being included in collaborative planning with partners, but they do not believe that CDOT should be the agency convening and organizing collaborative planning. The general

CDOT perspective seems to be that a resource agency or a non-governmental organization should take charge of leading those efforts. In addition, there is a sense of “here we go again” related to implementing the IEF. Previous CDOT efforts to achieve the same ultimate goal as the IEF – that is, integration of environmental and transportation planning – have not been widely embraced or institutionalized within CDOT.

Even though the IEF Step 1 (Build and Strengthen Collaborative Partnerships) was not specifically part of the investigation in this project, it is interesting to consider the practicality of regional, inter-agency, collaborative planning within the context of jurisdictional boundaries and planning schedules. According to CDOT personnel who contributed to this project, discrepancies among partner geographies and planning timelines is a serious issue in collaborative planning. For example, within CDOT, there are Transportation Planning Regions, Engineering Regions, and Maintenance Regions, none of which are aligned with each other. This project is focusing on Engineering Region 1, but the Highway 285 analysis area contains portions of two Planning Regions: TPR 2 (Greater Denver Area) and TPR 14 (Central Front Range). It also covers two U.S. Forest Service Ranger Districts (South Platte and South Park) and two counties (Jefferson and Park). Each of these entities, in turn, overlaps multiple other CDOT Engineering Regions and Transportation Planning Regions, other counties, other Ranger Districts, and so on (and this is an area without any MPOs or sizeable municipalities to complicate matters further). Likewise, comprehensive planning processes employed by CDOT, the U.S. Forest Service, and individual counties are all occurring along different timelines and at different intervals. Also, each of these entities has different missions, corporate cultures, and mandated processes, as well as sometimes different stakeholders. This situation poses logistical challenges that are not insignificant for CDOT staff considering incorporating the IEF into already overloaded schedules.

Colorado’s Transportation Environmental Resource Council (TERC) has been suggested as an obvious forum for moving the IEF forward in the state. This Council, composed of 15 transportation and natural resource agencies, was formed to allow for discussion of state transportation decisions and to plan for environmental stewardship. Members of the research team attended the November TERC Meeting and have planned additional meetings with members of the Council to discuss the IEF and the C21A work. At the time this was written, the team was scheduled to appear on the February 2012 TERC agenda, but that meeting was postponed. As of this writing, the next available opportunity has not been scheduled.

Technical Considerations

IEF Step 2: Characterize Resource Status

Species Distribution Models

Species distribution modeling appears to be a cost-effective method of identifying areas that are likely to be important for the conservation of species of concern. Ideally, a highly tailored and specific individual model for each species would be developed and refined. However, even batch-produced potential habitat or range models appear to have utility as part of a preponderance-of-evidence approach to investigating the spatial patterns of biodiversity.

It is difficult to calculate a standard price per model that accounts for the variability inherent in knowledge of species of interest, and the consequent variable levels of effort required. It is almost always more efficient to produce models for multiple species as part of a single effort, because of the efficiencies of scale that can be achieved in data collection and curation. Many people are technically capable of importing vast amounts of data into a piece of modeling software and getting a species distribution model as a result. Far fewer people are capable of producing credible models that will be validated by field testing. Requirements for a good modeling process include:

- Access to, and ability to standardize, species location and life-history data while exercising quality control to account for varying levels of precision and accuracy in the data.
- Practical knowledge of the species in question, i.e., having carefully observed it in its natural habitat, inventory and/or monitoring experience with the species, familiarity with literature and authorities. Also, capacity to solicit and incorporate expert review by biologists familiar with the species.
- Ability to interpret what is known about the biology of the organism in the context of what can be represented by available data that is likely to be meaningful in determining the species distribution.
- Ability to coordinate the collection and curation of spatial data. Ability to manage large data sets in various formats, and to prepare them in a format that can be used by modeling process or software.
- Ability to interpret the output of the model and present it in the most useful and understandable format to non-technical end users.

State Natural Heritage Programs and Conservation Data Centers are well suited for this work because of the databases of species locations maintained as part of their core mission. Many program staff have personal experience with species in their natural habitats, and the program is also likely to possess additional data pertaining to the species and their habitats. Finally, program staff typically maintain good working relationships with a wide network of regional professionals who can review or contribute to models.

Conservation Value Summary

Spatial analyses that summarize large amounts of complex data are useful for long-term and initial planning phases. As such, the concept of the CVS was well received as a method of visualizing the “hot spots” or exceptional concentrations of resource values that warrant attention in planning and management. Of all the analyses the team conducted, this was the most valuable from the partners’ standpoint. It was tangible, based on data that everyone could understand, and very easy to interpret. In fact, this type of analysis is probably one of the most requested, soughtafter products in conservation planning. However, the invariable response of stakeholders involved in planning and project decision making is to ask what precise data is behind a particular high- or low-priority area identified by an analysis. In addition, users would like a dynamic product that includes everything known at this minute. This desire for more-or-less infinite scalability and near real-time data in natural resource data analysis appears repeatedly in interactions with partners from all points on the public-private spectrum of land management. Unfortunately, this is not easily accomplished for a number of reasons, briefly discussed here.

Foremost is the difficulty in presenting all information in a practical and understandable way. A summarization simply cannot be displayed simultaneously with all component pieces, requiring the interested person to first select a specific area of interest before then being able to call out a list of component values for that area. A continuous surface dataset, like the CVS or the Landscape Integrity layer, holds unique information in each raster cell, which, in the example of this project, are 30 meters on a side (900 m^2), and there are more than 11 million cells in the study area (more than 200 million in the state of Colorado). There were more than 150 different inputs that could occur in any particular cell, and neighboring cells will, to some degree, contain different combinations of these inputs. This makes "drilling down" to determine the component data behind a summary extremely unwieldy, unhelpful, and in some cases technically impossible. Converting continuous layers into larger, summarized areas, such as the 150-acre hexagons used in the Marxan analysis, reduces the number of unique combinations of data somewhat, but at the expense of resolution.

A second issue is that of data sensitivity, ownership, and distribution. CNHP is able to provide derived products based on precise EO data and thereby avoid most data sensitivity and data license issues. Due to concern for land owner rights and potential collection pressure or other location sensitivity information, CNHP is unable to release precise data without land owner consent, released data cannot be redistributed to others, and a data license and purchase contract must be negotiated. Other data used in such analyses may also have similar restrictions. These factors greatly complicate release of component information.

Finally, data accuracy, precision, and interpretation are also issues in enumerating the component data layers of a data analysis. Summary analyses are intended for initial prioritization and planning only. Input data used are frequently at statewide or coarser scales, and quickly lose relevance and meaning when results are examined at too fine a scale. The creation of the summary analysis may have necessitated manipulation in the representation and combination of component pieces, as is the case in the Landscape Integrity analysis, where for example, some component scores were summed and others were given the maximum value of all overlapping scores. One reason to combine multiple inputs is to make up for incomplete information from a particular data source, but complementary datasets should not be additively combined. Additionally, the distance-decay function used to represent anthropogenic impacts in the Landscape Integrity analysis is a non-linear formula used as a proxy for complex interactions that can be documented but cannot be quickly explained.

A quick search of online resources devoted to presenting the type of geospatial data in question indicates that methods for addressing these issues continue to be developed. Some county assessor websites are able to present ownership and other information that is accessed by the user clicking on a parcel map. Although the capacity for map serving and dynamic report generation via scripting languages querying frequently updated databases is available, the application of these techniques in conservation planning and resource management has typically been limited by insufficient time and money, and the lack of a centralized entity responsible for the data flow. The development of a really useful service requires close coordination between the programmers who construct the system and the users who understand the content and how it should be presented or accessed. Finally, the lack of provision for continual updates has doomed many such attempts to a gradual fade into irrelevance.

All of these issues aside, a relational database associated with the final analysis layer could conceivably be created that contains information on all or most input data associated with every discrete parcel/unit within the study area for use by stakeholders to "drill down" and see why a particular unit has a given summary score. Such a dataset would take additional time and funding to create beyond the effort of the analysis itself, and it would be a snapshot of conditions that would ideally need to be recreated/updated on a periodic basis as updated information becomes available.

The team was largely unsuccessful in integrating information on significant resources other than natural/biological values. Cultural and historic values were not incorporated into the summary, primarily due to two factors:

- Dearth of available spatial data, or the extreme reluctance of agencies who are responsible for such data to release location information about sensitive cultural resources; and
- Incompatibility with biological values (i.e., a historic mining area may have high cultural value but may be beyond even the most strenuous restoration efforts where biological value is concerned).

Input from CDOT and resource partners confirmed that cultural and historic resource data are extremely significant to their work. However, they felt that it would be inappropriate and ineffective to attempt to combine cultural and natural resources on the same map. Their strong preference was to see these values represented side-by-side instead.

IEF Steps 3 and 4: Create Regional Ecosystem Framework and Assess Impacts

Although the Regional Ecosystem Framework is intended to integrate information about transportation long-range plans and other land use, infrastructure, and socio-economic information, the team was largely unsuccessful in integrating information on resources other than natural/biological values. A significant drawback in this regard was the absence of geospatially explicit data from CDOT. The Statewide Transportation Plan is a very generalized and strategic document – it does not contain information on specific transportation improvement projects. A corridor study was available as a reference, but its findings were comprised of proposed improvements only. To the best of the team's ability to determine, these are already under way, or are not planned. The STIP is not prioritized or digitized into GIS, and not all the projects in this document will actually be pursued. The team did digitize projects in the current STIP, but they were located only to milemarker, and almost all would be considered categorical exclusions. The final GIS overlay essentially highlighted the entire highway.

Because most of the significant improvements to Highway 285 through Jefferson County have already been completed, the team focused the most effort on the South Park portion of the study area. Though very significant growth is projected for this area in the future, for now it still retains an essentially rural character. The Park County comprehensive plan does not delineate future development plans (e.g., zoning) that could be used to identify likely future impacts. Therefore, the team created a Landscape Integrity map to serve as a surrogate for the impact analysis that the REF is intended to support.

The Landscape Integrity dataset was well accepted. Transportation partners were enthusiastic about the fact that impacts from non-transportation sources were included, giving a broader, landscape context to anthropogenic disturbance. Comments on the landscape integrity data from a variety of partners indicated that land managers are typically intimately familiar with the exact locations and intensity of existing disturbances on their lands, but somewhat less familiar with conditions outside their immediate area of responsibility. Although the Landscape Integrity model met with approval, there was little feedback about the proposed application of this technique for tracking the cumulative effects of anthropogenic impacts.

IEF Step 5: Establish and Prioritize Ecological Actions

The analyses that result in relatively fine resolution continuous surface datasets, such as the CVS and the Landscape Integrity layer, tend to be more visually compelling and intuitive to stakeholders, and these sorts of datasets are useful for initial planning and reference. However, the utility of these results is limited when it comes time to start making decisions that require prioritization of limited time and resources. These analyses can give decision makers a good overview, but do not help them determine where to start.

The conservation network design with management strategies (i.e., Marxan solution), in contrast, is not as visually compelling or appealing to stakeholders, but does provide decision makers with a more focused prioritization of where and how to start project planning. These different approaches are therefore complimentary and can inform different phases of the planning process.

The results of the Marxan analysis were generally accepted as valid demonstrations of the technique by partners. Participants clearly understood that outcomes depend on how goals and costs are parameterized in the analysis. However, most participants were uncomfortable with having to explicitly state goals for conservation targets. The lack of detailed information about the environmental requirements of many target species makes biologists and resource managers nervous about how to know if they are "saving enough." The commitment to specific conservation goals is a component of the IEF and of all decision-support tools with which the team is familiar. This is, without doubt, the biggest hurdle for partners working on this type of project. Specific guidance on how to do this is badly needed. Goal setting usually takes the form of number of occurrences or percent of area or number of acres (e.g., of habitat) needed to maintain healthy populations into the future. In which situations is it appropriate to use hard numbers versus percentages? Should goals be based on average home range size? Territory size? What about accommodating dispersal needs and meta-population dynamics? Some general guidance that can be vetted by the agencies and accepted by resource managers, conservation organizations, and infrastructure developers would be a very significant benefit if such a component could be added to the IEF. Anticipating the difficulty of the goal-setting process, the team provided a straw man set of goals for partners to respond to. It would be fair to say that the overall response was "deer in the headlights." An approach that allows the investigation of various scenarios might be able to break through the general decision-making paralysis, but such a tool would have to be highly flexible, and easily loaded with data to accommodate the need for users to play with and revise a large number of variables and conditions. Scenario evaluation tools that require a lot of decision making and data manipulation upfront in order to parameterize will run into the same inertia issues.

For the resource agencies, the desire to be good stewards in as many aspects as possible is in constant tension with the reality of regulatory requirements and financial constraints. Participants were daunted by the scope and irreducible nature of the complete conservation network solution presented by Marxan. Although participants agreed that ideally this type of approach could be adopted at a programmatic level, and would be especially useful for long-range planning, they felt that in reality, any prioritization of ecological actions must be scalable to the requirements of various project and agency combinations.

Focus Group Interviews

Methods

After completing the quantitative conservation analyses, the team conducted focus groups to assess whether transportation planners would use the data generated through the Integrated Ecological Framework. Focus groups were conducted in order to create interaction and discussion from multiple respondents (Morgan 1988) regarding the feasibility of using the proposed conservation planning process. The focus group sessions used standardized open-ended questions for each session to prevent bias and anchoring (Fern 2001). These open-ended questions were followed by focused follow-up questions. The focused follow-up questions were conducted according to procedures described in Johnston et al. (1995). For example, language common to respondents was utilized to avoid translation bias and miscommunication. Focus group participants were questioned in a way that would allow them to explain how the conservation planning process might be used. Diversity of expression regarding resource values and descriptions was encouraged throughout each session.

There is a vast literature on qualitative research techniques—Creswell (2003) notes that 19 complete qualitative procedures have been outlined in the sociological literature alone—which form a continuum of qualitative research strategies. This continuum ranges from unstructured ethnographic data collection techniques where the researcher is a passive observer who listens to the language of the natives (Spradley 1979), to a highly structured interview or case study methods where the interviewer controls the delivery of the questions with almost rigid precision (Yin 2003). As previously stated, structured interviews were used for the qualitative data collection. However, the spectrum of qualitative data collection techniques should be considered for future transportation and conservation planning research, and a purely ethnographic approach that involves strict observation of conservation planners should also be considered.

The focused interview sessions lasted 60 to 120 minutes, depending upon the size of the group. Each session followed a similar format. The first half of the session consisted of a presentation of results from the species and habitat distribution models from CDOT Region 1. The maps were mailed ahead to participants so that they could "preview" the results and so that the learning process could be conducted more efficiently and effectively. The last part of the session consisted of structured focus group interviews where individuals were queried about how they would use the information generated by the species and habitat distribution models.

Four of the six focus groups were conducted via teleconference and interactive program instruction, where the facilitator presented results from species and habitat model and answered the participants' technical questions. Participants demonstrated a sincere interest in understanding how the maps, and conservation values, were generated. Two in-person focus groups were held at the Denver CDOT location, where the maps and the results were presented live. During all focus groups, participants demonstrated were interactive and demonstrated a genuine interest in understanding the habitat and species distribution models.

The last 30 minutes were reserved for conducting the structured focus group interviews. While the objective of the structured focus group interviews was consistent between all groups (i.e., How would you use the conservation maps as part of your planning process?), the questions were not phrased consistently, and the facilitator asking the questions varied between groups. Although it is preferred to structure the focus group interviews in a consistent manner, establishing a social science research process was somewhat exploratory in nature; hence, the questions were modified as necessary. For example, many times the participants spontaneously shared feedback during the middle of a technical description of the habitat and species distribution models. The feedback was recorded and the follow-up interview questions were subsequently modified.

With the exception of one focus group, all focus group participants were identified as transportation partners and were generally familiar with the SHRP 2 C21A project. The exception was focus group 6, which consisted of four land conservation specialists. In total, 6 focus groups were held with 31 participants involved in conservation or transportation planning. Demographics of the six focus groups are listed below:

Group 1: Teleconference with five transportation planners, environmental engineers, and CDOT conservation specialists. Conducted 2/13/2012.
Group 2: In-person meeting with 12 CDOT Region 1 employees. Conducted 2/15/2012.
Group 3: Conducted with two transportation engineers. Conducted 2/16/2012.
Group 4: In-person meeting with seven agency professionals (primarily wildlife biologists). Conducted 2/21/2012.
Group 5: Teleconference with one transportation planner and one environmental engineer as a follow-up to the CDOT Region 1 meeting. Conducted 2/22/2012.
Group 6: Teleconference with four conservation specialists from Mountain Area Land Trust. Conducted 2/28/2012.

Results

The following paragraphs summarize opinions expressed during the focus group interviews:

Group 1: The consensus was that this information would be "nice to have," but that more specificity is required to use the tool for project-level or long-range planning. There were mixed opinions as to how the tool could be used, and whether it could be used for mitigation purposes. In general, the group felt that the tool provided information about where to conduct more field work, but more specificity would be necessary for practical use. The group emphasized that public input (or community survey) is most valuable during the NEPA process. The group also emphasized that money might be better spent conducting a "water quality analysis" compared to a "wildlife analysis."

Group 2: The group was engaged with the technical material, but struggled with understanding how the process would be used to generate public input outside of the NEPA process. The group emphasized that they were forced to follow procedural guidelines for permitting, although the mapping process might be used for long-term (i.e., 20 year) plans. Participants emphasized that a layer of historic/cultural data would be extremely useful, because the historic/cultural data derails their projects not infrequently; however, they articulated that much of the other information is already known.

Group 3: Participants queried about the time and labor intensiveness of the mapping process, and whether it was worthwhile to provide maps that still required additional "ground truthing." However, the participants articulated that these maps would be useful for conducting their field work, if the process was not too arduous. They articulated that the maps would be useful for planning at the corridor level, in order to accommodate wildlife (e.g., wildlife overpass). In summary, the group emphasized that this process could be a good "early warning" system, but that more detail would be required for the process to be used practically.

Group 4: Group 4 emphasized that the species and habitat mapping adequately reflected the study region to the best of their knowledge, but that the criteria needed more ground truthing for practical use. The group also emphasized that the process did not seem useful for the permitting process, which is a large part of their day-to-day activities. While the results were useful on a gross scale level, the process was not useful on a project level, although it could help the agencies initiate much needed discussion with long-range planners.

The group expressed that their interaction with private conservation partners was positive, but not necessarily proactive. Conservation partners often emerged during the project mitigation phases. A professional from the Army Corps of Engineers stated that her agency has been approached by land developers or wetland mitigation professionals, and that she would like some assurance about whom to trust, although private-public partnerships had been positive in the past. The group emphasized fen layers and historic/cultural layers would be particularly useful, but obtaining these data might not necessarily be feasible due to proprietary issues.

The heart of the matter was summarized by one attendee: “We look at long-range planning and then we get project money and then we react. This project seems more useful at the long-range planning stage than environmental; however, by the time it comes down to our level, the project has to get built. Practically speaking, I don’t see how we can stop being reactive.”

Group 5: The Region 1 engineer and environmental planner were already familiar with the IEF process, but were willing to provide additional feedback on its efficacy. They reiterated that the tool would be most useful to review cumulative impacts with the NEPA process, and for engaging stakeholders during the NEPA process. They added that they thought that the IEF process would be useful at a project level for identifying mitigation sites. They further elaborated that the Marxan model looks like it shows areas that should be conserved, high-value areas, and those are the type of areas they target for mitigation. This group reiterated the importance of mapping water quality, cultural/historic values, and fens, and that they would prefer to see time and effort put towards generating information for these areas. They reported that they have worked very successfully with private conservation partners, government agencies, and conservation groups, but that they have not been proactive in their relationships.

Group 6: This group consisted of a private conservation organization, a land trust, identified during the ecosystem-service/private market phase of the study. The land trust primarily used conservation easements for their conservation practices. Of the six focus groups, they were the most enthusiastic about the mapping process, and they believed that data generated from the IEF process would inform them sufficiently to affect their conservation planning. They reported that they had never considered contacting CDOT proactively for conservation, even though they have land within the study region, seek to protect similar conservation values (e.g., wildlife habitat and mitigation of wildlife/human conflict), and have protected land along highway corridors. They believed that the data generated was “critical” to support their mission and they concluded that they would be more likely to contact transportation professionals in the future.

Conclusions

In conclusion, it is apparent that more social science research is necessary to address the barriers to adoption for the IEF Process. A meta-analysis of the social science piece showed that the species and habitat mapping **(quantitative)** process could be useful to generate information from the transportation partners **(qualitative)** and the conservation community. It is clear that the transportation partners are somewhat necessarily preoccupied with compliance and permitting process, which somewhat restricts them from being proactive others that have similar conservation values. Likewise, conservation organizations appear to contact transportation professionals on a project level, rather than proactively.

Unfortunately, in order to wrap up the study by the due date, only six focus groups were conducted. A logical next step might be to interview more conservation partners (e.g., land trusts or wetlands mitigation groups), and to conduct a quantitative study to generate stakeholder input. From a scientific perspective, it would be useful to expand the social science work to another pilot study, as has been discussed with the University of California, Davis. This would allow testing of the hypothesis that the habitat and species mapping process can serve to inform transportation professionals about the ecological integrity of their region.

Another logical step is to use the IEF process to solicit public input. The transportation planners pointed out that public input might be useful in the long-term planning process and during the NEPA process. However, it is clear that the public (and those in the conservation community) do not necessarily understand the conservation values that might be affected by transportation projects or that their input could influence CDOT and long-range planning. A reasonable next step might be to expand TCAPP in a way that could be user-friendly to the public and the conservation community.

CHAPTER 4
Lessons Learned and Recommendations

The insights obtained by the research team in the course of completing this pilot are summarized in this section. Lessons learned are organized under three themes: Partner Collaboration, Technical Analyses, and Social Science Analysis. Recommendations are based on these themes.

Partner Collaboration

1. Planning fatigue is a serious issue for planners, agencies, and experts. Collaborative planning for conservation (e.g., The Nature Conservancy's ecoregional planning, State Wildlife Action Plan development, to name just two) is a widespread practice at this point. The predictable result is that the same agency staff and experts tend to get tapped over and over. It is increasingly difficult to get intense and/or long-term participation, leading to Lesson #2.
2. Partners were more responsive to requests for discrete input (e.g., review this model, answer this question, provide this reference) than to longer process involvement and difficult "figure this out" requests.
3. Partners lack the time and resources to investigate new methods and tools, and are easily overwhelmed by the sheer number of initiatives, programs, tools, and data portals.
4. A frequently updated database of regional and national non-governmental conservation organizations (potential collaborators) could help highway planners and professionals become proactive with their private partnerships. For example, a link to the Land Trust Alliance website could be added to TCAPP.
    - Partners reported that past experiences and collaboration with regional conservation organizations (e.g., land trusts, city/county open space programs) were positive and effectively facilitated the protection of conservation values. However, highway department employees generally do not proactively initiate the conservation planning process with these organizations. Some of this is due to lack of knowledge about points of contact within the conservation organizations.

5. Conservation organizations seeking to protect land along highways should have access to and be knowledgeable about transportation professionals who facilitate highway conservation planning.

    - The conservation organizations interviewed reported that they do not actively solicit assistance from the state highway department even when their targeted conservation values are along a highway.
6. When collaborations take place between the state highway department and conservation organizations, the collaboration most often is driven by the need to comply with federal,

state, and local laws (e.g., NEPA). Collaboration also takes place when the highway department is contacted by a conservation organization directly.

7. General public input is reported to be most useful at times when it has been anticipated or planned as required by permitting, by law (e.g., NEPA), or as part of the procedural long-term planning process.

Technical Analyses

General

1. Species distribution modeling appears to be a cost-effective method of identifying areas that are likely to be important for the conservation of species of concern.
2. Some general guidance on setting conservation goals that can be vetted by the agencies and accepted by resource managers, conservation organizations, and infrastructure developers would be a very significant benefit if such a component could be added to the IEF.
3. Persuading partners and other entities to share data requires a previously existing network of good and trusted professional relationships. People may have data that are incomplete or of poor quality that they are reluctant to share because they think it will reflect poorly on them. The time frame for this project was too short to allow these relationships to be developed from the ground up.
4. As is typical with projects involving large data sets and complicated analyses, the primary time requirements were for data acquisition and preparation, and then for review and modification of the analysis output. Although the datasets are large, and the analyses computationally intensive, the actual run-time is comparatively short and can usually be scheduled to take place during off hours. Therefore, it was most efficient to include multiple similar analyses (i.e. multiple similar species models) in order to realize the savings effect from batch processing.
5. Scheduling is critical, since some analyses depend on the output from others. With a longer time frame, results from the wetland mapping component would have been incorporated into additional analyses.
6. Issues of scale are an inescapable part of ecological analyses; more attention is needed to the presentation and explanation of this issue earlier in project work whenever possible. The ability to address the desire of users to access data at all scales is needed.
7. Partners generally understood the summarized outcomes of complex analyses, but also wanted very detailed, non-summarized information in order to enable decision making.
8. Data from many different sources are often incompatible without a lot of effort to standardize and quality check.
9. Methods for realistic and useful integration of spatial and non-spatial data are needed. Also, a quick and easy method of evaluating the ramifications of various GIS input alternatives would go a long way towards breaking the decision paralysis that is characteristic of these projects.

Specific

Species Distribution Models

Effort: This task took the most time (~6 months) of all the technical tasks except wetland mapping, which was comparable, because it required literature research, extensive data collection and processing, output evaluation, and soliciting and incorporating expert feedback.

Pitfalls:

1. Limitations of available data being truly representative of relevant environmental factors determining species distribution.
2. Getting useable (concrete, practical) feedback from experts.

Value: While not a substitute for on-the-ground surveys, distribution models can greatly enhance planning exercises at landscape scales when comprehensive species distribution data are lacking. If the target species list adequately covers the range of ecological systems in a study area, models may also (in some cases) serve as a surrogate for separate coarse-filter targets. Derived data products such as models are an excellent way to make sensitive data useful and available to partners without confronting data security issues. They are also valuable in identifying underlying biological influences on the distribution of species and in understanding the bio-physical envelope in which they exist. This in turn supports climate change adaptation efforts and management. Overall, the value of having distribution models given the incomplete state of data that would otherwise be available definitely warrants the investment of resources required to generate them.

Conservation Value Summary

Effort: This task could not be completed until all the inputs (Element Occurrences, distribution models, wetland mapping, and third-party species data) were created or compiled. The actual creation of the CVS once all data was in place took a relatively short amount of time to complete (approximately one week).

Pitfalls:

1. Wetland mapping was not complete for the entire study area by the time this task needed to be completed.
2. Stakeholders who reviewed the results wanted to have all 156 input components readily displayed/enumerated with the CVS.

Value: The conservation value summary provided an at-a-glance snapshot of current understanding of the distribution of biological values across the study area that was very simple for partners to understand. It was very useful for focusing discussion around priority conservation areas. CVS is an extremely valuable tool for long-range and corridor planning where general data are needed to support strategic decision-making. For project design, the CVS has limited utility, unless it is built in a way that facilitates drilling down into the base layers.

Wetland Mapping

Effort: New, up-to-date wetland mapping from aerial photography is a time-consuming process. Multiple image and data sources are visually inspected at a fine scale. The amount of time it takes to map each quad depends on the number of wetland features within the area. To estimate time per quad, the wetland mapping specialists consider three levels of landscape “wetness”: areas with less than 300 wetland polygons per quad, areas with 300 to 800 polygons per quad, and areas with more than 800 polygons per quad. Delineating wetland features within the driest areas of the landscape can take ~1/2 day/quad. Each tier of wetness increases the amount of time needed for delineation, meaning mid-range areas take ~1 day/quad and the wettest areas take up to ~2 days/quad. On top of the initial delineation of wetland features, the QA/QC process is also time-consuming. The initial delineation for each quad is inspected by a second wetland mapping specialist to ensure consistency between mappers and across the project area. Along with the visual screen, there are a number of automated GIS queries to ensure data integrity and each flagged error is manual check and corrected.

Pitfalls:

1. Wetland mapping was done concurrently with other project components and was not available to use in other analyses
2. It would have been more ideal to finish the wetland mapping in the summer in order to conduct post-mapping quality checks in the field. The pre-mapping field visits, however, were likely more valuable and contributed substantially to map accuracy.

Value: Though time-consuming, the rigor applied by the team was done to the federal standard for wetland mapping, is consistent with similar projects across the country, and is important for creating high quality wetland data. Modeling wetlands in GIS based on either geographic factors or image recognition has been tested in other parts of the country, but no model has been shown to be as accurate as manual photo interpretation. The quality of updated wetland maps using this process is definitely worth the time and effort it takes to complete.

Landscape Integrity Model

Effort: A statewide model had been previously created for another project. After determining that the study area would benefit from a slightly revised version, the team only had to re-combine previously created input components. Therefore, this task took very little time. If the methods and data had not already been available, it would probably have taken approximately another month to complete this model (not including vetting by experts and partners).

Pitfall:

1. The input datasets used for the local version are still at the statewide scale, presenting some accuracy and precision issues. Equivalent local-scale data are not available.

Value: While this model highlights only past development, it provides a relatively quick and easy way to display areas of habitat degradation at a landscape scale. It provides a more accurate baseline against which to measure future impacts compared to simple "footprint" data layers. The techniques for generating this model are now available and can be applied relatively easily to available statewide datasets on infrastructure. Thus, the cost/benefit ratio of the Landscape Integrity Model indicates that it is worth the time it takes to complete it.

Marxan Analysis

Effort: This task could not be completed until all the inputs (Element Occurrences, distribution models, third-party species data, cost layers) were created or compiled. All inputs must then be processed for use with the software tool, which is a time intensive task. Set up for the analysis also requires the creation of goals and a thorough evaluation of other parameter values to determine the best configuration for this specific analysis. Once all inputs and parameters are in place, running the actual tool took less than an hour per solution, though solutions were then evaluated and re-run iteratively many times. [~6 months]

Pitfalls:

1. Wetlands would have been used as a conservation input, but mapping was occurring simultaneously and the data was not ready yet.
2. Getting stakeholders to agree on a final target list. Getting experts to give meaningful feedback on goals and other parameters.
3. Getting stakeholders invested in the output.

Value: Given the number of assumptions and judgment calls required by this program, its best utility is likely to be in long-range planning exercises for which relatively coarse-scale data are appropriate.

Social Science Analyses

General

1. The social science dimension of a transportation study should consist of both qualitative and quantitative data collection phases. Integrating both types of research phases is called "mixed methods research". A mixed methods approach would be necessary to adequately assess stakeholder preferences for a highway project.
2. For example, conservation values could be identified through a qualitative stakeholder input process (e.g., agency professionals or public input) or could be identified through the bio-physical data collection and mapping (e.g., Marxan).
3. In order to adequately assess stakeholder preferences for highway projects, it is critical to identify:

    a. **Conservation values** proposed for protection (e.g., reduced wildlife kills by vehicles);
    b. Proposed **highway project management options** (e.g., wildlife overpass versus rerouting highway); and
    c. **Policy mechanism** that would require stakeholder input (e.g., gasoline tax).

4. Policy mechanisms should be expanded to include private partnerships with entities that have similar interests in the conservation values that will be protected (e.g., wetland banking).
5. Tremendous opportunity exists to engage private partners who have an interest in protecting conservation values along highways, but there is a "matching problem" engaging the transportation professionals with those interested in protecting specific conservation values. These private partnerships could infuse more money into the transportation/conservation planning process.
6. Project partners (e.g., transportation planners and environmental engineers) consistently requested the desire for a map "layer" of **cultural and historic values**. However, the definition of the conservation values desired for protection (e.g., mine sites) remains somewhat elusive. Furthermore, it is reportedly difficult to integrate this data into a map, in part, due to concerns about proprietary information and an overwhelming amount of data. Future projects should focus on defining and compiling historic and cultural values so that they can be used by planners.

7. With respect to systematically collecting information about highway user preferences, it is important to obtain a representative sample from the population of highway users. In order to collect a representative sample of highway users, data should be collected from both local residents and non-local travelers. One suggested technique is to conduct sampling at a local gas station. In other words, a highway user survey could be conducted at a local gas station to obtain a representative sample of local and non-local highway users.
8. Transferability: Collaboration between multiple sites is important in order to develop a social science process that can be used in different projects and locations across the nation.

Specific

Integrating Stakeholder Input into Transportation Planning

Effort: The team investigated a social science process for obtaining and integrating meaningful stakeholder input (including public input) into transportation planning. In essence, a mixed methods research process is necessary for obtaining stakeholder input. The conservation value needing protection could either be generated through stakeholders (a qualitative method), or through the GIS mapping process (quantitative method). In the study, the transportation planners were not able to identify the conservation values where they would seek public input. The transportation professionals needed to be informed by the research team of conservation values that could be affected by highway planning (e.g., Highway 24 near Hartsel, Colorado) before they could determine situations where they would like stakeholder input. In other words, the quantitative research came before the qualitative research. If time permitted, a user survey (follow-up with another quantitative method) could be pursued—i.e., the social science research process in this case would be:

> **quantitative research (mapping)→ qualitative research (input from transportation professionals to identify conservation values)→ quantitative research (public input)**

This task was challenging because the team thought that highway partners would already be able to identify projects where they wanted stakeholder input. Instead, the quantitative method (i.e., the mapping process) was needed to facilitate qualitative research by informing highway partners, and thus generate ideas about the conservation values that they would like to protect. Because the highway partners in the selected region were not able to identify a specific project where meaningful stakeholder input could be obtained, the stakeholder input process was prolonged.

Pitfalls: At the project level, details for the currently planned projects (e.g., a proposed bike path along Highway 9) would not be affected by stakeholder input. Bio-physical data revealed that some habitat could be protected in a cost-effective manner; however, there was not enough time to work with transportation professionals to develop policy options to merit stakeholder input. In other words, when the mapping process (quantitative research) serves to inform the transportation professionals, the public input process will be delayed.

Value: Social science research addresses how, when, and under what circumstances the C21A process will be adopted for conservation and transportation planning. The C21A mapping process can inform planners of the projects that might require stakeholder input. Using the example above, a Region 1 planner and engineer stated that they will now consider public preferences for transportation planning on Highway 24 near Hartsel because they are now aware that this is an area of high conservation value.

Establish Social Science Model for Collecting Data and for Integrating Stakeholder Input

Effort: During the past year, the team established a working social science model (based upon mixed methods research) that integrates stakeholder input into the conservation planning process. Assessing stakeholder preferences and integrating bio-physical and social science data collection approaches took longer than expected. The complete process should be expected to take at least two years.

Pitfalls: An inter-disciplinary approach is important to implementing change in the conservation planning process. However, bio-physical and social scientists seem to "speak different languages." Considerable time investment is necessary so that the different disciplines are able to communicate their research methodology, data collection process, and results effectively.

Values: The process of applying the social science model facilitated communication about conservation among a broader array of stakeholders than would otherwise have occurred.

Identify Private Markets for Conservation and Ecosystem Service Protection in Highway Projects

Effort: As previously discussed, non-governmental organizations (e.g., land trusts), and governmental organizations (e.g., county open space organizations) provide considerable opportunity for conservation and ecosystem service protection. These organizations were identified within the transportation planning region, but only a handful of the organizations were interviewed as part of the study. There is a disconnect between transportation professionals and conservation organizations that share similar interests in conservation values. Even though some of these communities reported working together in the past, these communities do not actively seek one another for conservation planning and protection, even though they may have similar goals. This prolongs the conservation planning process, when they inevitably "meet" during a NEPA or zoning meeting.

Pitfalls: Transportation professionals remain anchored in the current conservation planning process in order to ensure that they are compliant with permitting requirements and federal environmental laws (e.g., Endangered Species Act, NEPA, Clean Water Act). At this time, it does not appear as though there is incentive for transportation professionals to be proactive with conservation organizations. It may be more feasible for conservation organizations to approach the transportation sector, and transportation professionals seem receptive to their input. However, a professional from the Army Corps of Engineers expressed that there are concerns about the potential credibility of some conservation organizations, namely wetlands banking groups, looking to acquire undervalued properties. Conservation organizations will likely need to demonstrate that they have experience and a willingness to work with the transportation community in order to establish credibility (e.g., Palmer Land Trust).

Value: Private markets for ecosystem services protection are emerging as a valuable and successful tool for conservation that may provide additional options to partners involved in transportation projects. Hence, it behooves transportation project partners to promote the development of such markets and explore the possibility of using them to advance project objectives for mitigation.

Recommendations

Short Term

1. Draw clear lines between TCAPP/IEF and other similar initiatives such as PEL. This will help avoid confusion on the part of planners and scientists as to what they should be focused on.

2. Enhance TCAPP to include a summary of all existing, relevant planning processes, data portals, web services, and decision-support tools. Web links to conservation organizations that might have a joint interest in protecting conservation values could also be included.

3. Publish a white paper to explain the need for this proposed paradigm shift in transportation planning. The message is clearly that landscape-scale planning will lead to better mitigation. However, a succinct and focused document that details problems with the existing mitigation approach would help make the case for why planners and agency experts should expend mental energy on this issue. Ideally, multiple versions of this summary could be crafted to highlight specific examples from different regions of the country, which will be more likely to resonate with intended audience(s).

4. Consider the implementation of incentives and processes within the IEF that would encourage DOTs to investigate the cumulative effects of projects that fit under NEPA's categorical exclusion, which do not require regulatory action and represent the majority of transportation infrastructure improvements undertaken by CDOT today.

Long Term

1. Reconvene Eco-Logical agencies to put forth one coordinated initiative and one data portal. This is not to suggest that one planning method or dataset can be appropriate for all local situations. Rather, the idea would be to align the agencies with regard to the plethora of disparate initiatives, methods, and tools, which are a source of confusion for planners. Providing clear guidance on a limited number of approaches and tools that are acceptable or preferable to all the cooperating agencies would make the evolution of planning paradigms much simpler for the planning and permitting staff.
2. Convince funders and agencies to invest in new data development (such as models and mapping), improvement of existing base data, data sharing agreements, and data management methods that address data sensitivity issues but allow existing data to be widely accessible. Some old base data layers have artifacts that each individual who uses them has to correct. A multi-agency approved data portal where corrected data layers and new datasets could be stored would be helpful in streamlining technical analyses.
3. Place strategic planning level liaisons for the DOTs in the natural resource agencies, and encourage DOTs to include resource experts within their long-range planning departments.
4. Encourage large-scale programmatic planning and mitigation projects (e.g., CDOT's Shortgrass Prairie Initiative) that use longer time horizons (e.g., 20 years) and cover the majority of transportation projects (e.g., categorical exclusions). This will help reduce planning fatigue and show real results that can be used to inspire participation when the next time comes around.
5. Build social science research capacity in order to effectively develop a process for obtaining and integrating stakeholder input. Enhancements in communication and social media have made it more convenient to obtain public community input; however, as previously articulated, the legal and planning processes currently appear to be too rigid to effectively utilize this input in a meaningful way. As technological advances continue, it is likely that stakeholders will expect to be given the opportunity to voice their input about conservation and highway planning. Thus, it is recommended that transportation research be expanded to create a formalized protocol for integrating social science research in the highway transportation planning process.

6. Realign agency jurisdictional boundaries (e.g., Forest Service Ranger Districts, BLM Resource Areas) by watersheds. Though this would be a massive and complicated undertaking, it would be easier than adjusting political boundaries. Some means of reducing the mismatch of jurisdictions would ultimately go a long way toward simplifying collaborative planning.

7. Expand highway planning research to include collaborations with other agencies to eventually develop a systems approach. For example, the Department of Energy hosts joint proposals with the U.S. Department of Agriculture for agriculture-based bioenergy research. NSF and the USDA also have joint proposals for agro-ecosystems. TRB could develop joint research proposals with the National Science Foundation to study the relationship between highway transportation planning at ecosystem service and systems planning levels.

References

Ardron, J.A., Possingham, H.P., and Klein, C.J. (eds). 2010. Marxan Good Practices Handbook, Version 2. Pacific Marine Analysis and Research Association, Victoria, BC, Canada. 165 pages. www.pacmara.org.

Ball, I.R., H.P. Possingham, and M. Watts. 2009. Marxan and relatives: Software for spatial conservation prioritisation. Chapter 14: Pages 185-195 *in* Spatial conservation prioritisation: Quantitative methods and computational tools. Eds Moilanen, A., K.A. Wilson, and H.P. Possingham. Oxford University Press, Oxford, UK. Marxan version 2.4.3 x64 at www.uq.edu.au/marxan.

Cambridge Systematics. 2011. A practitioner's handbook: Optimizing conservation and improving mitigation through the use of progressive approaches. National Cooperative Highway Research Program Project 25-25, Task 67. www.camsys.com/pubs/NCHRP25-25-67_FR.pdf

Cochran, B. and N.R. Maness. 2011. Measuring up: Synchronizing biodiversity measurement systems for markets and other incentive systems. Willamette Partnership. http://willamettepartnership.org/measuring-up/Measuring%20Up.pdf

Colorado Coalition of Land Trusts (CCLT). www.cclt.org/cclt/member-organizations.html.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRow. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Services, Washington, DC.

Creswell, J.W., 2003. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches.* Thousand Oaks, CA: Sage Publications.

Drewitt, A.L. and R.H.W. Langston. 2006. Assessing the impacts of wind farms on birds. Ibis 148:29-42.

Dudik, M. S.Phillips, and R. Shapire. Maximum Entropy Modeling software, version 3.3.1e. www.cs.princeton.edu/~schapire/maxent.

Elith, J., S.J. Phillips, T. Hastie, M. Dudik, Y.E. Chee, and C.J. Yates. 2011. A statistical explanation of MaxEnt for ecologists. Diversity and Distributions 17:43-57.

Environmental Research & Technology, Inc. 1986. Status Report on the Pawnee Montane Skipper (*Hesperia leonardus montana* Skinner). Prepared for the Denver Water Department, Denver, Colorado. 45 pp.

Fern, E.F. 2001 Advanced Focus Group Research. Sage Publications, Thousand Oaks, California.

FGDC. 2009. Wetland Mapping Standard. FGDC Document Number FGDC-STD-015-2009. Wetlands Subcommittee, Federal Geographic Data Committee, Reston, Virginia. www.fgdc.gov/standards/projects/FGDC-standards-projects/wetlands-mapping

Forest Trends and the Ecosystem Marketplace. 2008. Payments for ecosystem services: Market profiles. http://moderncms.ecosystemmarketplace.com/repository/moderncms_documents/PES_Matrix_Profiles_PROFOR.1.pdf

Forman, R.T.T., and R.D. Deblinger. 2000. The ecological road-effect zone of a Massachusetts (USA) suburban highway. Conservation Biology 14:36-46.

Game, E. T. and H. S. Grantham. 2008. Marxan User Manual for Marxan version 1.8.10. University of Queensland, St. Lucia, Queensland, Australia, and Pacific Marine Analysis and Research Association, Vancouver, British Columbia, Canada.

Gartner, T. and C.J. Donlan. 2011. Insights from the field: Forests for species and habitat. World Resources Institute Issue Brief No. 10. Southern Forests for the Future Incentive Series. www.wri.org/publication/forests-for-species-and-habitat

Houlahan, J.E., P.A. Keddy, K. Makkay, and C.S.Findlay. 2006. The effects of adjacent land use on wetland species richness and community composition. Wetlands 26:79:96.

Johnson Environmental Consulting, LLC, and Denver Water, 2007. Mitigation baking prospectus for the Four Mile Creek Mire, Park County, Colorado. Submitted to the U.S. Army Corps of Engineers, Denver Regulatory Office; U.S. Environmental Protection Agency, Region 8; and the U.S. Fish and Wildlife Serve. Submitted by The City and County of Denver acting by and through its board of Water Commissioners “Denver Water”.

Johnston, R.J., Weaver, T.F., Smith, L.A., and Swallow, S.K., 1995. Contingent valuation focus groups: Insights from ethnographic interview techniques. *Agricultural and Resource Economics Review*, April 1995, pp. 57-69.

McDonald, R.I., R.T.T. Rorman, P. Kareiva, R. Neugarten, D. Salzer, and J. Fisher. 2009. Urban effects, distance, and protected areas in an urbanizing world. Landscape and Urban Planning 93:63-75.

Millennium Ecosystem Assessment. 2005. Ecosystems and human well-being: Synthesis. Washington, D.C., Island Press. 137 p.

Morgan, D.L. 1997 Focus Groups as Qualitative Research, second edition. Sage Publications, Thousand Oaks, California.

Nasen, L.C. 2009. Environmental Effects Assessment of Oil and Gas Development on a Grassland Ecosystem. Masters thesis. Department of Geography and Planning, University of Saskatchewan, Saskatoon.

New Mexico Cooperative Fish and Wildlife Research Unit. 2005. SWReGAP Vertebrate Habitat Distribution Models, Edition: 1.0. Raster digital data. Las Cruces, New Mexico.

Park County, Colorado. N.d. Information about the South Park National Heritage Area Designation. Maintained by the Park County Government. http://parkco.us/index.aspx?NID=169.

Phillips, S. J., M. Dudik, M. & R.E. Schapire. 2004. A maximum entropy approach to species distribution modeling. Pages 655-662 *in* Proceedings of the 21st International Conference on Machine Learning. ACM Press, New York.

Phillips, S. J., R. P. Anderson, and R. E. Schapire. 2006. Maximum entropy modeling of species geographic distributions. Ecological Modelling 190:231-259.

Rondeau, R., K. Decker, J. Handwerk, J. Siemers, L. Grunau, and C. Pague. 2011. The state of Colorado's biodiversity 2011. Prepared for The Nature Conservancy. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

Spradley, J.P., 1979. *The Ethnographic Interview*. Wadsworth, California: Wadsworth Thomson Learning.

TNC. 2008. Conservation Management Status Measure for Colorado. GIS dataset. The Nature Conservancy.

USFWS. 2009. A system for mapping riparian areas in the western United States. U.S. Fish and Wildlife Service, Arlington, VA.

Wilcox, G., D. M. Theobald, and J. Whisman. 2007. Colorado Ownership, Management, and Protection V6.

Yin, R.K. 2003. *Case Study Research: Design and Methods, 3rd Edition.* Thousand Oaks, CA: Sage Publications.

APPENDIX A
Natural Heritage Methodology

NatureServe, a non-profit conservation organization whose mission is to provide the scientific basis for effective conservation action of rare and endangered species and threatened ecosystems, represents an international network of biological inventories-known as natural heritage programs or conservation data centers-operating in all 50 U.S. states, Canada, Latin America, and the Caribbean. The standardized methods used by NatureServe and its member programs incorporate a rigorous set of procedures for identifying, inventorying, and mapping species and ecosystems of conservation concern (Master 1991, Master et al. 2000, NatureServe 2008). Species, natural communities, and ecological systems are “elements of biodiversity,” and as such are often identified as conservation targets in planning and management efforts. The central concept in tracking imperiled elements is the “element occurrence,” a spatial representation of a species or ecological community at a specific location (Stein et al. 2000, NatureServe 2002). An element occurrence delineates a species population or contiguous tract of ecological community or system, and is intended to represent the biological feature that is the target of conservation and management efforts. Element occurrence records contain information about the extent, population size, condition, and management status of each occurrence. Elements are tracked by state natural heritage programs or conservation data centers according to their degree of imperilment and taxonomic status.

The standard natural heritage methodology is a consistent method for evaluating the relative imperilment of species, and designating a conservation status rank (Master 1991, Stein et al. 2000). In addition to the information contained in element occurrence records, NatureServe and the individual natural heritage programs in each state compile and maintain qualitative and descriptive information about each element. Together with the element occurrence records, this data serves as the basis for an element’s global and state conservation ranking. For plant and animal species, these ranks provide an estimate of extinction risk.

Conservation Status Ranks

To determine the status of species within Colorado, CNHP gathers information on plants, animals and plant communities. Each of these elements of natural diversity is assigned a rank that indicates its relative degree of imperilment on a five-point scale (for example, 1 = extremely rare/imperiled, 5 = abundant/secure). The primary criterion for ranking elements is the number of occurrences (in other words, the number of known distinct localities or populations). This factor is weighted more heavily than other factors because an element found in one place is more imperiled than something found in 21 places. Also of importance are the size of the geographic range, the number of individuals, the trends in both population and distribution, identifiable threats, and the number of protected occurrences. The CNHP uses the Biodiversity Tracking and Conservation System (BIOTICS) database to track species and plant community elements.

Status is assessed and documented at both the global (G), and state/provincial (S) geographic scales. Infraspecific taxon ranks (T-ranks) refer to subspecies, varieties, and other designations below the level of the species, and have a similar interpretation. Conservation status ranks are on a scale from 1 to 5, ranging from critically imperiled (G1, S1, or T1) to demonstrably secure (G5, S5, or T5). These ranks are based on the best available information, and incorporate a variety of factors such as abundance, viability, distribution, population trends, and threats. CNHP actively collects maps and electronically processes specific occurrence information for animal and plant species considered extremely imperiled to vulnerable in the state (S1 through S3). Several factors, such as rarity, evolutionary distinctiveness, and endemism (specificity of habitat requirements), contribute to the conservation priority of each species. Certain species are "watchlisted," meaning that specific occurrence data are collected and periodically analyzed to determine whether more active tracking is warranted. A complete description of each of the Natural Heritage ranks is provided in Table A.1.

This single rank system works readily for all species except those that are migratory. Those animals that migrate may spend only a portion of their life cycles within the state. In these cases, it is necessary to distinguish between breeding, non-breeding, and resident species. As noted in Table A.1, ranks followed by a "B," for example S1B, indicate that the rank applies only to the status of breeding occurrences. Similarly, ranks followed by an "N," for example S4N, refer to non-breeding status, typically during migration and winter. Elements without this notation are believed to be year-round residents within the state.

Table A.1. Definition of Natural Heritage Imperilment Ranks

G/S1	Critically imperiled globally/state because of rarity (5 or fewer occurrences in the world/state; or 1,000 or fewer individuals), or because some factor of its biology makes it especially vulnerable to extinction.
G/S2	Imperiled globally/state because of rarity (6 to 20 occurrences, or 1,000 to 3,000 individuals), or because other factors demonstrably make it very vulnerable to extinction throughout its range.
G/S3	Vulnerable through its range or found locally in a restricted range (21 to 100 occurrences, or 3,000 to 10,000 individuals).
G/S4	Apparently secure globally/state, though it may be quite rare in parts of its range, especially at the periphery. Usually more than 100 occurrences and 10,000 individuals.
G/S5	Demonstrably secure globally/state, though it may be quite rare in parts of its range, especially at the periphery.
G/SX	Presumed extinct globally, or extirpated within the state.
G#?	Indicates uncertainty about an assigned global rank.
G/SU	Unable to assign rank due to lack of available information.
GQ	Indicates uncertainty about taxonomic status.

