Upper Colorado River Ecosystem: Alternative Futures Study, Phase One Report

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Upper Colorado River Ecosystem: Alternative Futures Study Phase One Report
Phase One Report

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Cover Photo: (Top Left: Rocky Mountain National Park - ©Louis Hurst) (Top Right: Grand Staircase-Escalante National Monument - © Richard Toth) (Bottom Left: Manti-La Sal National Forest- © Jacob Gibson) (Bottom Right: Yampa Valley - © Lisa Vander Wal)

Report should be cited as:

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Introduction

The origins of this study were initiated in the summer of 2004, with the U.S. Fish & Wildlife Service (FWS) Region 6. Several individuals from the Region 6 office inquired to Utah State University about our willingness to assist them in the identification of appropriate data to be used in wildlife habitat analysis and management at the landscape-scale. The study was to demonstrate GIS applications at the ecosystem-level planning scale. At the end of the summer, 2004, results of the study were presented to FWS Region 6 staff. There were 6 elements to the work: 1) Develop criteria for choosing which data is needed for these analysis; 2) Initiate a data search to find out which data are available; 3) Collect data and assemble data files; 4) Process, Merge, and Clip data to projected boundary; 5) Produce descriptive maps; 6) Define and display sample models using various criteria (data).

This work was presented to the FWS staff on October 27, 2004.

Given various FWS budget constraints, continuation of the work was not proposed at that time. However in early 2006, FWS Region 6, inquired as to the USU research team’s interest in applying several of the planning concepts to the Upper-Colorado River Ecosystem. A “Prospectus” was submitted to FWS Region 6, which outlined an approach for this project over a two-year period. The following is abstracted from portions of that prospectus:

Management agencies such as the Fish and Wildlife Service have traditionally focused on point-level processes, working to conserve and maintain ecological functions, and plant and animal species of small spatial extents. Many of these efforts have been successful. However, management of systems and species of concern at the point level also requires an understanding of the landscape context in which the system or species resides. As part of the growing awareness, FWS Region 6 has embarked on a process of landscape- and Ecosystem- level planning and management seeking to identify key resources (Elements), within identified ecosystems on how they are likely to be affected by anthropogenic stressors.
The anthropocentric perspective is emphasized in this work, in that it hopes to better understand the ecological constraints extending beyond those typically analyzed under traditional, multiple-use philosophies. This view defines the context for this study. This work seeks to formulate a process by which a range of potential stressors can be identified and extended to landscapes, offering a framework in which stressor impacts can be analyzed.

**Objectives:**

*We propose to evaluate the utility of a process for assessing stressor effects on the landscape. Our proposed ecosystem for development of this process is the Upper Colorado River Ecosystem (UCRE), as defined by FWS Region 6. We will identify likely stressors in the UCRE, and prioritize possible relationships (both negative and positive) of each stressor with a set of landscape elements and selective plant and animal species (multiple species were also to be explored).*

*The proposed process focused on the completion of four major elements over a two-year period:*

- Characterize landscape-level biological and physical elements of the Upper Colorado River Ecosystem
- Organize existing data on selective plant and animal species, including but not limited to migratory birds, listed and sensitive species fisheries, and important habitats.
- Identify current and potential stressors potentially affecting the identified landscape-level elements and the plant and animal species of interest.
- Determine and assess possible relationships among stressors- how each is manifest and consequently measure able and the identified landscape-level elements and the animal plant and animal species of interest.

No primary data collection is proposed in this work; instead, data will come from existing geo-spatial databases, including state and federal management agencies. The types of data collected will follow closely but not limited to that which was outlined in the October 2004 project.
For this phase of work, the identification of landscape stressors that will, by necessity, be broad based and includes those commonly identified with expanding oil and gas explorations, areas of potential urbanization, and recreation. Stressor impacts will be evaluated via literature review.

All information which follows has been organized in a Geographic Information System (GIS). Basic descriptive analyses on the interactions of stressors with landscape elements have also been performed. This first phase report is a summary of these activities.