G/SH	Historically known, but not verified for an extended period of time.
G#T#	Trinomial rank (T) is used for subspecies or varieties. These taxa are ranked on the same criteria as G1-G5.
S#B	Refers to the breeding season imperilment of elements that are not residents.
S#N	Refers to the non-breeding season imperilment of elements that are not permanent residents. Where no consistent location can be discerned for migrants or non-breeding populations, a rank of SZN is used.
SZ	Migrant whose occurrences are too irregular, transitory and/or dispersed to be reliably identified, mapped, and protected.
SA	Accidental in the state.
SR	Reported to occur in the state but unverified.
S?	Unranked. Some evidence that species may be imperiled, but awaiting formal rarity ranking.

Note: Where two numbers appear in a state or global rank (for example, S2S3), the actual rank of the element is uncertain, but falls within the stated range.

Legal Designations for Rare Species

Natural Heritage imperilment ranks should not be interpreted as legal designations. Although most species protected under state or federal endangered species laws are extremely rare, not all rare species receive legal protection. Legal status is designated by both the U.S. Fish and Wildlife Service under the Endangered Species Act or by the Colorado Parks and Wildlife under Colorado Statutes 33-2-105 Article 2. In addition, the U.S. Forest Service recognizes some species as “Sensitive,” as does the Bureau of Land Management. Table A.2 defines the special status assigned by these agencies and provides a key to abbreviations used by CNHP.

Table A.2. Federal and State Agency Special Designations for Rare Species

Federal Status:	
1. U.S. Fish and Wildlife Service (58 Federal Register 51147, 1993) and (61 Federal Register 7598, 1996)	
LE	Listed Endangered: defined as a species, subspecies, or variety in danger of extinction throughout all or a significant portion of its range.
LT	Listed Threatened: defined as a species, subspecies, or variety likely to become endangered in the foreseeable future throughout all or a significant portion of its range.
P	Proposed: taxa formally proposed for listing as Endangered or Threatened (a proposal has been published in the Federal Register, but not a final rule).
C	Candidate: taxa for which substantial biological information exists on file to support proposals to list them as endangered or threatened, but no proposal has been published yet in the Federal

	Register.
PDL	Proposed for delisting.
XN	Nonessential experimental population.
2. U.S. Forest Service (Forest Service Manual 2670.5) (noted by the Forest Service as "S")	
FS	Sensitive: those plant and animal species identified by the Regional Forester for which population viability is a concern as evidenced by:
	Significant current or predicted downward trends in population numbers or density.
	Significant current or predicted downward trends in habitat capability that would reduce a species' existing distribution.
3. Bureau of Land Management (BLM Manual 6840.06D) (noted by BLM as "S")	
BLM	Sensitive: those species found on public lands designated by a State Director that could easily become endangered or extinct in a state. The protection provided for sensitive species is the same as that provided for C (candidate) species.
4. State Status:	
Colorado Parks and Wildlife has developed categories of imperilment for nongame species (refer to the CPW Chapter 10 – Nongame Wildlife of the Wildlife Commission's regulations). The categories being used and the associated CNHP codes are provided below.	
E	Endangered: those species or subspecies of native wildlife whose prospects for survival or recruitment within this state are in jeopardy, as determined by the Commission.
T	Threatened: those species or subspecies of native wildlife which, as determined by the Commission, are not in immediate jeopardy of extinction but are vulnerable because they exist in such small numbers, are so extremely restricted in their range, or are experiencing such low recruitment or survival that they may become extinct.
SC	Special Concern: those species or subspecies of native wildlife that have been removed from the state threatened or endangered list within the last five years; are proposed for federal listing (or are a federal listing "candidate species") and are not already state listed; have experienced, based on the best available data, a downward trend in numbers or distribution lasting at least five years that may lead to an endangered or threatened status; or are otherwise determined to be vulnerable in Colorado.

Potential Conservation Areas

In order to successfully protect populations or occurrences CNHP designs Potential Conservation Areas (PCAs). These PCAs focus on capturing the ecological processes that are necessary to support the continued existence of a particular element occurrence of natural heritage significance. PCAs may include a single occurrence of a rare element, or a suite of rare element occurrences or significant features. The PCA is designed to identify a land area that can provide the habitat and ecological processes upon which a particular element occurrence, or suite of element occurrences, depends for its continued existence. The best available knowledge about each species' life history is used in conjunction with information about topographic, geomorphic, and hydrologic features; vegetative cover; and current and potential land uses. In developing the boundaries of a PCA, CNHP scientists consider a number of factors that include, but are not limited to:

- Ecological processes necessary to maintain or improve existing conditions;
- Species movement and migration corridors;
- Maintenance of surface water quality within the PCA and the surrounding watershed;
- Maintenance of the hydrologic integrity of the groundwater;
- Land intended to buffer the PCA against future changes in the use of surrounding lands;
- Exclusion or control of invasive exotic species; and
- Land necessary for management or monitoring activities.

The boundaries presented are meant to be used for conservation planning purposes and have no legal status. The proposed boundary does not automatically recommend exclusion of any activity. Rather, the boundaries designate ecologically significant areas in which land managers may wish to consider how specific activities or land use changes within or near the PCA affect the natural heritage resources and sensitive species on which the PCA is based. Please note that these boundaries are based on a best estimate of the primary area supporting the long-term survival of targeted species and plant communities. A thorough analysis of the human context and potential stresses has not been conducted. However, CNHP's conservation planning staff is available to assist with these types of analyses where conservation priority and local interest warrant additional research.

CNHP uses element and element occurrence ranks to assess the overall biological diversity significance of a PCA, which may include one or many element occurrences. Based on these ranks, each PCA is assigned a biological diversity rank (or B-rank). See Table A.3 for a summary of these B-ranks.

Table A.3. Natural Heritage Program Biological Diversity Ranks and their Definitions

B1	Outstanding Significance (indispensable): only known occurrence of an element A-ranked occurrence of a G1 element (or at least C-ranked if best available occurrence) concentration of A- or B-ranked occurrences of G1 or G2 elements (four or more)
B2	Very High Significance: B- or C-ranked occurrence of a G1 element A- or B-ranked occurrence of a G2 element One of the most outstanding (for example, among the five best) occurrences rangewide (at least A- or B-ranked) of a G3 element. Concentration of A- or B-ranked G3 elements (four or more) Concentration of C-ranked G2 elements (four or more)
B3	High Significance: C-ranked occurrence of a G2 element A- or B-ranked occurrence of a G3 element D-ranked occurrence of a G1 element (if best available occurrence) Up to five of the best occurrences of a G4 or G5 community (at least A- or B-ranked) in an ecoregion (requires consultation with other experts)
B4	Moderate Significance: Other A- or B-ranked occurrences of a G4 or G5 community C-ranked occurrence of a G3 element A- or B-ranked occurrence of a G4 or G5 S1 species (or at least C-ranked if it is the only state, provincial, national, or ecoregional occurrence) Concentration of A- or B-ranked occurrences of G4 or G5 N1-N2, S1-S2 elements (four or more) D-ranked occurrence of a G2 element At least C-ranked occurrence of a disjunct G4 or G5 element Concentration of excellent or good occurrences (A- or B-ranked) of G4 S1 or G5 S1 elements (four or more)
B5	General or Statewide Biological Diversity Significance: good or marginal occurrence of common community types and globally secure S1 or S2 species.

References

Master, L.L. 1991. Assessing Threats and Setting Priorities for Conservation. Conservation Biology 5:559-563.

Master, L.L., Stein, B.A., Kutner, L.S., Hammerson, G. 2000. Vanishing Assets: Conservation Status of US Species. In Bruce, A., Stein, Kutner, L.S., Adams, J.S., eds. Precious Heritage: Status of Biodiversity in the United States. Oxford University Press, pp. 93–118.

NatureServe. 2002. Element Occurrence Data Standard. NatureServe, in cooperation with the network of Natural Heritage Programs and Conservation Data Centers. www.natureserve.org/prodServices/eodata.jsp

NatureServe. 2008. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, Virginia. www.natureserve.org/explorer

Stein, B.A., L.S. Kutner, J.S. Adams. 2000. Precious Heritage. The Status of Biodiversity in the United States. Oxford University Press, New York, New York.

APPENDIX B
Data Sources used in Potential Habitat Distribution Models

Table B.1. Habitat Groups Used for Plant Species Models

General Group	*Astragalus sparsiflorus*	*Oligoneuron album*
	Carex oreocharis	*Potentilla ambigens*
	Cypripedium parviflorum	*Townsendia rothrockii*
	Machaeranthera coloradoensis	*Viola pedatifida*
	Mentzelia speciosa	
Alpine Group	*Armeria maritima ssp. sibirica*	*Draba grayana*
	Astragalus molybdenus	*Draba oligosperma*
	Braya glabella ssp. glabella	*Draba porsildii*
	Braya humilis	*Draba streptobrachia*
	Castilleja puberula	*Eutrema penlandii*
	Crepis nana	*Ipomopsis globularis*
	Draba borealis	*Physaria alpina*
	Draba crassa	*Ranunculus karelinii*
	Draba exunguiculata	***Saxifraga foliolosa***
	Draba fladnizensis	*Saussurea weberi*
	Draba globosa	
Cliff Group	*Aquilegia saximontana*	*Potentilla rupincola*
	Mimulus gemmiparus	*Telesonix jamesii*
Wetland Group	*Arabidopsis salsuginea*	*Primula egaliksensis*
	Carex limosa	*Ptilagrostis porteri*
	Carex livida	*Ribes americanum*
	Carex scirpoidea	***Rubus arcticus ssp. acaulis***
	Carex tenuiflora	*Salix candida*
	Carex viridula	***Salix lanata ssp. calcicola***
	Eriophorum altaicum var. neogaeum	***Salix myrtillifolia***
	Eriophorum gracile	*Salix serissima*
	Kobresia simpliciuscula	***Sisyrinchium demissum***
	Malaxis brachypoda	*Sisyrinchium pallidum*
	Packera pauciflora	*Sphagnum girgensohnii*
	Parnassia kotzebuei	*Trichophorum pumilum*
	Phippsia algida	*Utricularia ochroleuca*

Annual Growing Degree Days

Peter E. Thornton, National Center for Atmospheric Research. 2002. Daymet: Climatological Summaries for the Conterminous United States, 1980-1997.

Online link: www.daymet.org
Other citation details: Annual Growing Degree-days
Source scale denominator: 1 km resolution raster
Source contribution: Habitat model environmental input.

Daymet Annual Growing degree-days for Colorado (The summation for a year of the daily average air temperatures for the period that are greater than 0.0 °C. Units are degree-days). Daymet represents an average from 1980 - 1997, at 1 kilometer resolution. Raster was downsampled to 30m, re-projected and snapped to be compatible with other environmental inputs.

Annual Precipitation

Peter E. Thornton, National Center for Atmospheric Research. 2002. Daymet: Climatological Summaries for the Conterminous United States, 1980-1997.

Online link: www.daymet.org
Other citation details: Annual Total Precipitation
Source scale denominator: 1 km resolution raster
Source contribution: Habitat model environmental input.

Daymet total annual precipitation (centimeters) for Colorado. Daymet represents an average from 1980 - 1997, at 1 kilometer resolution. Raster was downsampled to 30m, re-projected and snapped to be compatible with other environmental inputs.

Annual Precipitation Frequency ("Wet Days")

Peter E. Thornton, National Center for Atmospheric Research. 2002. Daymet: Climatological Summaries for the Conterminous United States, 1980-1997.

Online link: www.daymet.org
Other citation details: Annual Precipitation Frequency
Source scale denominator: 1 km resolution raster
Source contribution: Habitat model environmental input.

Daymet Annual Precipitation Frequency for Colorado (proportion of days in a year with any precipitation, range 0 to 1). Daymet represents an average from 1980 - 1997, at 1 kilometer resolution. Raster was downsampled to 30m, re-projected and snapped to be compatible with other environmental inputs.

April Minimum Temperature

Peter E. Thornton, National Center for Atmospheric Research. 2002. Daymet: Climatological Summaries for the Conterminous United States, 1980-1997.

Online links: www.daymet.org
Other citation details: Monthly Minimum Temperature; April
Source scale denominator: 1 km resolution raster
Source contribution: Habitat model environmental input.

Daymet Monthly Minimum Temperature in April for Colorado. Units are degrees Celsius. Daymet represents an average from 1980 - 1997, at 1 kilometer resolution. Raster was downsampled to 30m, re-projected and snapped to be compatible with other environmental inputs.

Aspect

Derived from U.S. Geological Survey. 2006. 30m Digital Elevation Model for Colorado.

Source scale denominator: 30 m resolution raster
Source contribution: Habitat model environmental input.
The Elevation raster was used to create an Aspect raster, which was then used to create two separate rasters representing northness and eastness.
northness = cos(aspect)
eastness = sin(aspect)

Values range from -1 to +1. Northness will take values close to 1 if the aspect is generally northward, close to -1 if the aspect is southward, and close to 0 if the aspect is either east or west. Eastness behaves similarly, except that values close to 1 represent east-facing slopes.

For more information on method used, see: http://ordination.okstate.edu/envvar.htm

CNHP EORs

The Colorado Natural Heritage Program, Colorado State University. 08/2011. Colorado Biodiversity Tracking and Conservation System Element Occurrence Records.

Source scale denominator: 24,000
Source contribution: Known species occurrence input training and testing points.

CNHP Observations

The Colorado Natural Heritage Program, Colorado State University. 08/2011. Colorado Natural Heritage Program Rare Species Observations.

Source scale denominator: 24,000
Source contribution: Known species observations input training and testing points.

Depth to Bedrock

Miller, D.A. and R.A. White. 1998. A Conterminous United States Multi-Layer Soil Characteristics Data Set for Regional Climate and Hydrology Modeling.

Online links: www.essc.psu.edu/soil_info/index.cgi?soil_data&conus
Other citation details: Data derived from Natural Resources Conservation Service (NRCS) State Soil Geographic database (STATSGO).
Source scale denominator: 12,000 - 63,360
Source contribution: Environmental Input

Depth to bedrock (field ROCKDEPM) is a single value per STATSGO polygon. Units are centimeters. Note that a value of 152 really means >= 152 cm and a value of 0 is really NoData (occurs on Water polygons only).

Tabular data was joined to NRCS STATSGO dataset (ArcInfo coverage) for Colorado and exported as a 30m raster.

Distance to Prairie Dogs

Colorado Natural Heritage Program. 2011. Distance to prairie dog towns in Colorado.
Source scale denominator: various
Source contribution: Habitat model environmental input.

CNHP prairie dog (all species) EORs (Element Occurrence Records) were combined with a previous black-tailed prairie dog model created by CNHP for the Central Shortgrass Prairie. This model, in turn, is based on prairie dog aerial survey data from the wildlife agencies of multiple states. This compilation was necessary because CNHP prairie dog EO data is incomplete in the northeast of the state. A 30m resolution distance raster was then calculated from these combined inputs.

Distance to Water

Derived from U.S. Geological Survey. 05/2010 (last update). High Resolution National Hydrography Dataset.

Online link: http://nhd.usgs.gov/index.html
Other citation details: NHDFlowline NHDWaterbody NHDPoint
Source scale denominator: 12,000 - 24,000
Source contribution: Habitat model environmental input.

USGS High Resolution National Hydrography Dataset (NHD) for Colorado was queried for permanent water (polygon, line, and point). Results were converted to 30m raster and a distance raster calculated. Queries used:

NHDFlowline: ("FType" = 460 OR "FType" = 558) AND (("FCode" = 46000 OR "FCode" = 46006) OR ("GNIS_Name" IS NOT Null))

NHDWaterbody: "FCode" = 39000 OR "FCode" = 39004 OR "FCode" = 39009 OR "FCode" = 39010 OR "FCode" = 39011 OR "FCode" = 39012 OR "FCode" = 43600 OR "FCode" = 43617 OR "FCode" = 43618 OR "FCode" = 43621

NHDPoint: "FType" = 458

Distance to Wetland

Derived from United States Forest Service. 2006. LANDFIRE Current Vegetation for Colorado
and
U.S. Geological Survey. 05/2010 (last update). High Resolution National Hydrography Dataset.

Online links: http://landfire.cr.usgs.gov/viewer/viewer.html, http://nhd.usgs.gov/index.html

Source scale denominator: 12,000 - 24,000
Source contribution: Habitat model environmental input.

There is not a complete statewide dataset for wetland or riparian areas. Using available partial datasets (NWI, CPW riparian) may just bias to mapped areas. Used NHD & LandFire as described below, although this is known to be an imperfect solution.

USGS High Resolution NHD for Colorado and USFS LandFire Current Vegetation were queried for wetland and riparian areas. Results were converted to 30m raster and a distance raster calculated. Queries used:

NHDWaterbody: "FType" = 361 OR "FType" = 466 OR "FCode" = 39001 OR "FCode" = 39005 OR "FCode" = 39006

LandFire Current Veg: "SYSTMGRPNA" LIKE '%Riparian%' OR "SYSTMGRPNA" LIKE '%Wet%'

Elevation

U.S. Geological Survey. 2006. 30m Digital Elevation Model for Colorado.

Online link: http://seamless.usgs.gov/website/seamless/viewer.php
Source scale denominator: 30 m resolution raster
Source contribution: Habitat model environmental input.

Geology

RS/GIS Laboratory, College of Natural Resources, Utah State University, USGS GAP Analysis Program. 09/17/2004. 1:500,000 Scale Geology for the Southwestern U.S..

Online links: http://earth.gis.usu.edu/swgap/, http://fws-nmcfwru.nmsu.edu/swregap/default.htm
Source scale denominator: 500,000
Source contribution: Habitat model environmental input - categorical.

Original vector data was rasterized and clipped to Colorado.

Landform

RS/GIS Laboratory, College of Natural Resources, Utah State University and USGS GAP Analysis Program. 09/15/2004. Ten Class DEM Derived Landform for the Southwest United States.

Online link: http://earth.gis.usu.edu/swgap/
Source scale denominator: 30 m resolution raster
Source contribution: Habitat model environmental input - categorical.

Local Relief

Derived from U.S. Geological Survey. 2006. 30m Digital Elevation Model for Colorado.

Source scale denominator: 30 m resolution raster
Source contribution: Habitat model environmental input.

A measure of surface roughness. Created from 30m DEM for Colorado by using FocalRange command:
FOCALRANGE(coelev30, Circle, 16, DATA)

May Minimum Temperature

Peter E. Thornton, National Center for Atmospheric Research. 2002. Daymet: Climatological Summaries for the Conterminous United States, 1980-1997.

Online links: www.daymet.org
Other citation details: Monthly Minimum Temperature; May
Source scale denominator: 1 km resolution raster
Source contribution: Habitat model environmental input.

Daymet Monthly Minimum Temperature in May for Colorado. Units are degrees Celsius. Daymet represents an average from 1980 - 1997, at 1 kilometer resolution. Raster was downsampled to 30m, re-projected and snapped to be compatible with other environmental inputs.

Number of Frost Days

Peter E. Thornton, National Center for Atmospheric Research. 2002. Daymet: Climatological Summaries for the Conterminous United States, 1980-1997.

Online link: www.daymet.org
Other citation details: Annual average number of frost days
Source scale denominator: 1 km resolution raster
Source contribution: Habitat model environmental input.

Daymet number of days in a year when the daily minimum air temperature is less than or equal to 0.0 °C for Colorado. Daymet represents an average from 1980 - 1997, at 1 kilometer resolution. Raster was downsampled to 30m, re-projected and snapped to be compatible with other environmental inputs.

PMJM Block Clearance

U.S. Fish and Wildlife Service. 2010. Approved_Block_Clearance_2010.shp.

Source contribution: Component of mask used to limit Preble's mouse model extent to known species distribution.

PMJM Critical Habitat

U.S. Fish and Wildlife Service. December, 2010. Preble's Meadow Jumping Mouse Critical Habitat Buffers Proposed 2010.

Online link: www.fws.gov/mountain-prairie/species/mammals/preble
Source contribution: Added to the finished Preble's mouse model to ensure these areas were included.

Relative Forest Cover

Derived from Wildland Fire Science, Earth Resources Observation and Science Center, U.S. Geological Survey. 2010. LANDFIRE Forest Canopy Cover.

Online link: www.landfire.gov/
Source scale denominator: 30 m resolution raster
Source contribution: Habitat model environmental input.

Used LandFire 2010 Percent Forest Canopy Cover. Did a Focal Sum using 1 km radius circle (33 cells) with NoData option to create a measure of relative forest cover at a resolution identified in the literature as relevant to the species.

Slope

Derived from U.S. Geological Survey. 2006. 30m Digital Elevation Model for Colorado.

Source scale denominator: 30 m resolution raster
Source contribution: Habitat model environmental input.

Degrees slope derived from USGS 30m DEM.

Soil pH

Derived from Miller, D.A. and R.A. White. 1998. A Conterminous United States Multi-Layer Soil Characteristics Data Set for Regional Climate and Hydrology Modeling.

Online link: www.essc.psu.edu/soil_info/index.cgi?soil_data&conus
Other citation details: Data derived from Natural Resources Conservation Service (NRCS) State Soil Geographic database (STATSGO).
Source scale denominator: 12,000 - 63,360
Source contribution: Habitat model environmental input.

Soil pH values are supplied for each of 11 standard soil levels, down to 2.5m. Values of 0 are really NoData. Non-zero pH values were averaged from layers 1 - 6 for this project. Note - a mathematical mean is not technically the appropriate way to lump multiple pH values, but options are restricted by how the data were originally recorded. Surface pH alone was not seen as sufficient information, so averaged values of the first six layers as a proxy for actual total pH down to 60cm soil depth was used.

Tabular data was joined to NRCS STATSGO dataset (ArcInfo coverage) for Colorado and exported as a 30m raster.

Soil Texture

Derived from Miller, D.A. and R.A. White. 1998. A Conterminous United States Multi-Layer Soil Characteristics Data Set for Regional Climate and Hydrology Modeling.

Online link: www.essc.psu.edu/soil_info/index.cgi?soil_data&conus
Other citation details: Data derived from NRCS State Soil Geographic database (STATSGO).
Source scale denominator: 12,000 - 63,360
Source contribution: Habitat model environmental input - categorical.

Soil texture classes are supplied for each of 11 standard soil levels, down to 2.5m. For this modeling, the team focused on the first six layers (to 60 cm). Because these data are categorical, the mode (majority) was used. A mode over six inputs creates too many ties to be useful, so values for layers 1- 5 only were used instead.

Tabular data was joined to NRCS STATSGO dataset (ArcInfo coverage) for Colorado and exported as a 30m raster.

Spring Precipitation

Derived from Peter E. Thornton, National Center for Atmospheric Research. 2002. Daymet: Climatological Summaries for the Conterminous United States, 1980-1997.

Online link: www.daymet.org
Other citation details: Monthly Total Precipitation
Source scale denominator: 1 km resolution raster
Source contribution: Habitat model environmental input.

Daymet total precipitation (centimeters) for March, April, & May for Colorado were totaled to represent average spring precipitation. Daymet represents an average from 1980 - 1997, at 1 kilometer resolution. Raster was downsampled to 30m, re-projected and snapped to be compatible with other environmental inputs.

Spring Snow Depth

Derived from National Operational Hydrologic Remote Sensing Center. 2004 – 2011. Snow Data Assimilation System (SNODAS) Data Products at NSIDC, 2004 - 2011 snow depth.

Online link: http://nsidc.org/data/docs/noaa/g02158_snodas_snow_cover_model/index.html
Other citation details: Boulder, Colorado USA: National Snow and Ice Data Center.
Source scale denominator: 30 arc seconds resolution raster
Source contribution: Habitat model environmental input.

SNODAS snow depth (mm) data for March, April, and May were averaged over the years 2004 - 2011. Data for each month was treated as a separate input into the model.

Outputs were projected, downsampled to 30 m, and snapped to be consistent with all other inputs.

Summer Precipitation

Derived from Peter E. Thornton, National Center for Atmospheric Research. 2002. Daymet: Climatological Summaries for the Conterminous United States, 1980-1997.

Online link: www.daymet.org
Other citation details: Monthly Total Precipitation
Source scale denominator: 1 km resolution raster
Source contribution: Habitat model environmental input.

Daymet total precipitation (centimeters) for June, July, and August for Colorado were totaled to represent average summer precipitation. Daymet represents an average from 1980 - 1997, at 1 kilometer resolution. Raster was downsampled to 30m, re-projected and snapped to be compatible with other environmental inputs.

USFS Aerial Surveys

USDA Forest Service, Rocky Mountain Region, Forest Health Management. 2007 – 2010. Annual Aerial Detection Overview Survey (2007, 2008, 2009, 2010).

Online link: www.fs.fed.us/r2/resources/fhm/aerialsurvey/
Other citation details: 4 separate surveys from 2007, 2008, 2009, 2010.
Source contribution: Used to modify original Lynx habitat layer. Areas of recent beetle kill were used to show habitat degradation. Surveys from 2007 - 2010 were filtered to only show areas of heavy beetle infestation mortality:

("DMG_TYPE1" = 1 AND "SEVERITY1" = 2) OR "DMG_TYPE1" = 2 OR "DMG_TYPE1" = 7

These were then combined into a dataset of cumulative recent beetle kill.

Vegetation type

RS/GIS Laboratory, College of Natural Resources, Utah State University and USGS GAP Analysis Program. 09/15/2004. Southwest Regional GAP Analysis Project Landcover.

Online link: http://fws-nmcfwru.nmsu.edu/swregap/default.htm
Source scale denominator: 30 m resolution raster

Source contribution: Environmental Input – categorical.

Vegetation type (LANDFIRE)

Wildland Fire Science, Earth Resources Observation and Science Center, U.S. Geological Survey. 2010. LANDFIRE Existing Vegetation Cover.

Online link: http://landfire.cr.usgs.gov/viewer/viewer.html
Source scale denominator: 30 m resolution raster
Source contribution: Habitat model environmental input - categorical.

Note - SWReGAP Landcover was used for most models. Initial Bald Eagle model using SWReGAP Landcover was deemed too inaccurate, so model was re-run with LandFire Current Vegetation.

APPENDIX C
CNHP Potential Habitat Distribution Models

Aquilegia saximontana habitat model
Predictive species distribution model of potential habitat for *Aquilegia saximontana* in Colorado.

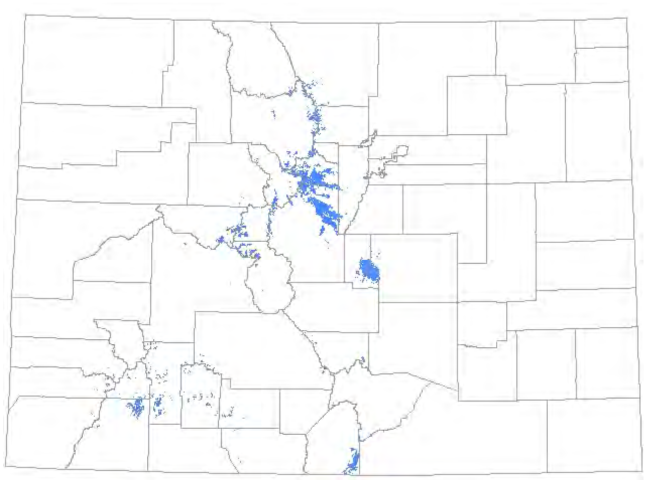
This is a MaxEnt (v. 3.3.3e) inductive model using the Cliff Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Initial cut-off of 0.086 was deemed too low, so that model results with a value of 0.40 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado botany professionals.

The model is based on 27 EORs, which were translated into 68 input points. 55 input points used for training, 13 for testing. Training AUC is 0.989, test AUC is 0.973. The Cliff Plant Group environmental inputs are:

elevation
aspect (as a measure of northness and eastness)
geology
average spring precipitation
average summer precipitation
April minimum temperature
May minimum temperature
local relief
landform

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Aquilegia saximontana* habitat model. Raster digital data.

Thumbnail:



Arabidopsis salsuginea habitat model

Predictive species distribution model of potential habitat for *Arabidopsis salsuginea* in Colorado. Species also known as *Thellungiella salsuginea*.

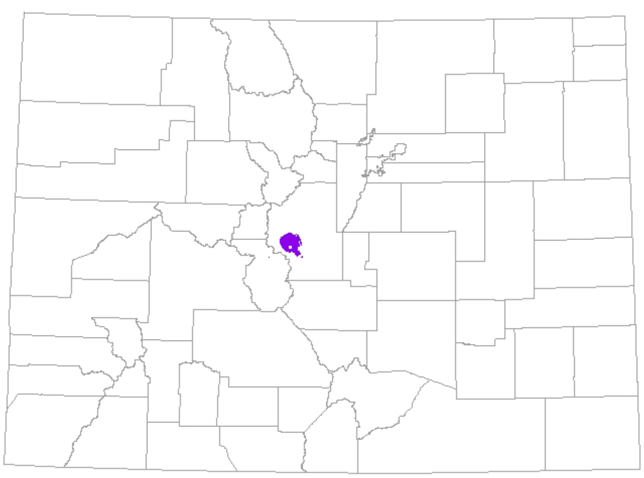
This is a MaxEnt (v. 3.3.3e) inductive model using the Wetland Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.516 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado botany professionals.

The model is based on 2 EORs, which were translated into 11 input points. 9 input points used for training, 2 for testing. Training AUC is 0.999, test AUC is 1.000. The Wetland Plant Group environmental inputs are:

- distance to water
- distance to wetland
- soil pH
- elevation
- slope
- average annual precipitation
- proportion of wet days
- growing degree days
- April minimum temperature
- May minimum temperature

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Arabidopsis salsuginea* habitat model. Raster digital data.

Thumbnail:



Armeria maritima ssp. *sibirica* habitat model

Predictive species distribution model of potential habitat for *Armeria maritima* ssp. *sibirica* in Colorado. Species also known as *Armeria scabra* ssp. *sibirica*.

This is a MaxEnt (v. 3.3.3e) inductive model using the Alpine Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.565 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado botany professionals.

The model is based on 2 EORs, which were translated into nine input points. 8 input points used for training, 1 for testing. Training AUC is 1.000, test AUC is 1.000. The Alpine Plant Group environmental inputs are:

- elevation
- slope
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average annual precipitation
- May minimum temperature
- soil pH
- soil texture
- spring snow depth
- number of frost days

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Armeria maritima* ssp. *sibirica* habitat model. Raster digital data.

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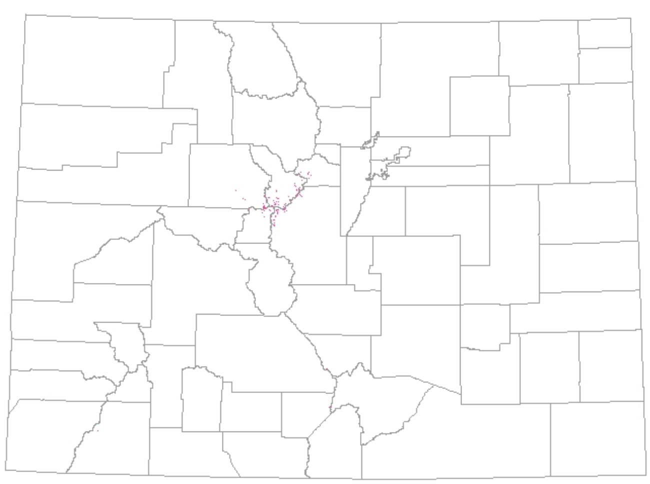

Astragalus molybdenus habitat model

Predictive species distribution model of potential habitat for *Astragalus molybdenus* in Colorado.

This is a MaxEnt (v. 3.3.3e) inductive model using the Alpine Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.252 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado botany professionals.

The model is based on 12 EORs, which were translated into 50 input points. 40 input points used for training, 10 for testing. Training AUC is 0.998, test AUC is 0.995. The Alpine Plant Group environmental inputs are:

- elevation
- slope
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average annual precipitation
- May minimum temperature
- soil pH
- soil texture
- spring snow depth
- number of frost days

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Astragalus molybdenus* habitat model. Raster digital data.

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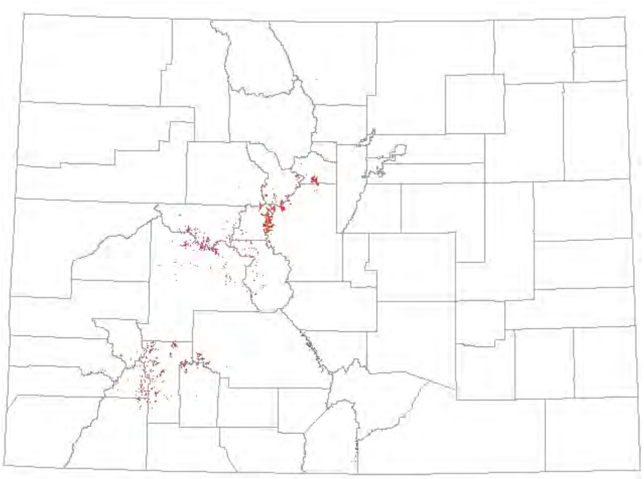


Astragalus sparsiflorus habitat model

Predictive species distribution model of potential habitat for *Astragalus sparsiflorus* in Colorado.

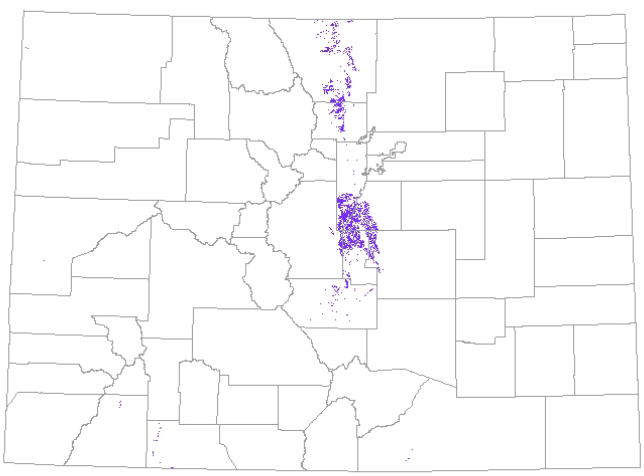
This is a MaxEnt (v. 3.3.3e) inductive model using the General Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.22 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado botany professionals.

The model is based on 7 EORs, which were translated into seven input points. 6 input points used for training, 1 for testing. Training AUC is 0.999, test AUC is 0.922. The General Plant Group environmental inputs are:

- elevation
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average spring precipitation
- average summer precipitation
- proportion of wet days
- growing degree days
- April minimum temperature
- May minimum temperature

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Astragalus sparsiflorus* habitat model. Raster digital data.

Thumbnail:



Braya glabella **ssp.** ***glabella*** **habitat model**

Predictive species distribution model of potential habitat for *Braya glabella* ssp. *glabella* in Colorado. Species also known as *Braya glabella* var. *glabella*.

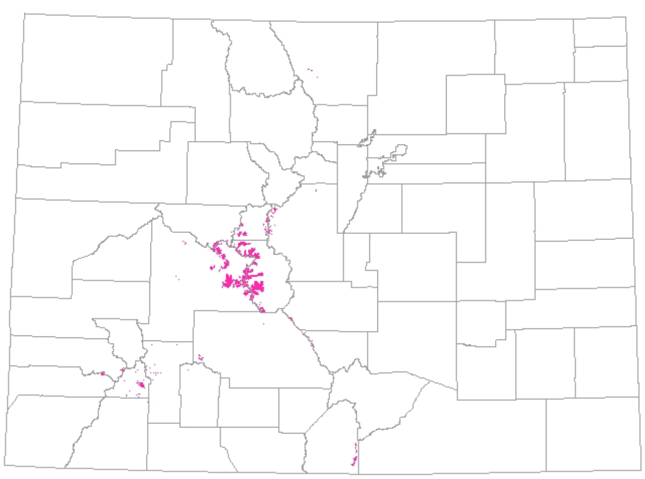
This is a MaxEnt (v. 3.3.3e) inductive model using the Alpine Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.194 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 4 EORs, which were translated into 12 input points. 10 input points used for training, 2 for testing. Training AUC is 0.999, test AUC is 1.000. The Alpine Plant Group environmental inputs are:

- elevation
- slope
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average annual precipitation
- May minimum temperature
- soil pH
- soil texture
- spring snow depth
- number of frost days

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Braya glabella* ssp. *glabella* habitat model. Raster digital data.

Thumbnail:



Braya humilis habitat model

Predictive species distribution model of potential habitat for *Braya humilis* in Colorado.

This is a MaxEnt (v. 3.3.3e) inductive model using the Alpine Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.239 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 3 EORs, which were translated into 33 input points. 27 input points used for training, 6 for testing. Training AUC is 0.998, test AUC is 0.998. The Alpine Plant Group environmental inputs are:

- elevation
- slope
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average annual precipitation
- May minimum temperature
- soil pH
- soil texture
- spring snow depth
- number of frost days

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Braya humilis* habitat model. Raster digital data.

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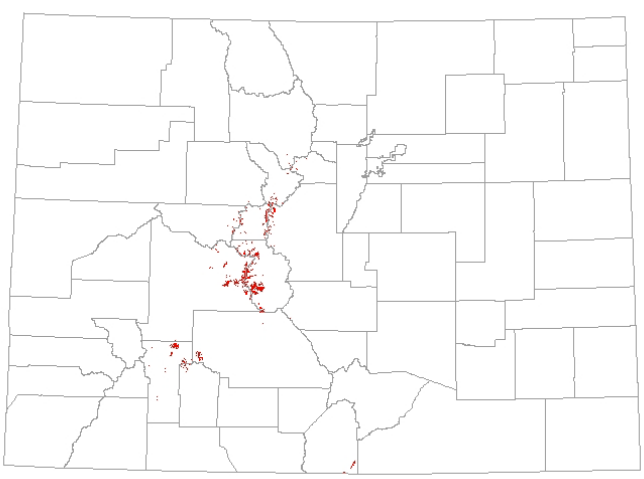

Carex limosa habitat model

Predictive species distribution model of potential habitat for *Carex limosa* in Colorado.

This is a MaxEnt (v. 3.3.3e) inductive model using the Wetland Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.071 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 17 EORs, which were translated into 30 input points. 24 input points used for training, 6 for testing. Training AUC is 0.996, test AUC is 0.998. The Wetland Plant Group environmental inputs are:

- distance to water
- distance to wetland
- soil pH
- elevation
- slope
- average annual precipitation
- proportion of wet days
- growing degree days
- April minimum temperature
- May minimum temperature

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Carex limosa* habitat model. Raster digital data.

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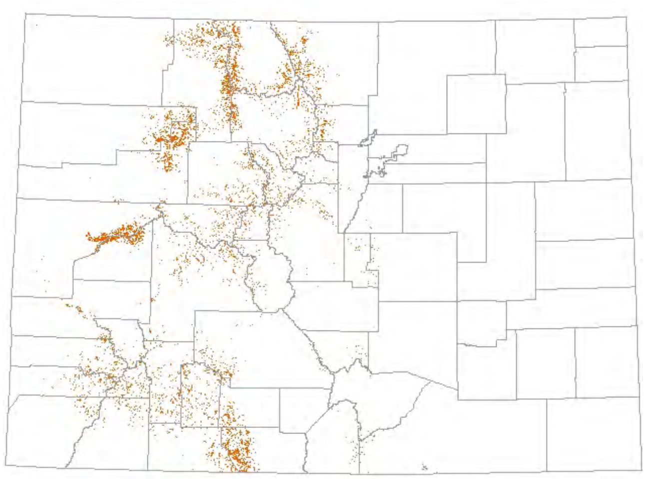

Carex livida habitat model

Predictive species distribution model of potential habitat for *Carex livida* in Colorado.

This is a MaxEnt (v. 3.3.3e) inductive model using the Wetland Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.383 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado botany professionals.

The model is based on 6 EORs, which were translated into nine input points. 8 input points used for training, 1 for testing. Training AUC is 0.996, test AUC is 0.995. The Wetland Plant Group environmental inputs are:

- distance to water
- distance to wetland
- soil pH
- elevation
- slope
- average annual precipitation
- proportion of wet days
- growing degree days
- April minimum temperature
- May minimum temperature

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Carex livida* habitat model. Raster digital data.

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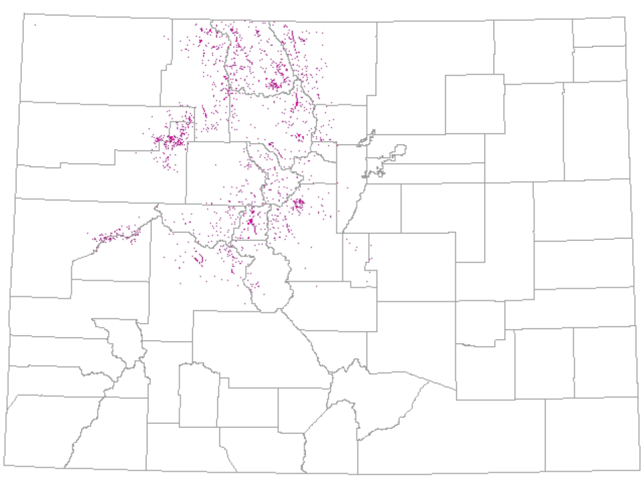

Carex oreocharis habitat model

Predictive species distribution model of potential habitat for *Carex oreocharis* in Colorado.

This is a MaxEnt (v. 3.3.3e) inductive model using the General Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.199 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado botany professionals.

The model is based on 8 EORs, which were translated into 11 input points. 9 input points used for training, 2 for testing. Training AUC is 0.995, test AUC is 0.765. The General Plant Group environmental inputs are:

- elevation
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average spring precipitation
- average summer precipitation
- proportion of wet days
- growing degree days
- April minimum temperature
- May minimum temperature

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Carex oreocharis* habitat model. Raster digital data.

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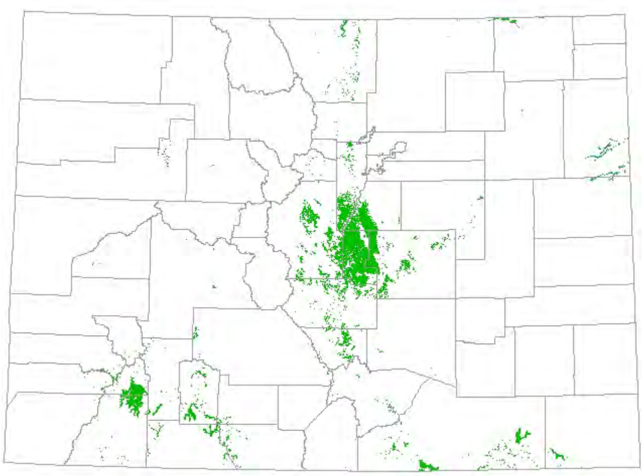


Carex scirpoidea habitat model

Predictive species distribution model of potential habitat for *Carex scirpoidea* in Colorado.

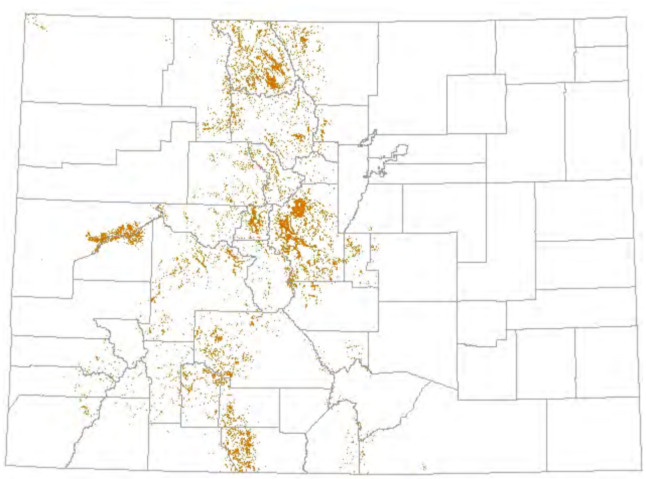
This is a MaxEnt (v. 3.3.3e) inductive model using the Wetland Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.145 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 16 EORs, which were translated into 16 input points. 13 input points used for training, 3 for testing. Training AUC is 0.995, test AUC is 0.999. The Wetland Plant Group environmental inputs are:

- distance to water
- distance to wetland
- soil pH
- elevation
- slope
- average annual precipitation
- proportion of wet days
- growing degree days
- April minimum temperature
- May minimum temperature

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Carex scirpoidea* habitat model. Raster digital data.

Thumbnail:



***Carex viridula* habitat model**

Predictive species distribution model of potential habitat for *Carex viridula* in Colorado.

This is a MaxEnt (v. 3.3.3e) inductive model using the Wetland Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.466 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 9 EORs, which were translated into 12 input points. 10 input points used for training, 2 for testing. Training AUC is 0.977, test AUC is 0.998. The Wetland Plant Group environmental inputs are:

- distance to water
- distance to wetland
- soil pH
- elevation
- slope
- average annual precipitation
- proportion of wet days
- growing degree days
- April minimum temperature
- May minimum temperature

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Carex viridula* habitat model. Raster digital data.

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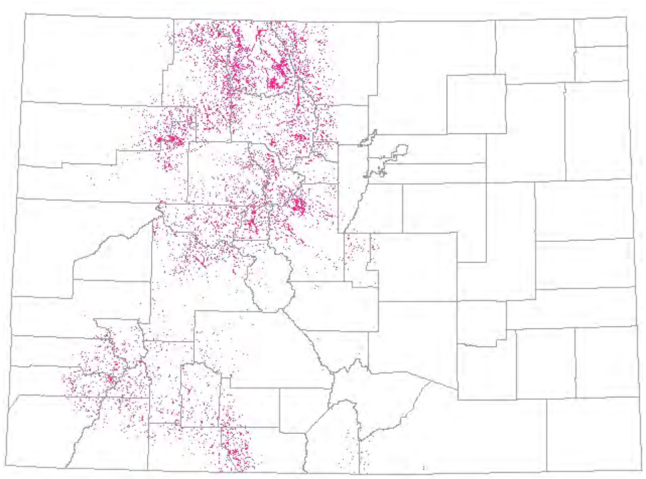


Castilleja puberula habitat model

Predictive species distribution model of potential habitat for *Castilleja puberula* in Colorado.

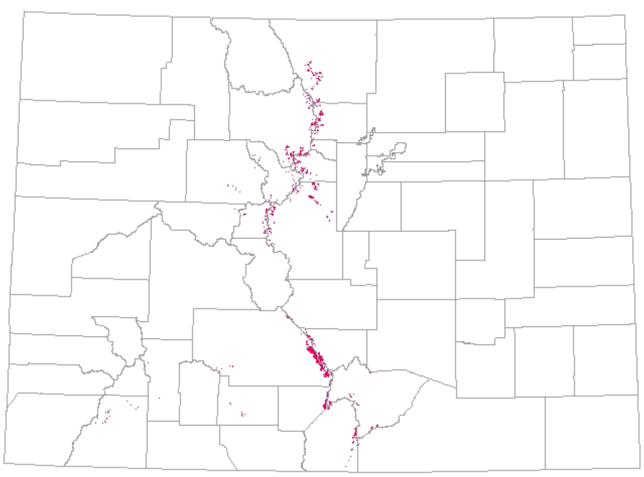
This is a MaxEnt (v. 3.3.3e) inductive model using the Alpine Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.256 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 13 EORs, which were translated into 19 input points. 16 input points used for training, 3 for testing. Training AUC is 0.999, test AUC is 0.998. The Alpine Plant Group environmental inputs are:

- elevation
- slope
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average annual precipitation
- May minimum temperature
- soil pH
- soil texture
- spring snow depth
- number of frost days

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Castilleja puberula* habitat model. Raster digital data.

Thumbnail:



Crepis nana habitat model

Predictive species distribution model of potential habitat for *Crepis nana* in Colorado. Species also known as *Askellia nana*.

This is a MaxEnt (v. 3.3.3e) inductive model using the Alpine Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.232 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 13 EORs, which were translated into 27 input points. 22 input points used for training, 5 for testing. Training AUC is 0.998, test AUC is 0.998. The Alpine Plant Group environmental inputs are:

- elevation
- slope
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average annual precipitation
- May minimum temperature
- soil pH
- soil texture
- spring snow depth
- number of frost days

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Crepis nana* habitat model. Raster digital data.

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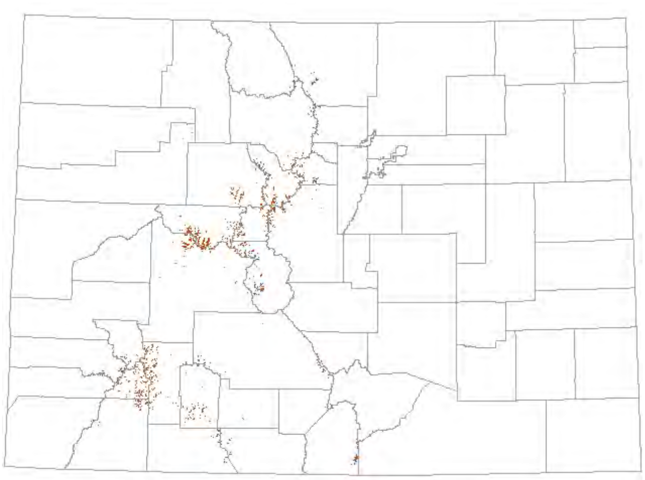

Cypripedium parviflorum habitat model

Predictive species distribution model of potential habitat for *Cypripedium parviflorum* in Colorado. Species also known as *Cypripedium calceolus* ssp. *parviflorum*.

This is a MaxEnt (v. 3.3.3e) inductive model using the General Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Initial cut-off of 0.135 was deemed too low, so that model results with a value of 0.35 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado botany professionals.

The model is based on 15 EORs, which were translated into 31 input points. 25 input points used for training, 6 for testing. Training AUC is 0.997, test AUC is 0.996. The General Plant Group environmental inputs are:

- elevation
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average spring precipitation
- average summer precipitation
- proportion of wet days
- growing degree days
- April minimum temperature
- May minimum temperature

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Cypripedium parviflorum* habitat model. Raster digital data.

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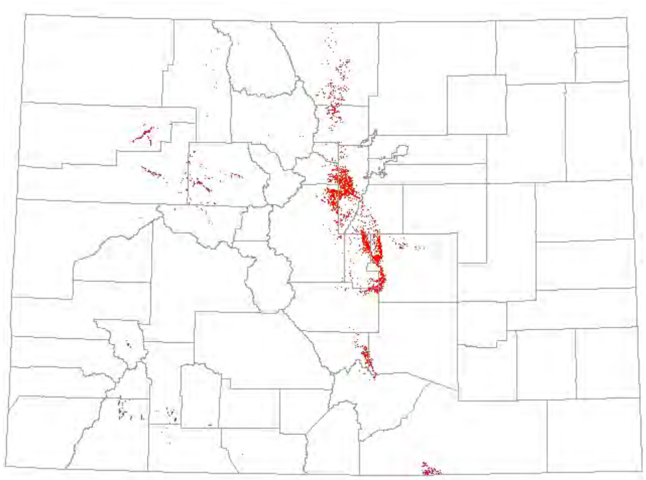


Draba borealis habitat model

Predictive species distribution model of potential habitat for *Draba borealis* in Colorado.

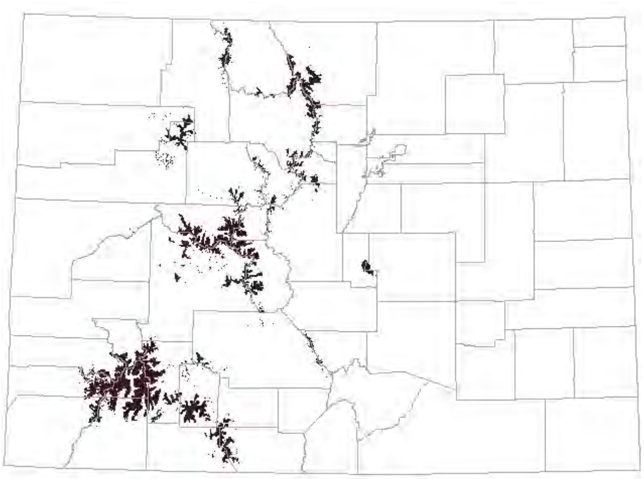
This is a MaxEnt (v. 3.3.3e) inductive model using the Alpine Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.156 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 11 EORs, which were translated into 11 input points. 9 input points used for training, 2 for testing. Training AUC is 0.995, test AUC is 0.971. The Alpine Plant Group environmental inputs are:

- elevation
- slope
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average annual precipitation
- May minimum temperature
- soil pH
- soil texture
- spring snow depth
- number of frost days

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Draba borealis* habitat model. Raster digital data.

Thumbnail:



Draba crassa habitat model

Predictive species distribution model of potential habitat for *Draba crassa* in Colorado.

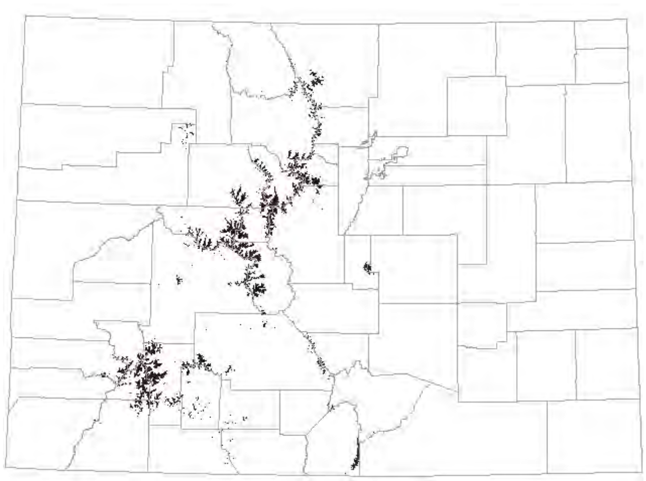
This is a MaxEnt (v. 3.3.3e) inductive model using the Alpine Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.192 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado botany professionals.

The model is based on 38 EORs, which were translated into 77 input points. 62 input points used for training, 15 for testing. Training AUC is 0.993, test AUC is 0.991. The Alpine Plant Group environmental inputs are:

- elevation
- slope
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average annual precipitation
- May minimum temperature
- soil pH
- soil texture
- spring snow depth
- number of frost days

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Draba crassa* habitat model. Raster digital data.

Thumbnail:



Draba exunguiculata habitat model

Predictive species distribution model of potential habitat for *Draba exunguiculata* in Colorado.

This is a MaxEnt (v. 3.3.3e) inductive model using the Alpine Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.368 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 10 EORs, which were translated into 20 input points. 16 input points used for training, 4 for testing. Training AUC is 0.999, test AUC is 0.993. The Alpine Plant Group environmental inputs are:

- elevation
- slope
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average annual precipitation
- May minimum temperature
- soil pH
- soil texture
- spring snow depth
- number of frost days

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Draba exunguiculata* habitat model. Raster digital data.

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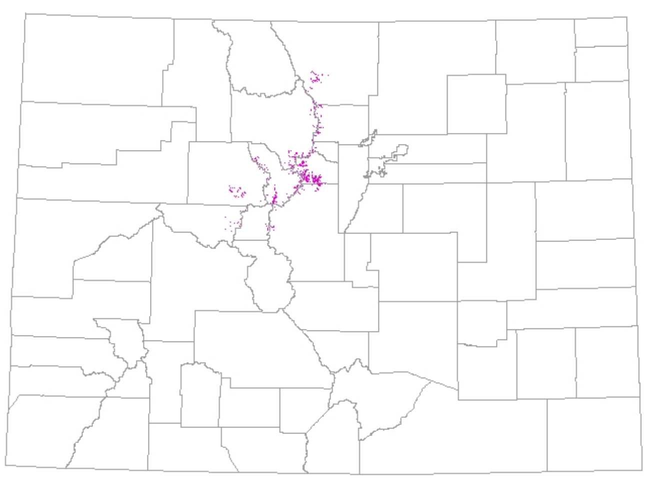


Draba fladnizensis habitat model

Predictive species distribution model of potential habitat for *Draba fladnizensis* in Colorado.

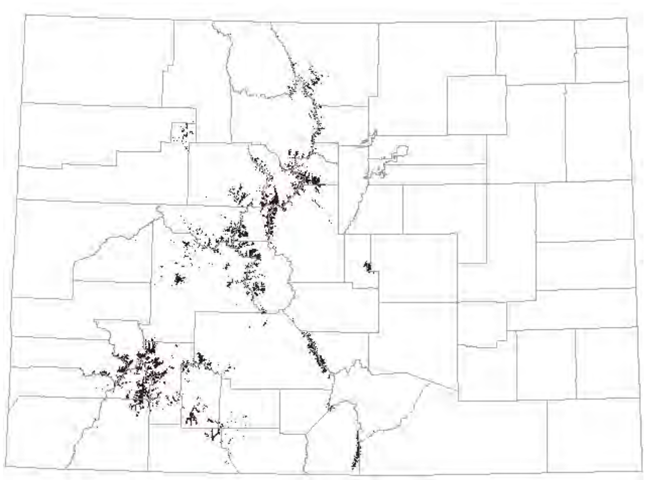
This is a MaxEnt (v. 3.3.3e) inductive model using the Alpine Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.159 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado botany professionals.

The model is based on 30 EORs, which were translated into 43 input points. 35 input points used for training, 8 for testing. Training AUC is 0.996, test AUC is 0.995. The Alpine Plant Group environmental inputs are:

- elevation
- slope
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average annual precipitation
- May minimum temperature
- soil pH
- soil texture
- spring snow depth
- number of frost days

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Draba fladnizensis* habitat model. Raster digital data.

Thumbnail:



Draba globosa habitat model

Predictive species distribution model of potential habitat for *Draba globosa* in Colorado.

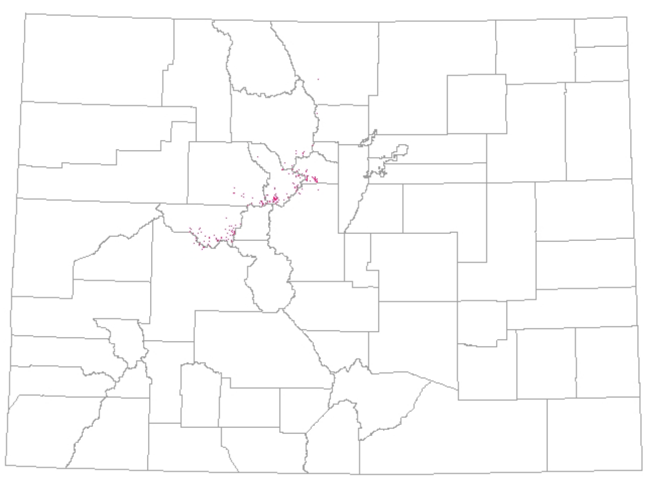
This is a MaxEnt (v. 3.3.3e) inductive model using the Alpine Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.517 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 5 EORs, which were translated into seven input points. 6 input points used for training, 1 for testing. Training AUC is 1.000, test AUC is 0.998. The Alpine Plant Group environmental inputs are:

- elevation
- slope
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average annual precipitation
- May minimum temperature
- soil pH
- soil texture
- spring snow depth
- number of frost days

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Draba globosa* habitat model. Raster digital data.

Thumbnail:



Draba grayana habitat model

Predictive species distribution model of potential habitat for *Draba grayana* in Colorado.

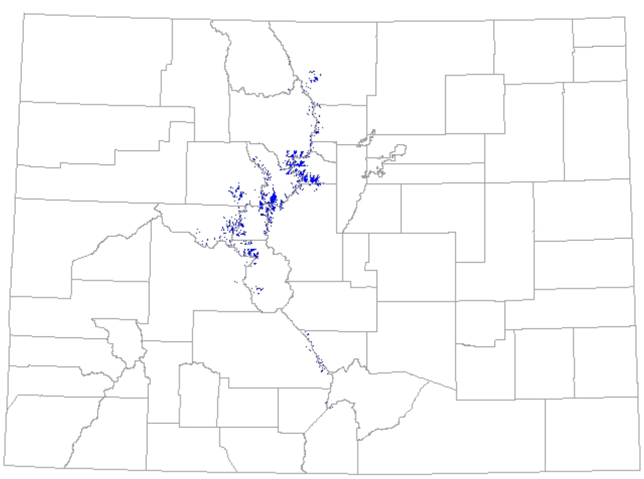
This is a MaxEnt (v. 3.3.3e) inductive model using the Alpine Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.232 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 16 EORs, which were translated into 27 input points. 22 input points used for training, 5 for testing. Training AUC is 0.998, test AUC is 0.992. The Alpine Plant Group environmental inputs are:

- elevation
- slope
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average annual precipitation
- May minimum temperature
- soil pH
- soil texture
- spring snow depth
- number of frost days

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Draba grayana* habitat model. Raster digital data.

Thumbnail:



Draba oligosperma habitat model

Predictive species distribution model of potential habitat for *Draba oligosperma* in Colorado.

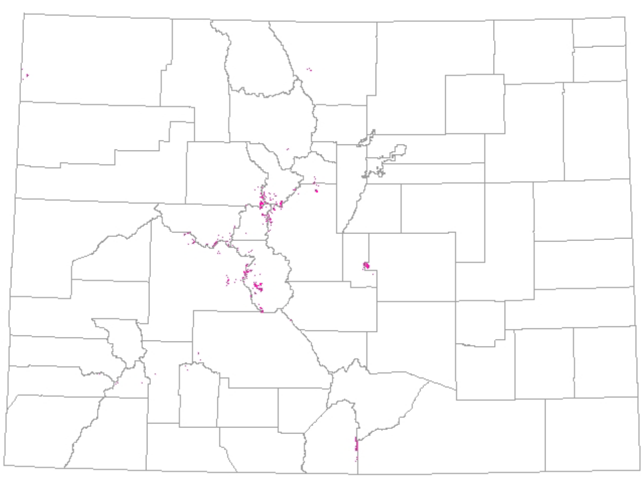
This is a MaxEnt (v. 3.3.3e) inductive model using the Alpine Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.462 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado botany professionals.

The model is based on 8 EORs, which were translated into 22 input points. 18 input points used for training, 4 for testing. Training AUC is 0.999, test AUC is 0.936. The Alpine Plant Group environmental inputs are:

- elevation
- slope
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average annual precipitation
- May minimum temperature
- soil pH
- soil texture
- spring snow depth
- number of frost days

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Draba oligosperma* habitat model. Raster digital data.

Thumbnail:



Draba porsildii habitat model

Predictive species distribution model of potential habitat for *Draba porsildii* in Colorado.

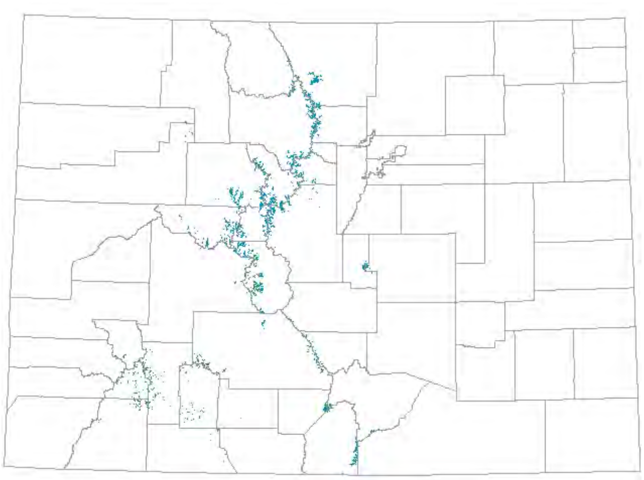
This is a MaxEnt (v. 3.3.3e) inductive model using the Alpine Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.220 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 6 EORs, which were translated into 17 input points. 14 input points used for training, 3 for testing. Training AUC is 0.997, test AUC is 0.998. The Alpine Plant Group environmental inputs are:

- elevation
- slope
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average annual precipitation
- May minimum temperature
- soil pH
- soil texture
- spring snow depth
- number of frost days

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Draba porsildii* habitat model. Raster digital data.

Thumbnail:



Draba streptobrachia habitat model

Predictive species distribution model of potential habitat for *Draba streptobrachia* in Colorado.

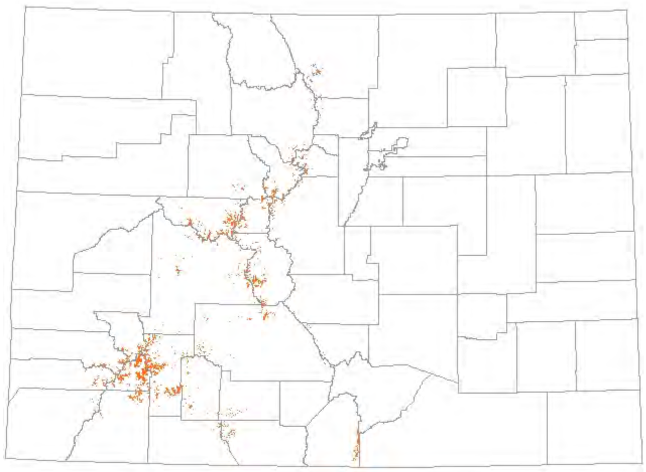
This is a MaxEnt (v. 3.3.3e) inductive model using the Alpine Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.335 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado botany professionals.

The model is based on 33 EORs, which were translated into 46 input points. 37 input points used for training, 9 for testing. Training AUC is 0.995, test AUC is 0.991. The Alpine Plant Group environmental inputs are:

- elevation
- slope
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average annual precipitation
- May minimum temperature
- soil pH
- soil texture
- spring snow depth
- number of frost days

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Draba streptobrachia* habitat model. Raster digital data.

Thumbnail:



Eriophorum altaicum var. *neogaeum* habitat model

Predictive species distribution model of potential habitat for *Eriophorum altaicum* var. *neogaeum* in Colorado.

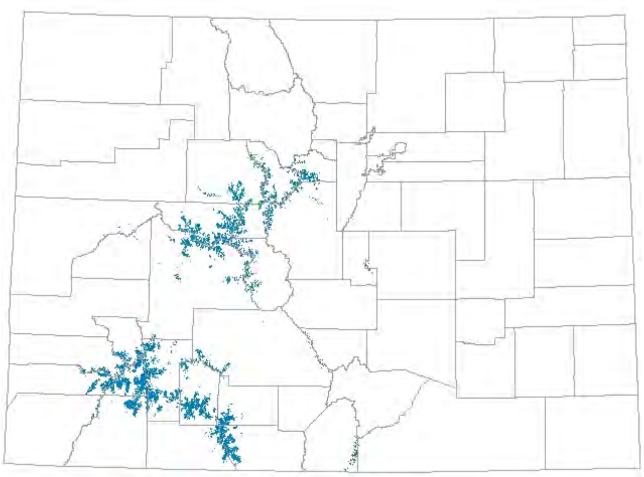
This is a MaxEnt (v. 3.3.3e) inductive model using the Wetland Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.056 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 31 EORs, which were translated into 62 input points. 50 input points used for training, 12 for testing. Training AUC is 0.994, test AUC is 0.996. The Wetland Plant Group environmental inputs are:

- distance to water
- distance to wetland
- soil pH
- elevation
- slope
- average annual precipitation
- proportion of wet days
- growing degree days
- April minimum temperature
- May minimum temperature

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Eriophorum altaicum* var. *neogaeum* habitat model. Raster digital data.

Thumbnail:



Eriophorum gracile habitat model

Predictive species distribution model of potential habitat for *Eriophorum gracile* in Colorado.

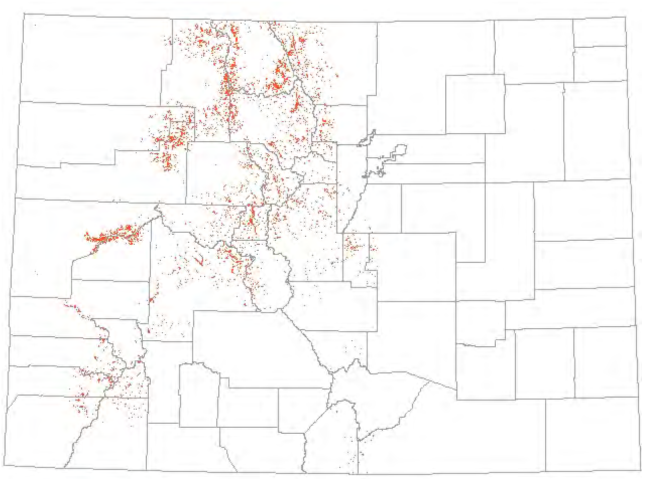
This is a MaxEnt (v. 3.3.3e) inductive model using the Wetland Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.121 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 13 EORs, which were translated into 20 input points. 16 input points used for training, 4 for testing. Training AUC is 0.996, test AUC is 0.995. The Wetland Plant Group environmental inputs are:

- distance to water
- distance to wetland
- soil pH
- elevation
- slope
- average annual precipitation
- proportion of wet days
- growing degree days
- April minimum temperature
- May minimum temperature

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Eriophorum gracile* habitat model. Raster digital data.

Thumbnail:



Eutrema penlandii habitat model

Predictive species distribution model of potential habitat for *Eutrema penlandii* in Colorado. Species also known as *Eutrema edwardsii* ssp. *penlandii*.

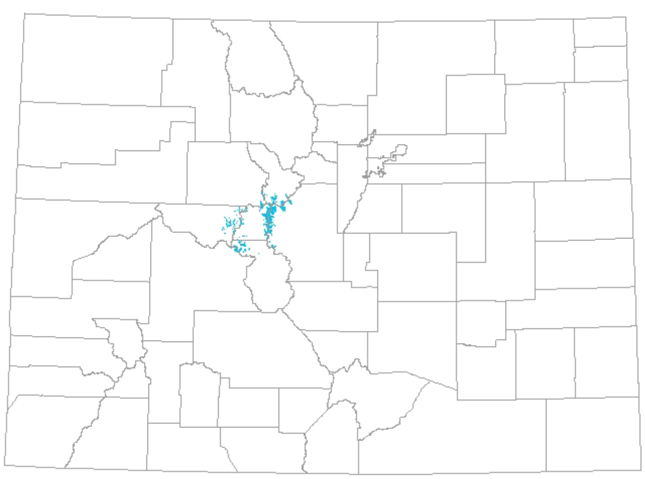
This is a MaxEnt (v. 3.3.3e) inductive model using the Alpine Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.154 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado botany professionals.

The model is based on 12 EORs, which were translated into 61 input points. 49 input points used for training, 12 for testing. Training AUC is 0.997, test AUC is 0.997. The Alpine Plant Group environmental inputs are:

- elevation
- slope
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average annual precipitation
- May minimum temperature
- soil pH
- soil texture
- spring snow depth
- number of frost days

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Eutrema penlandii* habitat model. Raster digital data.

Thumbnail:



Ipomopsis globularis habitat model

Predictive species distribution model of potential habitat for *Ipomopsis globularis* in Colorado.

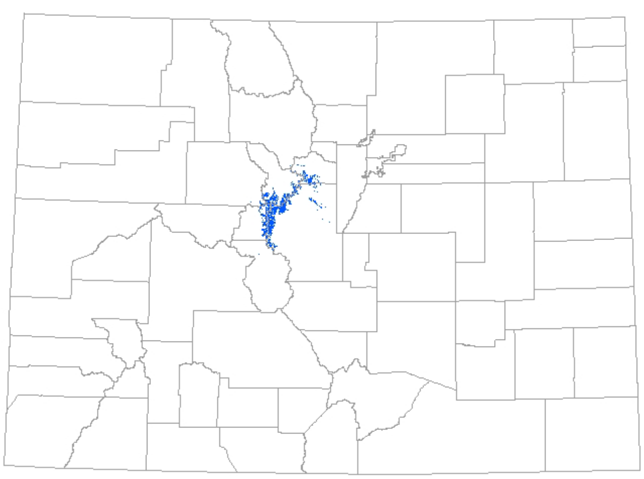
This is a MaxEnt (v. 3.3.3e) inductive model using the Alpine Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.265 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 4 EORs, which were translated into 59 input points. 48 input points used for training, 11 for testing. Training AUC is 0.997, test AUC is 0.997. The Alpine Plant Group environmental inputs are:

- elevation
- slope
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average annual precipitation
- May minimum temperature
- soil pH
- soil texture
- spring snow depth
- number of frost days

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Ipomopsis globularis* habitat model. Raster digital data.

Thumbnail:



Machaeranthera coloradoensis habitat model

Predictive species distribution model of potential habitat for *Machaeranthera coloradoensis* in Colorado.

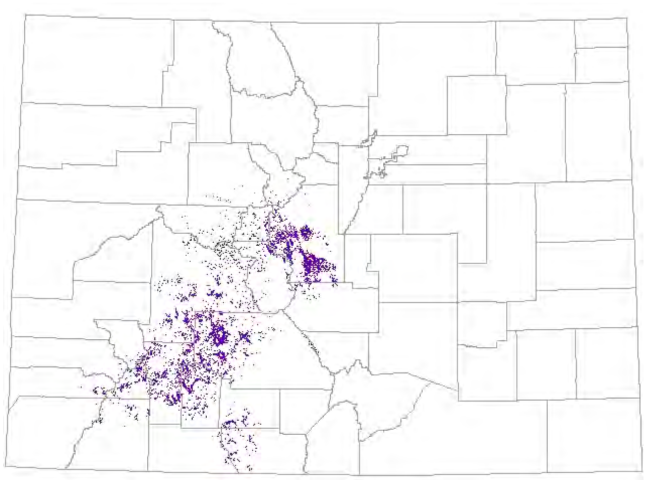
This is a MaxEnt (v. 3.3.3e) inductive model using the General Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.275 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified by a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 27 EORs, which were translated into 70 input points. 56 input points used for training, 14 for testing. Training AUC is 0.993, test AUC is 0.989. The General Plant Group environmental inputs are:

- elevation
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average spring precipitation
- average summer precipitation
- proportion of wet days
- growing degree days
- April minimum temperature
- May minimum temperature

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Machaeranthera coloradoensis* habitat model. Raster digital data.

Thumbnail:



Mentzelia speciosa habitat model

Predictive species distribution model of potential habitat for *Mentzelia speciosa* in Colorado. Species also known as *Nuttallia speciosa*.

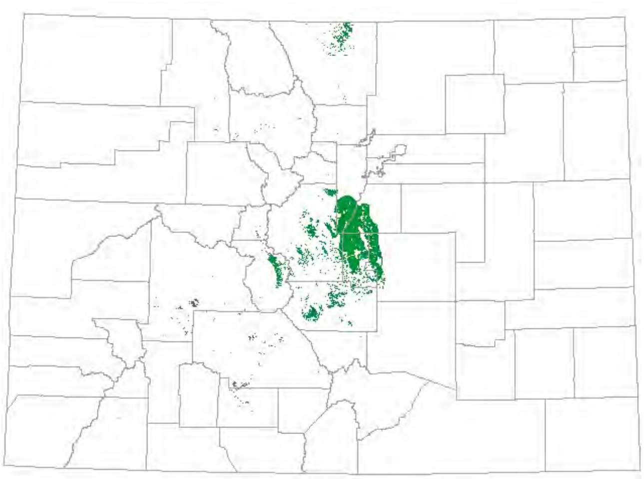
This is a MaxEnt (v. 3.3.3e) inductive model using the General Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.092 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado botany professionals.

The model is based on 19 EORs, which were translated into 47 input points. 38 input points used for training, 9 for testing. Training AUC is 0.997, test AUC is 0.990. The General Plant Group environmental inputs are:

- elevation
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average spring precipitation
- average summer precipitation
- proportion of wet days
- growing degree days
- April minimum temperature
- May minimum temperature

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Mentzelia speciosa* habitat model. Raster digital data.

Thumbnail:



Mimulus gemmiparus habitat model

Predictive species distribution model of potential habitat for *Mimulus gemmiparus* in Colorado.

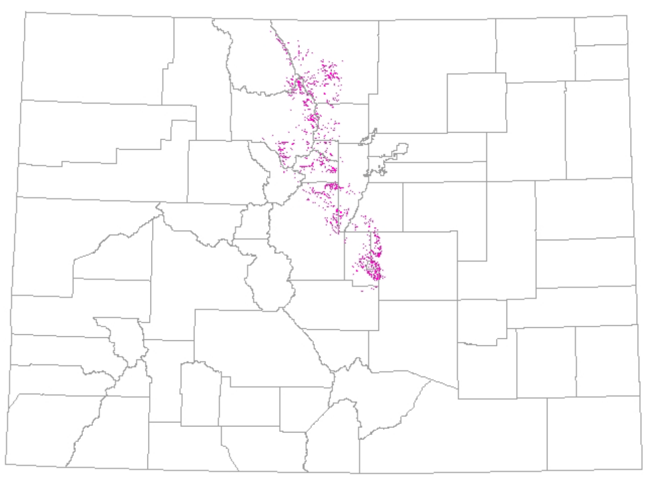
This is a MaxEnt (v. 3.3.3e) inductive model using the Cliff Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Initial cut-off of 0.048 was deemed too low, so that model results with a value of 0.25 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 8 EORs, which were translated into 22 input points. 18 input points used for training, 4 for testing. Training AUC is 0.997, test AUC is 0.980. The Cliff Plant Group environmental inputs are:

- elevation
- aspect (as a measure of northness and eastness)
- geology
- average spring precipitation
- average summer precipitation
- April minimum temperature
- May minimum temperature
- local relief
- landform

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Mimulus gemmiparus* habitat model. Raster digital data.

Thumbnail:



Oligoneuron album habitat model

Predictive species distribution model of potential habitat for *Oligoneuron album* in Colorado. Species also known as *Unamia alba*.

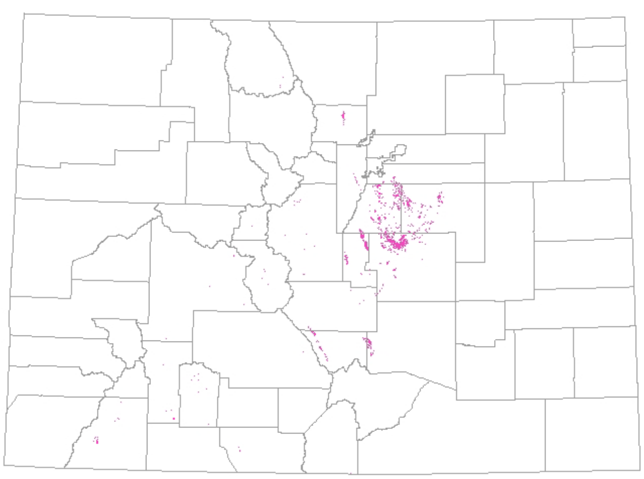
This is a MaxEnt (v. 3.3.3e) inductive model using the General Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.524 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado botany professionals.

The model is based on 5 EORs, which were translated into nine input points. 8 input points used for training, 1 for testing. Training AUC is 0.999, test AUC is 1.000. The General Plant Group environmental inputs are:

- elevation
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average spring precipitation
- average summer precipitation
- proportion of wet days
- growing degree days
- April minimum temperature
- May minimum temperature

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Oligoneuron album* habitat model. Raster digital data.

Thumbnail:



Packera pauciflora habitat model

Predictive species distribution model of potential habitat for *Packera pauciflora* in Colorado.

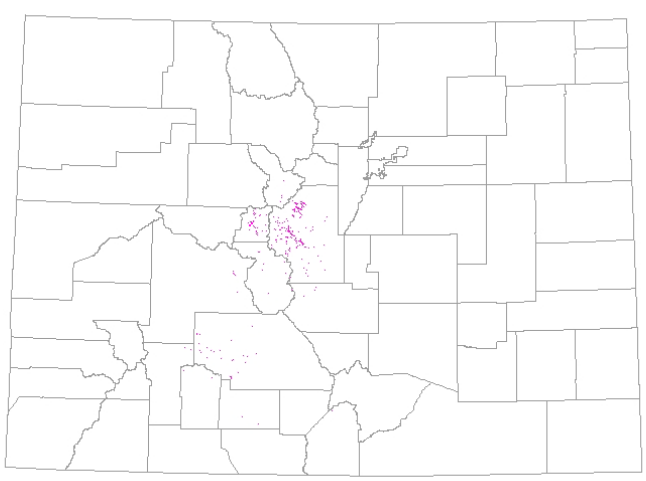
This is a MaxEnt (v. 3.3.3e) inductive model using the Wetland Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.452 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado botany professionals.

The model is based on 12 EORs, which were translated into 14 input points. 12 input points used for training, 2 for testing. Training AUC is 0.999, test AUC is 0.985. The Wetland Plant Group environmental inputs are:

- distance to water
- distance to wetland
- soil pH
- elevation
- slope
- average annual precipitation
- proportion of wet days
- growing degree days
- April minimum temperature
- May minimum temperature

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Packera pauciflora* habitat model. Raster digital data.

Thumbnail:



Parnassia kotzebuei habitat model

Predictive species distribution model of potential habitat for *Parnassia kotzebuei* in Colorado.

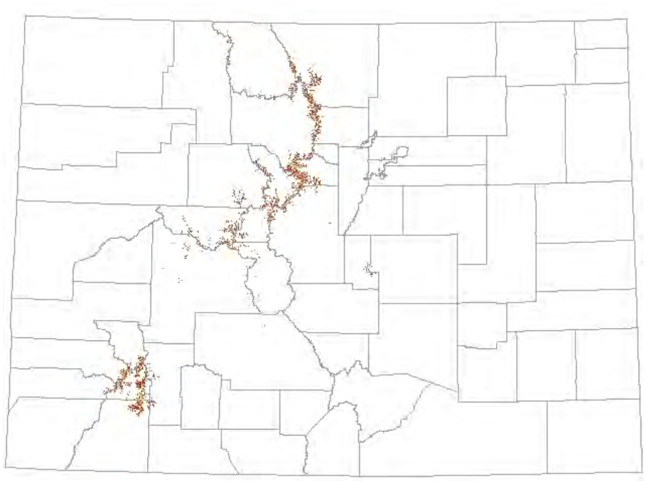
This is a MaxEnt (v. 3.3.3e) inductive model using the Wetland Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.241 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 8 EORs, which were translated into 13 input points. 11 input points used for training, 2 for testing. Training AUC is 0.998, test AUC is 0.993. The Wetland Plant Group environmental inputs are:

- distance to water
- distance to wetland
- soil pH
- elevation
- slope
- average annual precipitation
- proportion of wet days
- growing degree days
- April minimum temperature
- May minimum temperature

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Parnassia kotzebuei* habitat model. Raster digital data.

Thumbnail:



***Physaria alpina* habitat model**

Predictive species distribution model of potential habitat for *Physaria alpina* in Colorado.

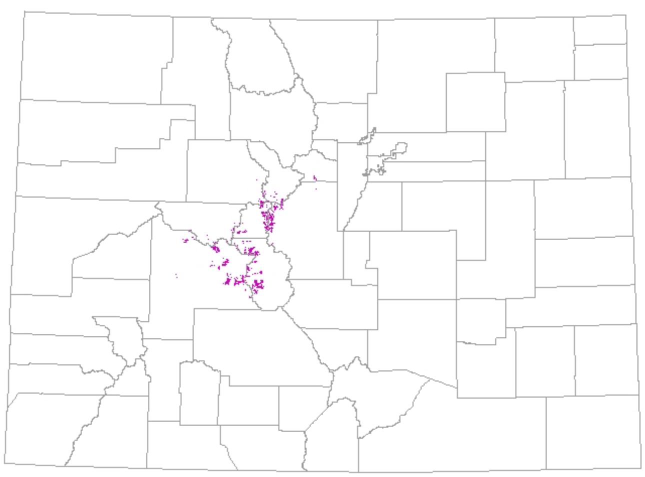
This is a MaxEnt (v. 3.3.3e) inductive model using the Alpine Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.320 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 5 EORs, which were translated into ten input points. 8 input points used for training, 2 for testing. Training AUC is 0.999, test AUC is 0.999. The Alpine Plant Group environmental inputs are:

- elevation
- slope
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average annual precipitation
- May minimum temperature
- soil pH
- soil texture
- spring snow depth
- number of frost days

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Physaria alpina* habitat model. Raster digital data.

Thumbnail:



Potentilla ambigens habitat model

Predictive species distribution model of potential habitat for *Potentilla ambigens* in Colorado.

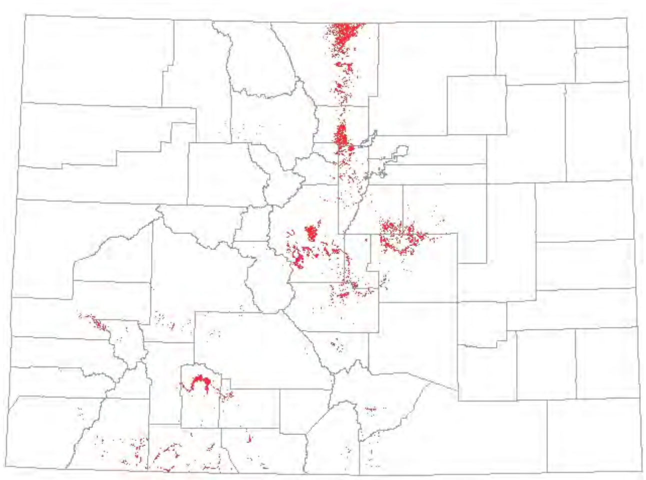
This is a MaxEnt (v. 3.3.3e) inductive model using the General Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Initial cut-off of 0.060 was deemed too low, so that model results with a value of 0.20 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 11 EORs, which were translated into 34 input points. 28 input points used for training, 6 for testing. Training AUC is 0.997, test AUC is 0.983. The General Plant Group environmental inputs are:

- elevation
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average spring precipitation
- average summer precipitation
- proportion of wet days
- growing degree days
- April minimum temperature
- May minimum temperature

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Potentilla ambigens* habitat model. Raster digital data.

Thumbnail:



Potentilla rupincola habitat model

Predictive species distribution model of potential habitat for *Potentilla rupincola* in Colorado.

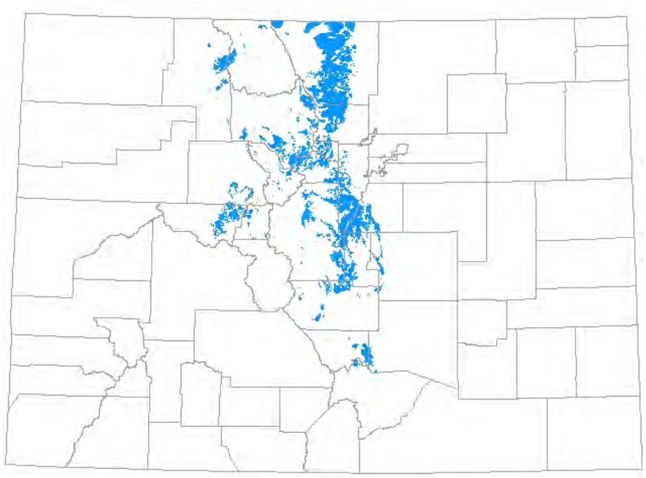
This is a MaxEnt (v. 3.3.3e) inductive model using the Cliff Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.028 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 18 EORs, which were translated into 46 input points. 37 input points used for training, 9 for testing. Training AUC is 0.995, test AUC is 0.995. The Cliff Plant Group environmental inputs are:

- elevation
- aspect (as a measure of northness and eastness)
- geology
- average spring precipitation
- average summer precipitation
- April minimum temperature
- May minimum temperature
- local relief
- landform

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Potentilla rupincola* habitat model. Raster digital data.

Thumbnail:



Primula egaliksensis habitat model

Predictive species distribution model of potential habitat for *Primula egaliksensis* in Colorado.

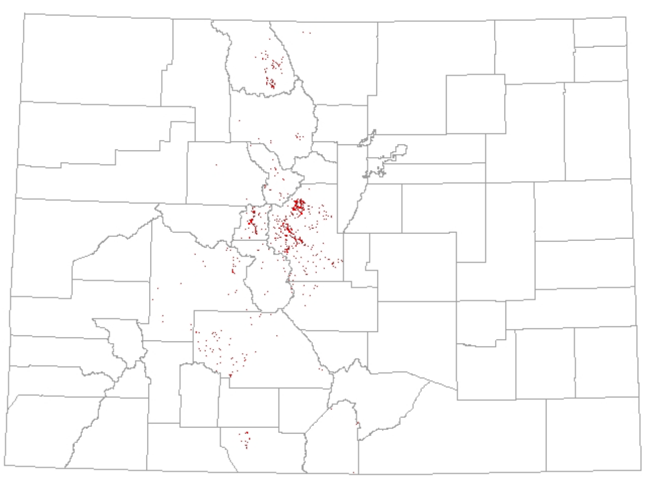
This is a MaxEnt (v. 3.3.3e) inductive model using the Wetland Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.179 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 11 EORs, which were translated into 17 input points. 14 input points used for training, 3 for testing. Training AUC is 0.999, test AUC is 0.991. The Wetland Plant Group environmental inputs are:

- distance to water
- distance to wetland
- soil pH
- elevation
- slope
- average annual precipitation
- proportion of wet days
- growing degree days
- April minimum temperature
- May minimum temperature

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Primula egaliksensis* habitat model. Raster digital data.

Thumbnail:



Ptilagrostis porteri habitat model

Predictive species distribution model of potential habitat for *Ptilagrostis porteri* in Colorado.

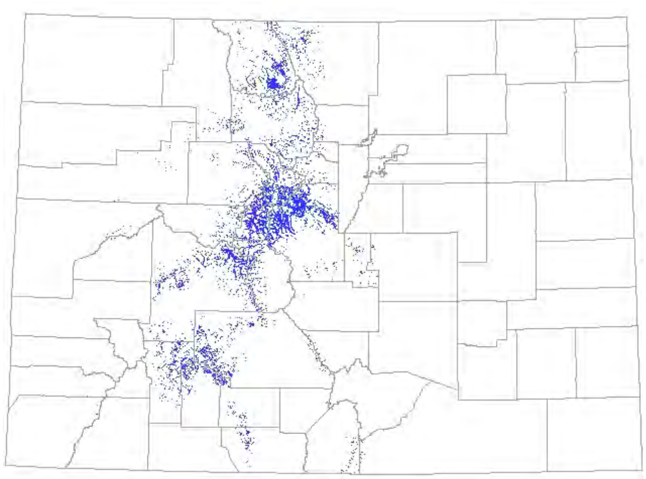
This is a MaxEnt (v. 3.3.3e) inductive model using the Wetland Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.064 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado botany professionals.

The model is based on 21 EORs, which were translated into 38 input points. 31 input points used for training, 7 for testing. Training AUC is 0.996, test AUC is 0.990. The Wetland Plant Group environmental inputs are:

- distance to water
- distance to wetland
- soil pH
- elevation
- slope
- average annual precipitation
- proportion of wet days
- growing degree days
- April minimum temperature
- May minimum temperature

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Ptilagrostis porteri* habitat model. Raster digital data.

Thumbnail:



Ranunculus karelinii habitat model

Predictive species distribution model of potential habitat for *Ranunculus karelinii* in Colorado. Species also known as Ranunculus gelidus ssp. grayi.

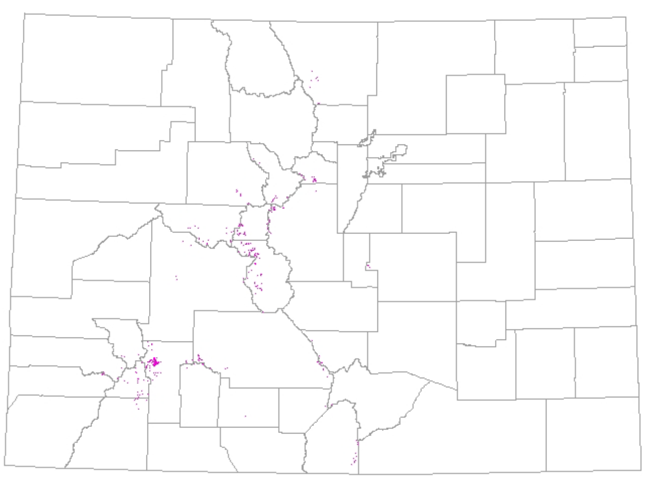
This is a MaxEnt (v. 3.3.3e) inductive model using the Alpine Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.410 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado botany professionals.

The model is based on 7 EORs, which were translated into nine input points. 8 input points used for training, 1 for testing. Training AUC is 0.999, test AUC is 0.995. The Alpine Plant Group environmental inputs are:

- elevation
- slope
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average annual precipitation
- May minimum temperature
- soil pH
- soil texture
- spring snow depth
- number of frost days

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Ranunculus karelinii* habitat model. Raster digital data.

Thumbnail:



Ribes americanum habitat model

Predictive species distribution model of potential habitat for *Ribes americanum* in Colorado.

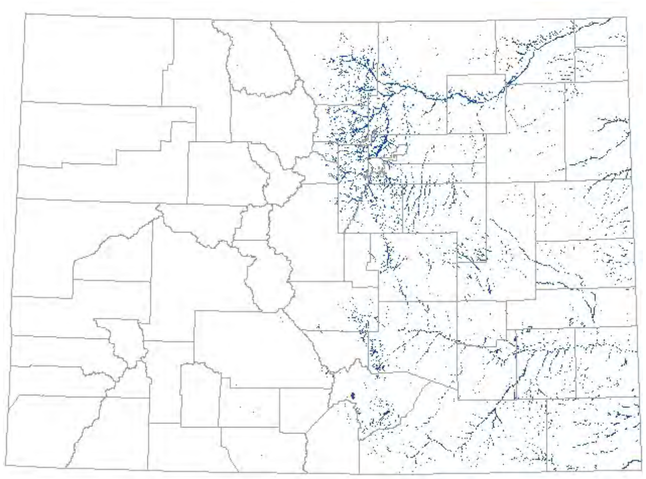
This is a MaxEnt (v. 3.3.3e) inductive model using the Wetland Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.173 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 7 EORs, which were translated into ten input points. 8 input points used for training, 2 for testing. Training AUC is 0.982, test AUC is 0.995. The Wetland Plant Group environmental inputs are:

- distance to water
- distance to wetland
- soil pH
- elevation
- slope
- average annual precipitation
- proportion of wet days
- growing degree days
- April minimum temperature
- May minimum temperature

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Ribes americanum* habitat model. Raster digital data.

Thumbnail:



Salix candida habitat model

Predictive species distribution model of potential habitat for *Salix candida* in Colorado.

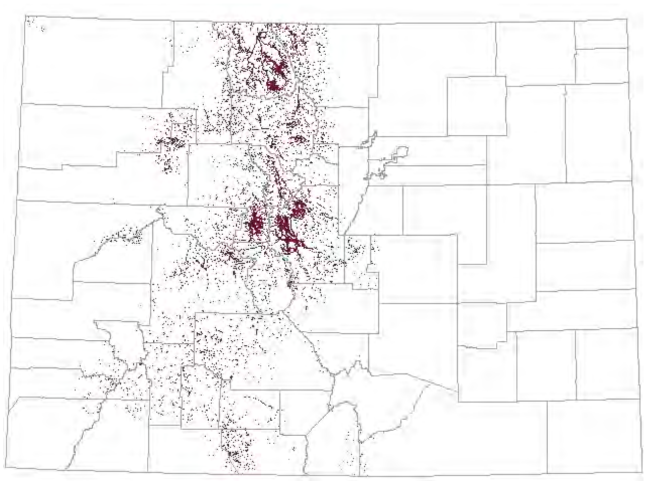
This is a MaxEnt (v. 3.3.3e) inductive model using the Wetland Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.119 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado botany professionals.

The model is based on 17 EORs, which were translated into 20 input points. 16 input points used for training, 4 for testing. Training AUC is 0.994, test AUC is 0.996. The Wetland Plant Group environmental inputs are:

- distance to water
- distance to wetland
- soil pH
- elevation
- slope
- average annual precipitation
- proportion of wet days
- growing degree days
- April minimum temperature
- May minimum temperature

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Salix candida* habitat model. Raster digital data.

Thumbnail:



Salix serissima habitat model

Predictive species distribution model of potential habitat for *Salix serissima* in Colorado.

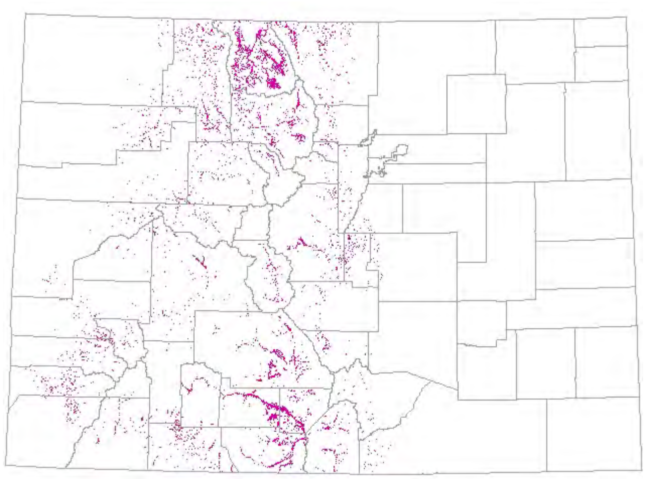
This is a MaxEnt (v. 3.3.3e) inductive model using the Wetland Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.412 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 6 EORs, which were translated into six input points. 5 input points used for training, 1 for testing. Training AUC is 0.984, test AUC is 0.999. The Wetland Plant Group environmental inputs are:

- distance to water
- distance to wetland
- soil pH
- elevation
- slope
- average annual precipitation
- proportion of wet days
- growing degree days
- April minimum temperature
- May minimum temperature

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Salix serissima* habitat model. Raster digital data.

Thumbnail:



Saussurea weberi habitat model

Predictive species distribution model of potential habitat for *Saussurea weberi* in Colorado.

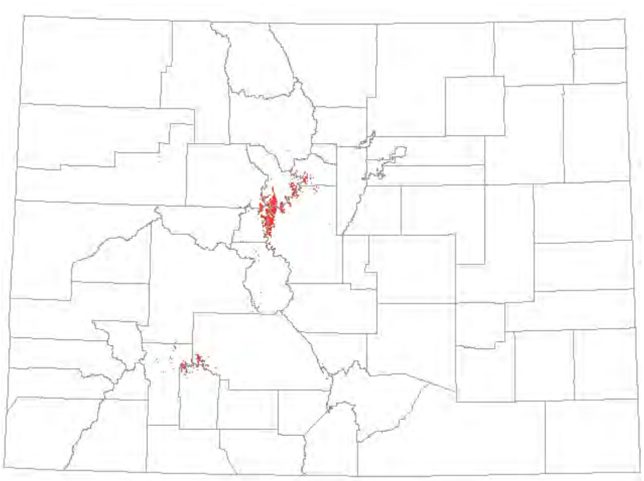
This is a MaxEnt (v. 3.3.3e) inductive model using the Alpine Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.167 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado botany professionals.

The model is based on 8 EORs, which were translated into 53 input points. 43 input points used for training, 10 for testing. Training AUC is 0.998, test AUC is 0.997. The Alpine Plant Group environmental inputs are:

- elevation
- slope
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average annual precipitation
- May minimum temperature
- soil pH
- soil texture
- spring snow depth
- number of frost days

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Saussurea weberi* habitat model. Raster digital data.

Thumbnail:



Sisyrinchium pallidum habitat model

Predictive species distribution model of potential habitat for *Sisyrinchium pallidum* in Colorado.

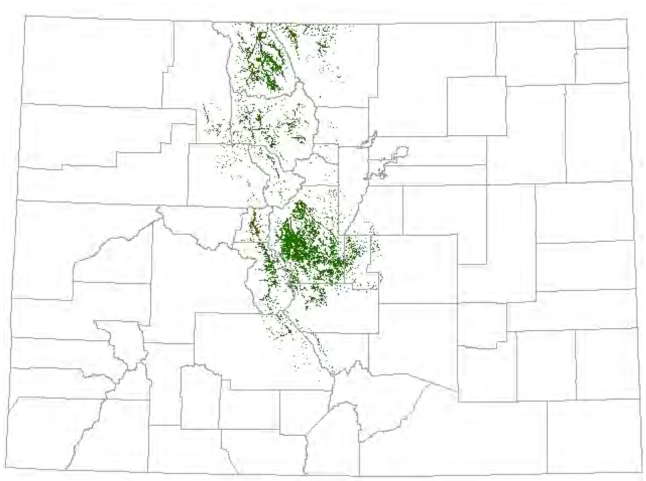
This is a MaxEnt (v. 3.3.3e) inductive model using the Wetland Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Initial cut-off of 0.089 was deemed too low, so that model results with a value of 0.25 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 40 EORs, which were translated into 68 input points. 55 input points used for training, 13 for testing. Training AUC is 0.973, test AUC is 0.989. The Wetland Plant Group environmental inputs are:

- distance to water
- distance to wetland
- soil pH
- elevation
- slope
- average annual precipitation
- proportion of wet days
- growing degree days
- April minimum temperature
- May minimum temperature

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Sisyrinchium pallidum* habitat model. Raster digital data.

Thumbnail:



Sphagnum girgensohnii habitat model

Predictive species distribution model of potential habitat for *Sphagnum girgensohnii* in Colorado.

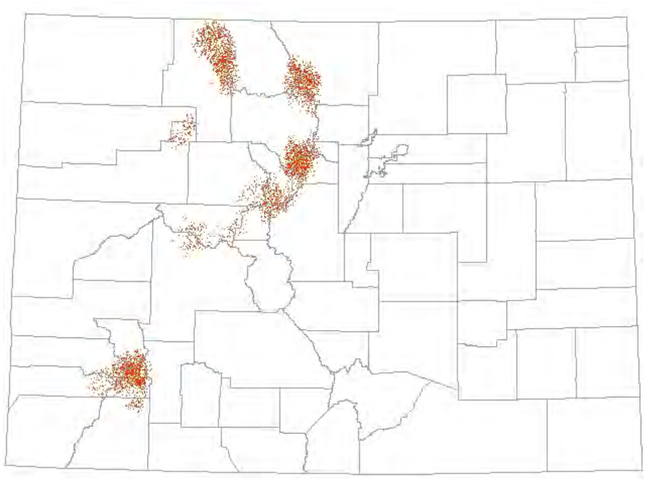
This is a MaxEnt (v. 3.3.3e) inductive model using the Wetland Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.210 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado botany professionals.