RET – September 12, 2008
Methodology

Planning is a very flexible discipline that addresses some of societies most complex and contentious problems. To address these problems, planners employ a variety of approaches and disciplines which each contain subtle to distinct differences in methodology.

For this study, the 2007-2008 Bioregional Planning Studio relied upon the past works completed within the Utah State University Bioregional Planning Program (Toth, et al., 2005, pp. 12-13) (Toth, et al., 2006, pp. 6-7) (Toth, Covington, Curtis, & Luce, 2007, pp. 2-3). Additionally, these past works and our studio relied upon the methodological work of Professor Richard Toth (Toth R. E., 1974).

The methodology for this study breaks down into six phases:

1. Project Proposal
2. Pre-Analysis
3. Analysis Phase 1
4. Analysis Phase 2
5. Conclusions
6. Reiteration

Each of the six phases contains many sub-steps, outlined in the detailed diagram upon the next page.

This methodology is a unique and fluid process, and it is important to remember that reiteration is vital within this process. Additionally, although the methodology breaks down the analysis into two separate phases, the phases intertwine and work often flows between these two phases. However, for this report the two phases remain separated for clarity.
Upper Colorado River Ecosystem

Methodology

Project Proposal

Pre-Analysis
- Initial Data Collection
- Initial Literature Review
- Case Studies
- Site Visits
- Guest Speakers
- Project Opinion Papers
- Function and Structure

Analysis Phase 1
- Assessment Model Research
- Outline Assessment Model Criteria
- Data Collection
- Peer Review
- Identification of Assessment Models

Analysis Phase 2
- Tiering of Assessment Models
- Development of Alternative Futures
- Conservation Status Evaluation

Conclusions
- Evaluation of Alternative Future Scenarios
- Recommendations to FWS

By Nick Kenczka and Louis Hurst
Pre-Analysis

In late August 2007, the study team, six graduate students, arrived on the campus of Utah State University and were introduced to this project. Pre-analysis began with a preliminary overview of the study area. After which, the students were introduced to a futures approach to planning. Furthermore, several other tasks were reviewed to familiarize the students with landscape level planning and the study site. These tasks oriented the students to the discipline of planning and provided a contextual foundation for dealing with the study site. These tasks included:

- Review of case studies
- Field trips
  - Northern (Colorado Headwaters)
  - Southern (Southern Utah)
- Project opinion papers based the field trips
- Guest lectures
- Function and structure research

To conclude the pre-analysis section, the study team researched a series of Upper Colorado River Ecosystem (UCRE) components. This examination produced six individual reports, (geology, soils, climate, hydrology, wildlife & vegetation, and history & culture) each addressing a separate component of the region. Later these reports were summarized and adapted for this report. Each of these five tasks outlined within the pre-analysis phase are summarized below.
Case Studies

As mentioned earlier, to gain background knowledge about planning, the study team examined a number of case studies. These were seminal works in the field of planning and specifically detailed regional planning as a discipline. Each student reviewed, analyzed, and summarized two case studies. Additionally, the student presented the material they covered in class and obtained copies of each other’s summaries. Each case study presents a different or unique approach to regional planning. The case studies reviewed by the students follow as:

**Early Seminal Works**

- *The Plan and Program for the Brandywine* (1968)
- *Honeyhill: A Systems Analysis for Planning the Multiple Use of Controlled Water Areas for U.S. Army Engineers* (1971)
- *Early Warning System. The Santa Cruz Mountains Regional Pilot Study* (1970)

**Recent Planning Works**

Field Trips

Within the pre-analysis phase of the project, the study team took two separate field trips to gain familiarity with the landscape within the study area. These trips were necessary due to the broad range of backgrounds within the study team and diverseness of the region.