The model is based on 5 EORs, which were translated into 11 input points. 9 input points used for training, 2 for testing. Training AUC is 0.996, test AUC is 0.997. The Wetland Plant Group environmental inputs are:

- distance to water
- distance to wetland
- soil pH
- elevation
- slope
- average annual precipitation
- proportion of wet days
- growing degree days
- April minimum temperature
- May minimum temperature

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Sphagnum girgensohnii* habitat model. Raster digital data.

Thumbnail:



Telesonix jamesii habitat model

Predictive species distribution model of potential habitat for *Telesonix jamesii* in Colorado.

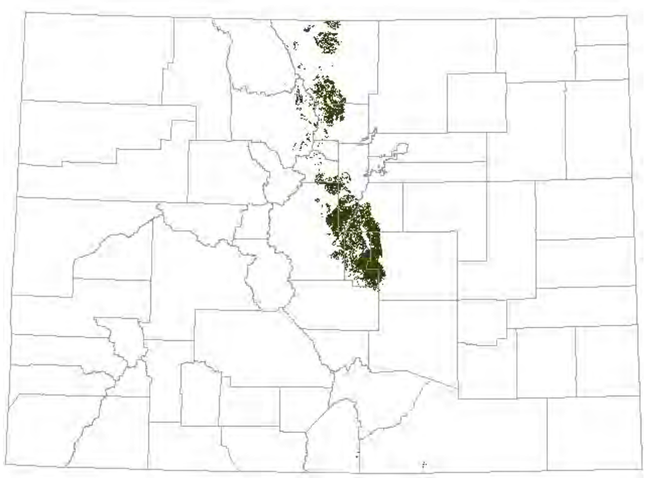
This is a MaxEnt (v. 3.3.3e) inductive model using the Cliff Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.126 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 15 EORs, which were translated into 67 input points. 54 input points used for training, 13 for testing. Training AUC is 0.997, test AUC is 0.997. The Cliff Plant Group environmental inputs are:

- elevation
- aspect (as a measure of northness and eastness)
- geology
- average spring precipitation
- average summer precipitation
- April minimum temperature
- May minimum temperature
- local relief
- landform

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Telesonix jamesii* habitat model. Raster digital data.

Thumbnail:



Townsendia rothrockii habitat model

Predictive species distribution model of potential habitat for *Townsendia rothrockii* in Colorado.

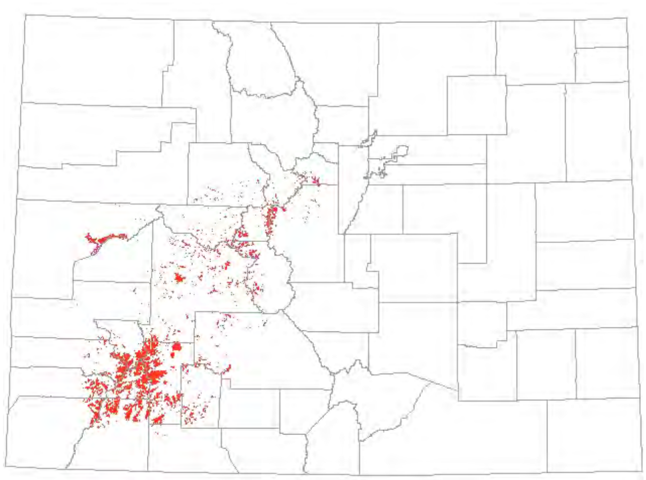
This is a MaxEnt (v. 3.3.3e) inductive model using the General Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.121 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado botany professionals.

The model is based on 15 EORs, which were translated into 24 input points. 20 input points used for training, 4 for testing. Training AUC is 0.996, test AUC is 0.992. The General Plant Group environmental inputs are:

- elevation
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average spring precipitation
- average summer precipitation
- proportion of wet days
- growing degree days
- April minimum temperature
- May minimum temperature

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Townsendia rothrockii* habitat model. Raster digital data.

Thumbnail:



Trichophorum pumilum habitat model

Predictive species distribution model of potential habitat for *Trichophorum pumilum* in Colorado.

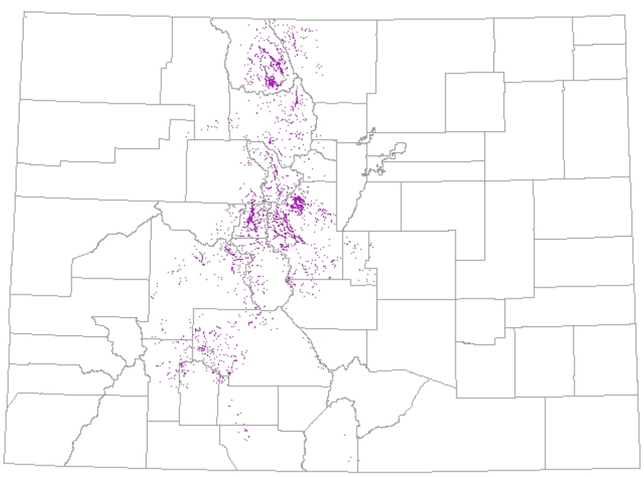
This is a MaxEnt (v. 3.3.3e) inductive model using the Wetland Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.203 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado botany professionals.

The model is based on 13 EORs, which were translated into 17 input points. 14 input points used for training, 3 for testing. Training AUC is 0.997, test AUC is 0.995. The Wetland Plant Group environmental inputs are:

- distance to water
- distance to wetland
- soil pH
- elevation
- slope
- average annual precipitation
- proportion of wet days
- growing degree days
- April minimum temperature
- May minimum temperature

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Trichophorum pumilum* habitat model. Raster digital data.

Thumbnail:



Viola pedatifida habitat model

Predictive species distribution model of potential habitat for *Viola pedatifida* in Colorado.

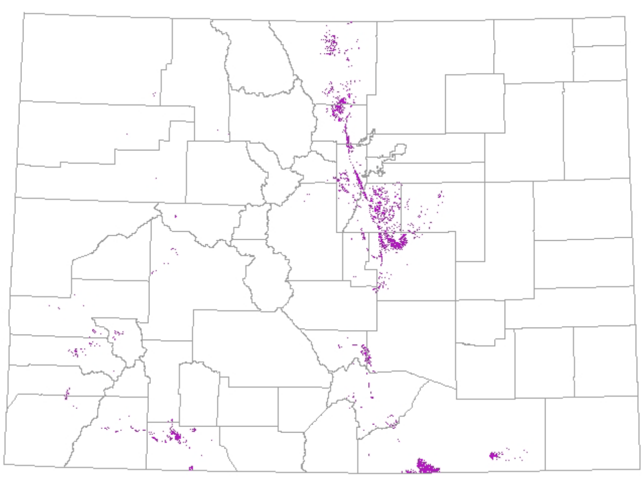
This is a MaxEnt (v. 3.3.3e) inductive model using the General Plant Group environmental inputs. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.282 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado botany professionals.

The model is based on 20 EORs, which were translated into 46 input points. 37 input points used for training, 9 for testing. Training AUC is 0.997, test AUC is 0.971. The General Plant Group environmental inputs are:

- elevation
- aspect (as a measure of northness and eastness)
- vegetation type
- geology
- depth to bedrock
- average spring precipitation
- average summer precipitation
- proportion of wet days
- growing degree days
- April minimum temperature
- May minimum temperature

For complete information, see the full metadata for this layer and the related report. *Citation:* Colorado Natural Heritage Program. 2/2012. *Viola pedatifida* habitat model. Raster digital data.

Thumbnail:



American Peregrine Falcon habitat model

Predictive species distribution model of potential nesting and roosting habitat for American Peregrine Falcon (*Falco peregrinus anatum*) in Colorado.

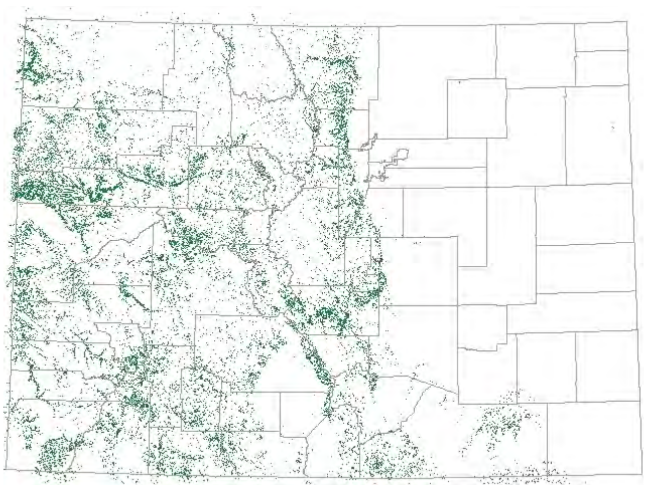
This is a MaxEnt (v. 3.3.3e) inductive model. Environmental Inputs used are listed below. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.081 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado zoology and wildlife professionals.

The model is based on 77 EORs, which were translated into 151 input points. 121 input points used for training, 30 for testing. Training AUC is 0.972, test AUC is 0.964. Environmental Inputs:

- elevation
- vegtype
- landform
- distance to water
- slope

Citation: Colorado Natural Heritage Program. 2/2012. American Peregrine Falcon habitat model. Raster digital data.

Thumbnail:



Bald Eagle habitat model

Predictive species distribution model of potential habitat for Bald Eagle (*Haliaeetus leucocephalus*) in Colorado.

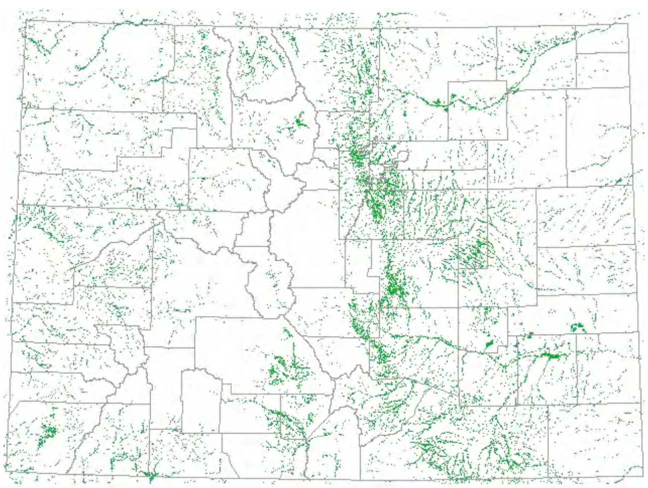
This is a MaxEnt (v. 3.3.3e) inductive model. Environmental Inputs used are listed below. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Initial cut-off of 0.102 was deemed too low, so that model results with a value of 0.214 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado zoology and wildlife professionals.

The model is based on 106 EORs, which were translated into 413 input points. 331 input points used for training, 82 for testing. Training AUC is 0.941, test AUC is 0.943. Environmental Inputs:

- elevation
- vegtype (LandFire)
- landform
- distance to water
- distance to wetlands

Citation Colorado Natural Heritage Program. 2/2012. Bald Eagle habitat model. Raster digital data.

Thumbnail:



Boreal Owl habitat model

Predictive species distribution model of potential habitat for Boreal Owl (*Aegolius funereus*) in Colorado.

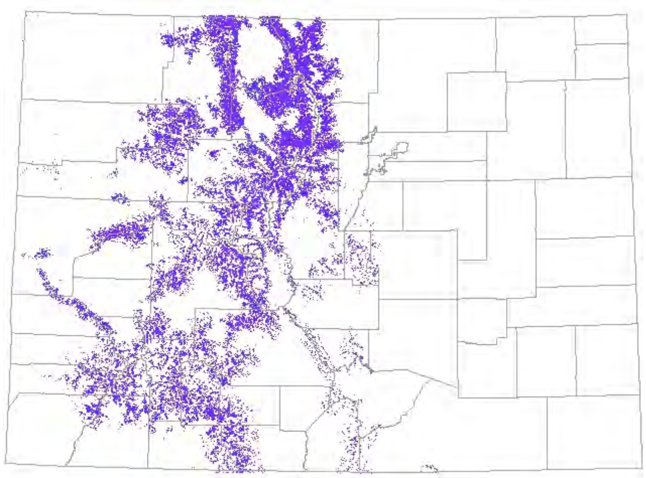
This is a MaxEnt (v. 3.3.3e) inductive model. Environmental Inputs used are listed below. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Initial cut-off of 0.221 was deemed too low, so that model results with a value of 0.292 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado zoology and wildlife professionals.

The model is based on 103 EORs, which were translated into 189 input points. 152 input points used for training, 37 for testing. Training AUC is 0.954, test AUC is 0.925. Environmental Inputs:

- elevation
- vegtype
- landform
- distance to water
- relative forest cover

Citation: Colorado Natural Heritage Program. 2/2012. Boreal Owl habitat model. Raster digital data.

Thumbnail:



Boreal toad habitat model

Predictive species distribution model of potential habitat for boreal toad (*Anaxyrus boreas*) in Colorado.

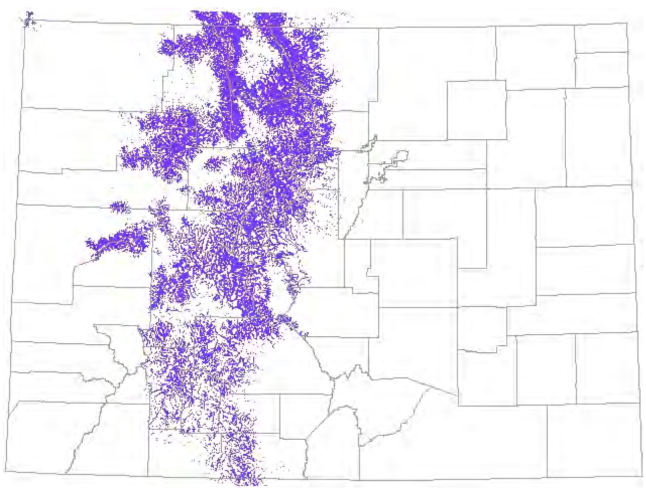
This is a MaxEnt (v. 3.3.3e) inductive model. Environmental Inputs used are listed below. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.150 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado zoology and wildlife professionals.

The model is based on 120 EORs, which were translated into 652 input points. 522 input points used for training, 130 for testing. Training AUC is 0.954, test AUC is 0.951. Environmental Inputs:

- elevation
- vegtype
- landform
- distance to water
- summer precipitation
- growing degree days

Citation: Colorado Natural Heritage Program. 2/2012. Boreal toad habitat model. Raster digital data.

Thumbnail:



Burrowing Owl habitat model

Predictive species distribution model of potential habitat for Burrowing Owl (*Athene cunicularia*) in Colorado.

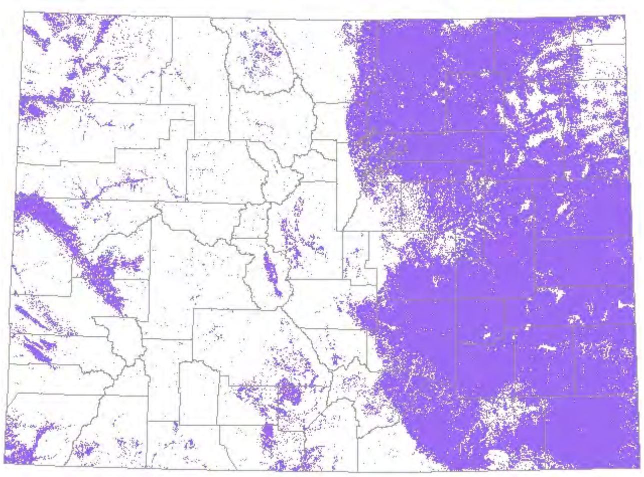
This is a MaxEnt (v. 3.3.3e) inductive model. Environmental Inputs used are listed below. The state of Colorado was the modeling extent. CNHP Observation records were used as known locations for the species. Initial cut-off of 0.202 was deemed too high, so that model results with a value of 0.066 or greater were retained for use in Marxan, based on model logs and expert review. Open water was masked out to prevent its selection in the final model. This model has been reviewed by Colorado zoology and wildlife professionals.

The model is based on 484 Observations. 388 input points used for training, 96 for testing. Training AUC is 0.922, test AUC is 0.901. Environmental Inputs:

- elevation
- vegtype
- landform
- distance to water
- distance to prairie dog towns
- slope
- soil pH
- soil texture

Citation: Colorado Natural Heritage Program. 2/2012. Burrowing Owl habitat model. Raster digital data.

Thumbnail:



Ferruginous Hawk habitat model

Deductive model of potential habitat for Ferruginous Hawk (*Buteo regalis*) in Colorado.

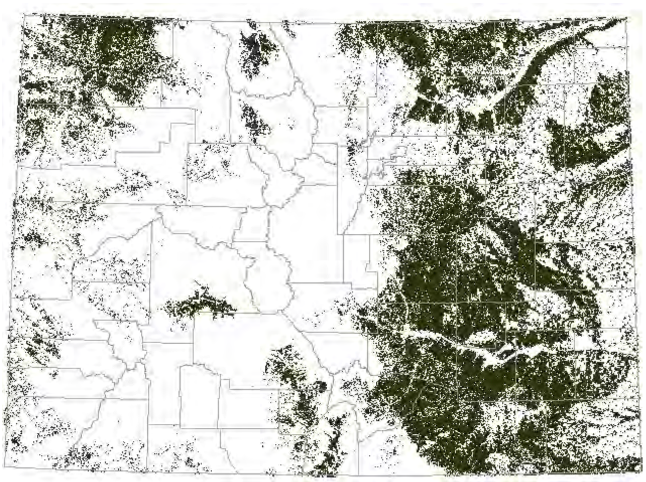
Attempts were made to create an inductive predictive species distribution model for this species using MaxEnt (v 3.3.3e), but a good fit could not be obtained with existing input data. The SWReGAP Vertebrate Habitat Model for the species was also reviewed and deemed too inaccurate as well. Therefore, a simple deductive model using vegetation type only was created, based on methods used in a previous CNHP project where species habitat was modeled for the Shortgrass Prairie Partnership.

The following SWReGAP landcover types were selected.

- Inter-Mountain Basins Active and Stabilized Dune
- Western Great Plains Sandhill Shrubland
- Inter-Mountain Basins Big Sagebrush Shrubland
- Western Great Plains Foothill and Piedmont Grassland
- Central Mixedgrass Prairie
- Western Great Plains Shortgrass Prairie
- Western Great Plains Sandhill Prairie
- Inter-Mountain Basins Greasewood Flat

Citation: Colorado Natural Heritage Program. 2/2012. Ferruginous Hawk habitat model. Raster digital data.

Thumbnail:



Greenback cutthroat trout habitat model

Predictive species distribution model of potential habitat for greenback cutthroat (*Oncorhynchus clarkii stomias*) trout in Colorado.

This is a MaxEnt (v. 3.3.3e) inductive model. Environmental Inputs used are listed below. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Initial cut-off of 0.139 was deemed too low, so that model results with a value of 0.333 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado zoology and wildlife professionals.

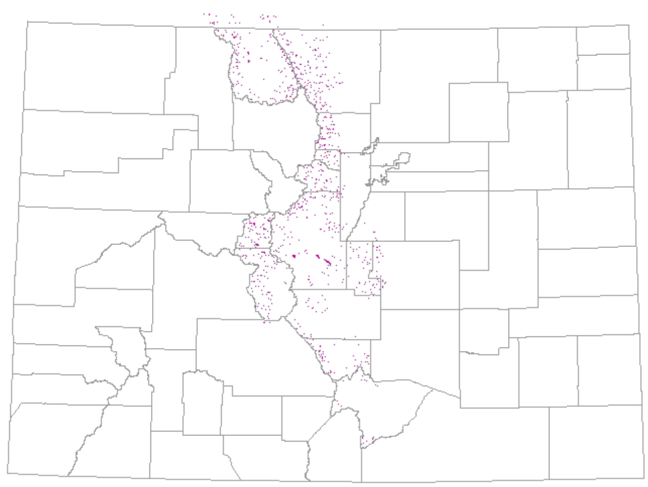
The model is based on 70 EORs, which were translated into 217 input points. 174 input points used for training, 43 for testing. Training AUC is 0.986, test AUC is 0.982.

Environmental Inputs:

- elevation
- vegtype
- landform
- distance to water
- slope

Citation: Colorado Natural Heritage Program. 2/2012. Greenback cutthroat trout habitat model. Raster digital data.

Thumbnail:



Gunnison's prairie dog habitat model

Predictive species distribution model of potential habitat for Gunnison's prairie dog (*Cynomys gunnisoni*) in Colorado.

This is a MaxEnt (v. 3.3.3e) inductive model. Environmental Inputs used are listed below. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Initial cut-off of 0.155 was deemed too low, so that model results with a value of 0.213 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado zoology and wildlife professionals.

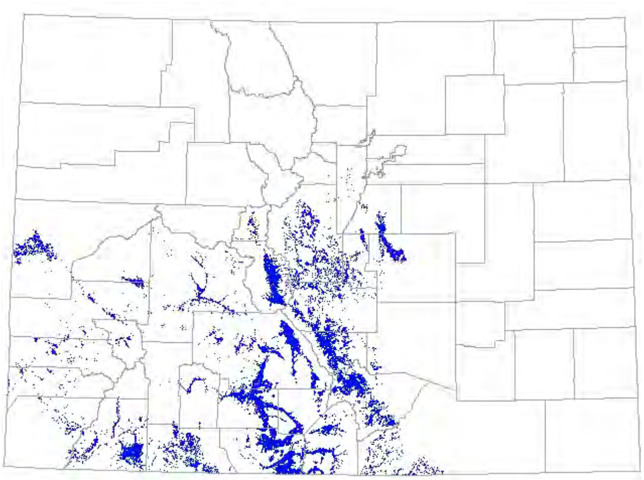
The model is based on 35 EORs, which were translated into 385 input points. 308 input points used for training, 77 for testing. Training AUC is 0.969, test AUC is 0.960.

Environmental Inputs:

- elevation
- vegtype
- landform
- distance to water
- depth to bedrock
- soil pH
- soil texture
- slope

Citation: Colorado Natural Heritage Program. 2/2012. Gunnison's prairie dog habitat model. Raster digital data.

Thumbnail:



Hops feeding azure habitat model

Predictive species distribution model of potential habitat for hops feeding azure in Colorado. The species is also known as hops azure (*Celastrina humulus*).

This is a MaxEnt (v. 3.3.3e) inductive model. Environmental Inputs used are listed below. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.460 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado zoology and wildlife professionals.

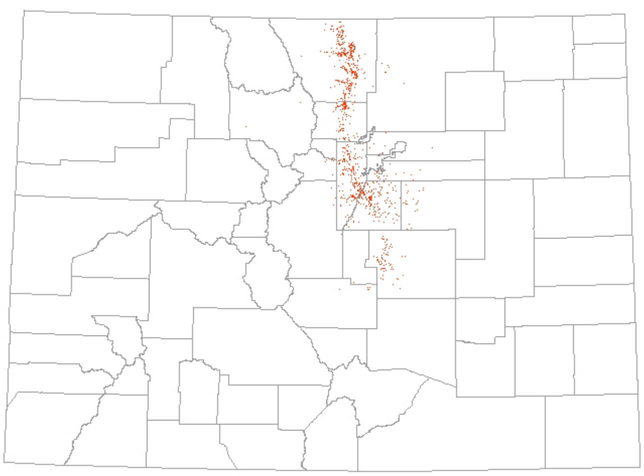
The model is based on 15 EORs, which were translated into 21 input points. 17 input points used for training, 4 for testing. Training AUC is 0.999, test AUC is 0.967.

Environmental Inputs:

- elevation
- vegtype
- landform
- distance to water
- distance to wetlands
- local relief
- aspect
- soil pH
- soil texture

Citation: Colorado Natural Heritage Program. 2/2012. Hops feeding azure habitat model. Raster digital data.

Thumbnail:



Lynx habitat model

Deductive model of potential habitat for lynx (*Lynx canadensis*) in Colorado. In 2002, a representation of lynx habitat on BLM and USFS lands in Colorado was created by the CNHP in collaboration with the above federal agencies. Landcover data and agency expert opinion were the primary inputs into this model. This dataset was updated for use in 2012 spatial analyses. Lynx field monitoring data were requested but not received, so the team implemented simple adjustments to the model with available data. The three listed types of habitat: Denning/Winter, Winter, and Other, were ranked in order of their perceived importance and representation of core habitat:

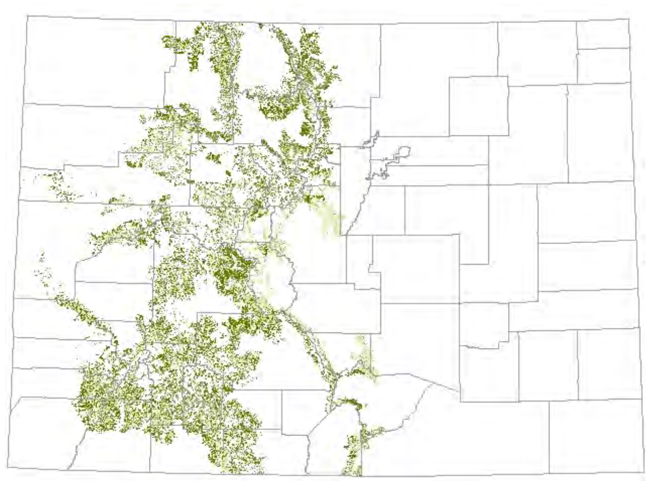
Habitat	Assigned Value
Denning/Winter	3
Winter	2
Other	1

The dataset was rasterized, using the above values, and then overlayed with a rasterized version of the USFS Aerial Surveys of beetle kill. Surveys from 2007 - 2010 were filtered to show only beetle kill areas and then combined for a presence/absence cumulative representation of recent and severe beetle kill tree mortality. The beetle kill areas were then subtracted from the lynx habitat, so that overlapping areas of Denning/Winter (3) became Winter (2); Winter (2) became Other (1); and Other (1) were removed from the model as no longer suitable. This modified model was then reviewed by wildlife experts. As a result of the review, suitable landcover within linkage areas identified by the USFS (lynx_linkage_83.shp) were added to the model and coded as "Other" habitat.

NOTE - This representation of lynx habitat was built around BLM and USFS lands. These are the primary landowners of forested habitat within the Colorado Rocky Mountains, but the property lines that this model follows are artificial and not a complete representation of all available habitat.

Citation: Colorado Natural Heritage Program. 2/2012. Lynx habitat model. Raster digital data.

Thumbnail:



Mexican Spotted Owl habitat model

Predictive species distribution model of potential habitat for Mexican Spotted Owl (*Strix occidentalis lucida*) in Colorado.

This is a MaxEnt (v. 3.3.3e) inductive model. Environmental Inputs used are listed below. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Initial cut-off of 0.221 was deemed too low, so that model results with a value of 0.168 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado zoology and wildlife professionals.

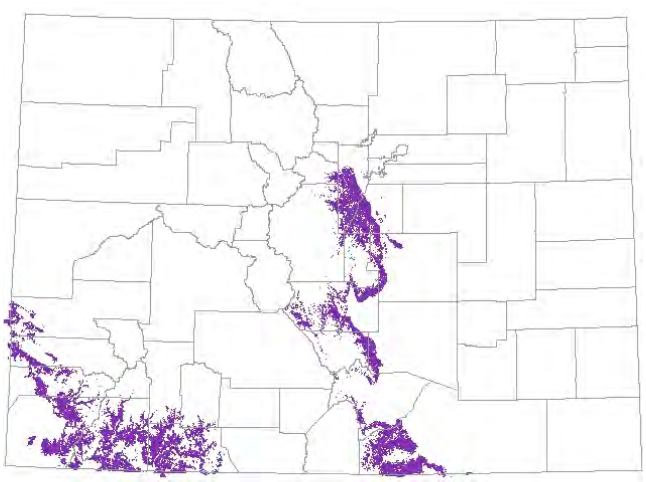
The model is based on 19 EORs, which were translated into 70 input points. 56 input points used for training, 14 for testing. Training AUC is 0.973, test AUC is 0.975.

Environmental Inputs:

- elevation
- vegtype
- landform
- distance to water
- relative forest cover

Citation: Colorado Natural Heritage Program. 2/2012. Mexican Spotted Owl habitat model. Raster digital data.

Thumbnail:



Moss's elfin habitat model

Predictive species distribution model of potential habitat for Moss's elfin in Colorado. The species is also known as Schryver's elfin (*Callophrys mossii schryveri*).

This is a MaxEnt (v. 3.3.3e) inductive model. Environmental Inputs used are listed below. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.104 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado zoology and wildlife professionals.

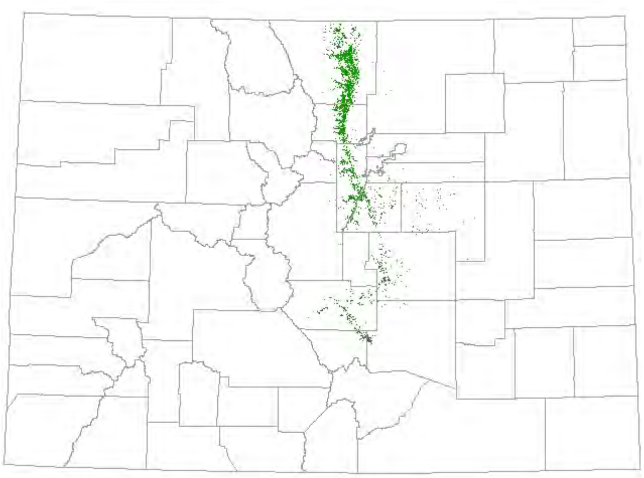
The model is based on 17 EORs, which were translated into 40 input points. 32 input points used for training, 8 for testing. Training AUC is 0.997, test AUC is 0.939.

Environmental Inputs:

- elevation
- vegtype
- landform
- distance to water
- distance to wetlands
- local relief
- aspect
- soil pH
- soil texture

Citation: Colorado Natural Heritage Program. 2/2012. Moss's elfin habitat model. Raster digital data.

Thumbnail:



Mottled dusky wing habitat model

Predictive species distribution model of potential habitat for mottled dusky wing (*Erynnis martialis*) in Colorado.

This is a MaxEnt (v. 3.3.3e) inductive model. Environmental Inputs used are listed below. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.344 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado zoology and wildlife professionals.

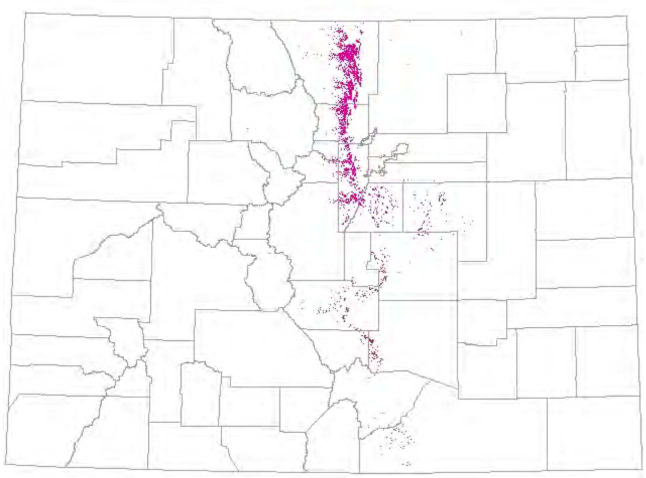
The model is based on 18 EORs, which were translated into 24 input points. 20 input points used for training, 4 for testing. Training AUC is 0.997, test AUC is 0.981.

Environmental Inputs:

- elevation
- vegtype
- landform
- distance to water
- local relief
- aspect
- soil pH
- soil texture

Citation: Colorado Natural Heritage Program. 2/2012. Mottled dusky wing habitat model. Raster digital data.

Thumbnail:



Mountain Plover habitat model

Predictive species distribution model of potential habitat for Mountain Plover (*Charadrius montanus*) in Colorado.

This is a MaxEnt (v. 3.3.3e) inductive model. Environmental Inputs used are listed below. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Initial cut-off of 0.218 was deemed too high, so that model results with a value of 0.087 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado zoology and wildlife professionals.

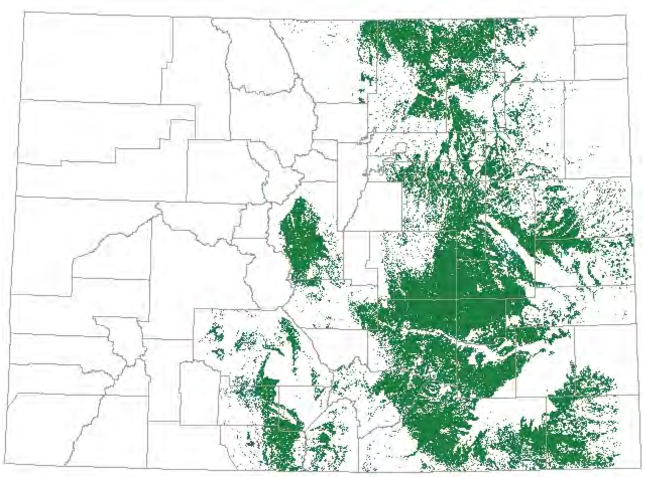
The model is based on 112 EORs, which were translated into 1748 input points. 1399 input points used for training, 349 for testing. Training AUC is 0.916, test AUC is 0.919.

Environmental Inputs:

- elevation
- vegtype
- landform
- distance to water
- depth to bedrock
- soil pH
- soil texture

Citation: Colorado Natural Heritage Program. 2/2012. Mountain Plover habitat model. Raster digital data.

Thumbnail:



Northern leopard frog habitat model

Predictive species distribution model of potential habitat for northern leopard frog (*Rana pipiens*) in Colorado.

This is a MaxEnt (v. 3.3.3e) inductive model. Environmental Inputs used are listed below. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Initial cut-off of 0.295 was deemed too low, so that model results with a value of 0.7 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado zoology and wildlife professionals.

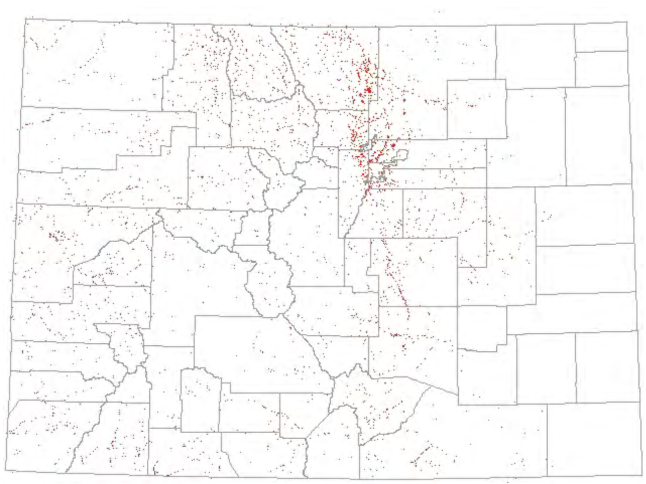
The model is based on 63 EORs and 646 Observations, which were translated into 788 input points. 631 input points used for training, 157 for testing. Training AUC is 0.883, test AUC is 0.879.

Environmental Inputs:

- elevation
- vegtype
- landform
- distance to water
- distance to wetlands

Citation: Colorado Natural Heritage Program. 2/2012. Northern leopard frog habitat model. Raster digital data.

Thumbnail:



Northern pocket gopher ssp *macrotis* habitat model

Predictive species distribution model of potential habitat for northern pocket gopher ssp *macrotis* (*Thomomys talpoides macrotis*) in Colorado.

This is a MaxEnt (v. 3.3.3e) inductive model. Environmental Inputs used are listed below. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.297 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado zoology and wildlife professionals.

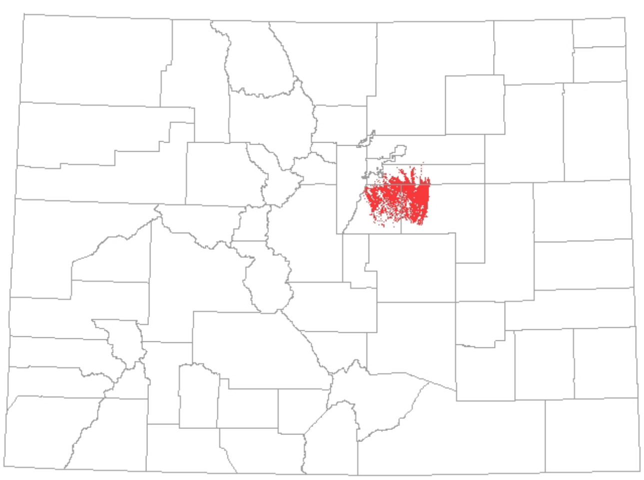
The model is based on 15 EORs, which were translated into 26 input points. 21 input points used for training, 5 for testing. Training AUC is 0.993, test AUC is 0.990.

Environmental Inputs:

- elevation
- vegtype
- landform
- distance to water
- depth to bedrock
- soil pH
- soil texture

Citation: Colorado Natural Heritage Program. 2/2012. Northern pocket gopher ssp *macrotis* habitat model. Raster digital data.

Thumbnail:



Northern redbelly dace habitat model

Predictive species distribution model of potential habitat for Northern redbelly (*Phoxinus eos*) dace in Colorado. NOTE - This is a model of species **historical** range. Current known range is a subset of this model.

This is a MaxEnt (v. 3.3.3e) inductive model. Environmental Inputs used are listed below. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.087 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to *historical* range. This model has been reviewed by Colorado zoology and wildlife professionals.

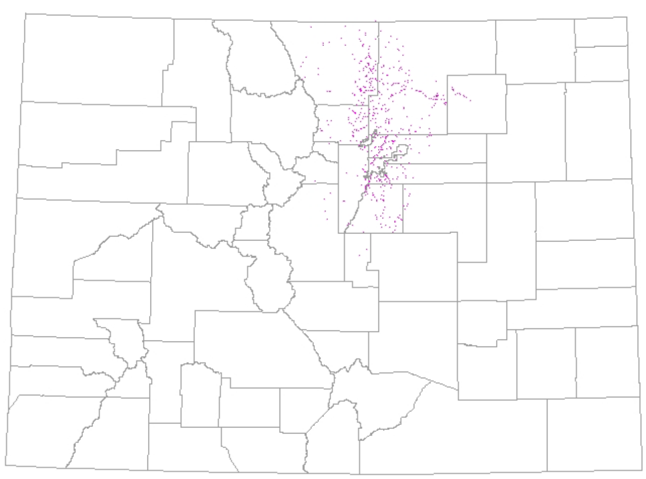
The model is based on 5 EORs, which were translated into seven input points. 6 input points used for training, 1 for testing. Training AUC is 0.997, test AUC is 1.000.

Environmental Inputs:

- elevation
- vegtype
- landform
- distance to water
- slope

Citation: Colorado Natural Heritage Program. 2/2012. Northern redbelly dace habitat model. Raster digital data.

Thumbnail:



Ovenbird habitat model

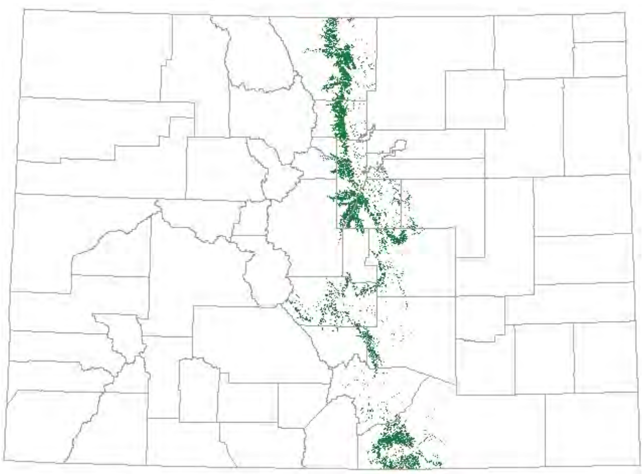
Deductive model of potential habitat for Ovenbird (*Seiurus aurocapilla*) in Colorado.

Attempts were made to create an inductive predictive species distribution model for this species using MaxEnt (v 3.3.3e), but a good fit could not be obtained with existing input data. The SWReGAP Vertebrate Habitat Model for the species was also reviewed and deemed too inaccurate as well. Therefore, a simple deductive model using vegetation type and elevation was created, based on species habitat requirements noted in the literature.

The model:
All SWReGAP forest types along the Colorado Front Range within the elevation range of 853-2,434 m (inclusive). A mask was used to restrict areas chosen to the Front Range.

Citation: Colorado Natural Heritage Program. 2/2012. Ovenbird habitat model. Raster digital data.

Thumbnail:



Prairie Falcon habitat model

Attempts were made to create an inductive predictive species distribution model for this species using MaxEnt, but a good fit could not be obtained with existing data. The SWReGAP Vertebrate Habitat Model for the species was also reviewed and deemed too inaccurate. Therefore, a deductive model using vegetation type and landform was created, based on information in the Colorado Breeding Bird Atlas. The SWReGAP landforms in the following list were selected and then constrained by the SWReGAP landcover types in Table C.1:

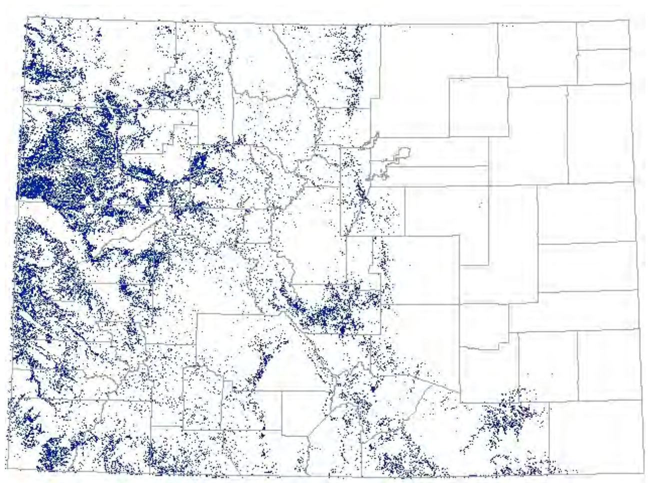
- very moist steep slopes
- moderately moist steep slopes
- moderately dry slopes
- very dry steep slopes
- cool aspect scarps, cliffs, canyons
- hot aspect scarps, cliffs, canyons

Table C.1. SWReGAP Landcover Types Used in the Prairie Falcon Model

Rocky Mountain Cliff and Canyon	Western Great Plains Cliff and Outcrop
Inter-Mountain Basins Cliff and Canyon	Colorado Plateau Mixed Bedrock Canyon and Tableland
Inter-Mountain Basins Shale Badland	Inter-Mountain Basins Wash
North American Warm Desert Bedrock Cliff and Outcrop	North American Warm Desert Wash
Southern Rocky Mountain Pinyon-Juniper Woodland	Colorado Plateau Pinyon-Juniper Woodland
Inter-Mountain Basins Mat Saltbush Shrubland	Rocky Mountain Gambel Oak-Mixed Montane Shrubland
Rocky Mountain Lower Montane-Foothill Shrubland	Inter-Mountain Basins Mountain Mahogany Woodland and Shrubland
Colorado Plateau Pinyon-Juniper Shrubland	Southern Rocky Mountain Juniper Woodland and Savanna
Inter-Mountain Basins Juniper Savanna	Inter-Mountain Basins Semi-Desert Shrub Steppe
Rocky Mountain Subalpine-Montane Riparian Shrubland	Rocky Mountain Subalpine-Montane Riparian Woodland
Rocky Mountain Lower Montane Riparian Woodland and Shrubland	Western Great Plains Riparian Woodland and Shrubland
Barren Lands, Non-specific	Invasive Southwest Riparian Woodland and Shrubland

Source: Colorado Natural Heritage Program. 2/2012. Prairie Falcon habitat model. Raster digital data.

Thumbnail:



Preble's meadow jumping mouse habitat model

Predictive species distribution model of potential habitat for Preble's meadow jumping mouse (*Zapus hudsonius preblei*) in Colorado.

This is a MaxEnt (v. 3.3.3e) inductive model. Environmental Inputs used are listed below. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Initial cut-off of 0.124 was deemed too low, so that model results with a value of 0.456 or greater were retained for use in Marxan, based on model logs and expert review. Areas designated as Critical Habitat for the species were added to the finished model and the output extent was modified with a mask to limit extent to known range. This model has been reviewed by Colorado zoology and wildlife professionals.

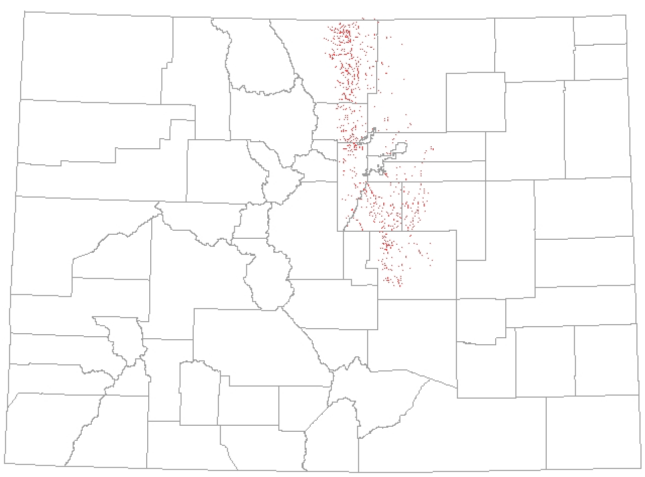
The model is based on 121 EORs, which were translated into 159 input points. 128 input points used for training, 31 for testing. Training AUC is 0.986, test AUC is 0.986.

Environmental Inputs:

- elevation
- vegtype
- landform
- distance to water
- distance to wetland

Citation: Colorado Natural Heritage Program. 2/2012. Preble's meadow jumping mouse habitat model. Raster digital data.

Thumbnail:



Veery habitat model

Predictive species distribution model of potential habitat for Veery (*Catharus fuscescens*) in Colorado.

This is a MaxEnt (v. 3.3.3e) inductive model. Environmental Inputs used are listed below. The state of Colorado was the modeling extent. CNHP Observation records were used as known locations for the species. Model results with a value of 0.279 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was modified with a mask to limit extent to known breeding range. This model has been reviewed by Colorado zoology and wildlife professionals.

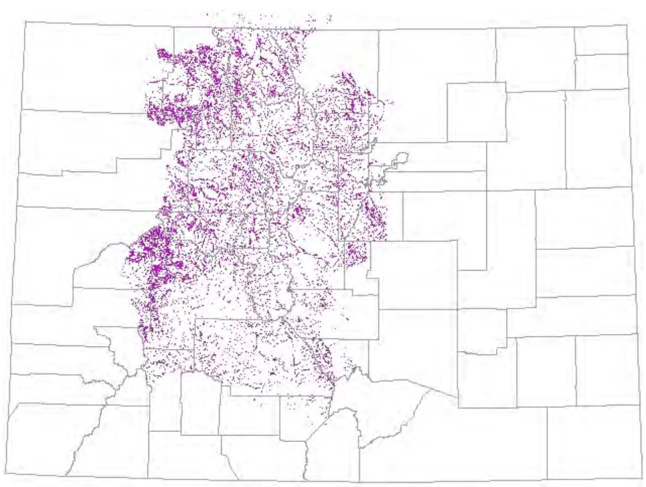
The model is based on 14 Observations. 12 input points used for training, 2 for testing. Training AUC is 0.970, test AUC is 0.933.

Environmental Inputs:

- elevation
- vegtype
- landform
- distance to water
- distance to wetlands

Citation: Colorado Natural Heritage Program. 2/2012. Veery habitat model. Raster digital data.

Thumbnail:



Willow Flycatcher habitat model

Predictive species distribution model of potential habitat for Willow Flycatcher (*Empidonax traillii*) in Colorado.

This is a MaxEnt (v. 3.3.3e) inductive model. Environmental Inputs used are listed below. The state of Colorado was the modeling extent. CNHP Observation records were used as known locations for the species. Model results with a value of 0.153 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado zoology and wildlife professionals.

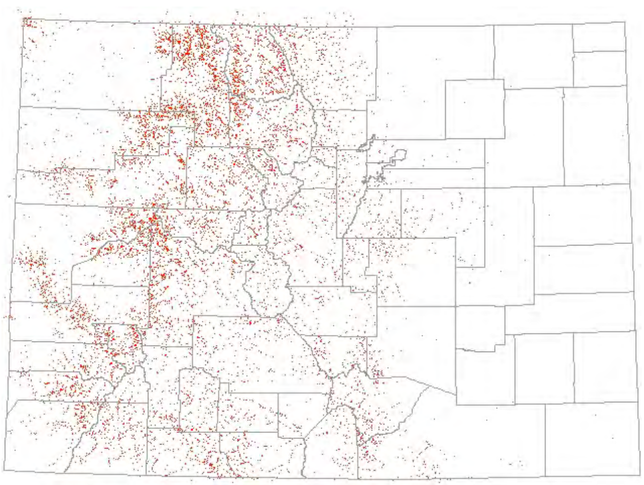
The model is based on 45 Observations. 36 input points used for training, 9 for testing. Training AUC is 0.982, test AUC is 0.921.

Environmental Inputs:

- elevation
- vegtype
- landform
- distance to water
- distance to wetlands

Citation: Colorado Natural Heritage Program. 2/2012. Willow Flycatcher habitat model. Raster digital data.

Thumbnail:



Wolverine habitat model

Predictive species distribution model of potential habitat for wolverine (*Gulo gulo*) in Colorado.

This is a MaxEnt (v. 3.3.3e) inductive model. Environmental Inputs used are listed below. The state of Colorado was the modeling extent. CNHP Element Occurrence Records (EORs) were used as known locations for the species. Model results with a value of 0.299 or greater were retained for use in Marxan, based on model logs and expert review. The output extent was not modified (no mask was necessary to limit extent to known range). This model has been reviewed by Colorado zoology and wildlife professionals.

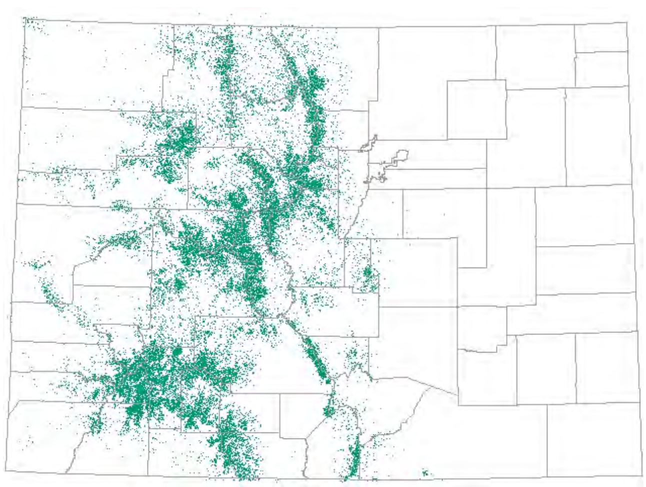
The model is based on 26 EORs, which were translated into 28 input points. 23 input points used for training, 5 for testing. Training AUC is 0.966, test AUC is 0.915.

Environmental Inputs:

- elevation
- vegtype
- landform
- distance to water
- distance to wetland
- relative forest cover
- slope

Citation: Colorado Natural Heritage Program. 2/2012. Wolverine habitat model. Raster digital data.

Thumbnail:



Additional species distribution and habitat data not created by CNHP

Species Activity Maps.
Colorado Parks and Wildlife, last updated 6/2011. http://ndis.nrel.colostate.edu/ftp/ftp_response.asp

The following separate vector layers were merged to represent important areas for the big game species on the project target list:

Bighorn sheep
Mineral licks, water source, migration corridors, summer concentration, production areas, severe winter range, winter concentration.

Black bear
Summer concentration, fall concentration.

Elk
Migration corridors, production areas, severe winter range, winter concentration areas, summer concentration areas.

Mule deer
Migration corridors, concentration area, winter concentration area, critical winter range, severe winter range.

Mountain lion
Bighorn severe winter and production areas, elk severe winter and production areas, and mule deer severe winter areas; *minus* mountain lion peripheral range.

SWReGAP Vertebrate Habitat Distribution Models.
New Mexico Cooperative Fish and Wildlife Research Unit, Southwest Regional GAP Analysis Project, last updated 9/2005. http://fws-nmcfwru.nmsu.edu/swregap/habitatreview/ModelQuery.asp

SWReGAP models were only used when CNHP was unable to build a model for the species, whether because of lack of data or lack of time. SWReGAP models were used in this project for the following species:

- American White Pelican
- Golden Eagle
- Lewis's Woodpecker
- Northern Goshawk
- White-tailed Ptarmigan
- Dwarf shrew

Pawnee Montane Skipper Survey Map.
Environmental Research & Technology, Inc. 1986. Status Report on the Pawnee Montane Skipper (*Hesperia leonardus montana* Skinner). Prepared for the Denver Water Department, Denver, Colorado. 45 pp.

The original shapefile, created by ERT, was modified by CNHP to erase high intensity burn areas from the 2002 Hayman Fire, received from the U.S. Forest Service.

APPENDIX D
Wetland Mapping Results by Quad

Agate Mountain

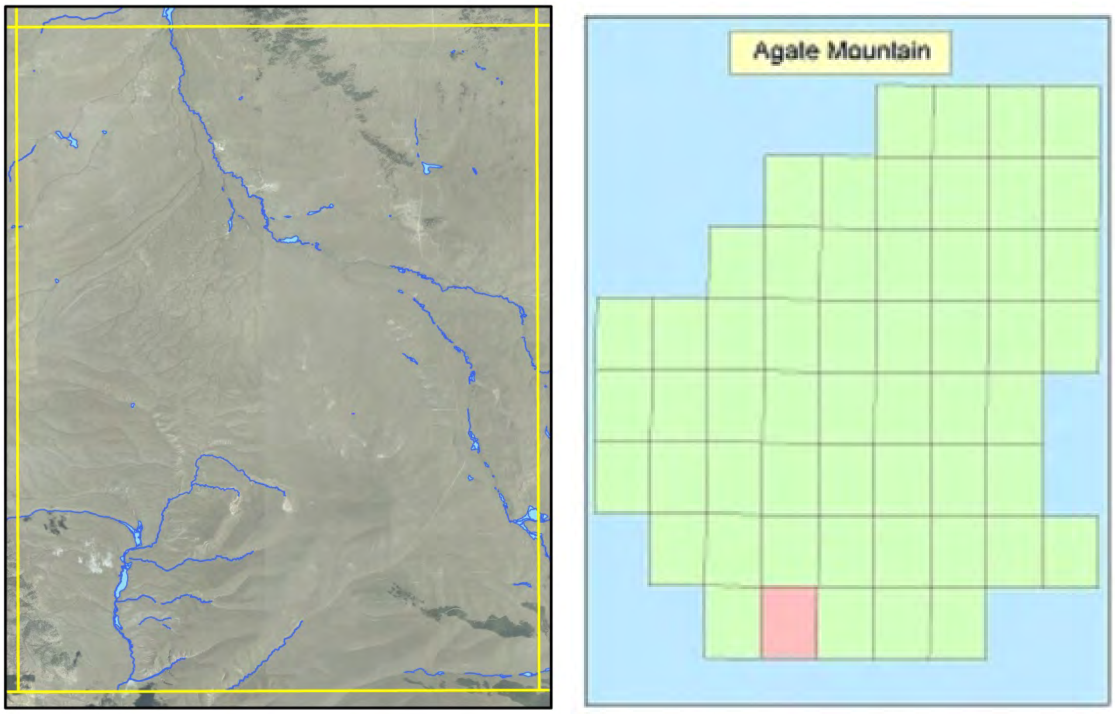


Figure D.1. Wetland polygons mapped within the Agate Mountain quad shown over 2009 true-color aerial photography (left). Location of Agate Mountain quad in relation to all quads in the study area (right).

The Agate Mountain quad is in the southern portion of the project area (Figure D.1). It has a minimum elevation of 9,104 feet and a max of 10,384 feet. The dominant vegetation types include: Foothills/Mountain Grassland at 96.7%, Mesic Upland Shrub at 0.4%, and Ponderosa Pine at 2.9%. The total number of wetland acres is 295.7 (Table D.1), which is 0.3% of total wetlands in the project area. This quad is generally low relief and sits at the south end of the South Park basin.

Table D.1. Acres of Wetlands Mapped in the Agate Mountain Quad by Wetland Type and Land Owner

Agate Mountain	BLM	PRIVATE	SLB	Total Acres
Freshwater Emergent Wetland	< 0.1	166.4	7.8	174.2
Freshwater Forested/Shrub Wetland	0.0	0.8	0.5	1.3
Freshwater Pond	0.2	7.7	0.0	7.9
Riverine	5.9	47.3	3.8	57.1
Total Acres	**6.1**	**222.3**	**12.1**	**240.5**

Alma

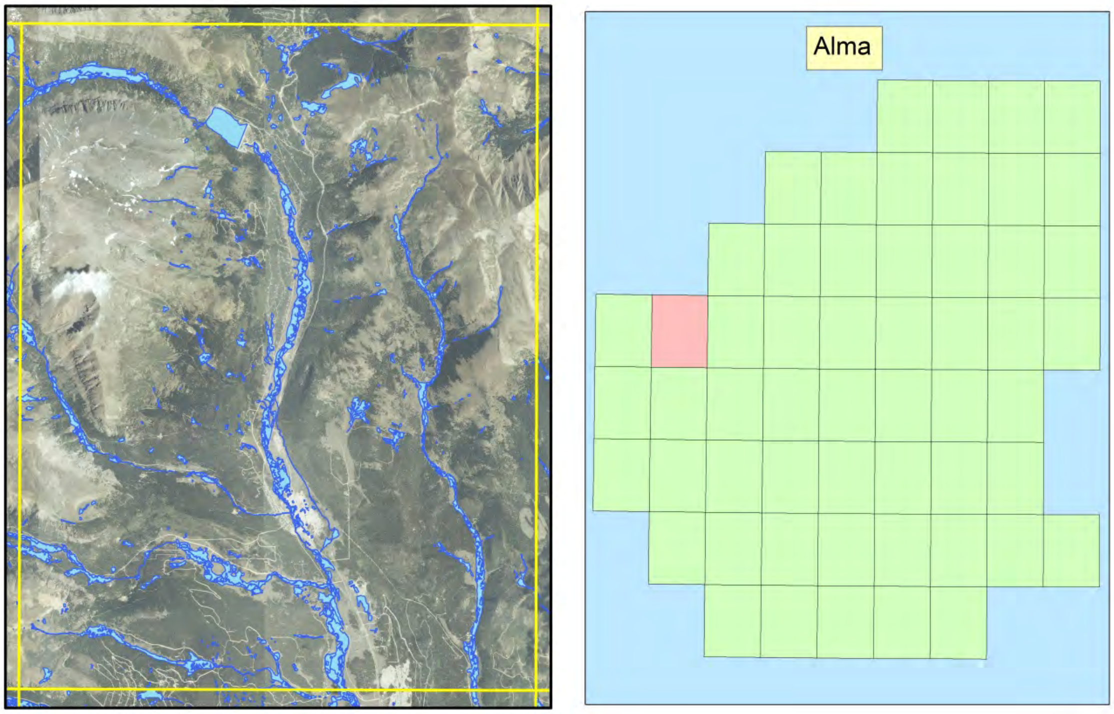


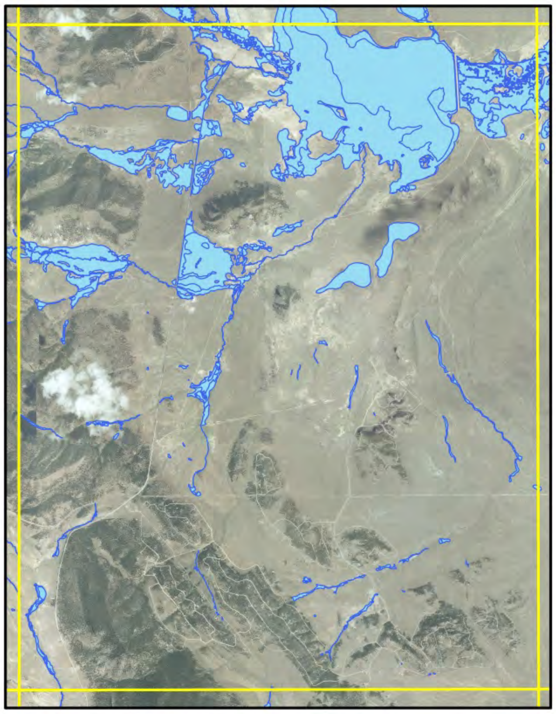
Figure D.2. Wetland polygons mapped within the Alma quad shown over 2009 true-color aerial photography (left). Location of Alma quad in relation to all quads in the study area (right).

The Alma quad is in the western portion of the project area (Figure D.2). It has a minimum elevation of 10,095 feet and a max of 14,236 feet. The dominant vegetation types include: Rocky Mountain Bristlecone Pine at 30.4%, Subalpine Meadow at 22.1%, and Tundra (several classes) combined at 35.7%. The total number of wetland acres is 1,937.8 (Table D.2), which is 2.3% of total wetlands in the project area. This quad contains a portion of the Middle Fork of the South Platte River and is flanked on the west by Mt. Bross and the east by Mount Silverheels.

Table D.2. Acres of Wetlands Mapped in the Alma Mountain Quad by Wetland Type and Land Owner

ALMA	CPW	CITY	COUNTY	PRIVATE	USFS - PIKE	USFS - WHITE RIVER	Total Acres
Freshwater Emergent Wetland	1.3	0.0	0.0	80.8	17.5	2.5	102.1
Freshwater Forested/Shrub Wetland	139.4	< 0.1	0.4	913.7	445.9	73.2	1,572.5
Freshwater Pond	20.4	0.0	0.0	75.7	14.7	0.1	110.9
Lake	0.0	0.0	0.0	92.2	0.3	1.1	93.7
Riverine	5.5	0.0	0.0	39.0	14.1	0.0	58.6
Total Acres	**166.6**	**< 0.1**	**0.4**	**1,201.4**	**492.6**	**76.9**	**1,937.8**

Antero Reservoir



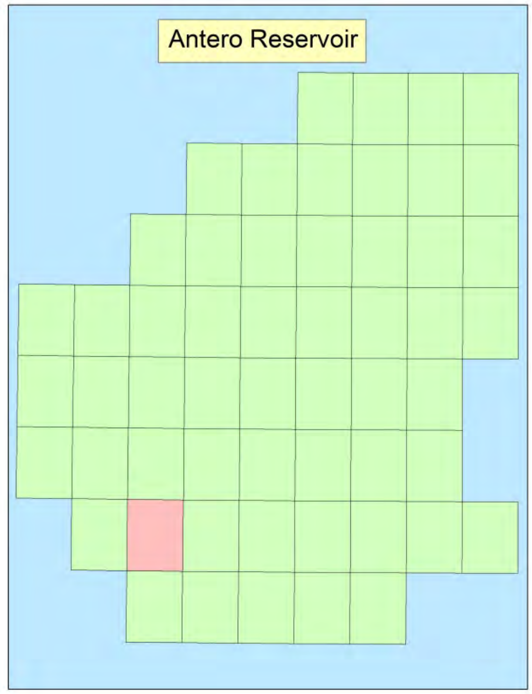


Figure D.3. Wetland polygons mapped within the Antero Reservoir quad shown over 2009 true-color aerial photography (left). Location of Antero Reservoir quad in relation to all quads in the study area (right).

The Antero Reservoir quad is in the south western portion of the project area (Figure D.3). It has a minimum elevation of 8,917 feet and a max of 10,509 feet. The dominant vegetation types include: Foothills/Mountain Grassland at 58.1%, Ponderosa Pine at 19.4%, and Douglas Fir at 10.0%. The total number of wetland acres is 4,509.5 (Table D.3), which is 5.3% of total wetlands in the project area. This quad includes Antero Reservoir and the Antero Junction of CO-285 and CO-24.

Table D.3. Acres of Wetlands Mapped in the Antero Reservoir Quad by Wetland Type and Land Owner

ANTERO RESERVOIR	BLM	NGO	PRIVATE	SLB	USFS - PIKE	Total Acres
Freshwater Emergent Wetland	8.5	487.0	417.5	678.4	69.1	1,660.4
Freshwater Forested/Shrub Wetland	0.0	31.0	0.3	2.2	0.9	34.4
Freshwater Pond	88.5	549.2	3.9	9.4	0.3	651.4
Lake	0.0	2,103.1	25.3	0.0	0.0	2,128.4
Riverine	0.0	21.6	1.4	7.2	4.7	34.9
Total Acres	**97.0**	**3,191.9**	**448.4**	**697.2**	**75.0**	**4,509.5**

Antero Reservoir NE

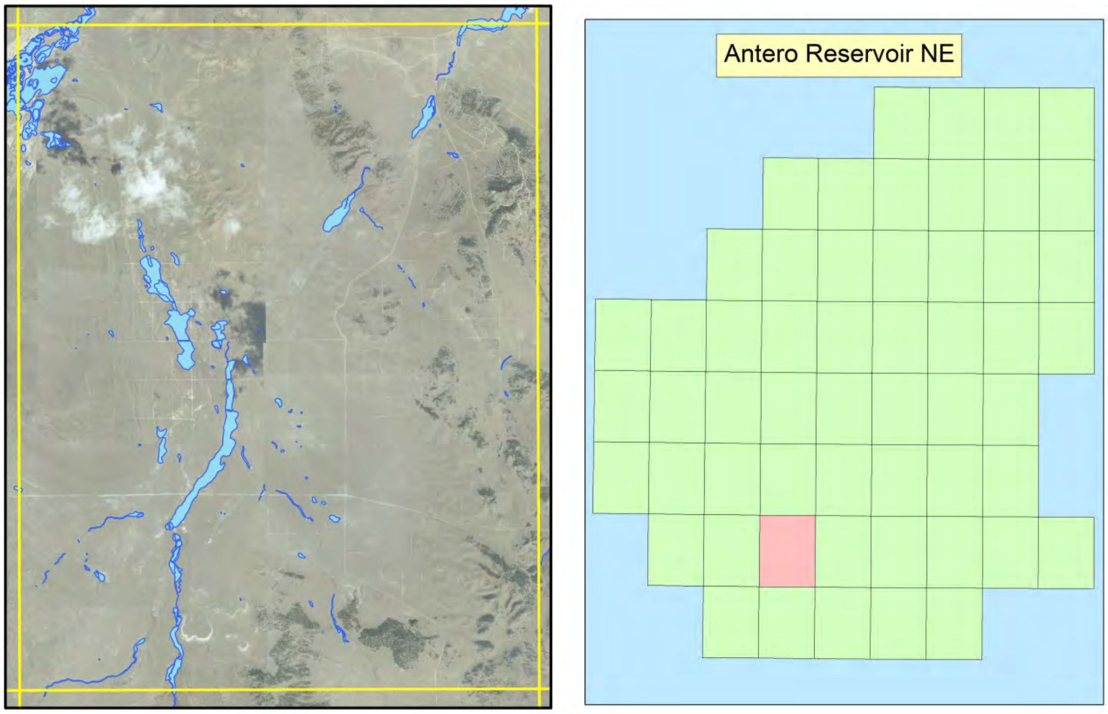


Figure D.4. Wetland polygons mapped within the Antero Reservoir NE quad shown over 2009 true-color aerial photography (left). Location of Antero Reservoir NE quad in relation to all quads in the study area (right).

The Antero Reservoir NE quad is in the south western portion of the project area (Figure D.4). It has a minimum elevation of 8,809 feet and a max of 9,852 feet. The dominant vegetation types include: Foothills/Mountain Grassland at 82.1%, Graminoid/Form Dominated Wetland at 8.8%, and Ponderosa Pine at 6.1%. The total number of wetland acres is 1,005.8 (Table D.4), which is 1.2% of total wetlands in the project area. This quad is mostly basin and low hills leading into Antero Reservoir to the northwest.

Table D.4. Acres of Wetlands Mapped in the Antero Reservoir NE Quad by Wetland Type and Land Owner

ANTERO RESERVOIR NE	BLM	NGO	PRIVATE	SLB	Total Acres
Freshwater Emergent Wetland	14.5	108.2	393.8	5.5	522.0
Freshwater Pond	16.2	168.2	274.3	0.0	458.6
Riverine	1.2	6.4	17.6	0.0	25.2
Total Acres	**31.9**	**282.8**	**685.6**	**5.5**	**1,005.8**

Bailey

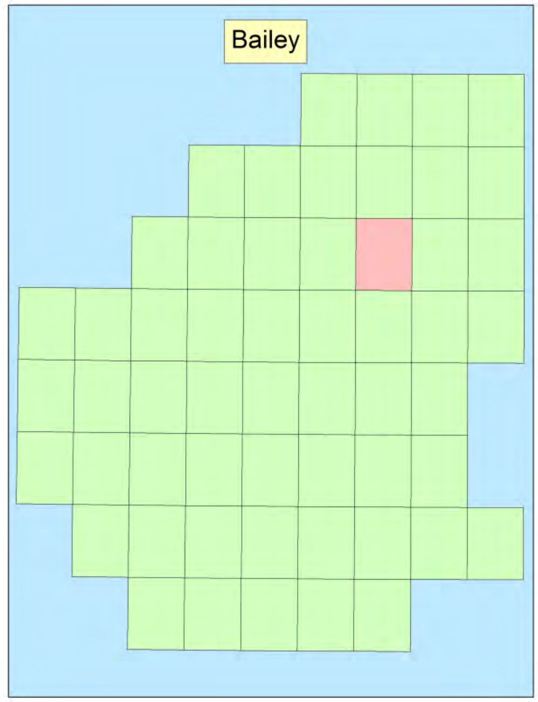


Figure D.5. Wetland polygons mapped within the Bailey quad shown over 2009 true-color aerial photography (left). Location of Bailey quad in relation to all quads in the study area (right).

The Bailey quad is in the central north eastern portion of the project area (Figure D.5). It has a minimum elevation of 6,955 feet and a max of 9,843 feet. The dominant vegetation types include: Ponderosa Pine at 93.9%, Spruce/Fir at 5.5%, and Urban/Built-up at 0.4%. The total number of wetland acres is 893.5 (Table D.5), which is 1.1% of total wetlands in the project area. CO-285 bisects this quad from SW to NE and there is significant rural development to the north and south of the highway.

Table D.5. Acres of Wetlands Mapped in the Bailey Quad by Wetland Type and Land Owner

BAILEY	NGO	PRIVATE	SLB	STPARKS	USFS - PIKE	Total Acres
Freshwater Emergent Wetland	0.5	483.8	2.1	43.8	1.2	531.4
Freshwater Forested/Shrub Wetland	3.8	217.0	1.0	4.7	12.8	239.3
Freshwater Pond	0.1	43.3	0.0	3.3	0.0	46.7
Riverine	2.6	55.4	0.0	1.6	16.6	76.1
Total Acres	**7.1**	**799.4**	**3.2**	**53.4**	**30.5**	**893.5**

Boreas Pass

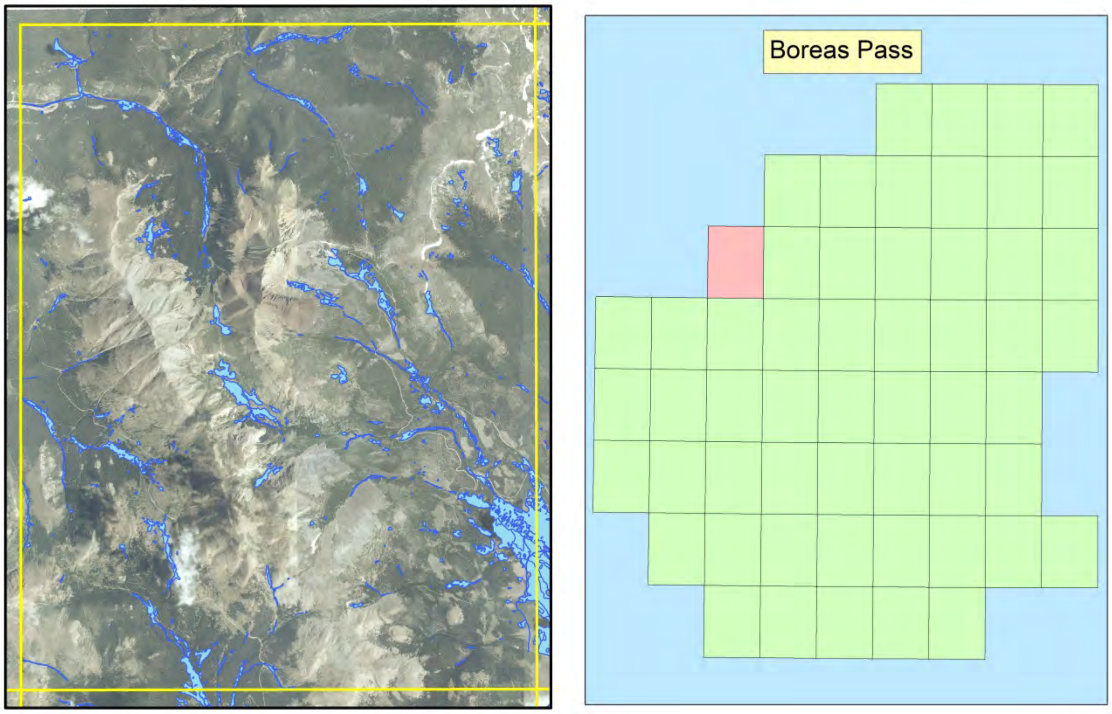


Figure D.6. Wetland polygons mapped within the Boreas Pass quad shown over 2009 true-color aerial photography (left). Location of Boreas Pass quad in relation to all quads in the study area (right).

The Boreas Pass quad is in the northwest portion of the project area (Figure D.6). It has a minimum elevation of 9,859 feet and a max of 13,688 feet. The dominant vegetation types include: Spruce/Fir at 45.8%, Subalpine Meadow at 13.6%, and Tundra (several classes) combined at 35.6%. The total number of wetland acres is 1,328.6 (Table D.6), which is 1.6% of total wetlands in the project area. This is a very mountainous quad with a significant area above treeline, dominated by Mount Guyot and its associated ridge to the south.

Table D.6. Acres of Wetlands Mapped in the Boreas Pass Quad by Wetland Type and Land Owner

BOREAS PASS	COUNTY	JOINT CITY/COUNTY	PRIVATE	USFS - PIKE	USFS - WHITE RIVER	Total Acres
Freshwater Emergent Wetland	0.3	2.6	100.7	61.7	44.8	210.2
Freshwater Forested/Shrub Wetland	22.9	1.2	256.9	575.1	203.9	1,060.0
Freshwater Pond	1.0	0.0	19.7	21.6	4.0	46.3
Riverine	0.0	0.3	7.8	1.8	2.2	12.1
Total Acres	**24.2**	**4.2**	**385.1**	**660.2**	**254.9**	**1,328.6**

Castle Rock Gulch

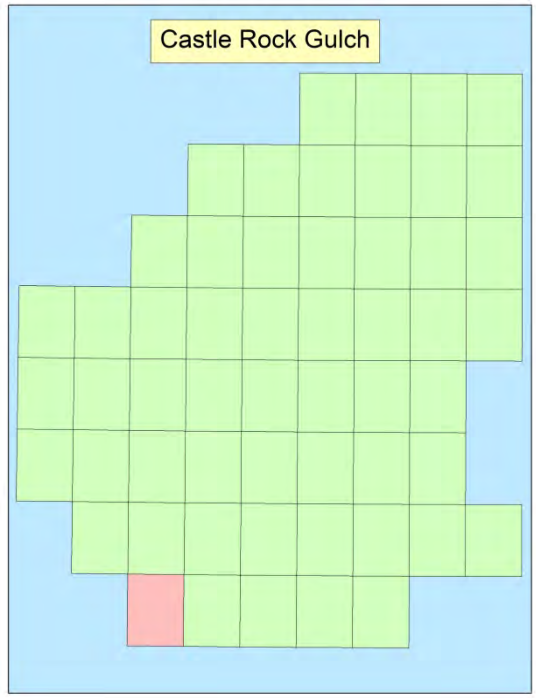


Figure D.7. Wetland polygons mapped within the Castle Rock Gulch quad shown over 2009 true-color aerial photography (left). Location of Castle Rock Gulch quad in relation to all quads in the study area (right).

The Castle Rock Gulch quad is in the extreme southwest portion of the project area (Figure D.7). It has a minimum elevation of 8,684 feet and a max of 10,761 feet. The dominant vegetation types include: Ponderosa Pine at 55.2%, Foothills/Mountain Grassland at 18.7%, and Douglas Fir at 12.0%. The total number of wetland acres is 401.9 (Table D.7), which is 0.5% of total wetlands in the project area. This area contains several headwater streams that feed into the Arkansas River to the west.

Table D.7. Acres of Wetlands Mapped in the Castle Rock Gulch Quad by Wetland Type and Land Owner

CASTLE ROCK GULCH	PRIVATE	USFS - PIKE	Total Acres
Freshwater Emergent Wetland	59.4	192.4	251.8
Freshwater Forested/Shrub Wetland	31.0	101.6	132.6
Freshwater Pond	2.2	6.3	8.5
Riverine	5.0	3.9	8.9
Grand Total	**97.6**	**304.3**	**401.9**

Cheesman Lake

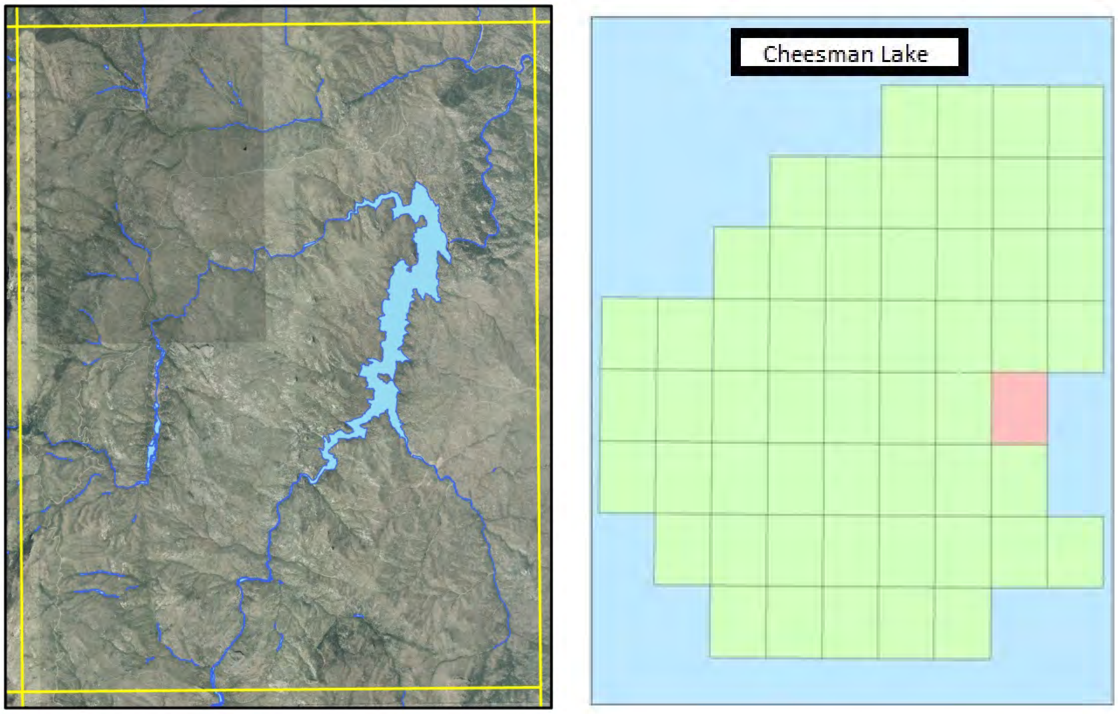


Figure D.8. Wetland polygons mapped within the Cheesman Lake quad shown over 2009 true-color aerial photography (left). Location of Cheesman Lake quad in relation to all quads in the study area (right).

The Cheesman Lake quad is in the eastern portion of the project area (Figure D.8). It has a minimum elevation of 6,460 feet and a max of 10,433 feet. The dominant vegetation types include: Douglas Fir at 64.5%, Ponderosa Pine at 31.3%, and Big Sagebrush at 2.06%. The total number of wetland acres is 1,101.0 (Table D.8), which is 1.3% of total wetlands in the project area. This quad contains the Cheesman Lake reservoir at the southern end of Jefferson and Douglas County.

Table D.8. Acres of Wetlands Mapped in the Cheesman Lake Quad by Wetland Type and Land Owner

CHEESMAN LAKE	NGO	PRIVATE	USFS - PIKE	Total Acres
Freshwater Emergent Wetland	0.0	23.3	8.3	31.5
Freshwater Forested/Shrub Wetland	4.9	21.7	69.8	96.3
Freshwater Pond	5.4	3.7	0.1	9.2
Lake	868.2	0.0	< 0.1	868.2
Riverine	14.1	7.9	73.8	95.7
Total Acres	**892.5**	**56.5**	**152.0**	**1,101.0**

Climax

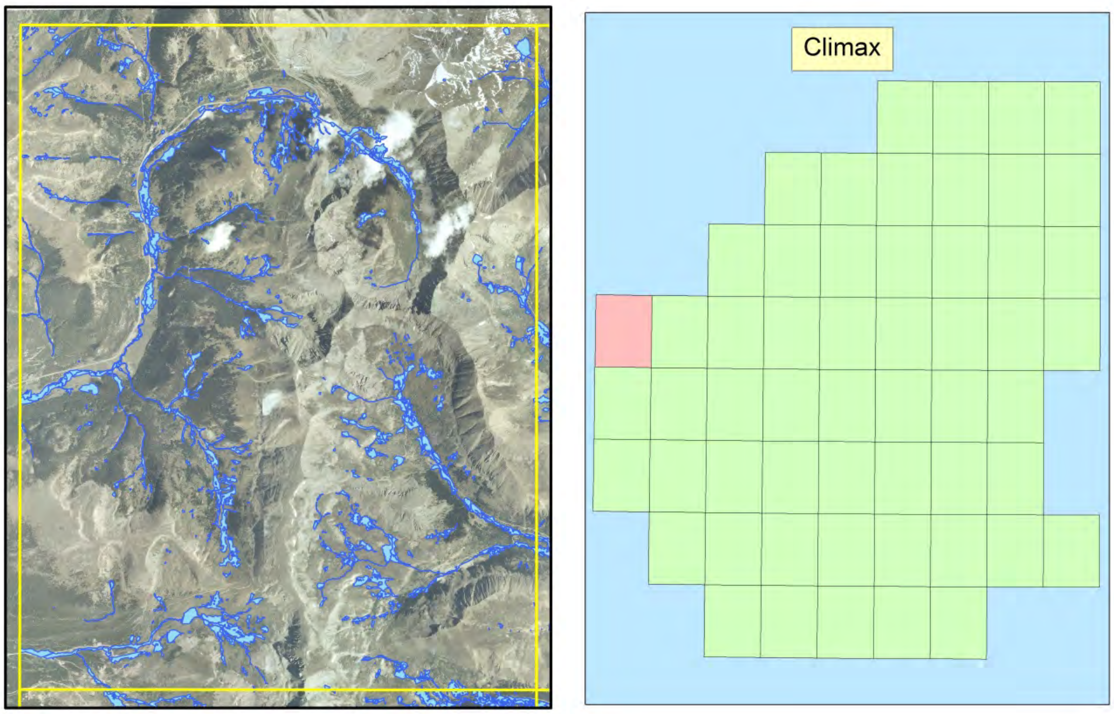


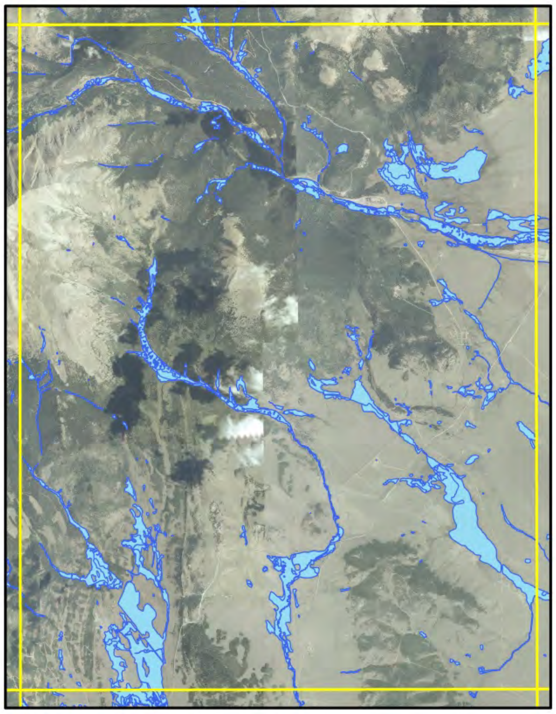
Figure D.9. Wetland polygons mapped within the Climax quad shown over 2009 true-color aerial photography (left). Location of Climax quad in relation to all quads in the study area (right).

The Climax quad is in the western portion of the project area (Figure D.9). It has a minimum elevation of 10,075 feet and a max of 14,078 feet. The dominant vegetation types include: Tundra (several classes) combined at 56.7%, Subalpine Meadow at 20.2%, and Lodgepole Pine at 14.0%. The total number of wetland acres is 1,863.5 (Table D.9), which is 2.2% of total wetlands in the project area. This quad is very mountainous with several tall peaks including Mount Democrat, Mount Arkansas, and Dyer Mountain.

Table D.9. Acres of Wetlands Mapped in the Climax Quad by Wetland Type and Land Owner

CLIMAX	BLM	LAND TRUST	PRIVATE	SLB	USFS - PIKE	USFS - WHITE RIVER	Total Acres
Freshwater Emergent Wetland	25.1	2.6	57.1	2.8	69.8	9.0	166.5
Freshwater Forested/Shrub Wetland	375.9	7.3	634.5	3.1	454.9	13.8	1,489.6
Freshwater Pond	12.9	0.1	30.9	0.4	11.8	0.0	56.1
Lake	2.3	0.0	48.0	1.2	48.2	0.0	99.7
Riverine	9.9	0.5	23.6	0.3	15.4	2.0	51.7
Total Acres	**426.2**	**10.4**	**794.2**	**7.7**	**600.1**	**24.9**	**1,863.5**

Como



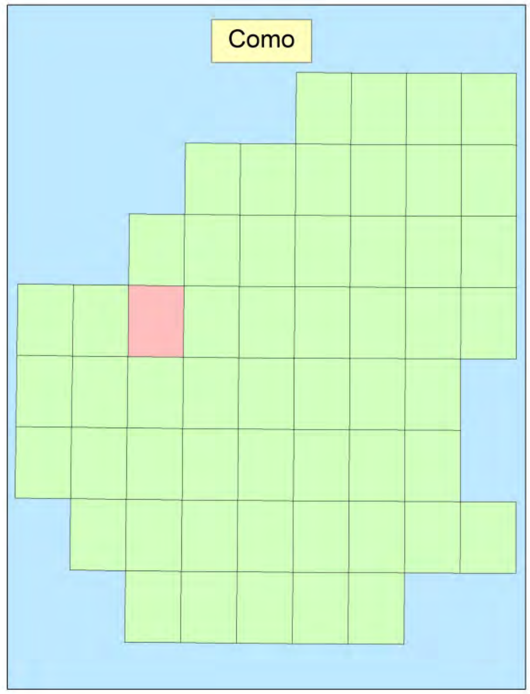


Figure D.10. Wetland polygons mapped within the Como quad shown over 2009 true-color aerial photography (left). Location of Como quad in relation to all quads in the study area (right).

The Como quad is in the central west portion of the project area (Figure D.10). It has a minimum elevation of 9,452 feet and a max of 13,717 feet. The dominant vegetation types include: Foothills/Mountain Grassland at 32.8%, Aspen at 26.6%, and Spruce/Fir at 18.1%. The total number of wetland acres is 2,684.0 (Table D.10), which is 3.2% of total wetlands in the project area. This area contains the foothills leading to Mount Silverheels to the west. It also contains the small community of Como.

Table D.10. Acres of Wetlands Mapped in the Como Quad by Wetland Type and Land Owner

COMO	BLM	PRIVATE	SLB	USFS - PIKE	Total Acres
Freshwater Emergent Wetland	23.3	1,485.0	28.4	107.1	1,643.8
Freshwater Forested/Shrub Wetland	8.6	521.4	0.0	342.9	872.9
Freshwater Pond	17.0	98.1	0.0	18.5	133.6
Riverine	0.2	30.0	0.0	3.6	33.7
Grand Total	**49.1**	**2,134.4**	**28.4**	**472.1**	**2,684.0**

Conifer

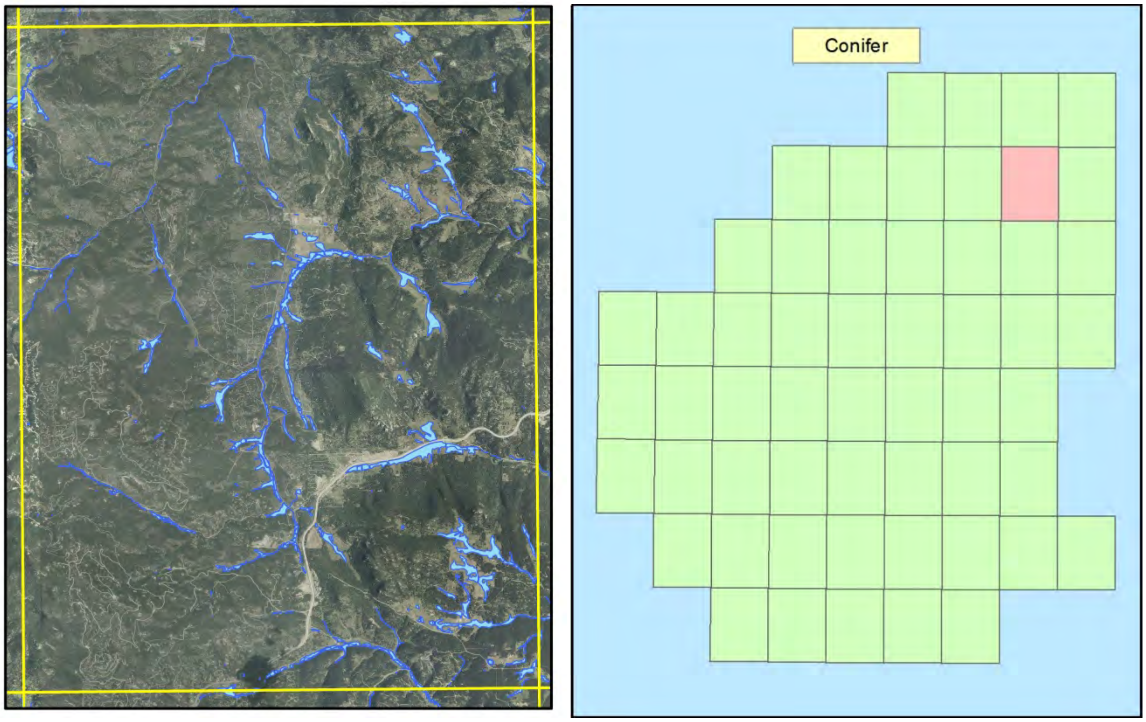


Figure D.11. Wetland polygons mapped within the Conifer quad shown over 2009 true-color aerial photography (left). Location of Conifer quad in relation to all quads in the study area (right).

The Conifer quad is in the northeast portion of the project area (Figure D.11). It has a minimum elevation of 7,037 feet and a max of 10,030 feet. The dominant vegetation types include: Ponderosa Pine at 45.8%, Lodgepole Pine at 44.9%, and Foothills/Mountain Grassland at 5.5%. The total number of wetland acres is 1,033.1 (Table D.11), which is 1.2% of total wetlands in the project area. This area is lower foothills containing the communities of Aspen Park and Conifer along CO-285.

Table D.11. Acres of Wetlands Mapped in the Conifer Quad by Wetland Type and Land Owner

CONIFER	CITY	COUNTY	PRIVATE	SLB	USFS - ARNF	Total Acres
Freshwater Emergent Wetland	11.2	121.8	710.0	2.8	0.0	845.8
Freshwater Forested/Shrub Wetland	5.5	15.8	98.7	1.2	1.9	123.0
Freshwater Pond	0.2	1.9	50.4	0.0	0.0	52.5
Riverine	0.5	1.9	6.0	0.0	3.4	11.8
Grand Total	**17.5**	**141.4**	**865.0**	**4.0**	**5.2**	**1,033.1**

Deckers

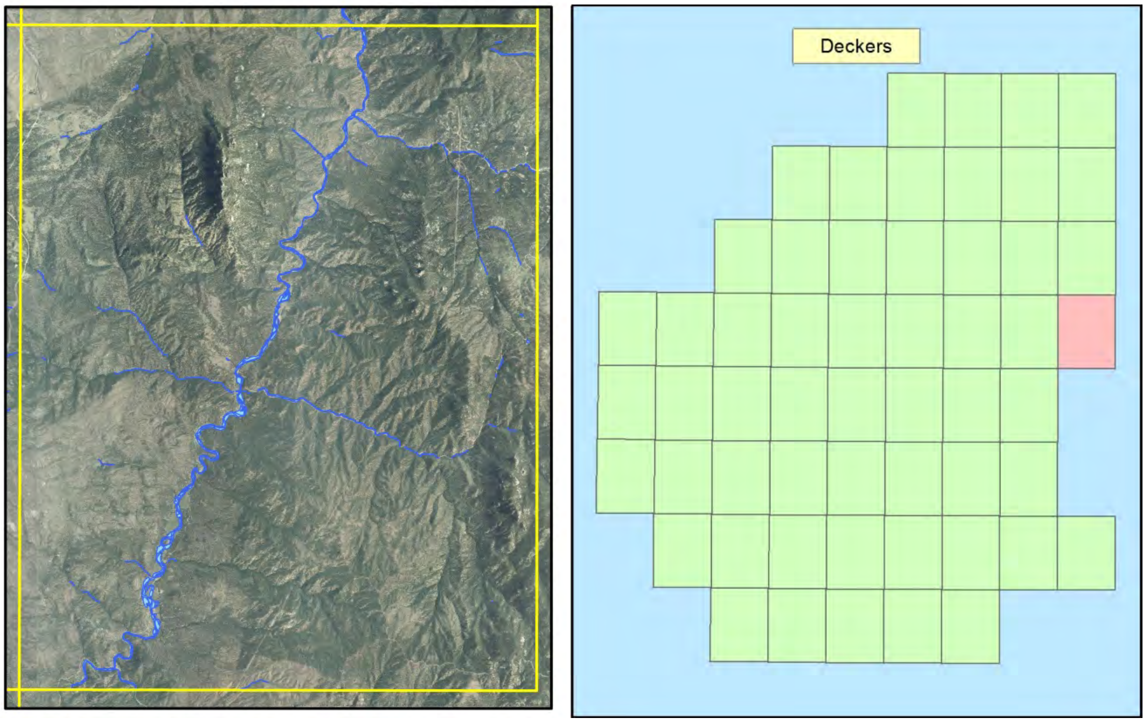


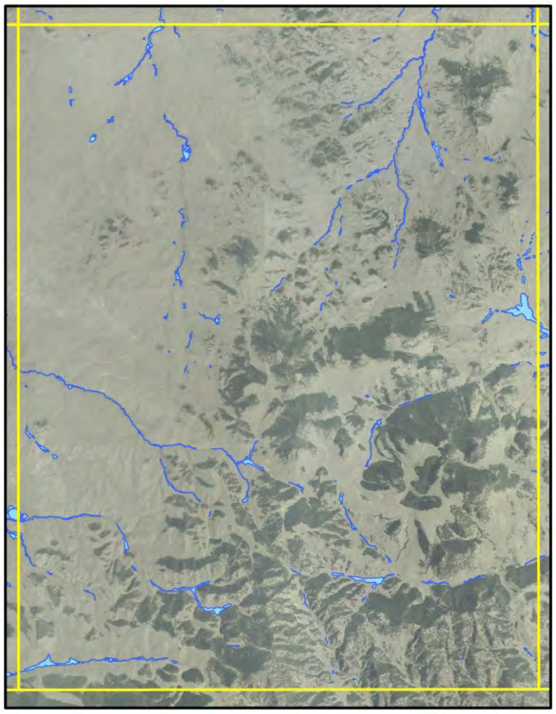
Figure D.12. Wetland polygons mapped within the Deckers quad shown over 2009 true-color aerial photography (left). Location of Deckers quad in relation to all quads in the study area (right).

The Deckers quad is in the central eastern portion of the project area (Figure D.12). It has a minimum elevation of 6,175 feet and a max of 8,858 feet. The dominant vegetation types include: Douglas Fir at 80.9%, and Ponderosa Pine at 19.1%. The total number of wetland acres is 374.9 (Table D.12), which is 0.4% of total wetlands in the project area. This quad has the main channel of the South Platte running through it with the high point of Long Scraggy Peak in the northern portion.

Table D.12. Acres of Wetlands Mapped in the Deckers Quad by Wetland Type and Land Owner

DECKERS	NGO	PRIVATE	USFS - PIKE	Total Acres
Freshwater Emergent Wetland	4.1	8.1	3.1	15.2
Freshwater Forested/Shrub Wetland	66.3	48.0	100.9	215.1
Freshwater Pond	0.8	2.4	0.5	3.7
Riverine	46.2	18.7	75.9	140.8
Total Acres	**117.3**	**77.2**	**180.4**	**374.9**

Dick's Peak



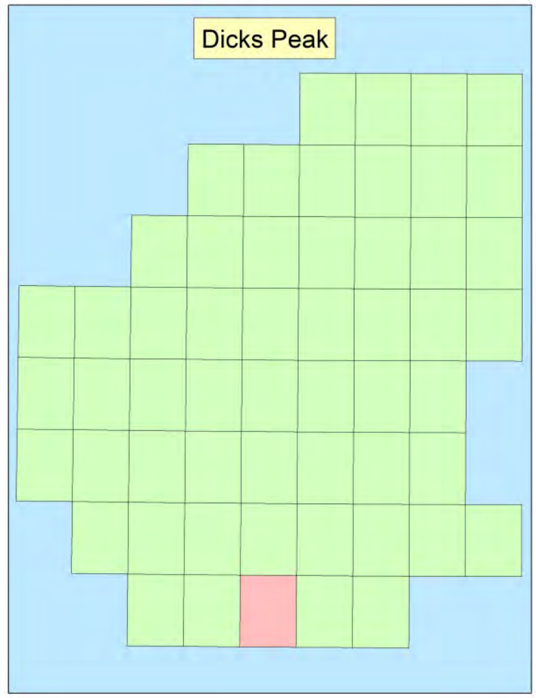


Figure D.13. Wetland polygons mapped within the Dicks Peak quad shown over 2009 true-color aerial photography (left). Location of Dicks Peak quad in relation to all quads in the study area (right).

The Dicks Peak quad is in the southern portion of the project area (Figure D.13). It has a minimum elevation of 9,072 feet and a max of 10,696 feet. The dominant vegetation types include: Foothills/Mountain Grassland at 68.2%, Mountain Big Sagebrush at 4.0%, and Ponderosa Pine at 27.8%. The total number of wetland acres is 295.7 (Table D.13), which is 0.3% of total wetlands in the project area. This area has very little development and no major roads.