Northern Field Trip

The first trip lasted three days. The focus of the trip was on the Rocky Mountain Range and western Colorado. This trip gave the students a unique perspective and helped prove both the beauty and expansiveness of the study area. The group was able to visit the following cities in or near the study area:

- Park City, UT
- Vernal, UT
- Green River, UT
- Price, UT
- Steamboat Springs, CO
- Granby, CO
- Estes Park, CO
- Boulder, CO
- Denver (Metro Area), CO
- Vail, CO
- Glenwood Springs, CO
- Grand Junction, CO

Additionally, the team visited other areas of interest that included:

- Dinosaur NM
- Rocky Mountain NP
- Curecanti NRA
- Black Canyon of the Gunnison NM
- Medicine Bow-Routt NF
- Arapaho NF
- White River NF
- Gunnison NF
- Grand Mesa NF
- Uinta NF
- Wasatch – Cache NF
Site Visits

Southern Field Trip

The second field trip again lasted three days. The focus of this trip was on southern Utah, the red rock country, and the Colorado River. This field trip gave the students an excellent baseline to compare the high mountains and wet meadows of the Rocky Mountains to the arid deserts and deep canyons of red rock country. The group was able to visit the following cities in or near the study area:

• Salt Lake City, UT
• Provo, UT
• Castle Dale, UT
• Moab, UT
• Blanding, UT
• Hanksville, UT
• Escalante, UT
• Panguitch, UT
• Richfield, UT

Additionally, team visited areas of interest that included:

• San Rafael Swell
• Arches NP
• Natural Bridges NM
• Glen Canyon NRA
• Capitol Reef NP
• Bryce Canyon NP
• Manti – La Sal NF
• Fishlake NF
• Dixie NF

Field Trips Overview

Both of these field trips provided an excellent learning experience for the study. Additionally, when juxtaposing the trips, they illustrate the diverse nature of the Upper Colorado River Ecosystem and the unique landscapes that make up the region.
Project Opinion Papers

After completing the two field trips, the study team looked at the site through a personal lens and completed an opinion paper. The team was asked to examine the site with specific elements. Originally, Kevin Lynch (1961) proposed these elements for the analysis of city form; however, these elements were adapted to this broader scale and they include paths, edges, districts, nodes, and landmarks.

Each team member produced a paper explaining his or her views on the study area. These papers allowed for open discussion to begin on the study area. Furthermore, this allowed team members to exchange ideas regarding the study area and view the landscape through their colleagues’ eyes.

Guest Lecturers

Beginning in early September, several guest lecturers came and gave their opinions about the study site. Often times these lectures took place at Utah State University; however, several did occur during the second field trip. These individuals spoke about topics ranging from tourism and recreation, geology, and water quality and quantity. Upon the next page is a table detailing information about the guest speakers and the topics they covered.
# Guest Lecturers