Table D.13. Acres of Wetlands Mapped in the Dicks Peak Quad by Wetland Type and Land Owner

DICKS PEAK	BLM	PRIVATE	SLB	USFS - PIKE	Total Acres
Freshwater Emergent Wetland	1.0	194.4	5.6	74.4	275.4
Freshwater Forested/Shrub Wetland	0.0	1.1	0.0	6.2	7.2
Freshwater Pond	0.0	5.2	0.0	0.1	5.3
Riverine	0.0	7.7	0.0	0.0	7.7
Total Acres	**1.0**	**208.4**	**5.6**	**80.7**	**295.7**

Divide

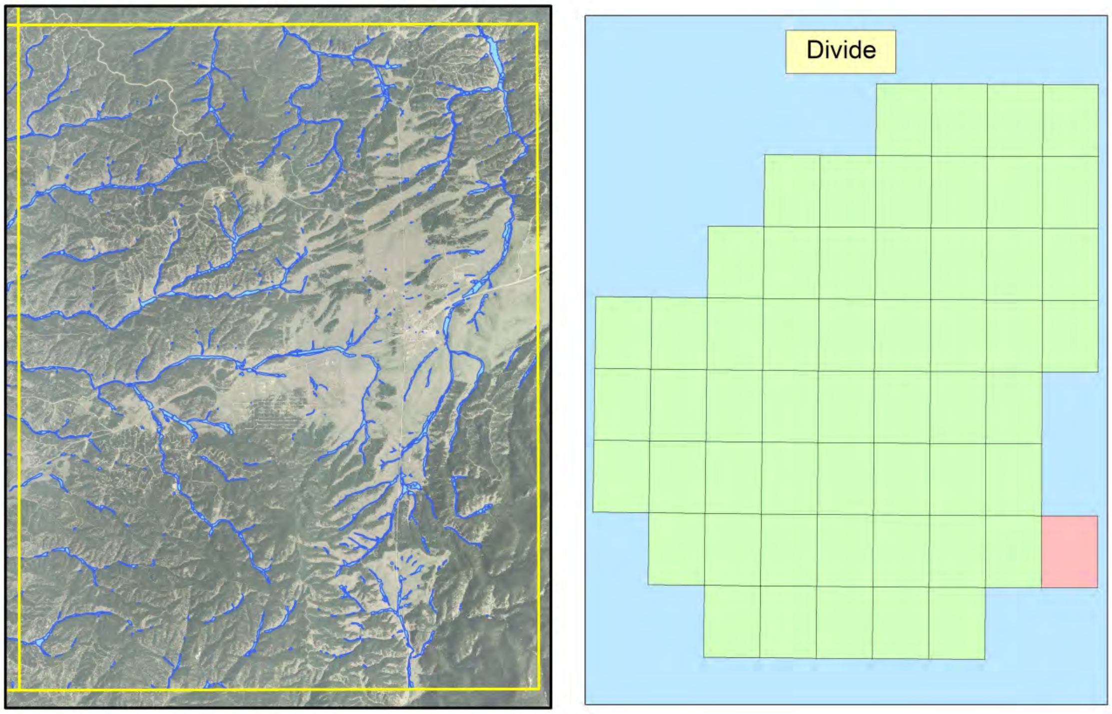


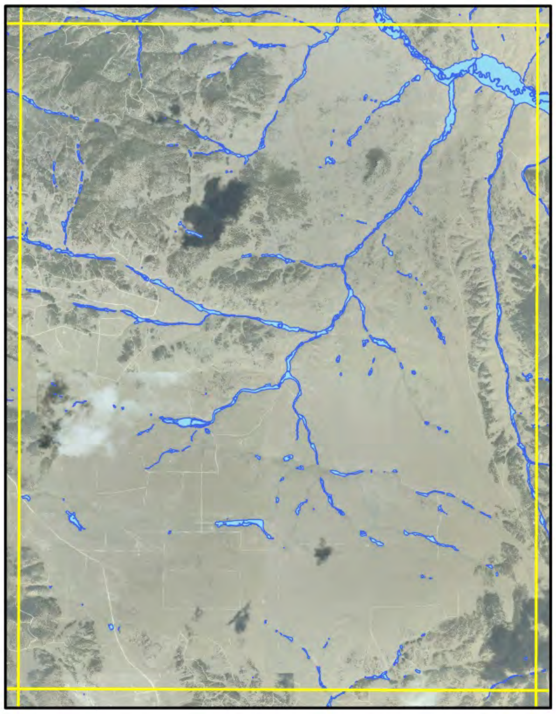
Figure D.14. Wetland polygons mapped within the Divide quad shown over 2009 true-color aerial photography (left). Location of Divide quad in relation to all quads in the study area (right).

The Divide quad is in the extreme south eastern portion of the project area (Figure D.14). It has a minimum elevation of 8,537 feet and a max of 10,686 feet. The dominant vegetation types include: Ponderosa Pine at 52.5%, Douglas Fir at 21.3%, and Foothills/Mountain Grassland at 18.6%. The total number of wetland acres is 1,225.2 (Table D.14), which is 1.4% of total wetlands in the project area. This area contains significant rural residential development along CO-24 which follows Twin Creek flowing west.

Table D.14. Acres of Wetlands Mapped in the Divide Quad by Wetland Type and Land Owner

DIVIDE	CPW	NPS	PRIVATE	STPARKS	USFS - PIKE	Total Acres
Freshwater Emergent Wetland	9.6	1.0	530.5	105.4	22.8	669.2
Freshwater Forested/Shrub Wetland	2.9	2.2	273.3	15.2	120.9	414.6
Freshwater Pond	0.1	0.0	110.3	2.5	4.3	117.2
Lake	0.0	0.0	23.8	0.0	0.0	23.8
Riverine	0.0	0.0	0.4	0.0	0.0	0.4
Total Acres	**12.6**	**3.3**	**938.2**	**123.1**	**148.0**	**1,225.2**

Eagle Rock



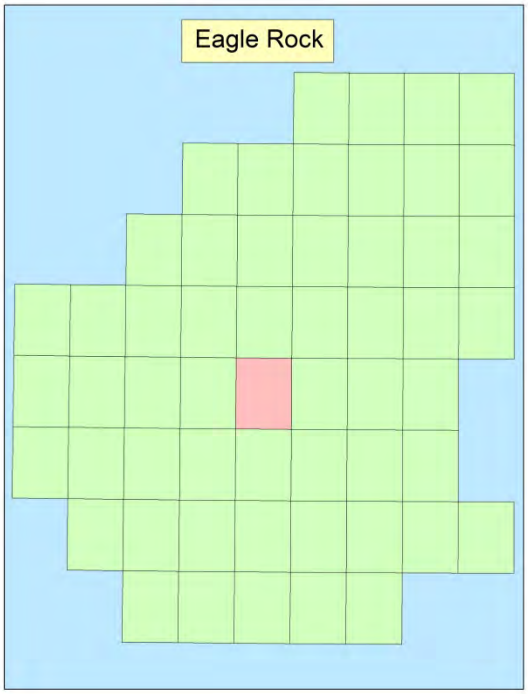


Figure D.15. Wetland polygons mapped within the Eagle Rock quad shown over 2009 true-color aerial photography (left). Location of Eagle Rock quad in relation to all quads in the study area (right).

The Eagle Rock quad is in the central portion of the project area (Figure D.15). It has a minimum elevation of 8,858 feet and a max of 10,377 feet. The dominant vegetation types include: Foothills/Mountain Grassland at 73.2% and Ponderosa Pine at 26.1%. The total number of wetland acres is 1,009.8 (Table D.15), which is 1.2% of total wetlands in the project area. This area is generally low relief grassland.

Table D.15. Acres of Wetlands Mapped in the Eagle Rock Quad by Wetland Type and Land Owner

EAGLE ROCK	BLM	CPW	PRIVATE	SLB	USFS - PIKE	Total Acres
Freshwater Emergent Wetland	4.9	70.8	592.8	0.9	163.0	832.3
Freshwater Forested/Shrub Wetland	0.0	11.7	51.3	0.0	49.7	112.7
Freshwater Pond	< 0.1	0.0	30.7	1.9	0.9	33.6
Riverine	0.0	8.6	17.9	0.0	4.7	31.2
Total Acres	**4.9**	**91.1**	**692.7**	**2.7**	**218.3**	**1,009.8**

Elevenmile Canyon

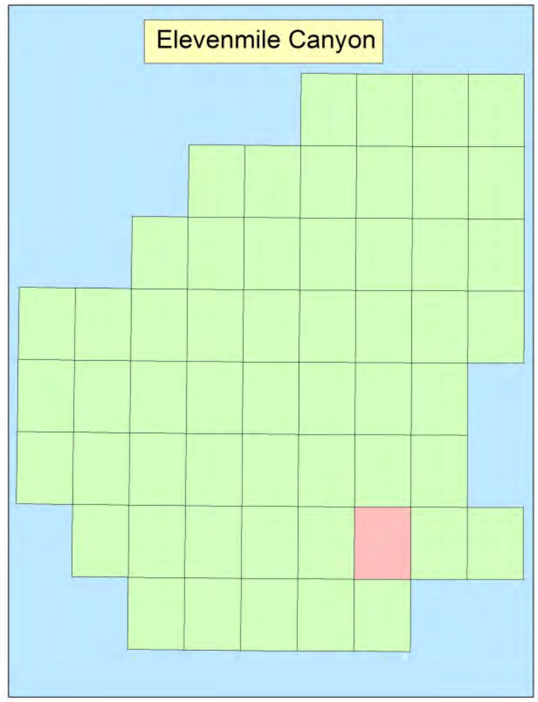


Figure D.16. Wetland polygons mapped within the Elevenmile Canyon quad shown over 2009 true-color aerial photography (left). Location of Elevenmile Canyon quad in relation to all quads in the study area (right).

The Elevenmile Canyon quad is in the south eastern portion of the project area (Figure D.16). It has a minimum elevation of 7,976 feet and a max of 10,823 feet. The dominant vegetation types include: Ponderosa Pine at 82.3%, Foothills/Mountain Grassland at 10.1%, and Spruce/Fir at 5.8%. The total number of wetland acres is 1,396.9 (Table D.16), which is 1.6% of total wetlands in the project area. This quad shows Elevenmile Canyon of the South Platte River.

Table D.16. Acres of Wetlands Mapped in the Elevenmile Canyon Quad by Wetland Type and Land Owner

ELEVENMILE CANYON	NGO	PRIVATE	SLB	USFS - PIKE	Total Acres
Freshwater Emergent Wetland	39.8	336.9	7.3	53.6	437.6
Freshwater Forested/Shrub Wetland	0.3	40.6	0.5	100.0	141.4
Freshwater Pond	0.2	28.8	0.4	1.0	30.3
Lake	628.0	0.0	0.0	101.9	730.0
Riverine	0.0	4.2	0.0	53.4	57.6
Total Acres	**668.3**	**410.5**	**8.2**	**309.9**	**1,396.9**

Elkhorn

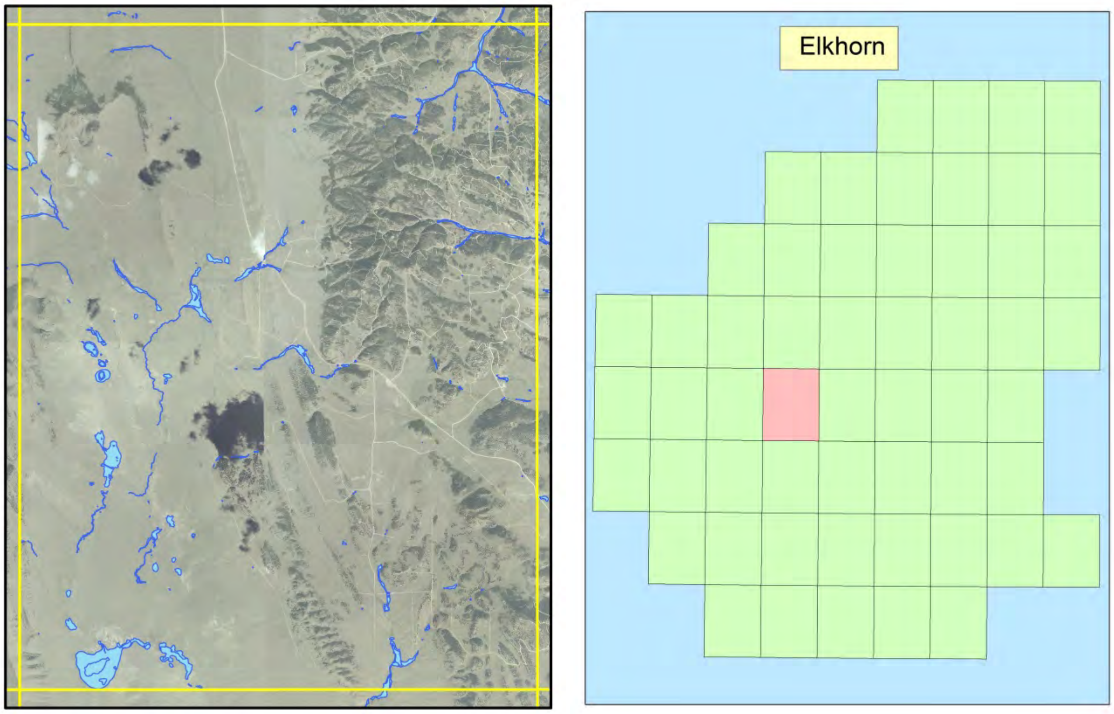


Figure D.17. Wetland polygons mapped within the Elkhorn quad shown over 2009 true-color aerial photography (left). Location of Elkhorn quad in relation to all quads in the study area (right).

The Elkhorn quad is in the central portion of the project area (Figure D.17). It has a minimum elevation of 9,052 feet and a max of 10,112 feet. The dominant vegetation types include: Foothills/Mountain Grassland at 73.0%, Ponderosa Pine at 23.5%, and Rocky Mountain Bristlecone Pine at 3.3%. The total number of wetland acres is 609.9 (Table D.17), which is 0.7% of total wetlands in the project area. This area is generally low relief with a few north-south oriented low ridges.

Table D.17. Acres of Wetlands Mapped in the Elkhorn Quad by Wetland Type and Land Owner

ELKHORN	BLM	CPW	PRIVATE	SLB	Grand Total
Freshwater Emergent Wetland	20.5	48.0	220.7	0.9	290.1
Freshwater Forested/Shrub Wetland	0.0	0.0	3.9	0.0	3.9
Freshwater Pond	5.0	267.2	35.1	0.1	307.4
Riverine	2.6	4.1	1.8	0.0	8.4
Grand Total	**28.1**	**319.3**	**261.6**	**1.0**	**609.9**

Evergreen

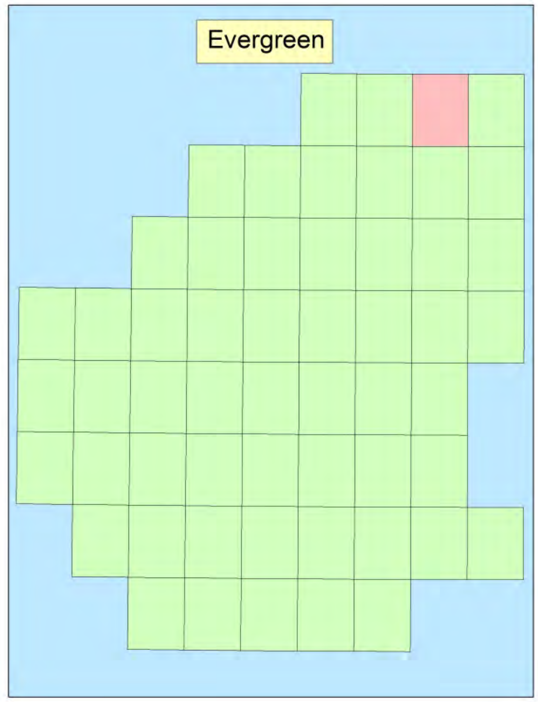


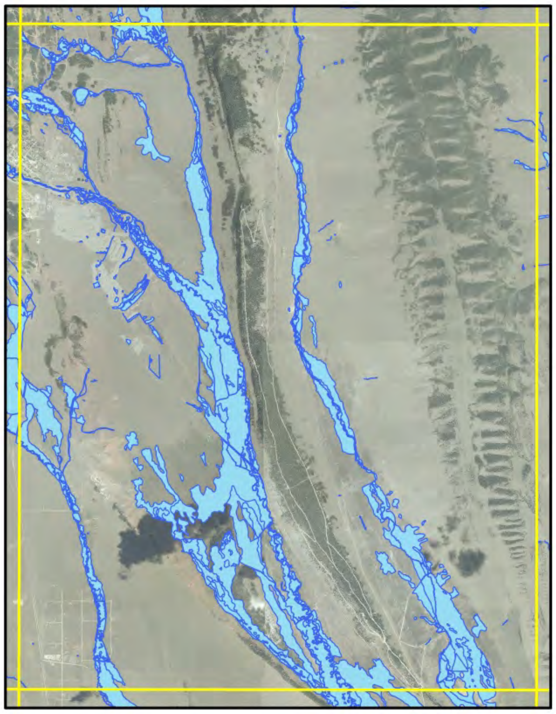
Figure D.18. Wetland polygons mapped within the Evergreen quad shown over 2009 true-color aerial photography (left). Location of Evergreen quad in relation to all quads in the study area (right).

The Evergreen quad is in the north eastern portion of the project area (Figure D.18). It has a minimum elevation of 5,810 feet and a max of 8,501 feet. The dominant vegetation types include: Ponderosa Pine at 66.0%, Mesic Upland Shrub at 9.9%, and Douglas Fir at 8.9%. The total number of wetland acres is 597.7 (Table D.18), which is 0.7% of total wetlands in the project area. This area has rural residential development scattered throughout the hills. Clear Creek Canyon lies at the northern boundary of this quad.

Table D.18. Acres of Wetlands Mapped in the Evergreen Quad by Wetland Type and Land Owner

EVERGREEN	BLM	CITY	COUNTY	PRIVATE	Grand Total
Freshwater Emergent Wetland	0.0	24.4	112.2	186.5	323.1
Freshwater Forested/Shrub Wetland	0.0	12.7	14.2	77.4	104.3
Freshwater Pond	0.0	0.7	0.0	39.7	40.4
Lake	0.0	40.2	0.0	1.3	41.6
Riverine	4.2	9.4	42.0	32.7	88.2
Grand Total	**4.2**	**87.4**	**168.4**	**337.7**	**597.7**

Fairplay East



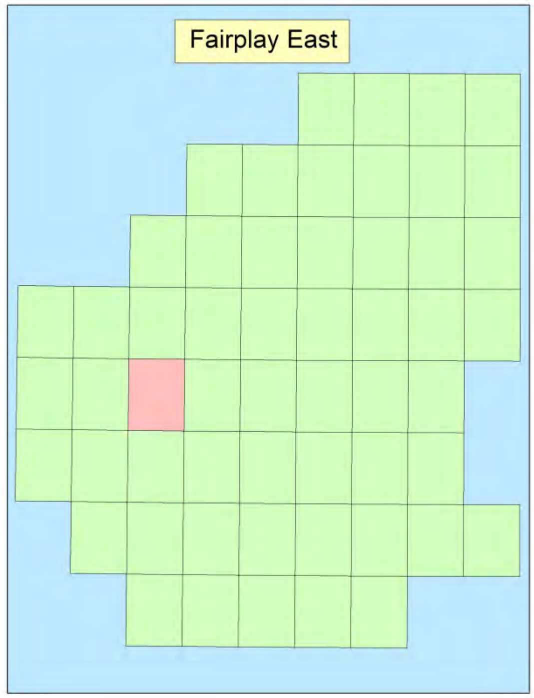


Figure D.19. Wetland polygons mapped within the Fairplay East quad shown over 2009 true-color aerial photography (left). Location of Fairplay East quad in relation to all quads in the study area (right).

The Fairplay East quad is in the central western portion of the project area (Figure D.19). It has a minimum elevation of 9,147 feet and a max of 10,558 feet. The dominant vegetation types include: Foothills/Mountain Grassland at 51.2%, Irrigated Agriculture at 14.4%, and Rocky Mountain Bristlecone Pine at 11.7%. The total number of wetland acres is 4,738.0 (Table D.19), which is 5.6% of total wetlands in the project area. This quad is centered on the Red Hill Ridge with the community of Fairplay at the northwest corner.

Table D.19. Acres of Wetlands Mapped in the Fairplay East Quad by Wetland Type and Land Owner

FAIRPLAY EAST	BLM	CPW	LAND TRUST	PRIVATE	SLB	Total Acres
Freshwater Emergent Wetland	79.4	1.0	0.1	3,780.3	108.8	3,969.6
Freshwater Forested/Shrub Wetland	14.9	0.0	0.0	425.4	85.0	525.2
Freshwater Pond	1.6	< 0.1	0.0	91.9	0.0	93.5
Lake	20.1	0.0	0.0	12.4	0.0	32.5
Riverine	2.1	0.0	0.0	113.9	1.1	117.1
Grand Total	**118.1**	**1.0**	**0.1**	**4,423.9**	**194.9**	**4,738.0**

Fairplay West

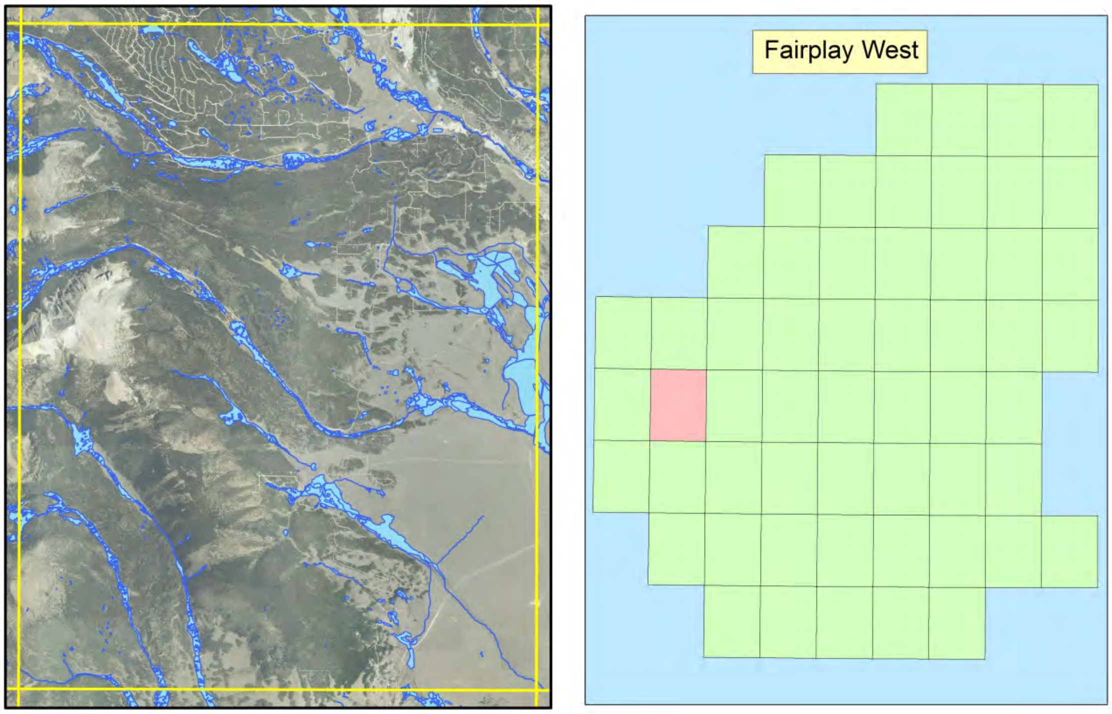


Figure D.20. Wetland polygons mapped within the Fairplay West quad shown over 2009 true-color aerial photography (left). Location of Fairplay West quad in relation to all quads in the study area (right).

The Fairplay West quad is in the central western portion of the project area (Figure D.20). It has a minimum elevation of 9,491 feet and a max of 12,815 feet. The dominant vegetation types include: Spruce/Fir at 27.8%, Foothills/Mountain Grassland at 18.1%, and Rocky Mountain Bristlecone Pine at 14.5%. The total number of wetland acres is 2,441.7 (Table D.20), which is 2.9% of total wetlands in the project area. This is the foothills to the southwest of the community of Fairplay.

Table D.20. Acres of Wetlands Mapped in the Fairplay West Quad by Wetland Type and Land Owner

FAIRPLAY WEST	BLM	LAND TRUST	PRIVATE	SLB	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	0.1	32.7	795.1	70.0	74.1	972.0
Freshwater Forested/Shrub Wetland	9.3	< 0.1	679.5	51.5	541.8	1,282.2
Freshwater Pond	1.0	< 0.1	65.2	2.7	34.3	103.2
Lake	0.0	0.0	18.2	0.0	0.0	18.2
Riverine	0.3	4.4	45.2	3.0	13.2	66.1
Grand Total	**10.8**	**37.1**	**1,603.2**	**127.2**	**663.3**	**2,441.7**

Farnum Peak

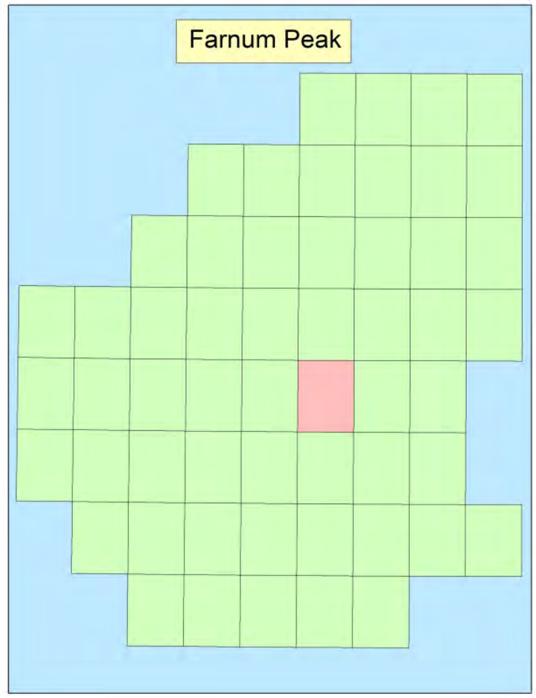


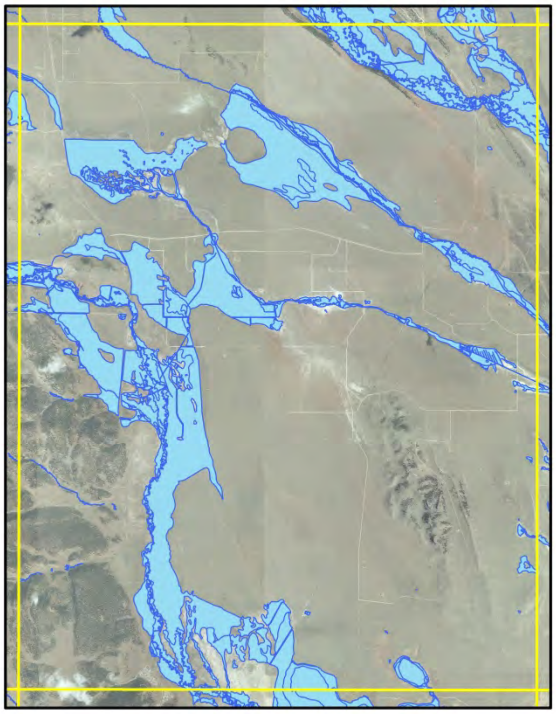
Figure D.21. Wetland polygons mapped within the Farnum Peak quad shown over 2009 true-color aerial photography (left). Location of Farnum Peak quad in relation to all quads in the study area (right).

The Farnum Peak quad is in the central portion of the project area (Figure D.21). It has a minimum elevation of 8,596 feet and a max of 12,185 feet. The dominant vegetation types include: Ponderosa Pine at 79.1%, Spruce/Fir at 14.2%, and Foothills/Mountain Grassland at 6.0%. The total number of wetland acres is 1,313.1 (Table D.21), which is 1.5% of total wetlands in the project area. Tarryall Creek, below the reservoir, heads southeast through the quad.

Table D.21. Acres of Wetlands Mapped in the Farnum Peak Quad by Wetland Type and Land Owner

FARNUM PEAK	CPW	PRIVATE	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	79.4	255.3	115.0	449.8
Freshwater Forested/Shrub Wetland	5.5	149.5	500.4	655.4
Freshwater Pond	0.7	2.2	0.3	3.2
Lake	148.1	0.0	6.5	154.6
Riverine	4.0	38.5	7.6	50.2
Grand Total	**237.7**	**445.6**	**629.9**	**1,313.1**

Garo



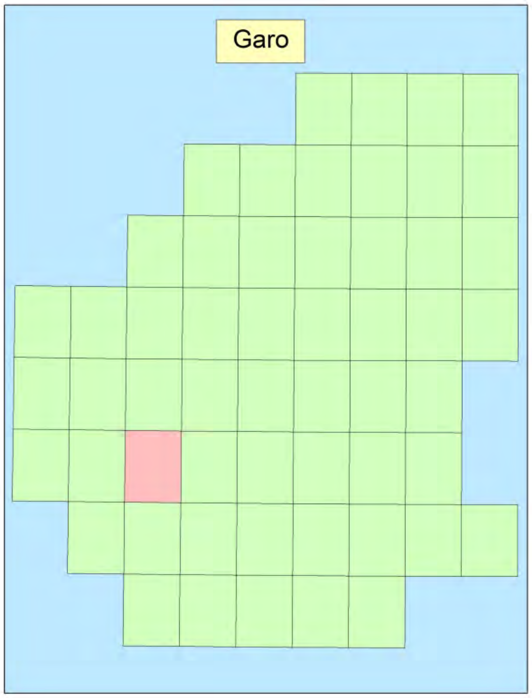


Figure D.22. Wetland polygons mapped within the Garo quad shown over 2009 true-color aerial photography (left). Location of Garo quad in relation to all quads in the study area (right).

The Garo quad is in the south western portion of the project area (Figure D.22). It has a minimum elevation of 8,934 feet and a max of 9,610 feet. The dominant vegetation types include: Foothills/Mountain Grassland at 62.5%, Irrigated Agriculture at 21.8%, and Ponderosa Pine at 7.8%. The total number of wetland acres is 6,598.1 (Table D.22), which is 7.8% of total wetlands in the project area. This area is a predominantly basin area, with extensive irrigated agriculture.

Table D.22. Acres of Wetlands Mapped in the Garo Quad by Wetland Type and Land Owner

GARO	BLM	LAND TRUST	NGO	PRIVATE	SLB	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	64.5	358.1	1,878.8	3,270.8	342.7	9.7	5,924.6
Freshwater Forested/Shrub Wetland	9.2	69.7	0.8	93.5	0.0	0.0	173.3
Freshwater Pond	9.8	11.3	107.1	83.8	1.2	0.0	213.3
Lake	0.0	0.0	170.1	13.4	0.0	0.0	183.6
Riverine	0.7	1.3	32.9	64.2	4.3	0.0	103.4
Grand Total	**84.3**	**440.4**	**2,189.8**	**3,525.7**	**348.2**	**9.7**	**6,598.1**

Glentivar

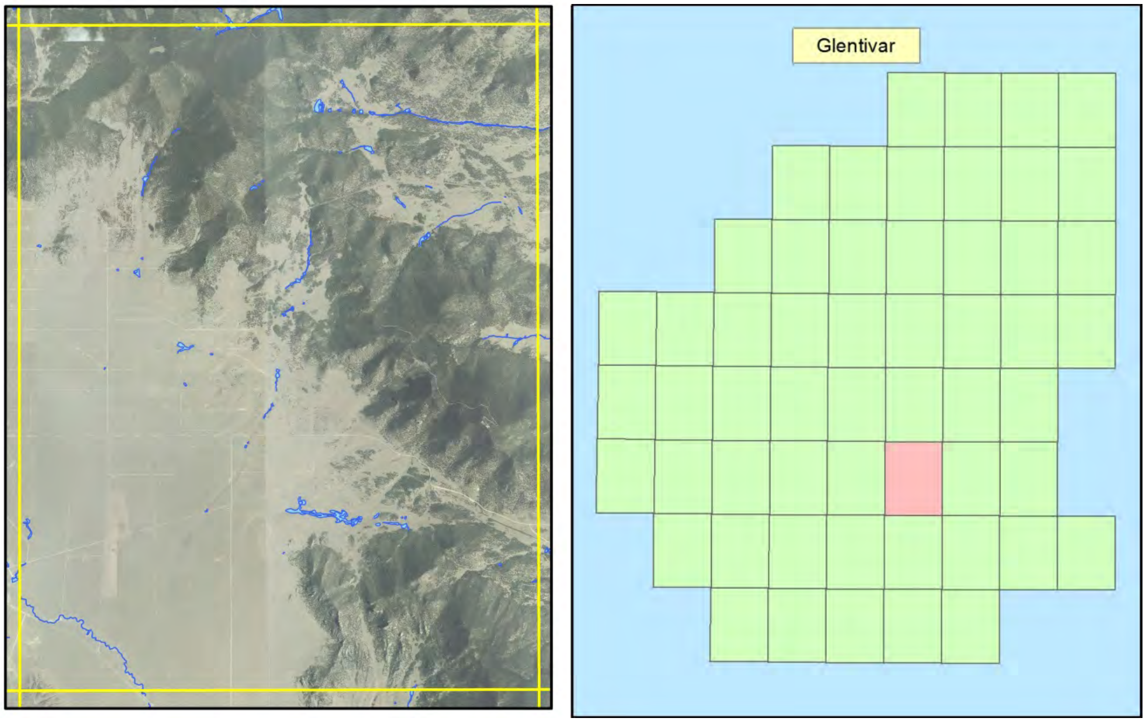


Figure D.23. Wetland polygons mapped within the Glentivar quad shown over 2009 true-color aerial photography (left). Location of Glentivar quad in relation to all quads in the study area (right).

The Glentivar quad is in the central portion of the project area (Figure D.23). It has a minimum elevation of 8,655 feet and a max of 11,358 feet. The dominant vegetation types include: Foothills/Mountain Grassland at 41.9%, Spruce/Fir at 7.3%, and Ponderosa Pine at 50.8%. The total number of wetland acres is 150.6 (Table D.23), which is 0.2% of total wetlands in the project area. This quad includes portions of the Puma Hills and CO-224 runs E-W through the center.

Table D.23. Acres of Wetlands Mapped in the Glentivar Quad by Wetland Type and Land Owner

GLENTIVAR	PRIVATE	SLB	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	84.1	0.0	16.9	101.0
Freshwater Forested/Shrub Wetland	13.6	0.0	19.4	33.0
Freshwater Pond	11.3	0.0	0.4	11.7
Riverine	3.6	1.3	0.0	4.9
Grand Total	**112.6**	**1.3**	**36.7**	**150.6**

Green Mountain

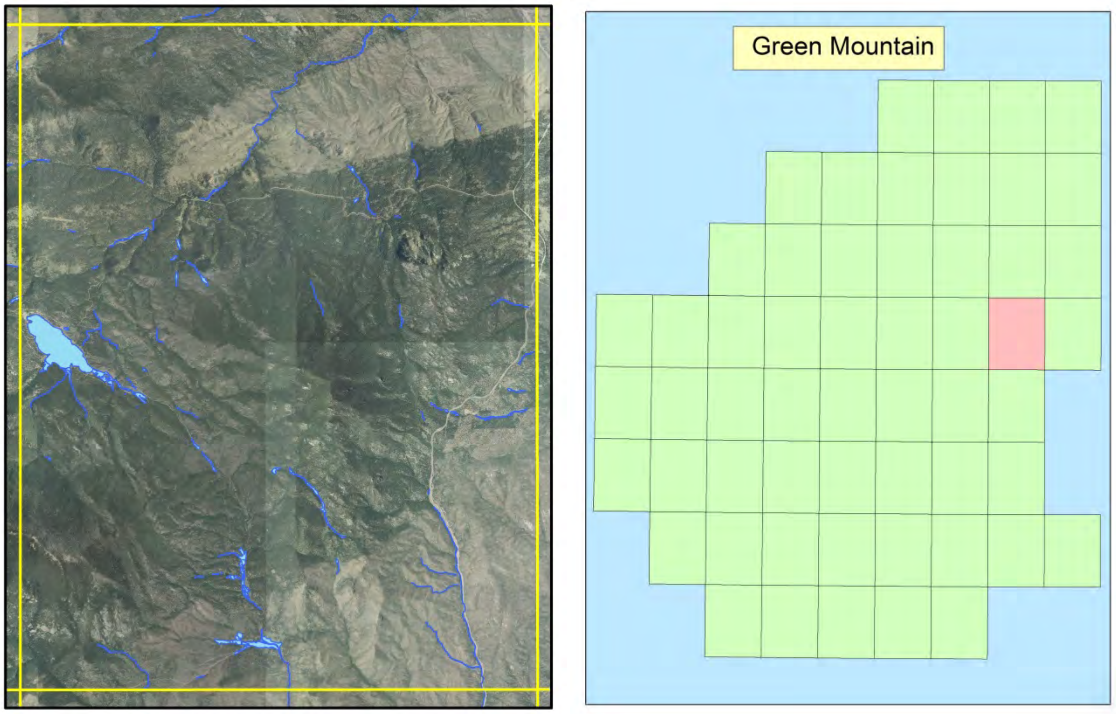


Figure D.24. Wetland polygons mapped within the Green Mountain quad shown over 2009 true-color aerial photography (left). Location of Green Mountain quad in relation to all quads in the study area (right).

The Green Mountain quad is in the central eastern portion of the project area (Figure D.24). It has a minimum elevation of 6,781 feet and a max of 11,549 feet. The dominant vegetation types include: Ponderosa Pine at 63.9%, Douglas Fir at 33.3%, and Aspen at 2.8%. The total number of wetland acres is 446.9 (Table D.24), which is 0.5% of total wetlands in the project area. This quad includes Green Mountain, Buffalo Peak, and Wellington Lake in a mountainous, but not alpine region.

Table D.24. Acres of Wetlands Mapped in the Green Mountain Quad by Wetland Type and Land Owner

GREEN MOUNTAIN	PRIVATE	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	50.9	7.6	58.5
Freshwater Forested/Shrub Wetland	75.1	101.9	177.0
Freshwater Pond	7.4	1.3	8.7
Lake	182.5	0.0	182.5
Riverine	3.9	16.3	20.2
Grand Total	**319.8**	**127.1**	**446.9**

Guffey NW

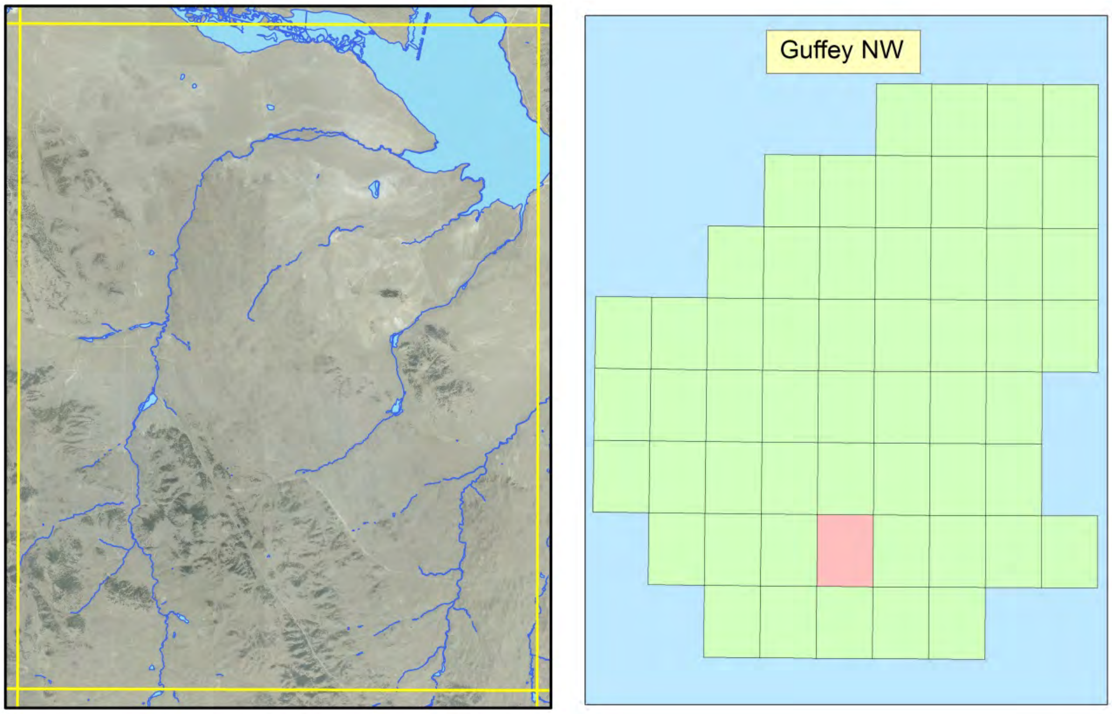


Figure D.25. Wetland polygons mapped within the Guffey NW quad shown over 2009 true-color aerial photography (left). Location of Guffey NW quad in relation to all quads in the study area (right).

The Guffey NW quad is in the central southern portion of the project area (Figure D.25). It has a minimum elevation of 8,648 feet and a max of 9,741 feet. The dominant vegetation types include: Foothills/Mountain Grassland at 90.5%, Ponderosa Pine at 3.0%, and Mesic Upland Shrub at 0.6%. The total number of wetland acres is 2,728.4 (Table D.25), which is 3.2% of total wetlands in the project area. This area is low relief hills leading to the South Platte River with mostly grasslands.

Table D.25. Acres of Wetlands Mapped in the Guffey NW Quad by Wetland Type and Land Owner

GUFFEY NW	BLM	CDOW	CITY	PRIVATE	SLB	Grand Total
Freshwater Emergent Wetland	13.9	118.9	217.7	135.5	27.9	513.9
Freshwater Forested/Shrub Wetland	0.0	0.0	5.5	< 0.1	0.0	5.6
Freshwater Pond	2.5	0.9	0.1	13.9	2.8	20.3
Lake	7.5	0.0	2,057.0	0.0	63.6	2,128.1
Riverine	14.6	0.9	7.9	31.3	5.7	60.5
Grand Total	**38.6**	**120.7**	**2,288.3**	**180.8**	**100.1**	**2,728.4**

Hackett Mountain

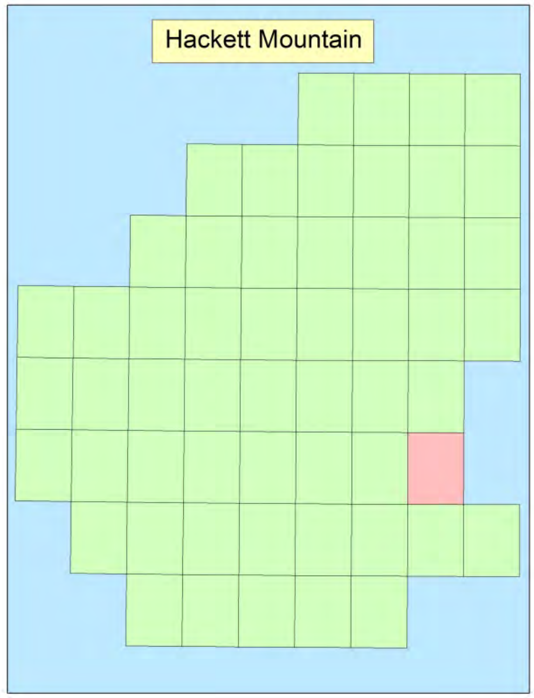


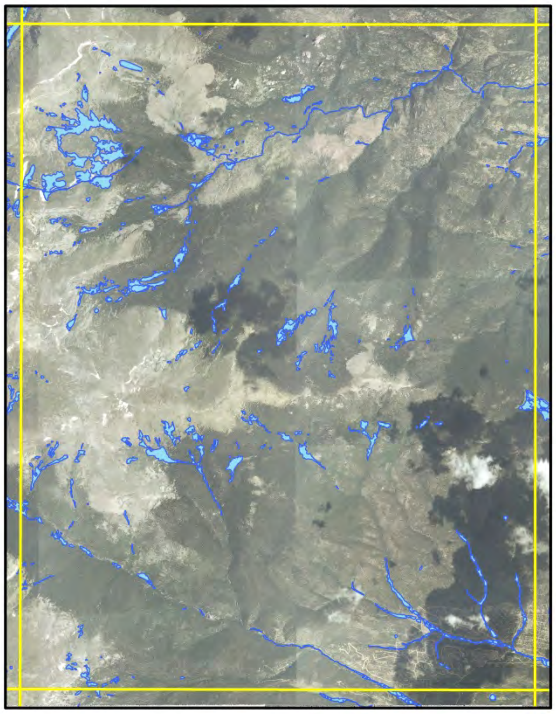
Figure D.26. Wetland polygons mapped within the Hackett Mountain quad shown over 2009 true-color aerial photography (left). Location of Hackett Mountain quad in relation to all quads in the study area (right).

The Hackett Mountain quad is in the south eastern portion of the project area (Figure D.26). It has a minimum elevation of 7,083 feet and a max of 9,544 feet. The dominant vegetation types include: Douglas Fir at 69.2%, Ponderosa Pine at 29.6%, and Foothills/Mountain Grassland at 0.8%. The total number of wetland acres is 777.4 (Table D.26), which is 0.9% of total wetlands in the project area. This quad shows the South Platte River as it flows north along the Park and Teller County boundary.

Table D.26. Acres of Wetlands Mapped in the Hackett Mountain Quad by Wetland Type and Land Owner

HACKETT MOUNTAIN	PRIVATE	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	130.2	56.4	186.5
Freshwater Forested/Shrub Wetland	156.5	294.7	451.3
Freshwater Pond	35.9	1.3	37.2
Riverine	22.4	80.0	102.4
Grand Total	**345.1**	**432.4**	**777.4**

Harris Park



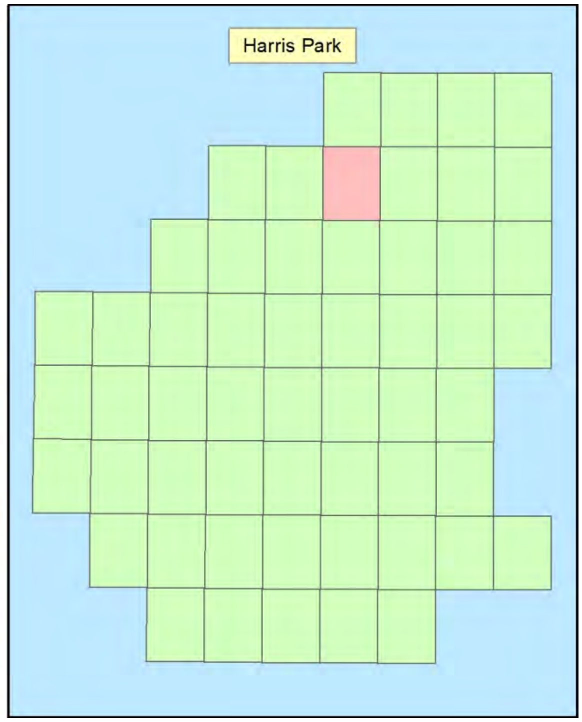


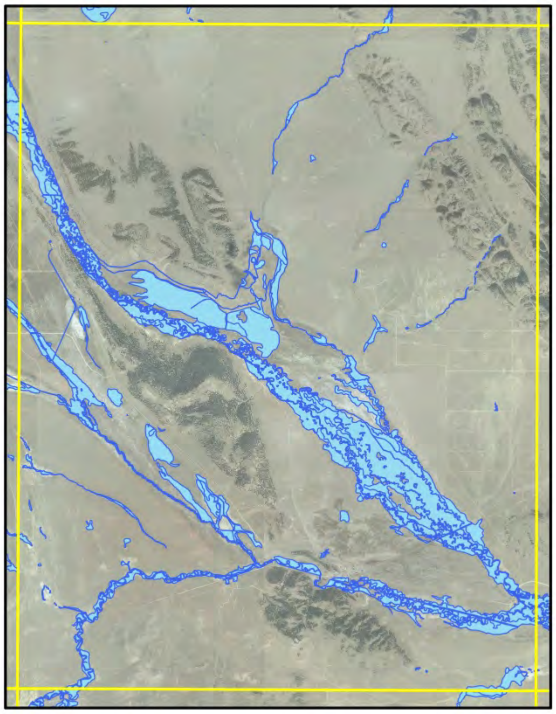
Figure D.27. Wetland polygons mapped within the Harris Park quad shown over 2009 true-color aerial photography (left). Location of Harris Park quad in relation to all quads in the study area (right).

The Harris Park quad is in the north central portion of the project area (Figure D.27). It has a minimum elevation of 8,373 feet and a max of 13,573 feet. The dominant vegetation types include: Spruce/Fir at 41.7%, Lodgepole Pine at 14.9%, and Meadow Tundra at 23.5%. The total number of wetland acres is 994.9 (Table D.27), which is 1.2% of total wetlands in the project area. This area is the Mount Evans Wilderness Area, leading up to the highest peak in Colorado.

Table D.27. Acres of Wetlands Mapped in the Harris Park Quad by Wetland Type and Land Owner

HARRIS PARK	CPW	PRIVATE	USFS - ARNF	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	9.1	6.0	115.8	10.2	141.1
Freshwater Forested/Shrub Wetland	8.3	54.2	446.7	280.2	789.4
Freshwater Pond	0.1	7.3	25.3	2.2	34.8
Lake	0.0	0.0	12.2	0.0	12.2
Riverine	3.1	1.7	11.7	1.0	17.5
Grand Total	**20.6**	**69.2**	**611.6**	**293.5**	**994.9**

Hartsel



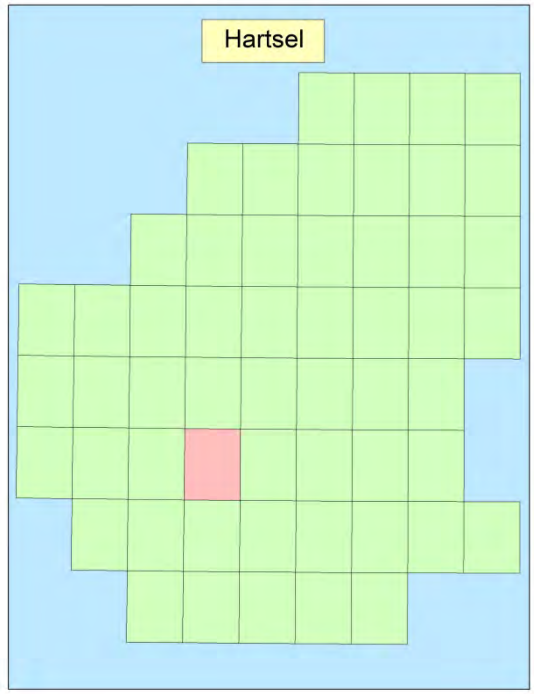


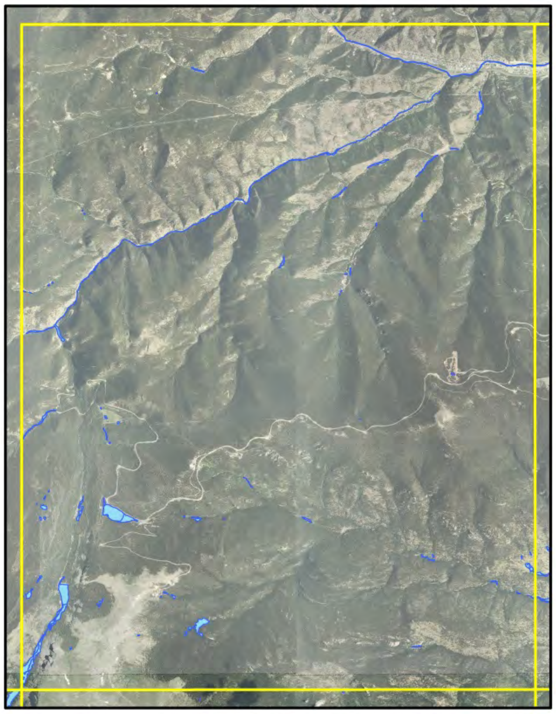
Figure D.28. Wetland polygons mapped within the Hartsel quad shown over 2009 true-color aerial photography (left). Location of Hartsel quad in relation to all quads in the study area (right).

The Hartsel quad is in the central southwestern portion of the project area (Figure D.28). It has a minimum elevation of 8,776 feet and a max of 9,715 feet. The dominant vegetation types include: Foothills/Mountain Grassland at 57.7%, Irrigated Agriculture at 22.1%, and Rocky Mountain Bristlecone Pine at 19.1%. The total number of wetland acres is 3,605.6 (Table D.28), which is 4.2% of total wetlands in the project area. This area is just upstream from the junction of the Middle Fork and South Fork of the South Platte River.