<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
<th>Status</th>
<th>Major Topic</th>
<th>Ancillary Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jim MacMahon</td>
<td>USU Ecology Center</td>
<td>Director &amp; Professor</td>
<td>Climate change</td>
<td>Thresholds unintended consequences</td>
</tr>
<tr>
<td>Tom Edwards</td>
<td>USU WILD</td>
<td>Professor</td>
<td>What shapes a landscape?</td>
<td>Climate model</td>
</tr>
<tr>
<td>Joseph Tainter</td>
<td>USU ENVS</td>
<td>Dept Head</td>
<td>Four questions on sustainability</td>
<td>What, how long, how much, and at what cost</td>
</tr>
<tr>
<td>Johan du Toit</td>
<td>USU Wildland Resources</td>
<td>Dept Head</td>
<td>Biodiversity &amp; migrating ecosystems</td>
<td>Climate change, slow drivers and rapid responses</td>
</tr>
<tr>
<td>Chris Monz</td>
<td>USU ENVS</td>
<td>Assistant Professor</td>
<td>Parks and recreation</td>
<td>Tourism management</td>
</tr>
<tr>
<td>Joel Pederson</td>
<td>USU GEOLOGY</td>
<td>Associate Professor</td>
<td>Energy deposits</td>
<td>Erosion defining the landscape</td>
</tr>
<tr>
<td>Jack Schmidt</td>
<td>USU Watershed Sciences</td>
<td>Professor</td>
<td>Yampa and Upper Green Rivers</td>
<td>Colorado an exotic river, water enters river from 15% of land mass</td>
</tr>
<tr>
<td>Rob Gillies</td>
<td>USU Climate Center</td>
<td>Director</td>
<td>Climate change</td>
<td>Hotter and drier/erratic precipitation</td>
</tr>
<tr>
<td>Jordy Guth</td>
<td>BRP StudentMS</td>
<td>MS</td>
<td>Sense of place</td>
<td>Rural quality of life</td>
</tr>
<tr>
<td>Mark Brunson</td>
<td>USU ENVS</td>
<td>Professor</td>
<td>Population distribution and Growth</td>
<td>Demographics, new west, amenity buyers</td>
</tr>
<tr>
<td>Matt Baker</td>
<td>USU Watershed Sciences</td>
<td>Assistant Professor</td>
<td>No escape from tamarisk</td>
<td>Effects of water levels, political will in water management</td>
</tr>
<tr>
<td>Name</td>
<td>Organization</td>
<td>Status</td>
<td>Major Topic</td>
<td>Ancillary Topic</td>
</tr>
<tr>
<td>----------------------</td>
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<td>---------------------------------------</td>
</tr>
<tr>
<td>Nancy Mesner</td>
<td>USU Watershed Sciences</td>
<td>Associate Dean CNR</td>
<td>Water quantity equals water quality</td>
<td>Cost of salinization</td>
</tr>
<tr>
<td>Mike McCandless</td>
<td>Emery County</td>
<td>Economic Development</td>
<td>Challenges of rural growth</td>
<td>Energy economies</td>
</tr>
<tr>
<td>Sue Phillips</td>
<td>USGS</td>
<td>Plant Physiology</td>
<td>Dust – climate change</td>
<td>Costs of tourism</td>
</tr>
<tr>
<td>Sue Fivecoat</td>
<td>BLM</td>
<td>Outdoor Recreation Planner</td>
<td>Challenges of managing ORV’s</td>
<td>Fragile and endangered species</td>
</tr>
<tr>
<td>Steve Burr</td>
<td>USU ENVS</td>
<td>Associate Professor</td>
<td>Recreation is very important for economy</td>
<td>Where is the next Moab? Ski industry now a four season industry</td>
</tr>
<tr>
<td>F.E. “Fee” Busby</td>
<td>USU Wildland Resources</td>
<td>Professor</td>
<td>Ranches hold off subdivisions, Roads and current population centers critical</td>
<td>Ranching and grazing, ranching a very small share in current economy</td>
</tr>
</tbody>
</table>

Dr. Fee Busby speaking to several students on aspects of rangelands
Pre-Analysis: Function and Structure

The most critical element of the pre-analysis phase is the research on the Upper Colorado River Ecosystem’s (UCRE) “biophysical” and “cultural elements.” By analyzing these two distinct systems, planners can more accurately address issues within the study area. The interactions between the biophysical and cultural systems are critical for the study to address.

To gain a clear understanding of these two systems and the associated issues, the report addresses a broad range of components. The study addresses seven components, with the majority of the attention focused upon the biophysical. The seven sections are:

- Geology
- Soils
- Climate
- Hydrology
- Wildlife
- Vegetation
- History and Culture

Research on these seven topics reveals both a description of the processes at work and the critical components of interactions. This research is an important link in the process contributing to the analysis phase, in both modeling and alternative future speculations. Finally, the scale and scope of the study create certain limitations with respect to time, and the materials that follow are only a summarization of the research conducted in the pre-analysis phase.
Geology

The history of the land is written in its geology. Rocks are an implicit record of their source and the forces that have shaped and placed them. Interpretation of the geologic record places a region into spatial and temporal context, offering an overarching story of the development of the region’s topography, soil, climate, and biota. On multiple scales, much of a region’s character derives from its geologic formations. For instance, human settlement patterns tightly correlate with both the topography and resources resulting from geologic formations.

The subsequent sections describe the different geologic time scales which formed the current geology of the UCRE. Preceding these descriptions is a figure depicting the time scales (below), which also serves as the legend for the map of surface geology on the next page. Finally, a graph showing the surface strata by age, type, and area appears after the map. The study team created all of the geology diagrams, maps, and graphs used within the phase one report.
Function and Structure: Geology
Precambrian

Precambrian rocks span over two billion years of history. They are exposed in only 5% of the area in the UCRE, but much of the land’s current state is a result of events during this period. Precambrian rocks exposed in the UCRE have generally been metamorphosed due to immense amounts of pressure as they were buried under thick deposits for hundreds of millions of years before being re-exposed. As such, they generally occur in the deepest canyons or on the tops of the highest mountains. However, their presence in the Wyoming basin attests to the many times the Rocky Mountains have been uplifted and eroded away. During the Precambrian, the UCRE was larger as the supercontinent of Rodinia formed ~750 m.y.a.
Precambrian rocks in the Wind River Range compose an ophiolite sequence – uplifted oceanic crust and underlying mantle – of the continental edge ~2.5 b.y.a. (Moores, 2002). In the depths of the Grand Canyon, mica schist of ~2 b.y.a. is exposed and is composed of deposits eroded from an even older mountain range. Precambrian rocks in the Southern Rockies are varieties of granite and other plutonic rocks formed which formed deep in the continent ~1.5 b.y.a. These basement rocks were sheared as they uplifted, and they later became a significant zone of mineralization known as the Colorado Mineral Belt- the basis of a multi-billion dollar industry (McCoy, Karlstrom, Shaw, & Williams, 2005). Precambrian rocks also form the spine of the Uinta Mountains but are quite younger, forming ~700 – 800 m.y.a. They consist of quartzite and shale-metamorphosed sandstone and mud, remnants of a land covered in red sand dunes at the edge of a sea.

Quartzite and granite are relatively resistant to erosion and consequently comprise the characteristic jagged spines of the UCRE’s major mountains: Wind River, Southern Rockies, Wasatch, and Uinta Mountains. Similarly, the erosion resistant granite and quartzite narrow the Grand Canyon narrows where these rocks cut though the Vishnu schist. As a parent material for alpine soils, where most precipitation enters the basin, quartzite and granite have no capacity to buffer acidity, leaving the alpine communities sensitive to acidic pollution.
Paleozoic

Paleozoic rocks, from ~545 to ~245 m.y.a., are exposed in roughly 10% of the area. The UCRE was at the equator when the Paleozoic opened and converged into the super-continent of Pangaea over this period. The UCRE was under shallow tropical seas during the early Paleozoic as indicated by marine sequences of limestone, shale, and sandstones. Towards the middle of the Paleozoic, an island arc collided with Laurentia, raising the Antler Mountains to the west of the UCRE. The ancestral Rocky Mountains began to rise as the Antlers were eroding, separating basins from the sea where evaporates later formed. Vast swamps existed in the lowlands, and their remains have become the coal formations of the UCRE.

The thick, expansive layers of limestone and dolomite comprise many of the mountains in the Bonneville Basin, and often ring the Precambrian rocks of the Upper Colorado River Ecosystem. Because these rocks are carbonaceous, watersheds with these rocks have alkaline soils and waters.

Mesozoic

Mesozoic rocks, from ~245 to ~65 m.y.a., occupy 30% of the UCRE surface. At the opening of the Mesozoic, the super continent of Pangaea began drifting apart. The ancestral Rocky Mountains had largely eroded away by this time, with another mountain range, the Sonoma, lifting in the west. Rivers draining the Sonoma Range left conglomerates in the eastern part of the UCRE. The seaway, which extended through the UCRE at the opening of the Mesozoic, retreated and arid conditions prevailed throughout the middle of the Mesozoic as the Nevadan Orogeny lifted mountains throughout the western UCRE. These
“orogeny” periods are simply episodes of geologic uplift, or folding of the earth’s crust. Wetland deposits from this time are associated with uranium, a regionally and nationally important resource. Towards the end of the Mesozoic, a seaway expanded throughout the middle of the North American continent, leaving marine and alluvial rocks across central and eastern UCRE. The Sevier Orogeny lifted mountains across the west, and the sea retreated by the end of the Mesozoic.

**Cenozoic**

Cenozoic rocks and unconsolidated sediments, from ~65 m.y.a. to present, occupy over 55% of the UCRE surface. The North American continent was largely in its present day location as the Cenozoic opened, and today’s mountains had already begun to rise as a result of tectonic events known as the Laramide Orogeny. The basins and plateaus also developed their present form in this period.