Table D.28. Acres of Wetlands Mapped in the Hartsel Quad by Wetland Type and Land Owner

HARTSEL	BLM	CPW	NGO	PRIVATE	SLB	Grand Total
Freshwater Emergent Wetland	10.8	438.1	16.4	2,834.2	10.5	3,310.0
Freshwater Forested/Shrub Wetland	0.0	42.6	0.0	20.8	0.0	63.4
Freshwater Pond	0.0	0.1	1.7	22.5	3.4	27.8
Riverine	0.5	30.0	2.7	170.9	0.4	204.4
Grand Total	**11.3**	**510.9**	**20.9**	**3,048.3**	**14.3**	**3,605.6**

Idaho Springs



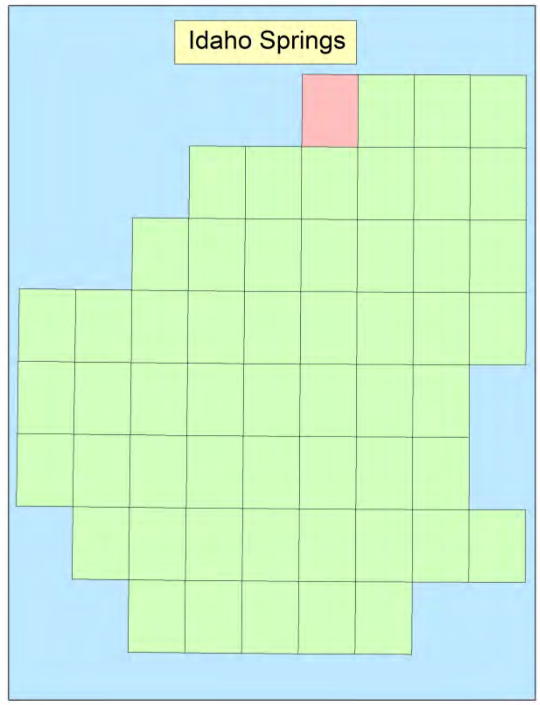


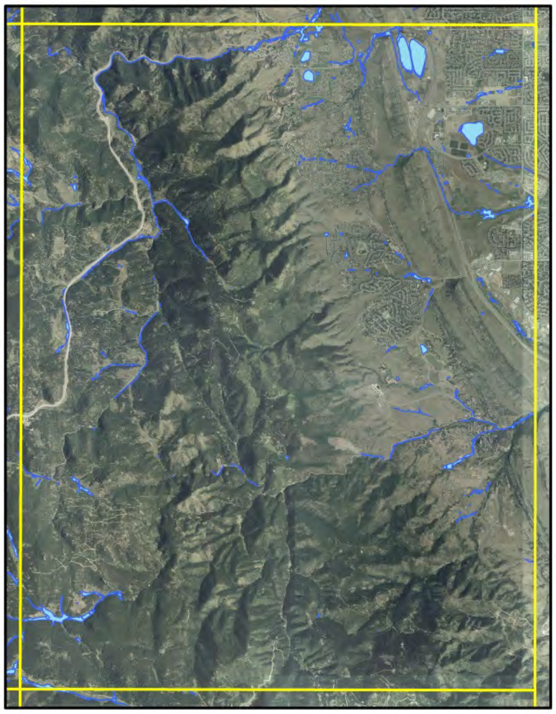
Figure D.29. Wetland polygons mapped within the Idaho Springs quad shown over 2009 true-color aerial photography (left). Location of Idaho Springs quad in relation to all quads in the study area (right).

The Idaho Springs quad is in the northern portion of the project area (Figure D.29). It has a minimum elevation of 7,461 feet and a max of 12,592 feet. The dominant vegetation types include: Lodgepole Pine at 65.3%, Spruce/Fir at 12.9%, and Ponderosa Pine at 10.5%. The total number of wetland acres is 194.0 (Table D.29), which is 0.2% of total wetlands in the project area. This area is mountainous, though not alpine. The quad includes the small urban area of Idaho Springs and the forested area to the south of I-70.

Table D.29. Acres of Wetlands Mapped in the Idaho Springs Quad by Wetland Type and Land Owner

IDAHO SPRINGS	CITY	PRIVATE	USFS - ARNF	Grand Total
Freshwater Emergent Wetland	0.0	7.3	6.0	13.3
Freshwater Forested/Shrub Wetland	8.9	18.4	56.5	83.9
Freshwater Pond	0.0	3.3	0.4	3.7
Lake	39.1	2.4	< 0.1	41.5
Riverine	0.2	37.2	14.1	51.5
Grand Total	**48.2**	**68.6**	**77.1**	**194.0**

Indian Hills



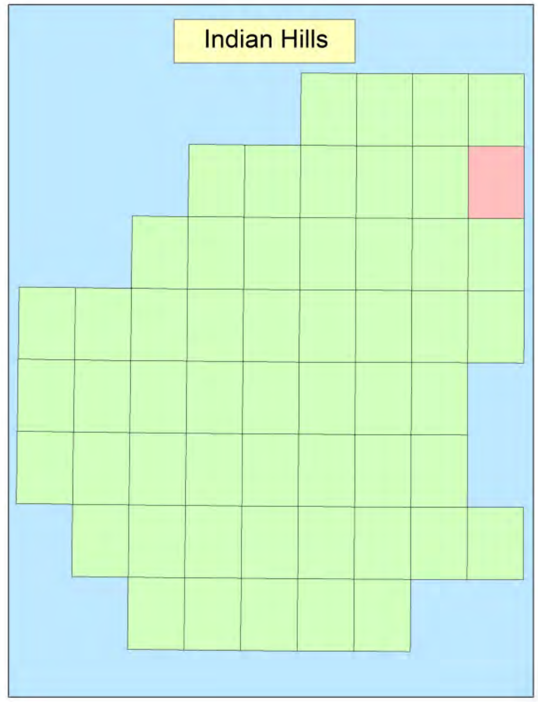


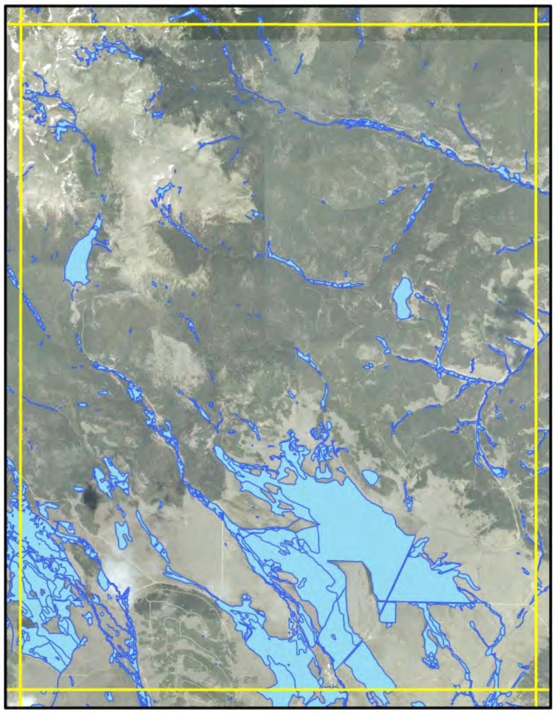
Figure D.30. Wetland polygons mapped within the Indian Hills quad shown over 2009 true-color aerial photography (left). Location of Indian Hills quad in relation to all quads in the study area (right).

The Indian Hills quad is in the north eastern portion of the project area (Figure D.30). It has a minimum elevation of 5,633 feet and a max of 8,629 feet. The dominant vegetation types include: Ponderosa Pine at 23.9%, Mesic Upland Shrub at 22.2%, and Midgrass Prairie at 20.2%. The total number of wetland acres is 435.0 (Table D.30), which is 0.5% of total wetlands in the project area. This quad shows the foothills to the west of the hogback, west of Littleton.

Table D.30. Acres of Wetlands Mapped in the Indian Hills Quad by Wetland Type and Land Owner

INDIAN HILLS	CITY	COUNTY	METRO DISTRICT	NGO	PRIVATE	Grand Total
Freshwater Emergent Wetland	0.0	5.7	8.2	0.5	87.2	101.6
Freshwater Forested/Shrub Wetland	2.1	3.9	1.5	0.3	102.7	110.5
Freshwater Pond	0.0	8.4	11.4	0.0	36.3	56.2
Lake	0.0	< 0.1	2.8	0.0	109.1	112.0
Riverine	2.9	7.6	1.7	0.2	42.4	54.8
Grand Total	5.0	25.5	25.6	1.0	377.8	435.0

Jefferson



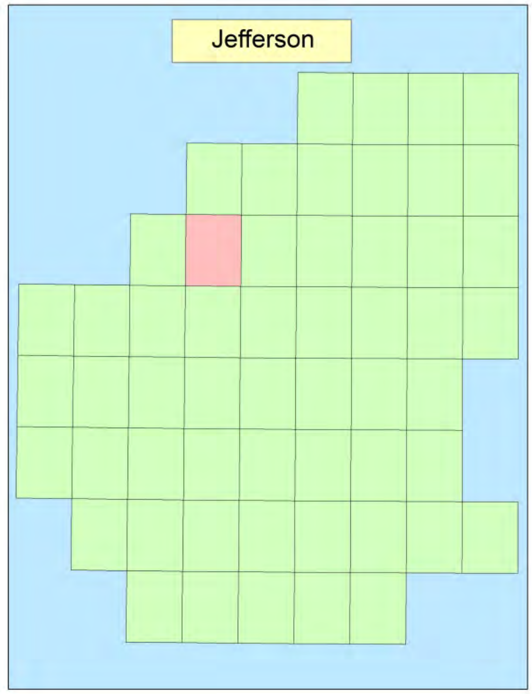


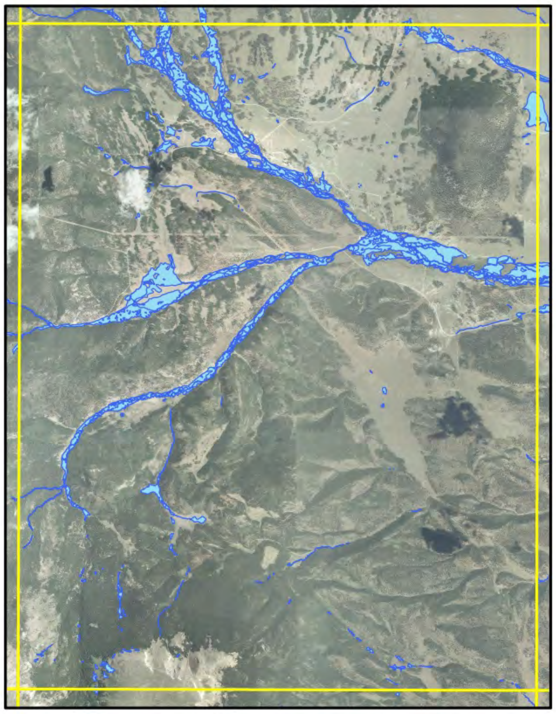
Figure D.31. Wetland polygons mapped within the Jefferson quad shown over 2009 true-color aerial photography (left). Location of Jefferson quad in relation to all quads in the study area (right).

The Jefferson quad is in the north western portion of the project area (Figure D.31). It has a minimum elevation of 9,354 feet and a max of 13,041 feet. The dominant vegetation types include: Spruce/Fir at 41.0%, Aspen at 18.2%, and Irrigated Agriculture at 16.3%. The total number of wetland acres is 4,941.7 (Table D.31), which is 5.8% of total wetlands in the project area. This quad is about 60% mountainous forest areas, and 40% flat basin area, where the agriculture is based.

Table D.31. Acres of Wetlands Mapped in the Jefferson Quad by Wetland Type and Land Owner

JEFFERSON	CPW	PRIVATE	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	100.2	3,136.8	134.3	3,371.3
Freshwater Forested/Shrub Wetland	52.2	748.0	454.4	1,254.5
Freshwater Pond	2.5	94.5	25.8	122.9
Lake	0.0	138.5	22.3	160.7
Riverine	3.2	15.9	13.3	32.3
Grand Total	**158.1**	**4,133.6**	**650.0**	**4,941.7**

Jones Hill



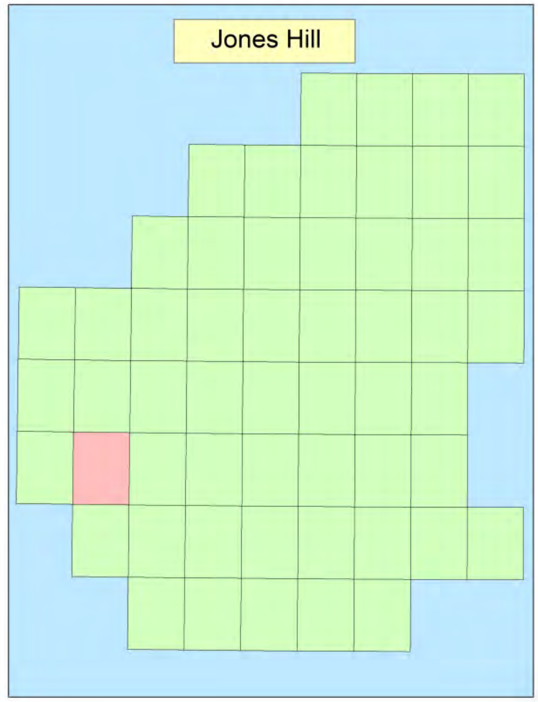


Figure D.32. Wetland polygons mapped within the Jones Hill quad shown over 2009 true-color aerial photography (left). Location of Jones Hill quad in relation to all quads in the study area (right).

The Jones Hill quad is in the south western portion of the project area (Figure D.32). It has a minimum elevation of 9,222 feet and a max of 12,631 feet. The dominant vegetation types include: Aspen at 25.9%, Foothills/Mountain Grassland at 24.8%, and Ponderosa Pine at 13.6%. The total number of wetland acres is 1,693.2 (Table D.32), which is 2.0% of total wetlands in the project area. This area is the foothills of the mountains on the west side of the South Park basin.

Table D.32. Acres of Wetlands Mapped in the Jones Hill Quad by Wetland Type and Land Owner

JONES HILL	BLM	PRIVATE	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	8.9	595.5	45.4	649.9
Freshwater Forested/Shrub Wetland	5.7	720.6	184.2	910.4
Freshwater Pond	0.7	75.7	12.4	88.7
Riverine	0.2	37.8	6.3	44.2
Grand Total	**15.4**	**1,429.6**	**248.2**	**1,693.2**

Lake George

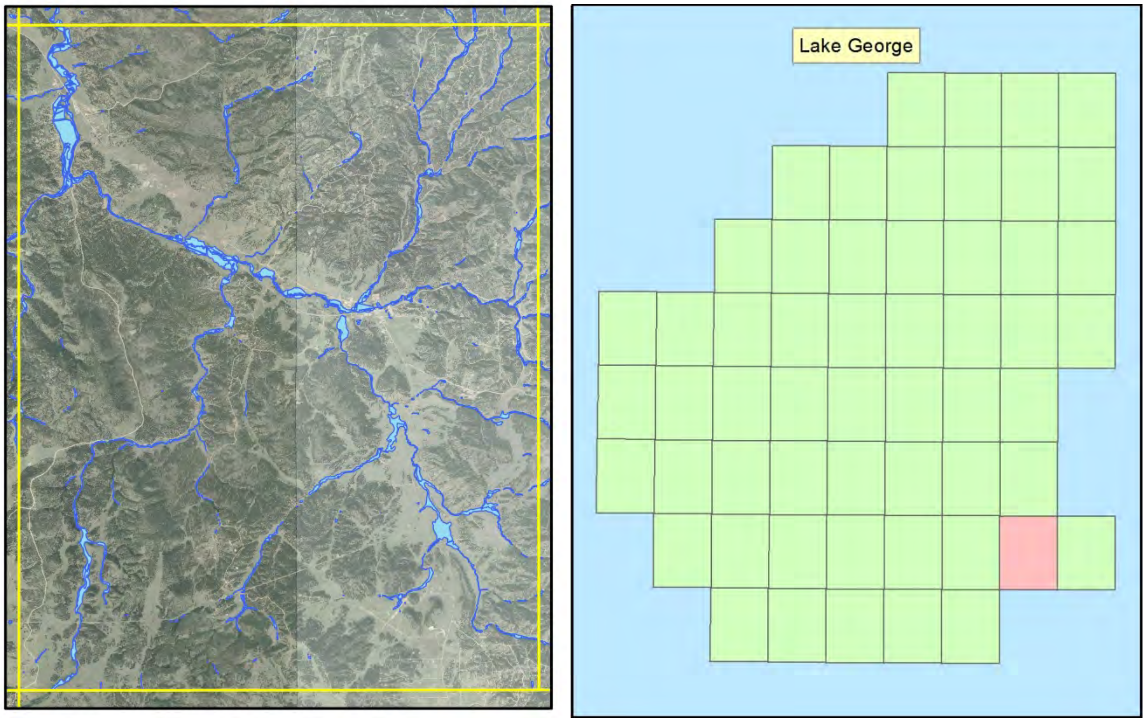


Figure D.33. Wetland polygons mapped within the Lake George quad shown over 2009 true-color aerial photography (left). Location of Lake George quad in relation to all quads in the study area (right).

The Lake George quad is in the south eastern portion of the project area (Figure D.33). It has a minimum elevation of 7,887 feet and a max of 9,580 feet. The dominant vegetation types include: Ponderosa Pine at 77.8%, Foothills/Mountain Grassland at 16.7%, and Douglas Fir at 5.5%. The total number of wetland acres is 1,032.9 (Table D.33), which is 1.2% of total wetlands in the project area. This area includes the Florissant Fossil Beds National Monument, an interesting collection of fossilized plants and insects.

Table D.33. Acres of Wetlands Mapped in the Lake George Quad by Wetland Type and Land Owner

LAKE GEORGE	NPS	PRIVATE	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	177.4	418.1	23.6	619.1
Freshwater Forested/Shrub Wetland	10.6	197.9	43.6	252.1
Freshwater Pond	2.7	57.1	3.2	63.0
Lake	0.0	53.7	0.0	53.7
Riverine	2.3	35.3	7.4	45.0
Grand Total	**193.0**	**762.1**	**77.8**	**1,032.9**

Marmot Peak

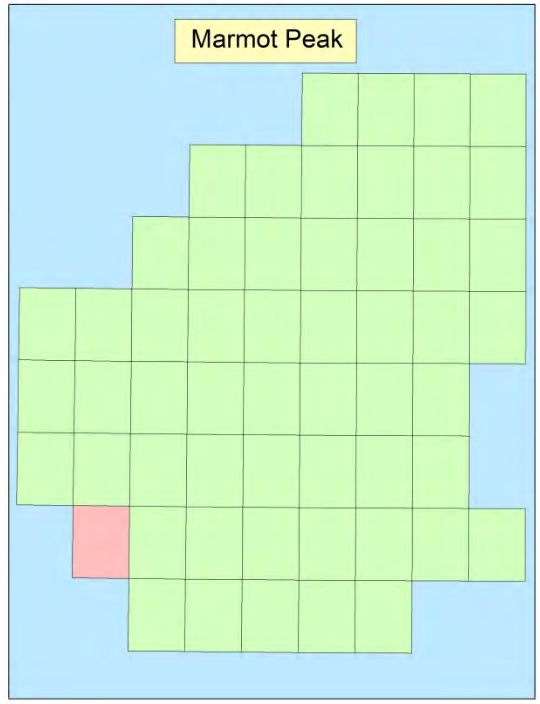


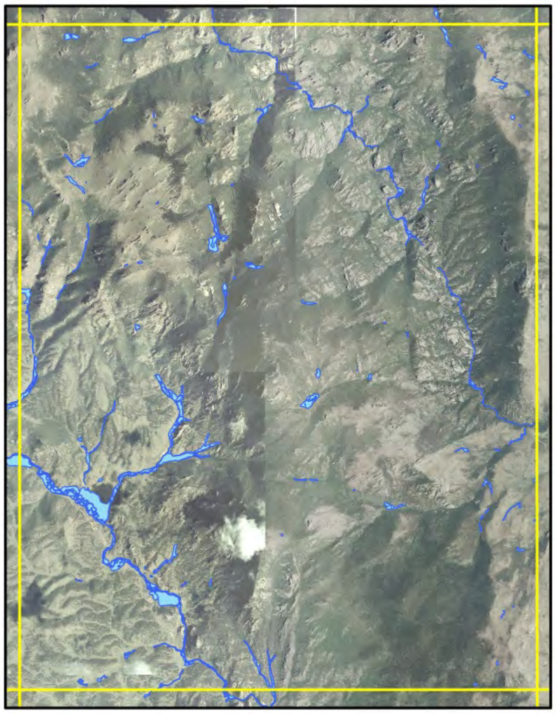
Figure D.34. Wetland polygons mapped within the Marmot Peak quad shown over 2009 true-color aerial photography (left). Location of Marmot Peak quad in relation to all quads in the study area (right).

The Marmot Peak quad is in the south western portion of the project area (Figure D.34). It has a minimum elevation of 8,287 feet and a max of 13,304 feet. The dominant vegetation types include: Lodgepole Pine at 21.6%, Ponderosa Pine at 20.0%, and Aspen at 17.3%. The total number of wetland acres is 540.8 (Table D.34), which is 0.6% of total wetlands in the project area. This area is the foothills of the mountains on the west side of the South Park basin.

Table D.34. Acres of Wetlands Mapped in the Marmot Peak Quad by Wetland Type and Land Owner

MARMOT PEAK	BLM	PRIVATE	SLB	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	0.2	1.9	21.3	182.8	206.2
Freshwater Forested/Shrub Wetland	0.0	8.7	7.7	298.1	314.5
Freshwater Pond	0.0	1.0	1.7	9.6	12.3
Riverine	0.0	0.6	0.8	6.5	7.9
Grand Total	**0.2**	**12.2**	**31.5**	**497.0**	**540.8**

McCurdy Mountain



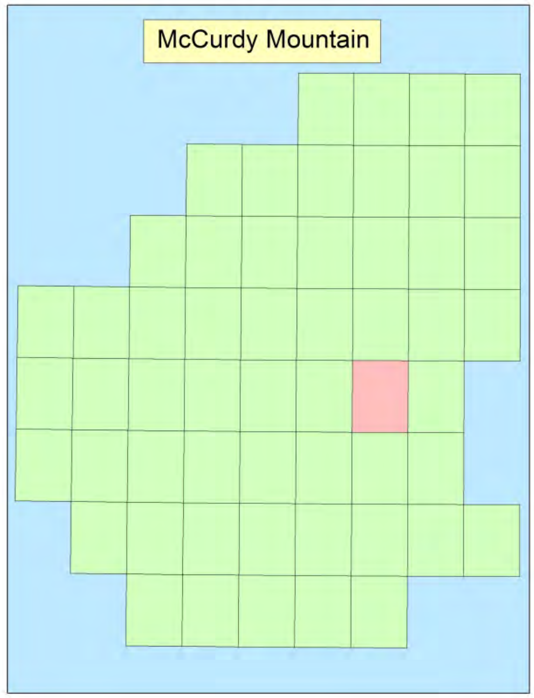


Figure D.35. Wetland polygons mapped within the McCurdy Mountain quad shown over 2009 true-color aerial photography (left). Location of McCurdy Mountain quad in relation to all quads in the study area (right).

The McCurdy Mountain quad is in the central eastern portion of the project area (Figure D.35). It has a minimum elevation of 8,041 feet and a max of 12,408 feet. The dominant vegetation types include: Ponderosa Pine at 60.9%, Spruce/Fir at 15.0%, and Aspen at 12.0%. The total number of wetland acres is 617.0 (Table D.35), which is 0.7% of total wetlands in the project area. This area is mountainous with some alpine areas.

Table D.35. Acres of Wetlands Mapped in the McCurdy Mountain Quad by Wetland Type and Land Owner

MCCURDY MOUNTAIN	NGO	PRIVATE	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	1.1	172.5	32.7	206.2
Freshwater Forested/Shrub Wetland	9.1	105.4	225.1	339.6
Freshwater Pond	0.5	2.4	2.0	4.8
Lake	0.0	26.0	0.0	26.0
Riverine	1.7	18.9	19.8	40.4
Grand Total	**12.4**	**325.1**	**279.5**	**617.0**

Meridian Hill

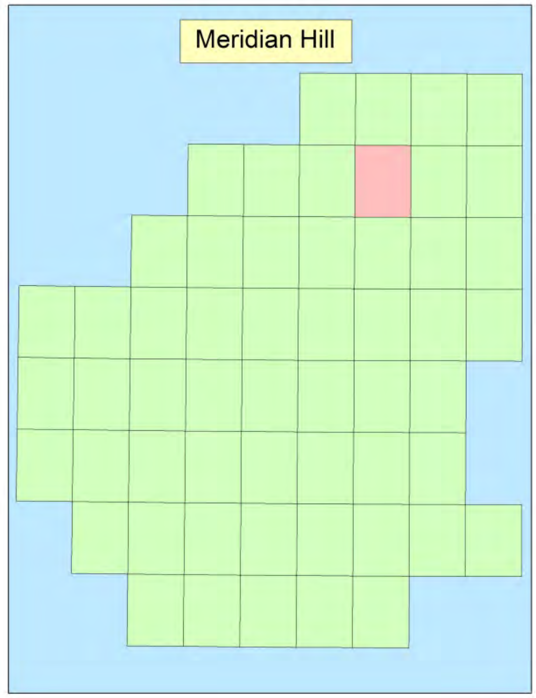


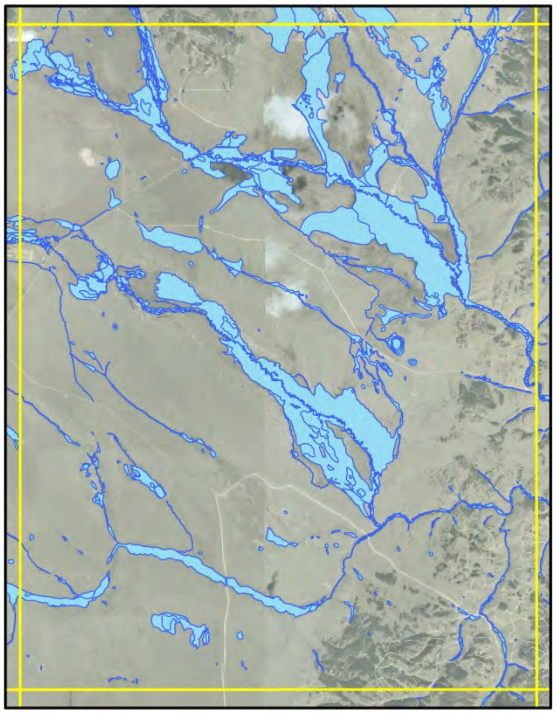
Figure D.36. Wetland polygons mapped within the Meridian Hill quad shown over 2009 true-color aerial photography (left). Location of Meridian Hill quad in relation to all quads in the study area (right).

The Meridian Hill quad is in the north eastern portion of the project area (Figure D.36). It has a minimum elevation of 7,556 feet and a max of 11,490 feet. The dominant vegetation types include: Lodgepole Pine at 39.1%, Spruce/Fir at 20.5%. and Ponderosa Pine at 27.7%. The total number of wetland acres is 728.7 (Table D.36), which is 0.9% of total wetlands in the project area. This area is fairly continuous forested low mountains.

Table D.36. Acres of Wetlands Mapped in the Meridian Hill Quad by Wetland Type and Land Owner

MERIDIAN HILL	CPW	JOINT	PRIVATE	SLB	STPARKS	USFS - ARNF	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	36.8	0.1	426.9	6.3	22.9	22.7	50.3	566.0
Freshwater Forested/Shrub Wetland	1.4	0.0	69.3	2.6	0.4	21.4	4.2	99.2
Freshwater Pond	0.0	0.1	22.9	0.0	1.7	10.9	0.2	35.9
Riverine	6.4	0.0	20.5	0.2	0.0	0.4	0.0	27.7
Grand Total	**44.6**	**0.2**	**539.6**	**9.2**	**25.0**	**55.5**	**54.7**	**728.7**

Milligan Lakes



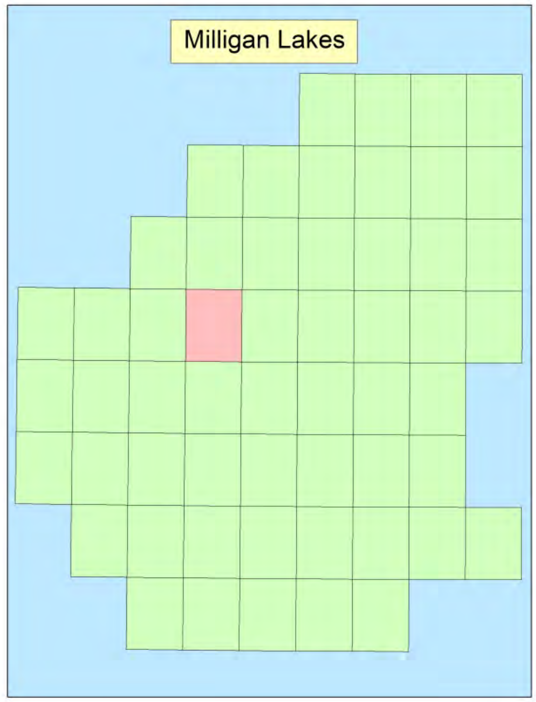


Figure D.37. Wetland polygons mapped within the Milligan Lakes quad shown over 2009 true-color aerial photography (left). Location of Milligan Lakes quad in relation to all quads in the study area (right).

The Milligan Lakes quad is in the central portion of the project area (Figure D.37). It has a minimum elevation of 9,160 feet and a max of 9,967 feet. The dominant vegetation types include: Foothills/Mountain Grassland at 66.9%, Irrigated Agriculture at 23.2%, and Ponderosa Pine at 3.2%. The total number of wetland acres is 5,278.8 (Table D.37), which is 6.2% of total wetlands in the project area. This quad is centered on the low relief South Park basin with several large and small creeks entering from the northwest.

Table D.37. Acres of Wetlands Mapped in the Milligan Lakes Quad by Wetland Type and Land Owner

MILLIGAN LAKES	BLM	CPW	COUNTY	PRIVATE	SLB	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	181.5	93.8	13.2	4,441.4	12.2	8.4	4,750.5
Freshwater Forested/Shrub Wetland	4.6	6.6	0.0	127.4	0.0	3.2	141.9
Freshwater Pond	86.8	12.9	1.3	169.4	0.0	0.2	270.6
Lake	0.0	0.0	0.0	22.5	0.0	0.0	22.5
Riverine	8.3	0.7	0.0	81.7	0.6	2.1	93.3
Grand Total	**281.2**	**114.1**	**14.5**	**4,842.4**	**12.8**	**13.8**	**5,278.8**

Montezuma

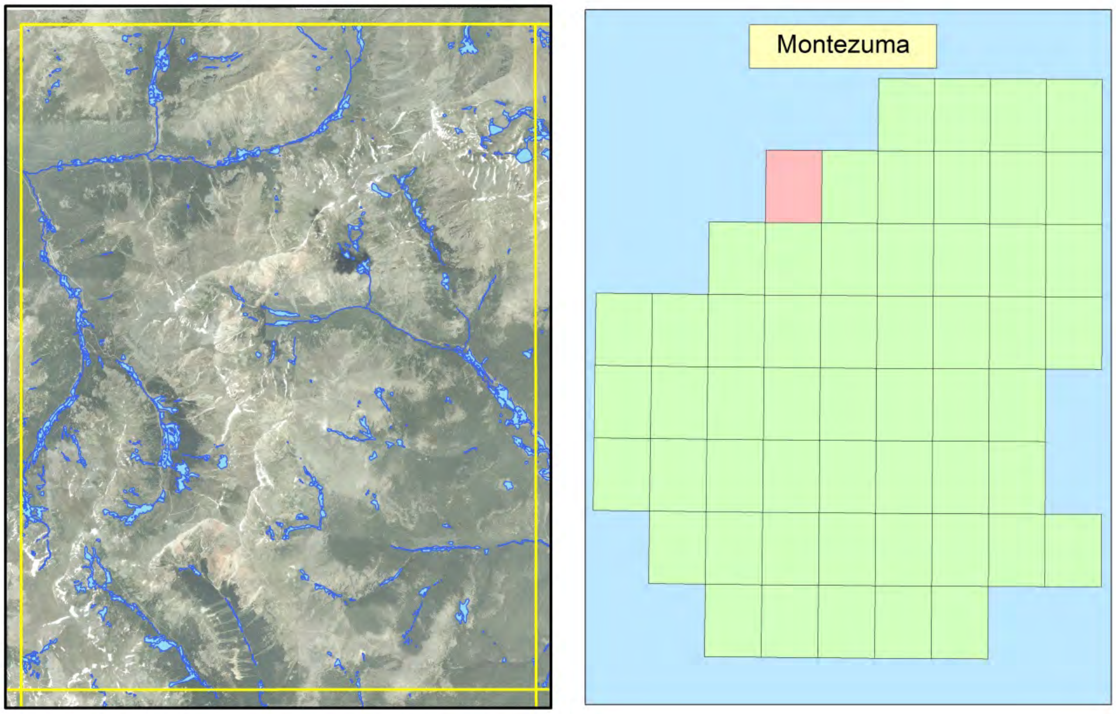


Figure D.38. Wetland polygons mapped within the Montezuma quad shown over 2009 true-color aerial photography (left). Location of Montezuma quad in relation to all quads in the study area (right).

The Montezuma quad is in the northern portion of the project area (Figure D.38). It has a minimum elevation of 9,816 feet and a max of 13,793 feet. The dominant vegetation types include: Tundra (several classes) combined at 65.0%, Spruce/Fir at 35.3%, and Aspen at 0.7%. The total number of wetland acres is 1,238.6 (Table D.38), which is 1.5% of total wetlands in the project area. This quad is centered on the high relief ridge with several high mountains including Silver Mountain, Landslide Peak, and Copper Mountain.

Table D.38. Acres of Wetlands Mapped in the Montezuma Quad by Wetland Type and Land Owner

MONTEZUMA	COUNTY	PRIVATE	USFS - ARNF	USFS - PIKE	USFS - WHITE RIVER	Grand Total
Freshwater Emergent Wetland	22.7	9.4	13.3	106.2	114.6	266.1
Freshwater Forested/Shrub Wetland	2.8	51.7	47.2	346.9	384.4	833.0
Freshwater Pond	< 0.1	2.7	2.9	24.0	31.0	60.6
Lake	0.0	0.0	27.5	8.5	0.0	36.0
Riverine	1.0	5.7	1.6	14.4	20.1	42.8
Grand Total	**26.6**	**69.4**	**92.5**	**500.0**	**550.1**	**1,238.6**

Morrison

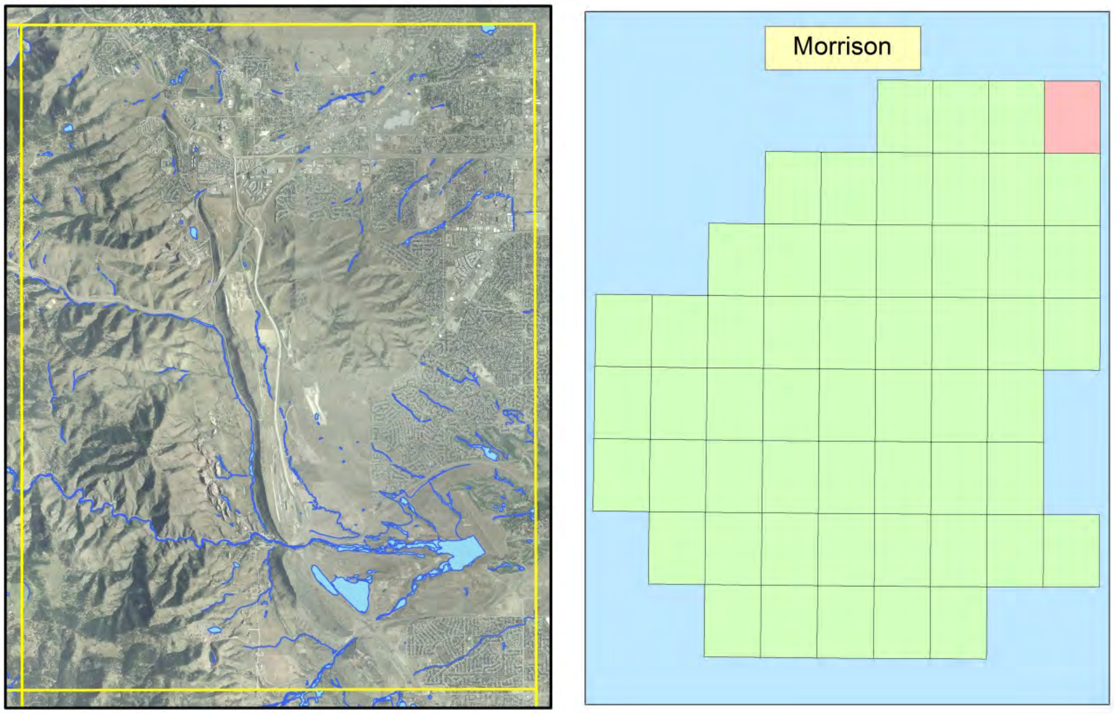


Figure D.39. Wetland polygons mapped within the Morrison quad shown over 2009 true-color aerial photography (left). Location of Morrison quad in relation to all quads in the study area (right).

The Morrison quad is in the extreme northeastern portion of the project area (Figure D.39). It has a minimum elevation of 9,816 feet and a max of 13,793 feet. The dominant vegetation types include: Urban/Built-up at 30.8%, Xeric Upland Shrub at 28.2%, and Midgrass Prairie at 17.9%. The total number of wetland acres is 708.6 (Table D.39), which is 0.8% of total wetlands in the project area. This quad is diverse and shows some foothills, the Hogback and urban portions of the greater Denver metro area.

Table D.39. Acres of Wetlands Mapped in the Morrison Quad by Wetland Type and Land Owner

MORRISON	CITY	COUNTY	FEDERAL	METRO DISTRICT	NGO	PRIVATE	Grand Total
Freshwater Emergent Wetland	35.8	0.6	0.0	0.1	0.0	22.7	59.1
Freshwater Forested/Shrub Wetland	167.9	17.8	1.2	2.3	< 0.1	108.0	297.2
Freshwater Pond	14.7	0.7	0.0	0.0	0.0	56.1	71.5
Lake	212.7	0.0	0.0	0.0	0.0	11.4	224.1
Riverine	24.5	2.7	0.4	5.1	0.1	23.9	56.6
Grand Total	455.5	21.8	1.6	7.5	0.1	222.1	708.6

Mount Evans

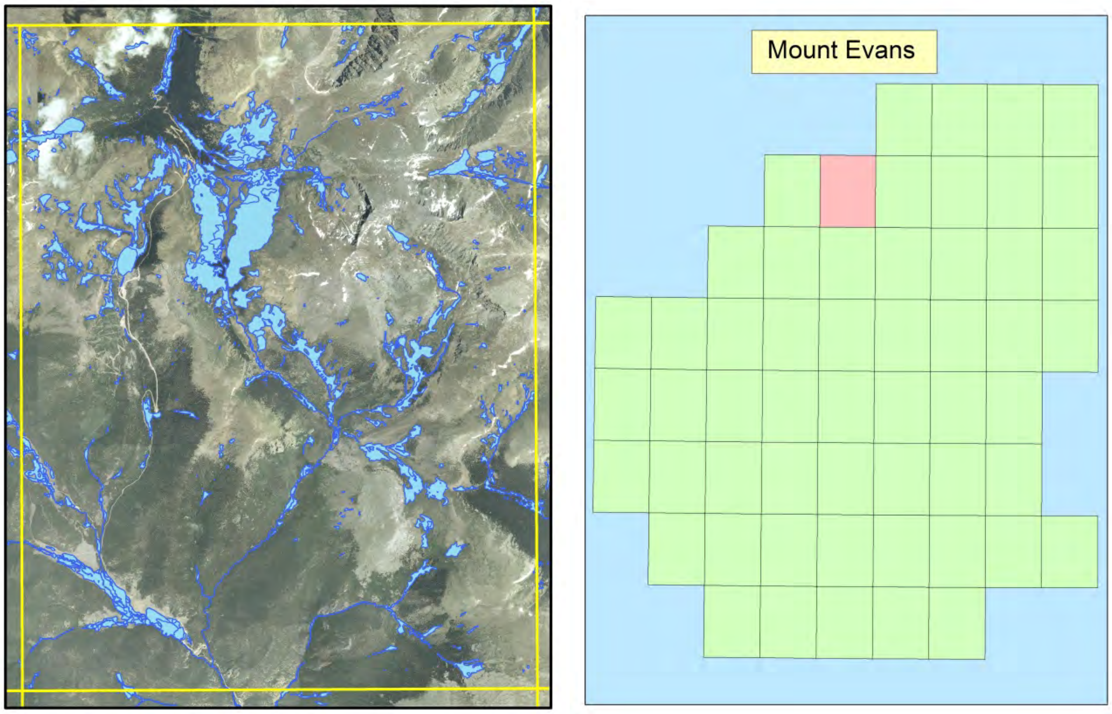


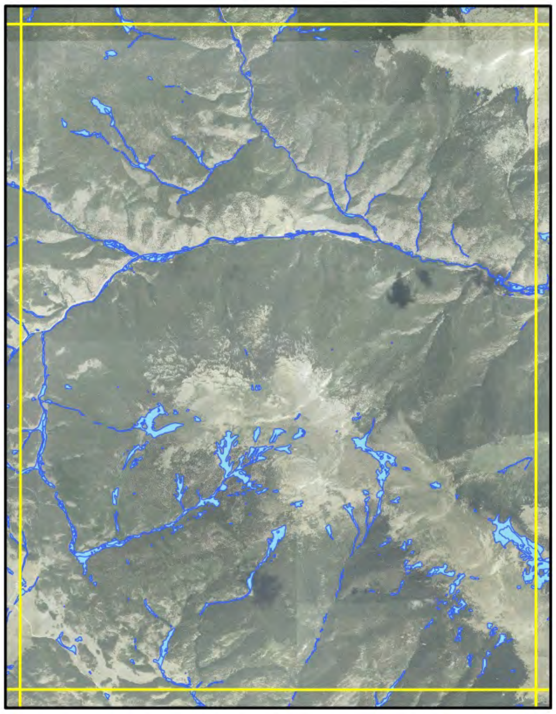
Figure D.40. Wetland polygons mapped within the Mount Evans quad shown over 2009 true-color aerial photography (left). Location of Mount Evans quad in relation to all quads in the study area (right).

The Mount Evans quad is in the extreme northern portion of the project area (Figure D.40). It has a minimum elevation of 9,190 feet and a max of 14,245 feet. The dominant vegetation types include: Tundra (several classes) combined at 58.1%, Spruce/Fir at 33.0%, and Subalpine Meadow at 6.9%. The total number of wetland acres is 3,266.9 (Table D.40), which is 3.8% of total wetlands in the project area. This quad shows the highest peak in Colorado, Mount Evans, and has a large portion above treeline.

Table D.40. Acres of Wetlands Mapped in the Mount Evans Quad by Wetland Type and Land Owner

MOUNT EVANS	CITY	PRIVATE	USFS - ARNF	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	18.4	7.9	89.4	239.0	354.7
Freshwater Forested/Shrub Wetland	0.0	92.7	553.9	1,985.1	2,631.7
Freshwater Pond	2.3	0.9	15.1	30.9	49.2
Lake	34.1	78.6	36.5	39.5	188.8
Riverine	0.1	1.8	4.9	35.8	42.5
Grand Total	**54.9**	**182.0**	**699.7**	**2,330.2**	**3,266.9**

Mount Logan



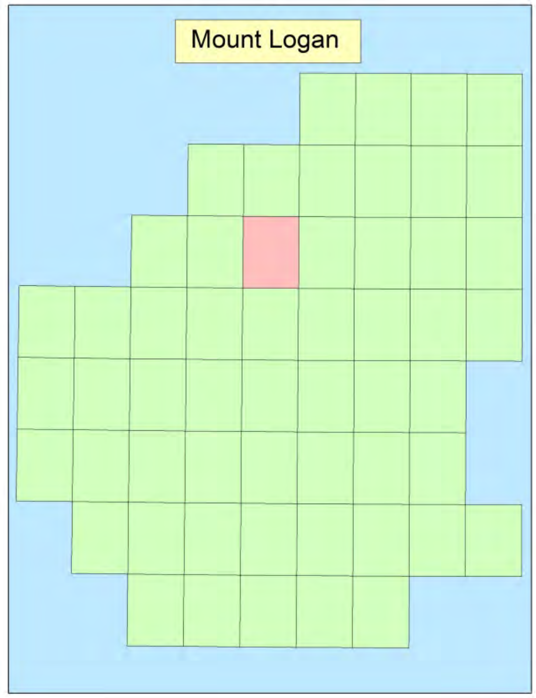


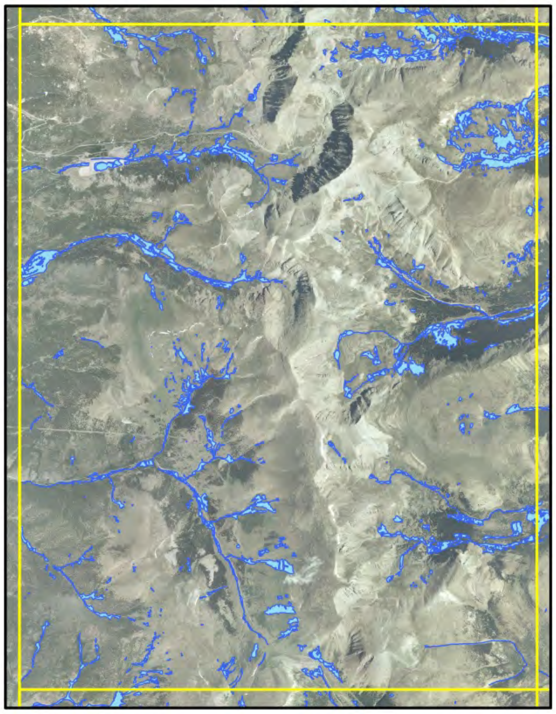
Figure D.41. Wetland polygons mapped within the Mount Logan quad shown over 2009 true-color aerial photography (left). Location of Mount Logan quad in relation to all quads in the study area (right).

The Mount Logan quad is in the extreme central north portion of the project area (Figure D.41). It has a minimum elevation of 8,392 feet and a max of 12,858 feet. The dominant vegetation types include: Spruce/Fir at 59.8%, Meadow Tundra at 16.3%, and Aspen at 11.0%. The total number of wetland acres is 1,086.7 (Table D.41), which is 1.3% of total wetlands in the project area. This quad shows the North Fork of the South Platte River and the Platte River Mountains.

Table D.41. Acres of Wetlands Mapped in the Mount Logan Quad by Wetland Type and Land Owner

MOUNT LOGAN	NGO	PRIVATE	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	0.2	35.6	123.2	159.0
Freshwater Forested/Shrub Wetland	8.5	105.6	769.3	883.4
Freshwater Pond	0.0	12.8	2.5	15.4
Riverine	7.4	11.8	9.7	28.9
Grand Total	**16.2**	**165.8**	**904.7**	**1,086.7**

Mount Sherman



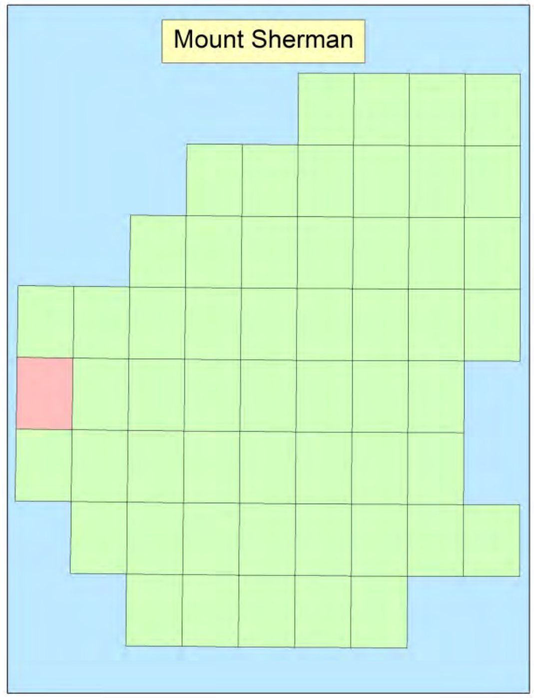


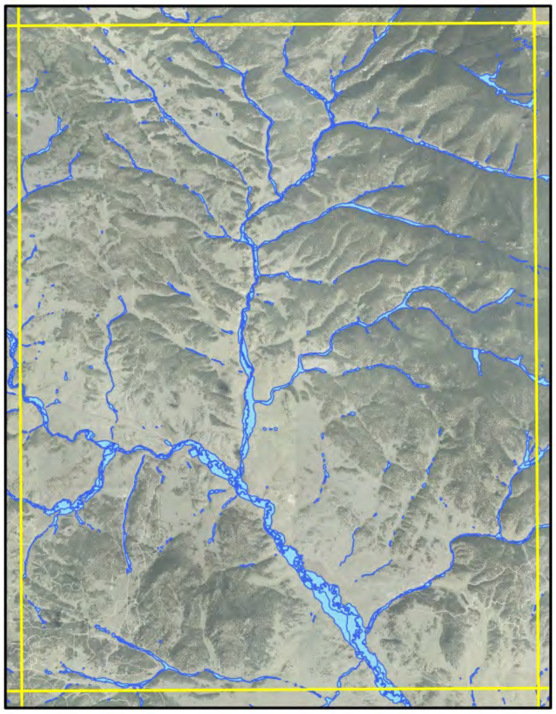
Figure D.42. Wetland polygons mapped within the Mount Sherman quad shown over 2009 true-color aerial photography (left). Location of Mount Sherman quad in relation to all quads in the study area (right).

The Mount Sherman quad is in the extreme western portion of the project area (Figure D.42). It has a minimum elevation of 10,072 feet and a max of 14,052 feet. The dominant vegetation types include: Tundra (several classes) combined at 61.7%, Lodgepole Pine at 22.0%, and Subalpine Meadow at 11.0%. The total number of wetland acres is 1,730.5 (Table D.42), which is 2.0% of total wetlands in the project area. This quad is centered on a very high ridge, with significant area above treeline.