The UCRE had a tropical climate during the first part of the Cenozoic. Basins filled with large lakes, particularly the Wyoming and Uinta basins. Organic deposits from these lakes have become natural gas fields. Throughout the early and middle Cenozoic, rising magma lifted the plateaus of the region and then left conglomerates of volcanic rock, which have yet to erode, unlike the many of the surrounding canyons.

In general, rivers eroded into the uplifting plateaus, but incision rates varied widely. The current drainage network of the Upper Colorado River is thought to have formed piecemeal, with
sections becoming integrated as lakes spilled out of closed basins. Incision of the Grand Canyon has continued into the Holocene (Schmidt, 2007).

Extensional forces opened the Bonneville Basin, now full of thick lacustran and alluvial deposits, because of ice ages beginning ~1.8 m.y.a. Lake Bonneville, one of the last glaciations, filled the Bonneville Basin, leaving terraces along the foothills, alluvial fans at the canyons, and lacustran deposits in the valleys. Glaciers in the mountains eroded U-shaped valleys into the Precambrian rocks of the high mountains and deposited till along the margins.

Overall, the general geologic theme of the UCRE is of advancing and retreating water bodies punctuated by mountain building events and, more recently, plateau uplift. Tectonic and climatic forces, along with the biota, are primary determinants of landforms. All three influence each other. For example, sedimentary rocks of the Paleozoic are primarily organic remains deposited in marine environments, which today comprise the mountains of the Bonneville Basin where extensional forces are stretching the crust. The earliest rocks, Precambrian, are the metamorphosed igneous and sedimentary rocks indicative of a continental edge environment. Mesozoic rocks are a combination of marine and terrestrial deposits left by an advancing and retreating epicontinental seaway and terrestrial sand dunes. Cenozoic sediments are those of vast lakes and glaciers, both of which shaped the land.
Soils

Soils of arid regions around the globe have posed unique challenges to civilization (Foth & Schafer, 1980). The UCRE is no different. Soils emerge from the interactions of the lithosphere, biosphere, and climate. Soil simultaneously forms from and moderates biotic and abiotic processes, which act on the lithosphere. Soil is both a history of the land and the potential for the land.

Soil classification comes from both parent material and the stage of development. The Natural Resource Conservation Service (NRCS) classifies soils into twelve orders. In the UCRE, just five of the orders comprise over 99% of the soil. The figure below illustrates the developmental pathways of these five soil types. A brief description of each follows in the next sections. Additionally, areas not covered in soil are expansive in some areas of the UCRE and are described later in this section.
Entisols

Entisols are referred to as the recent soils. Their development is minimal for one of three main reasons: they are developing from recent parent materials, they are on a substrate that is not prone to soil development, or a disturbance is continually undoing formative processes. They are a diverse group, with diverse conditions and potentials. They are distinguished only in their overarching lack of distinguishing features (Soil Survey Staff, 1999).

These soils can be particularly good farmland if formed in river deposits, or they can be quite delicate, such as stabilized sand dunes, which will be mobilized if disturbed (Soil Survey Staff, 1999). Globally they are widely distributed, comprising 16% of the world’s total soil surface, about 12% of North America, and about 24% within the UCRE.
Inceptisols

Inceptisols are referred to as young soils, as their features are in their inception. They are the Pleistocene entisols with some weathering. They have developed under humid conditions and alkaline inputs (like carbonates). Inceptisol uses vary throughout their range. Most of them in the UCRE are scantily vegetated. However, they do support limited agriculture. Globally, they range through all latitudes (Foth & Schafer, 1980). In the UCRE, they range from the lowest elevations to the highest. They occupy 9% of the United States soil area and roughly the same proportion in the Upper Colorado River Ecosystem.

Alfisols

Alfisols are often referred to as the forest soils. They are what entisols become under moist and cool climates. Like much of the northern hemisphere, the story of the UCRE’s alfisols interweaves with the story of its coniferous and mixed forests. The soils have formed largely on glacial deposits exposed after the last ice age, about 10,000 years ago. As the glaciers retreated, the coniferous forests migrated up the mountains onto the newly exposed sediments (Brady, 1999).