Table D.42. Acres of Wetlands Mapped in the Mount Sherman Quad by Wetland Type and Land Owner

MOUNT SHERMAN	BLM	PRIVATE	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	11.9	40.9	72.4	125.3
Freshwater Forested/Shrub Wetland	94.8	534.1	848.2	1,477.1
Freshwater Pond	4.0	24.0	26.4	54.4
Lake	0.6	22.3	8.4	31.3
Riverine	5.2	16.2	21.0	42.4
Grand Total	**116.5**	**637.6**	**976.5**	**1,730.5**

Observatory Rock



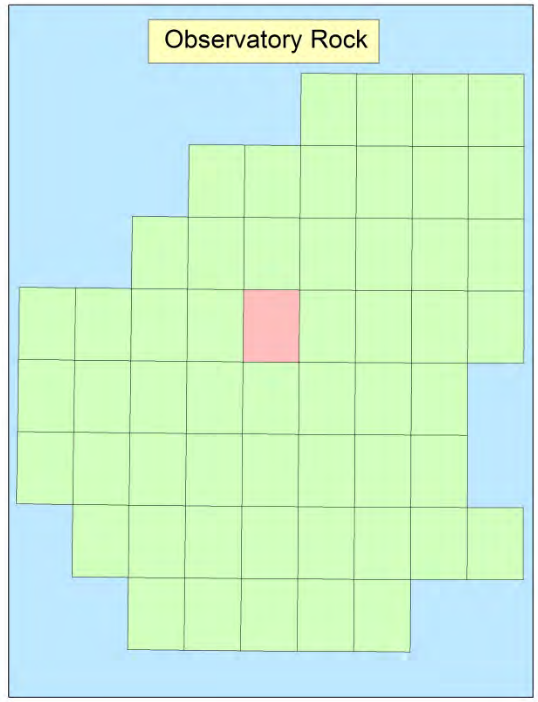


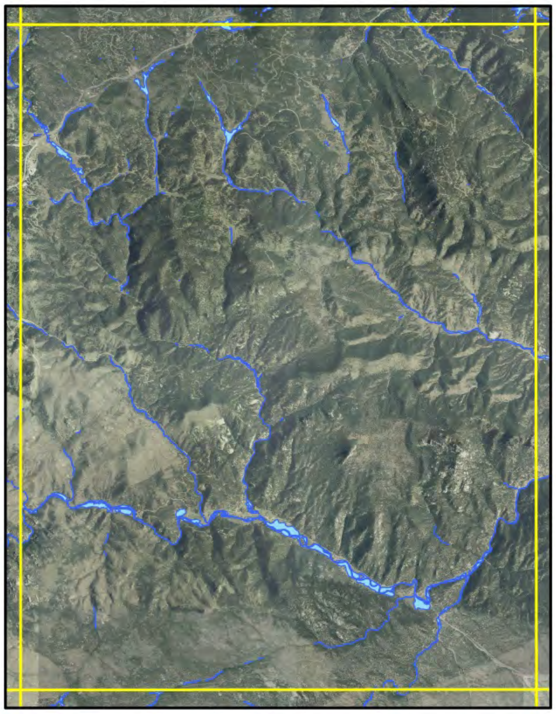
Figure D.43. Wetland polygons mapped within the Observatory Rock quad shown over 2009 true-color aerial photography (left). Location of Observatory Rock quad in relation to all quads in the study area (right).

The Observatory Rock quad is in the central portion of the project area (Figure D.43). It has a minimum elevation of 8,924 feet and a max of 11,591 feet. The dominant vegetation types include: Spruce/Fir at 48.4%, Ponderosa Pine at 25.6%, and Foothills/Mountain Grassland at 23.7%. The total number of wetland acres is 1,589.4 (Table D.43), which is 1.9% of total wetlands in the project area. This quad shows the lower foothills rising from the South Park basin on the east side.

Table D.43. Acres of Wetlands Mapped in the Observatory Rock Quad by Wetland Type and Land Owner

OBSERVATORY ROCK	BLM	CPW	PRIVATE	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	0.3	3.1	843.2	294.6	1,141.2
Freshwater Forested/Shrub Wetland	-	0.0	66.3	291.8	358.1
Freshwater Pond	0.0	0.0	12.1	2.5	14.7
Riverine	0.4	0.0	68.9	6.1	75.4
Grand Total	**0.6**	**3.1**	**990.6**	**595.1**	**1,589.4**

Pine



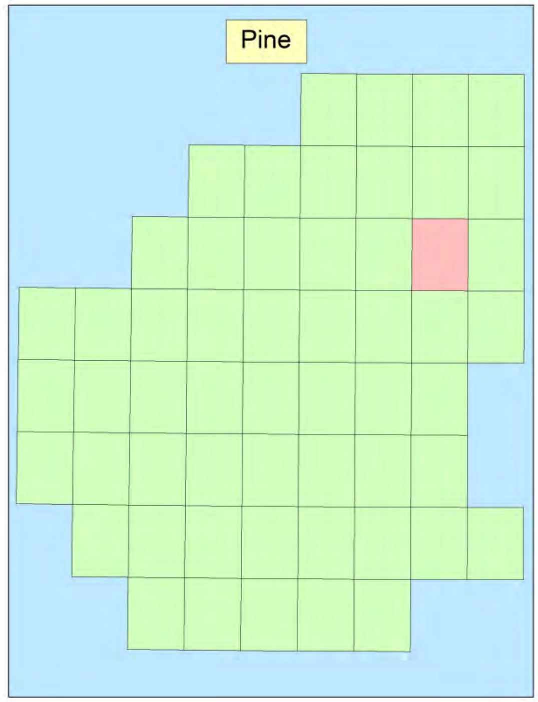


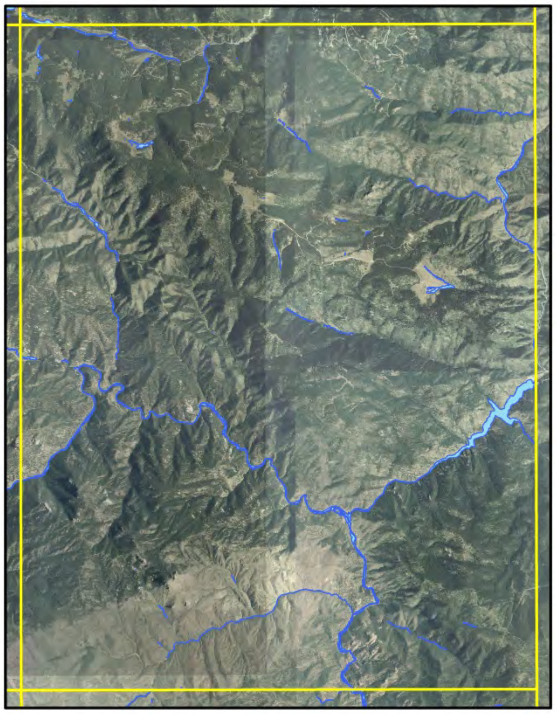
Figure D.44. Wetland polygons mapped within the Pine quad shown over 2009 true-color aerial photography (left). Location of Pine quad in relation to all quads in the study area (right).

The Pine quad is in the north eastern portion of the project area (Figure D.44). It has a minimum elevation of 6,499 feet and a max of 9,367 feet. The dominant vegetation types include: Ponderosa Pine at 87.7%, Lodgepole Pine at 11.7%, and Mesic Upland Shrub at 0.4%. The total number of wetland acres is 511.6 (Table D.44), which is 0.6% of total wetlands in the project area. This area is lower forest mountains.

Table D.44. Acres of Wetlands Mapped in the Pine Quad by Wetland Type and Land Owner

PINE	COUNTY	NGO	PRIVATE	STPARKS	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	12.2	0.0	179.7	1.0	1.1	193.9
Freshwater Forested/Shrub Wetland	17.1	6.7	144.7	0.0	9.3	177.7
Freshwater Pond	6.0	0.0	20.7	0.0	0.3	27.0
Riverine	13.0	4.7	81.9	0.0	13.3	112.8
Grand Total	**48.3**	**11.4**	**427.0**	**1.0**	**23.9**	**511.6**

Platte Canyon



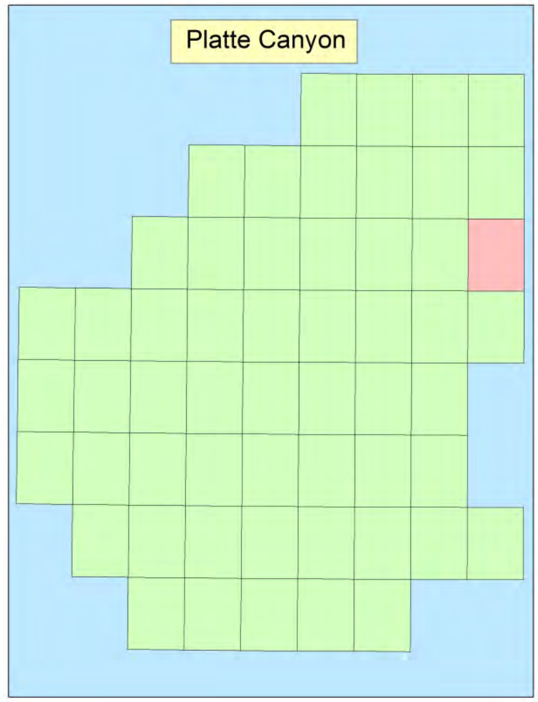


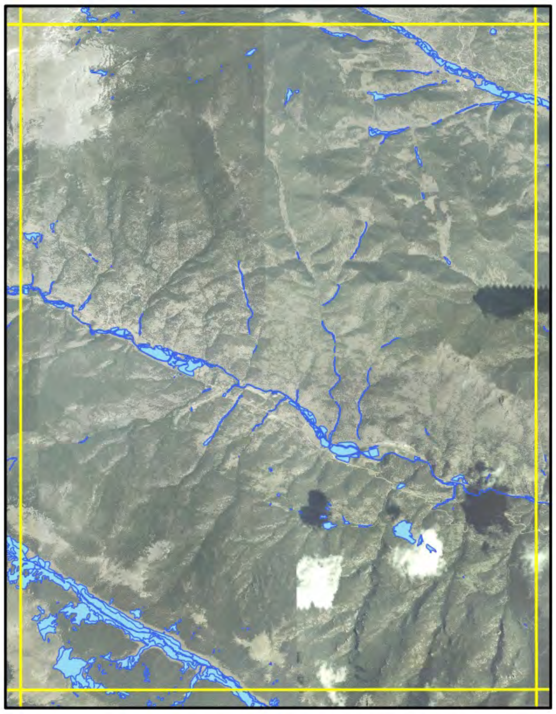
Figure D.45. Wetland polygons mapped within the Platte Canyon quad shown over 2009 true-color aerial photography (left). Location of Platte Canyon quad in relation to all quads in the study area (right).

The Platte Canyon quad is in the north eastern portion of the project area (Figure D.45). It has a minimum elevation of 6,499 feet and a max of 9,367 feet. The dominant vegetation types include: Mesic Upland Shrub at 38.1%, Douglas Fir at 29.1%, and Ponderosa Pine at 22.5%. The total number of wetland acres is 359.2 (Table D.45), which is 0.4% of total wetlands in the project area. This area is lower forest mountains with the North Fork of the South Platte River.

Table D.45. Acres of Wetlands Mapped in the Platte Canyon Quad by Wetland Type and Land Owner

PLATTE CANYON	COUNTY	NGO	PRIVATE	SLB	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	0.4	1.9	29.0	0.0	0.5	31.8
Freshwater Forested/Shrub Wetland	13.5	42.1	26.6	2.1	32.7	116.9
Freshwater Pond	0.0	< 0.1	3.6	0.2	0.1	4.0
Lake	0.0	65.6	0.0	0.0	29.6	95.2
Riverine	1.3	39.3	18.1	0.0	52.6	111.3
Grand Total	**15.1**	**149.0**	**77.2**	**2.3**	**115.5**	**359.2**

Shawnee



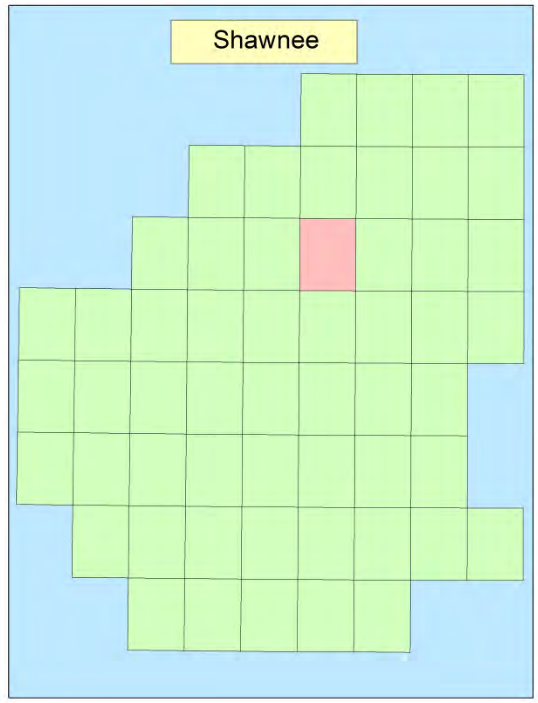


Figure D.46. Wetland polygons mapped within the Shawnee quad shown over 2009 true-color aerial photography (left). Location of Shawnee quad in relation to all quads in the study area (right).

The Shawnee quad is in the central portion of the project area (Figure D.46). It has a minimum elevation of 6,499 feet and a max of 9,367 feet. The dominant vegetation types include: Spruce/Fir at 53.5%, Ponderosa Pine at 37.7%, and Meadow Tundra at 5.1%. The total number of wetland acres is 1,173.6 (Table D.46), which is 1.4% of total wetlands in the project area. This area is lower forest mountains with the North Fork of the South Platte River and includes the small historic community of Shawnee.

Table D.46. Acres of Wetlands Mapped in the Shawnee Quad by Wetland Type and Land Owner

SHAWNEE	BLM	NGO	PRIVATE	SLB	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	0.6	0.0	227.9	36.2	158.7	423.4
Freshwater Forested/Shrub Wetland	2.7	< 0.1	123.6	1.2	526.2	653.7
Freshwater Pond	0.5	0.0	46.2	0.0	5.6	52.3
Riverine	0.0	0.3	35.5	0.0	8.4	44.2
Grand Total	**3.7**	**0.3**	**433.2**	**37.4**	**698.9**	**1,173.6**

South Peak

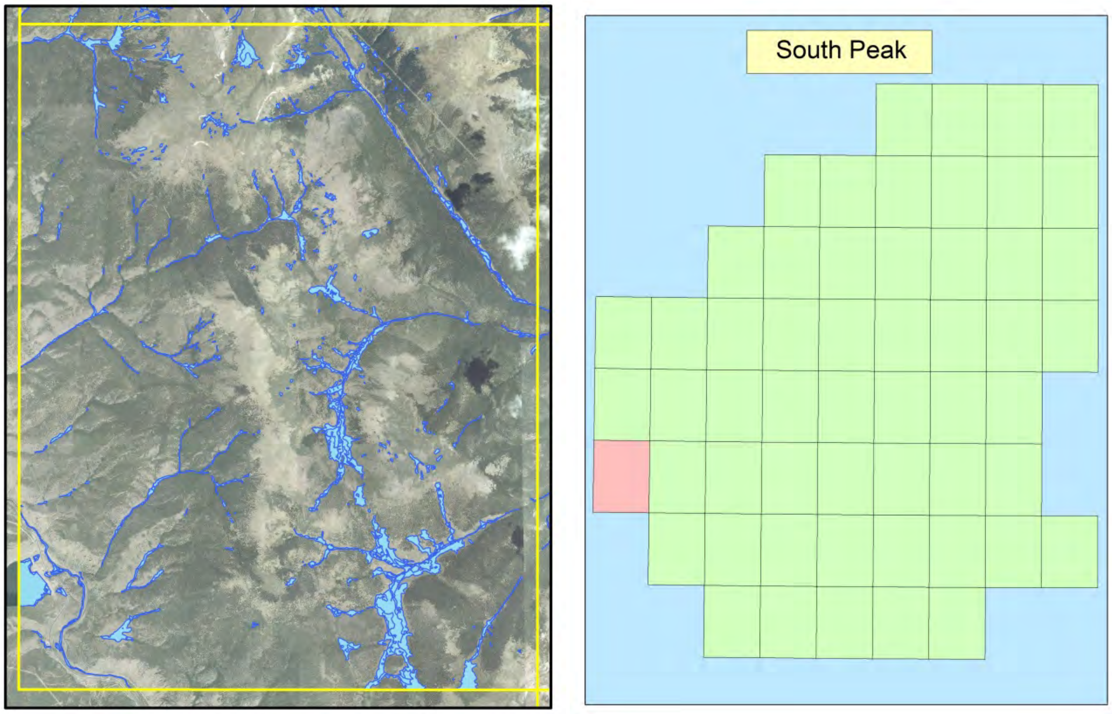


Figure D.47. Wetland polygons mapped within the South Peak quad shown over 2009 true-color aerial photography (left). Location of South Peak quad in relation to all quads in the study area (right).

The South Peak quad is in the south western portion of the project area (Figure D.47). It has a minimum elevation of 5,587 feet and a max of 8,802 feet. The dominant vegetation types include: Lodgepole Pine at 42.5%, Tundra (several classes) combined at 27.3%, and Spruce/Fir at 15.3%. The total number of wetland acres is 1,700.3 (Table D.47), which is 2.0% of total wetlands in the project area. This quad is centered on a high ridge.

Table D.47. Acres of Wetlands Mapped in the South Peak Quad by Wetland Type and Land Owner

SOUTH PEAK	BLM	PRIVATE	SLB	STPARKS	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	2.6	30.3	0.0	0.0	225.2	258.1
Freshwater Forested/Shrub Wetland	18.4	13.1	0.0	0.0	1,245.3	1,276.7
Freshwater Pond	2.7	1.8	0.0	0.0	19.4	24.0
Lake	0.0	102.9	0.0	0.0	0.0	102.9
Riverine	9.8	16.9	2.4	1.8	7.6	38.6
Grand Total	**33.6**	**165.0**	**2.4**	**1.8**	**1,497.5**	**1,700.3**

Spinney Mountain

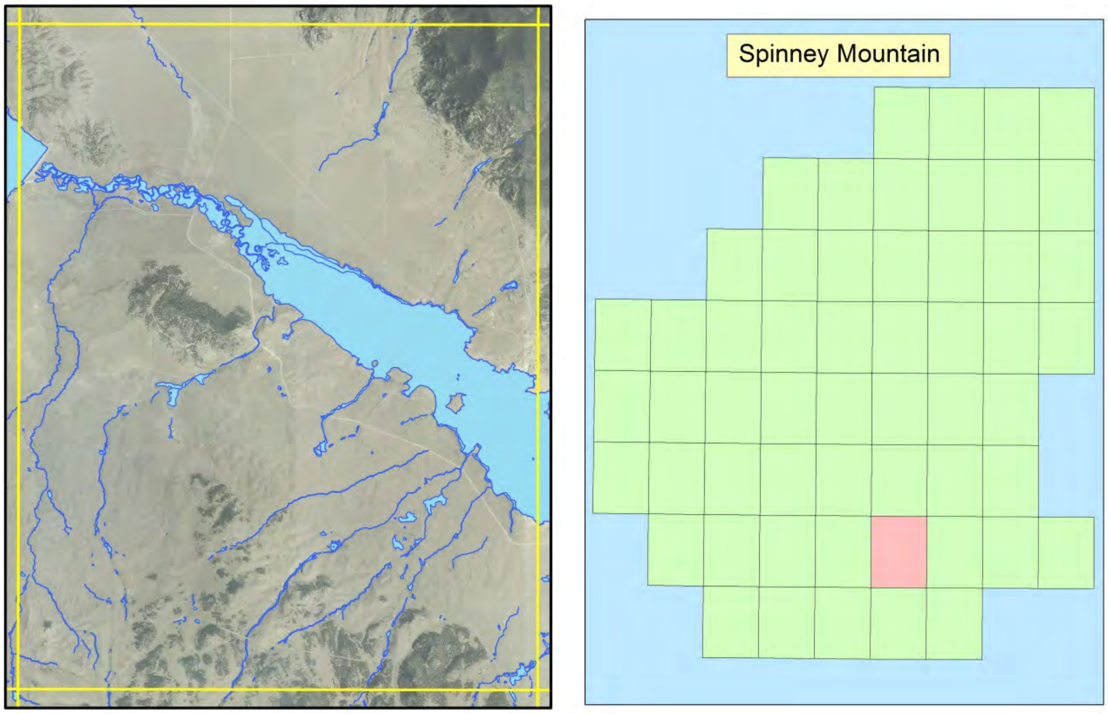


Figure D.48. Wetland polygons mapped within the Spinney Mountain quad shown over 2009 true-color aerial photography (left). Location of Spinney Mountain quad in relation to all quads in the study area (right).

The Spinney Mountain quad is in the south central portion of the project area (Figure D.48). It has a minimum elevation of 8,540 feet and a max of 10,869 feet. The dominant vegetation types include: Foothills/Mountain Grassland at 76.0%, Spruce/Fir at 7.2%, and Mesic Upland Shrub at 6.1%. The total number of wetland acres is 3,684.1 (Table D.48), which is 4.3% of total wetlands in the project area. This quad includes Elevenmile Canyon Reservoir and the South Platte River at the south eastern edge of the South Park basin.

Table D.48. Acres of Wetlands Mapped in the Spinney Mountain Quad by Wetland Type and Land Owner

SPINNEY MOUNTAIN	BLM	CITY	JOINT	NGO	PRIVATE	SLB	STPARKS	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	8.5	32.1	103.1	311.7	327.0	0.9	3.2	2.1	788.5
Freshwater Forested/Shrub Wetland	5.9	0.5	0.5	4.4	22.4	0.0	0.0	11.3	45.1
Freshwater Pond	< 0.1	2.4	0.1	1.9	18.6	0.0	4.6	0.0	27.7
Lake	0.0	90.7	0.0	2,630.6	0.0	0.0	0.0	0.0	2,721.2
Riverine	2.2	8.6	7.5	13.7	63.5	4.9	1.1	0.0	101.5
Grand Total	**16.6**	**134.3**	**111.3**	**2,962.2**	**431.5**	**5.9**	**8.9**	**13.4**	**3,684.1**

Squaw Pass

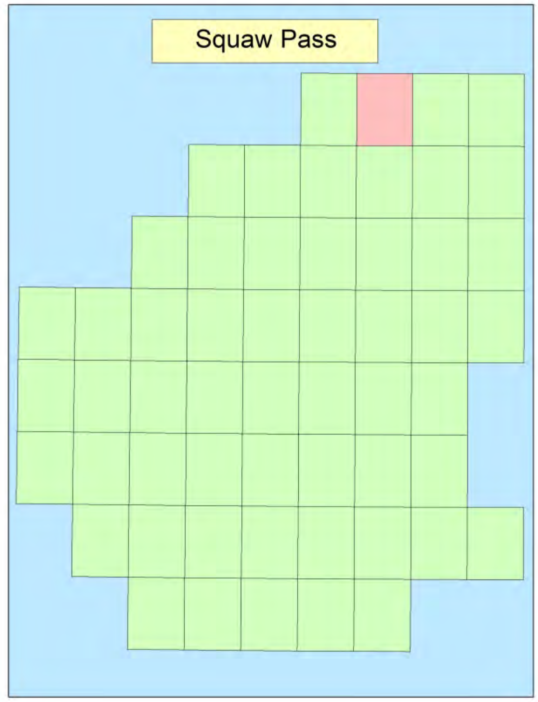


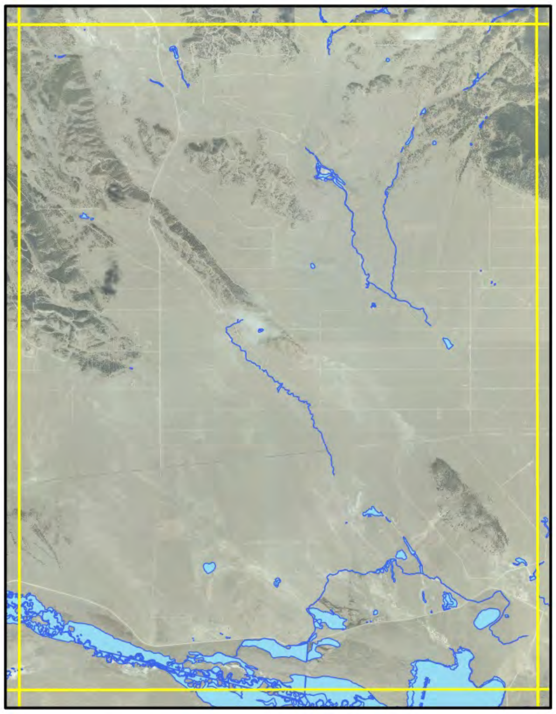
Figure D.49. Wetland polygons mapped within the Squaw Pass quad shown over 2009 true-color aerial photography (left). Location of Squaw Pass quad in relation to all quads in the study area (right).

The Squaw Pass quad is in the northern portion of the project area (Figure D.49). It has a minimum elevation of 6,775 feet and a max of 11,470 feet. The dominant vegetation types include: Lodgepole Pine at 47.0%, Ponderosa Pine at 30.8%, and Douglas Fir at 13.6%. The total number of wetland acres is 331.6 (Table D.49), which is 0.4% of total wetlands in the project area. This quad is dominantly forested low mountains with the Clear Creek Canyon to the north.

Table D.49. Acres of Wetlands Mapped in the Squaw Pass Quad by Wetland Type and Land Owner

SQUAW PASS	CITY	COUNTY	LAND TRUST	PRIVATE	SCHOOL DISTRICT	Grand Total
Freshwater Emergent Wetland	0.1	2.0	0.0	165.7	5.8	173.7
Freshwater Forested/Shrub Wetland	0.0	5.1	0.1	59.5	0.1	64.7
Freshwater Pond	< 0.1	0.1	0.0	18.0	1.2	19.3
Lake	0.0	0.0	0.0	11.3	0.0	11.3
Riverine	0.1	12.0	0.0	50.5	0.0	62.6
Grand Total	**0.2**	**19.2**	**0.1**	**305.0**	**7.1**	**331.6**

Sulphur Mountain



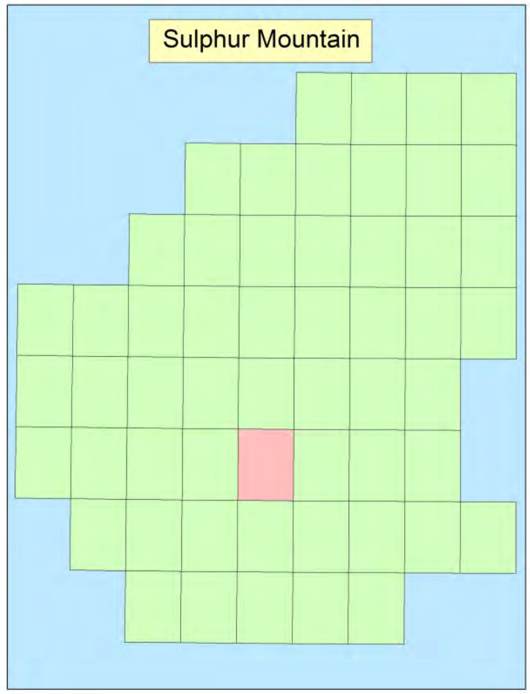


Figure D.50. Wetland polygons mapped within the Sulphur Mountain quad shown over 2009 true-color aerial photography (left). Location of Sulphur Mountain quad in relation to all quads in the study area (right).

The Sulphur Mountain quad is in the central portion of the project area (Figure D.50). It has a minimum elevation of 8,675 feet and a max of 10,390 feet. The dominant vegetation types include: Foothills/Mountain Grassland at 85.0%, Ponderosa Pine at 8.7%, and Rocky Mountain Bristlecone Pine at 3.4%. The total number of wetland acres is 1,201.7 (Table D.50), which is 1.4% of total wetlands in the project area. This quad shows the South Park basin with an undeveloped network of roads for an uncompleted subdivision.

Table D.50. Acres of Wetlands Mapped in the Sulphur Mountain Quad by Wetland Type and Land Owner

SULPHUR MOUNTAIN	BLM	CPW	CITY	PRIVATE	SLB	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	0.1	495.2	103.1	192.8	21.3	0.0	812.5
Freshwater Forested/Shrub Wetland	0.0	7.3	0.0	0.8	0.0	1.1	9.2
Freshwater Pond	1.5	8.6	57.3	50.6	10.2	0.0	128.3
Lake	0.0	0.0	191.8	0.0	0.0	0.0	191.8
Riverine	0.9	33.0	4.0	18.7	3.1	0.2	59.9
Grand Total	**2.5**	**544.2**	**356.2**	**262.9**	**34.6**	**1.3**	**1,201.7**

Tarryall

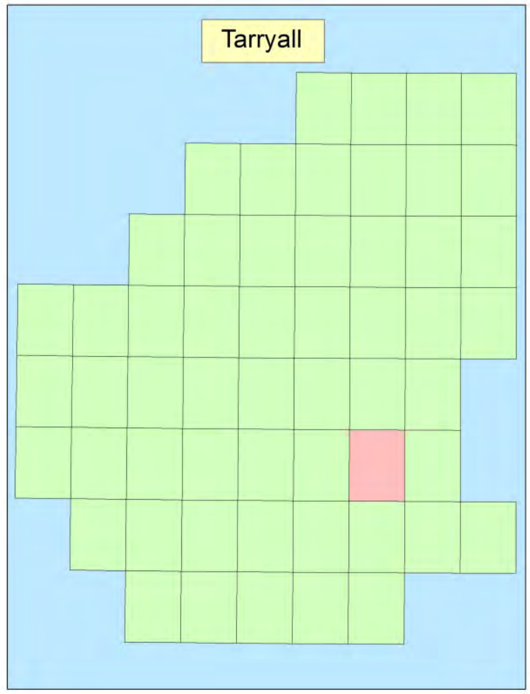


Figure D.51. Wetland polygons mapped within the Tarryall quad shown over 2009 true-color aerial photography (left). Location of Tarryall quad in relation to all quads in the study area (right).

The Tarryall quad is in the central portion of the project area (Figure D.51). It has a minimum elevation of 7,972 feet and a max of 10,610 feet. The dominant vegetation types include: Ponderosa Pine at 86.0%, Foothills/Mountain Grassland at 9.0%, and Spruce/Fir at 4.0%. The total number of wetland acres is 766.3 (Table D.51), which is 0.9% of total wetlands in the project area. This area is a flatter basin along Tarryall Creek.

Table D.51. Acres of Wetlands Mapped in the Tarryall Quad by Wetland Type and Land Owner

TARRYALL	PRIVATE	SLB	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	414.2	29.2	164.6	608.0
Freshwater Forested/Shrub Wetland	56.4	0.9	40.8	98.1
Freshwater Pond	16.6	1.2	1.2	18.9
Riverine	28.6	0.0	12.6	41.2
Grand Total	**515.8**	**31.3**	**219.2**	**766.3**

Thirtynine Mile Mountain

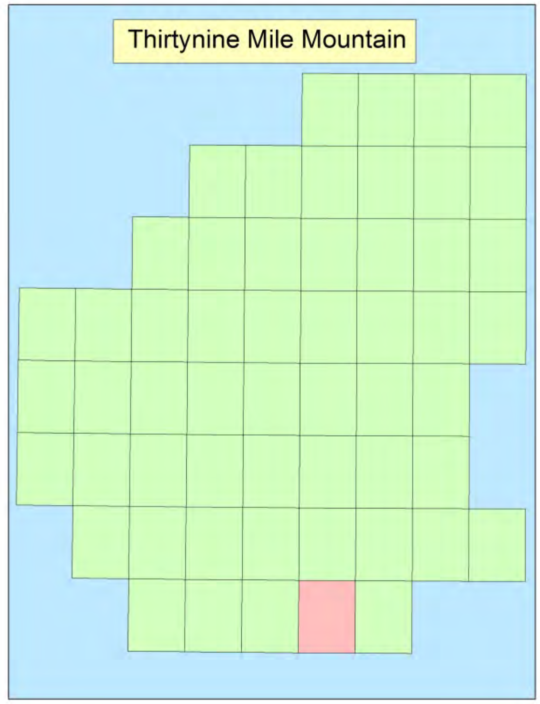


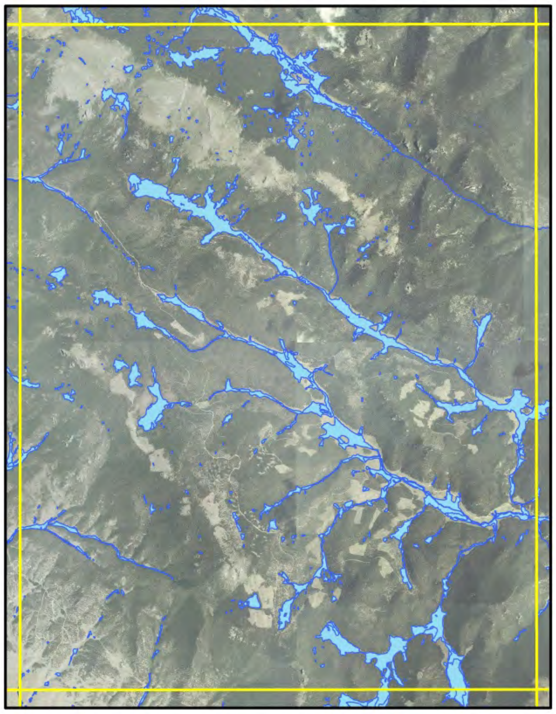
Figure D.52. Wetland polygons mapped within the Thirtynine Mile Mountain quad shown over 2009 true-color aerial photography (left). Location of Thirtynine Mile Mountain quad in relation to all quads in the study area (right).

The Thirtynine Mile Mountain quad is in the southern portion of the project area (Figure D.52). It has a minimum elevation of 8,514 feet and a max of 11,549 feet. The dominant vegetation types include: Ponderosa Pine at 51.7%, Spruce/Fir at 24.6%, and Foothills/Mountain Grassland at 23.0%. The total number of wetland acres is 222.5 (Table D.52), which is 0.3% of total wetlands in the project area. This focal region of this quad is the Thirtynine Mile Mountains.

Table D.52. Acres of Wetlands Mapped in the Thirtynine Mile Mountain Quad by Wetland Type and Land Owner

THIRTYNINE MILE MOUNTAIN	PRIVATE	SLB	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	132.6	1.4	9.1	143.2
Freshwater Forested/Shrub Wetland	32.0	1.2	26.0	59.2
Freshwater Pond	18.8	0.2	1.0	19.9
Riverine	0.2	0.0	0.0	0.2
Grand Total	**183.6**	**2.8**	**36.0**	**222.5**

Topaz Mountain



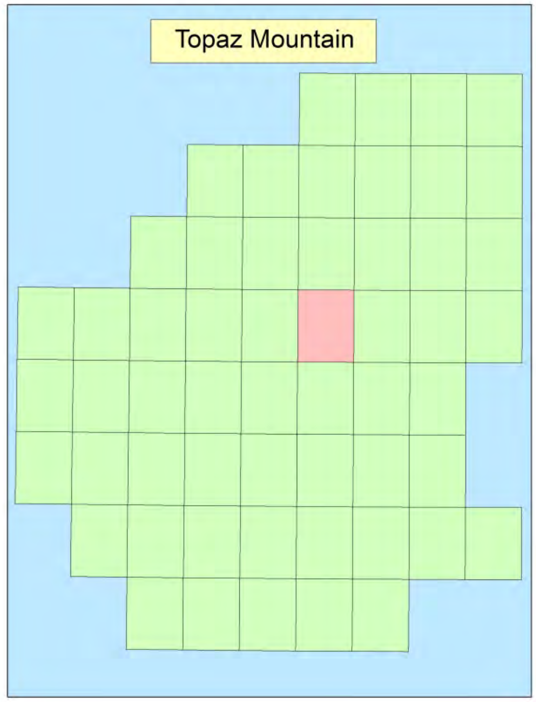


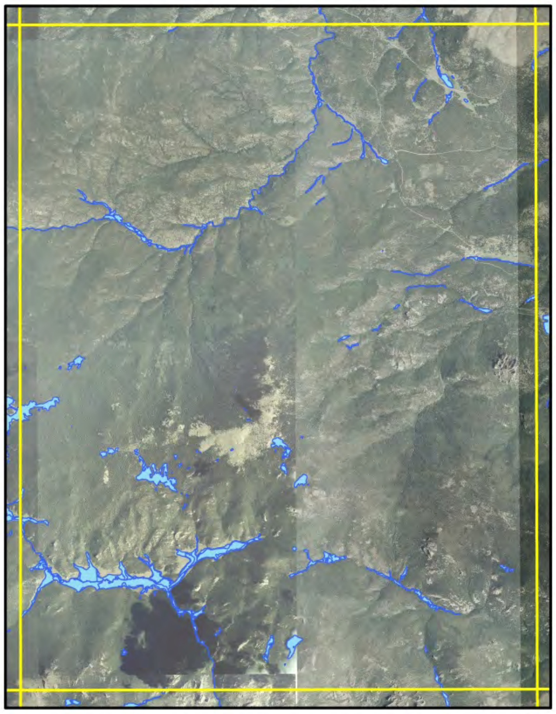
Figure D.53. Wetland polygons mapped within the Topaz Mountain quad shown over 2009 true-color aerial photography (left). Location of Topaz Mountain quad in relation to all quads in the study area (right).

The Topaz Mountain quad is in the southern portion of the project area (Figure D.53). It has a minimum elevation of 9,019 feet and a max of 12,415 feet. The dominant vegetation types include: Spruce/Fir at 81.1%, Ponderosa Pine at 7.6%, and Aspen at 3.8%. The total number of wetland acres is 2,372.5 (Table D.53), which is 2.8% of total wetlands in the project area. This area contains the Tarryall and Kenosha Mountains.

Table D.53. Acres of Wetlands Mapped in the Topaz Mountain Quad by Wetland Type and Land Owner

TOPAZ MOUNTAIN	PRIVATE	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	0.1	179.6	179.7
Freshwater Forested/Shrub Wetland	0.2	2,178.5	2,178.8
Freshwater Pond	0.0	1.1	1.1
Riverine	0.0	13.0	13.0
Grand Total	**0.4**	**2,372.2**	**2,372.5**

Windy Peak



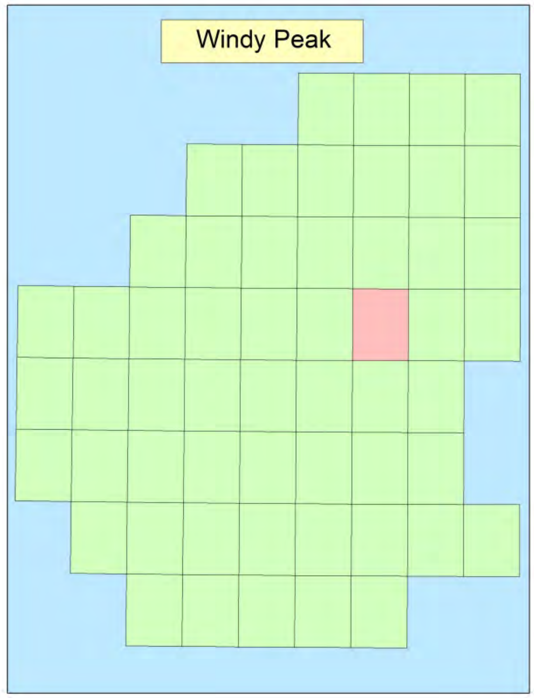


Figure D.54. Wetland polygons mapped within the Windy Peak quad shown over 2009 true-color aerial photography (left). Location of Windy Peak quad in relation to all quads in the study area (right).

The Windy Peak quad is in the central portion of the project area (Figure D.54). It has a minimum elevation of 7,625 feet and a max of 12,165 feet. The dominant vegetation types include: Spruce/Fir at 50.0%, Ponderosa Pine at 46.5%, and Subalpine Meadow at 2.0%. The total number of wetland acres is 684.2 (Table D.54), which is 0.8% of total wetlands in the project area. This area is centered on Windy Peak at the east ends of the Kenosha Mountains.

Table D.54. Acres of Wetlands Mapped in the Windy Peak Quad by Wetland Type and Land Owner

WINDY PEAK	PRIVATE	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	20.8	152.1	173.0
Freshwater Forested/Shrub Wetland	34.6	447.7	482.2
Freshwater Pond	5.5	2.6	8.1
Riverine	3.6	17.3	20.8
Grand Total	**64.5**	**619.7**	**684.2**

Witcher Mountain

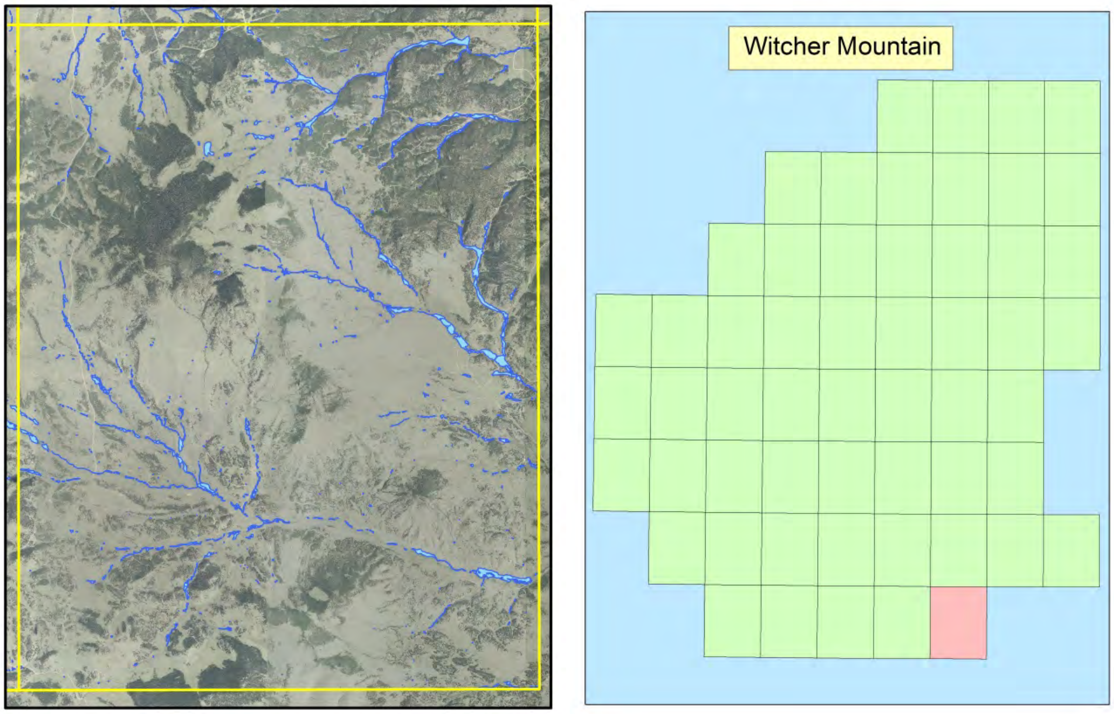


Figure D.55. Wetland polygons mapped within the Witcher Mountain quad shown over 2009 true-color aerial photography (left). Location of Witcher Mountain quad in relation to all quads in the study area (right).

The Witcher Mountain quad is in the extreme south eastern portion of the project area (Figure D.55). It has a minimum elevation of 8,320 feet and a max of 10,791 feet. The dominant vegetation types include: Ponderosa Pine at 54.4%, Foothills/Mountain Grassland at 34.1%, and Spruce/Fir at 11.4%. The total number of wetland acres is 592.9 (Table D.55), which is 0.7% of total wetlands in the project area. This area contains low hills and West Fourmile Creek at the south end.

Table D.55. Acres of Wetlands Mapped in the Witcher Mountain Quad by Wetland Type and Land Owner

WITCHER MOUNTAIN	BLM	PRIVATE	SLB	USFS - PIKE	Grand Total
Freshwater Emergent Wetland	0.1	473.9	0.8	22.5	497.4
Freshwater Forested/Shrub Wetland	0.0	44.7	1.1	11.1	56.9
Freshwater Pond	0.0	36.5	0.0	0.8	37.4
Riverine	0.0	1.0	0.0	0.3	1.3
Grand Total	**0.1**	**556.2**	**1.9**	**34.7**	**592.9**

APPENDIX E
Additional Wetland Mapping Summaries

Table E.1. Wetland Acreage in the C21A Study Area by Ecoregion and NWI System / Class

Level III / IV Ecoregion[a]	Total Land Area within Project		Total NWI Acres within Project		Wetland Acres by NWI System/Class								
	Total Acres	% of Project Area	Total Acres	% of NWI Acres	R2/3/4	L1/2	PAB	PUB	PUS	PEM	PSS	PFO	Rp1
25: High Plains	**19,544**	**1.0%**	**492**	**0.6%**	**18**	**191**	**2**	**49**	**1**	**54**	**59**	**108**	**11**
25d: Flat to Rolling Plains	323	< 0.1%	12	< 0.1%	0	11	0	2	0	0	0	0	0
25l: Front Range Fans	19,221	0.9%	480	0.6%	18	180	2	47	1	54	59	108	11
21: Southern Rockies	**2,014,692**	**99.0%**	**84,495**	**99.4%**	**2,622**	**10,525**	**706**	**908**	**2,300**	**41,428**	**25,021**	**795**	**189**
21a: Alpine Zone	192,145	9.4%	8,429	9.9%	113	359	77	104	16	1,010	6,699	51	0
21c: Crystalline Mid-Elevation Forests and Shrublands	675,717	33.2%	15,503	18.2%	1,041	1,186	225	442	61	6,369	5,855	194	129
21b: Crystalline Subalpine Forests	366,510	18.0%	8,854	10.4%	204	430	56	55	10	2,007	5,930	151	10
21d: Foothills and Shrublands	38,156	1.9%	570	0.7%	63	145	5	56	< 1	31	122	98	49
21j: Grassland Parks	461,232	22.7%	41,507	48.8%	968	8,239	126	166	2,166	28,017	1,577	248	0
21f: Sedimentary Mid-Elevation Forests and Shrublands	169,859	8.4%	5,979	7.0%	183	135	136	28	41	2,819	2,604	33	0
21e: Sedimentary Subalpine Forests	39,781	2.0%	3,054	3.6%	49	32	62	33	3	684	2,172	18	0
21h: Volcanic Mid-Elevation Forests and Shrublands	52,090	2.6%	552	0.7%	0	0	17	24	2	479	29	2	0
21g: Volcanic Subalpine Forests	19,202	0.9%	48	0.1%	0	0	< 1	1	< 1	13	33	0	0
Grand Total	**2,034,236**	**100%**	**84,987**	**100%**	**2,640**	**10,716**	**708**	**957**	**2,301**	**41,483**	**25,080**	**904**	**200**

Note: See Table 2.7 within the report for explanation of NWI codes.

[a]For more information on Level III/IV Ecoregions and to download GIS shapefiles, visit the following website: **www.epa.gov/wed/pages/ecoregions.htm**.

Table E.2. Wetland Acreage in the C21A Study Area by Ecoregion and NWI Hydrologic Regime.

Level III/ IV Ecoregion	Grand Total	NWI Hydrologic Regime							Beaver	Human	Un-altered
		A	B	C	F	G	H	Rip	Altered	Altered	
25: High Plains	**492**	**120**	**0**	**95**	**23**	**50**	**193**	**11**	**0**	**253**	**240**
25d: Flat to Rolling Plains	12	0	0	0	0	2	11	0	0	12	0
25l: Front Range Fans	480	120	0	95	23	49	182	11	0	241	240
21: Southern Rockies	**84,495**	**18,168**	**22,722**	**29,041**	**511**	**2,308**	**11,555**	**189**	**5,223**	**12,080**	**67,192**
21a: Alpine Zone	8,429	23	7,258	495	47	211	395	0	777	63	7,589
21c: Crystalline Mid-Elevation Forests and Shrublands	15,503	2,755	3,398	6,366	119	969	1,765	129	1,147	1,881	12,475
21b: Crystalline Subalpine Forests	8,854	612	5,518	1,973	64	234	443	10	473	443	7,938
21d: Foothills and Shrublands	570	175	4	80	6	71	185	49	0	210	360
21j: Grassland Parks	41,507	13,119	1,882	17,298	216	482	8,509	0	370	9,152	31,985
21f: Sedimentary Mid-Elevation Forests and Shrublands	5,979	1,216	2,521	1,793	34	201	213	0	1,525	198	4,255
21e: Sedimentary Subalpine Forests	3,054	100	2,140	650	21	99	44	0	931	65	2,058
21h: Volcanic Mid-Elevation Forests and Shrublands	552	128	< 1	378	5	41	0	0	0	66	486
21g: Volcanic Subalpine Forests	48	39	0	7	< 1	1	0	0	0	1	46
Grand Total	**84,987**	**18,288**	**22,722**	**29,136**	**534**	**2,359**	**11,748**	**200**	**5,223**	**12,333**	**67,432**

Note: "Human altered" includes all human influenced NWI modifiers. See Table 2.9 within the report for more detail on human alteration.

Table E.3. Wetland Acreage in the C21A Study Area by Ecoregion and the Nine Largest Grouped Land Owners

Level III/IV Ecoregion	Grand Total	BLM	CPW	CITY	NGO	PRIVATE	SLB	USFS - ARNF	USFS - PIKE	USFS - WHITE RIVER
25: High Plains	**492**	**0%**	**0%**	**66%**	**0%**	**27%**	**0%**	**0%**	**0%**	**0%**
25d: Flat to Rolling Plains	12	0%	0%	0%	0%	100%	0%	0%	0%	0%
25l: Front Range Fans	480	0%	0%	67%	0%	25%	0%	0%	0%	0%
21: Southern Rockies	**84,495**	**2%**	**3%**	**4%**	**12%**	**50%**	**2%**	**2%**	**22%**	**1%**
21a: Alpine Zone	8,429	3%	0%	1%	0%	16%	< 1%	13%	61%	6%
21c: Crystalline Mid-Elevation Forests and Shrublands	15,503	1%	2%	1%	8%	57%	< 1%	< 1%	26%	< 1%
21b: Crystalline Subalpine Forests	8,854	0%	1%	1%	< 1%	19%	< 1%	5%	72%	2%
21d: Foothills and Shrublands	570	0%	0%	23%	< 1%	63%	< 1%	0%	3%	0%
21j: Grassland Parks	41,507	2%	4%	7%	22%	59%	3%	0%	1%	0%
21f: Sedimentary Mid-Elevation Forests and Shrublands	5,979	1%	6%	0%	1%	58%	4%	0%	29%	0%
21e: Sedimentary Subalpine Forests	3,054	7%	0%	0%	0%	62%	< 1%	0%	25%	5%
21h: Volcanic Mid-Elevation Forests and Shrublands	552	0%	0%	0%	0%	94%	< 1%	0%	5%	0%
21g: Volcanic Subalpine Forests	48	0%	0%	0%	0%	8%	2%	0%	90%	0%
Grand Total	**84,987**	**1,382**	**2,344**	**3,448**	**10,523**	**42,871**	**1,734**	**1,542**	**18,676**	**907**