Alfisols are moderately fertile, and they are farmed in the warmer areas of their range (Foth & Schafer, 1980). In the UCRE, most of the alfisols lack a long enough growing season to support agriculture. Globally, alfisols occupy about 10% of the ice-free land and roughly the same percentage of the UCRE. They occur in the higher mountains and latitudes where they support forest growth.
Aridisols

Aridisols are called the desert soils and are what entisols become under arid conditions. Limited plant growth and weathering due to limitations on available water define these soils (Soil Survey Staff, 1999). Adding water to these soils can have surprising, and sometimes costly, consequences. The biomass is low in aridisols, consequently resulting in the familiar pale color of the nutrient poor ochric horizon.

Aridisols generally have any number of other horizons as well. Some are remnant horizons that formed during the moister climate of the last glacial period. Processes driven by the moisture balance of the current climate form the rest of the horizons. A mineral horizon forms when water never fully percolates through the soil. As the water percolates, it transports minerals in solution, and as the water evaporates out of the soil, the mineral solution left over forms a horizon.

The vegetation of this soil typically remains spaced apart, leaving large openings between them. Wind erosion can be significant in these areas, often blowing the soil around until it develops a biotic or abiotic crust. In the case of cold deserts, including the UCRE, soil is usually held in place by biotic crusts consisting of microbial communities. These biotic soil crusts are often referred to as cryptobiotic soils. The disturbance of such crusts drives the desertification in sub-Saharan Africa, China, and North America (Soil Survey Staff, 1999).
Agriculture and other uses are limited on aridisols. Salts can rapidly build up when these soils are irrigated, unless they are irrigated in excess and allowed to drain off. Remnant argillic horizons can form an impermeable layer between the subsurface and surface of the soil, which can prevent the water table from being a source of moisture or from water recharge. Aridisols occupy 18% of the world, 11% on North America, and 25% of the UCRE area (Foth & Schafer, 1980). They dominate the Bonneville Basin, which even contains a suborder that is endemic to North America’s Great Basin (Soil Survey Staff, 1999). In the Wyoming basin and the Colorado plateaus, the aridisols are intermixed with entisols, generally forming a zone between the entisols and mollisols.

**Mollisols**

Mollisols are often referred to as the grassland soils. The defining feature of mollisols is the mollic epipedon- the accumulated biomass at the top of the soil profile that is a unique result of grasses dense root systems (Soil Survey Staff, 1999). It is under grasses’ that the mollisols have formed, under the same climate and associated biotic elements of the grassland ecosystems (Brady, 1999). They are the primary agricultural soil in the UCRE area (Foth & Schafer, 1980) where they ring the basins and extend up onto the mountains. They form a zone on a continental scale in between the aridisols of the western deserts and the alfisols of the eastern forests (Foth & Schafer, 1980). They form a similar zone in the UCRE between the aridisols of the basins and plateaus, and the alfisols of the higher mountains.
Mollisols are the famous agricultural soil. They are the soils of the nation’s breadbasket. In the UCRE, they support over half of the total irrigated agricultural crop area and a third of the hay and pasture area.

They represent about 25% of the Upper Colorado River Ecosystem, which is the same amount they occupy on the North American continent. The mollisols of the UCRE trend from north to south, which is part of a larger band of the continental Mollisols that run in a long band from Canada to Mexico.

**Lands Lacking Soils**

In the UCRE, there is a significant amount of area not covered by soil. Badlands are highly dissected lands that exist in climates that do not support enough vegetation to keep soft sediments from eroding during the occasional rainstorms (NRCS, 2007). Dune lands are areas of mobile sand dunes. There are three main areas: Killpecker, in the central Wyoming basin; White, in the east-central Bonneville basin; and Coral Pink Sand Dunes, in southern Utah.

Gypsum lands are rich in gypsum (NRCS, 2007). Gypsum forms in highly saline environments, in this case a shallow Jurassic sea. The gypsum lands are located in a long patch, roughly 100 x 10 km. There is one populated place in this area, Lone Tree Crossing, Utah. Rocky outcrops occupy vast areas of the Colorado Plateaus, and are usually barren sandstone. Rubble Lands occur along the Rocky Mountains and are generally boulder and cobbles deposited by glaciers (NRCS, 2007). Finally, playas primarily occur in the Bonneville basin, where the closed sub-basins accumulate mineral deposits as the water evaporates.
Climate

The Upper Colorado River Ecosystem contains a variety of climate zones, ranging from arid to polar tundra. Interactions between geomorphic structures, oceanic processes, ranges in elevation, and latitudes and longitudes create the region’s diverse climate zones. The geomorphic structures of major importance to the region’s climate include the Sierra Nevada range, Wasatch range, and Rocky Mountain range, which cause rain shadows and influence weather patterns (Bailey, 1996). Likewise, the major Pacific oceanic processes, Pacific Decadal Oscillation (Mantua, 2000) and El Niño-Southern Oscillation (Walter, 2007), heavily influence the climate by way of shaping precipitation and drought cycles throughout the region (Hidalgo & Dracup, 2003).

Additionally, elevation and continental position complete the general climatic picture by shaping local and regional temperature and precipitation patterns (Ashcroft, Jensen, & Brown, 1992). As mentioned above, all of these influences shape the climate creating a distinctive climatic region.

The climatic zones described in detail below use a classification system based on the Modified Köppen Scheme (McKnight, 1999). Three main types occur within the region:

- **Desert Steppe climates**
- **Dry Desert climates**
- **Highlands climates**

Several smaller climate zones occur within the study area. **Humid Continental** climates appear sparsely throughout the landscape and, nestled within the highland climates, are a few **Polar Tundra** climates.
**Desert Steppe Zones**

*(BSk)* are the most prevalent climate zone within western United States (McKnight, 1999) and occur throughout the region. Trees occur within the *Desert Steppe* climates, but the vegetation is predominately shrub and a mixture of grasses. This climate zone occurs close to or within the rain shadows of the major mountain ranges (Bailey, 1996), but receives more precipitation than dry desert zones.

- **Structure**
  - *Semiarid*: ½ Evapotranspiration < Precipitation < Total Evapotranspiration
  - No pronounced seasonal precipitation distinction
  - Hot summers, but not extreme, and cold winters

- **Function**
  - Transitional zone between *Dry Desert* zone and *Highland* zone
  - *Desert Steppe* zone acts as rangeland throughout much of the region
Dry Desert Zones (BWk) generally occur within the rain shadows of major mountain ranges. These Dry Desert zones are very arid with sparse vegetation such as shrubs or grasses. Despite little precipitation and sparse vegetation, biodiversity within the dry desert climates is very high.

- **Structure**
  - *Arid*: Precipitation < ½ Evapotranspiration
  - Extremely hot summers with meager precipitation
  - Cold winters with erratic precipitation

- **Function**
  - Holds a large amount of biodiversity
  - *Dry desert* zones act as rangeland, despite limitations

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Dry Desert Climate, San Rafael Swell, Central Utah
Function and Structure: Climate

**Highland Zones (H)** classify differently than all other climate zones. This zone classifies based upon continuous elevation gain that causes changes in climate (McKnight, 1999), rather than classification based upon temperature and precipitation averages. Classification based upon elevation gain stems from the temperature lapse rates (Western Regional Climate Center) which influences change in precipitation, temperature, and evapotranspiration.

- **Structure**
  - Significant climatic changes over short horizontal distances (McKnight, 1999)
  - Temperature dependent on elevation (lapse rate):
    +1000 feet $\rightarrow$ -3.5°F
  - Mild to hot summer days with cold nights (temperature fluctuations)
  - Very cold winters
  - Unpredictable weather

- **Function**
  - Receives a majority of the region’s precipitation (snow)
  - Serves as water storage system late into summer (snowmelt)
Function and Structure: Climate

- Influences adjacent climate zones by shaping precipitation and weather patterns and creating atmospheric disturbances

**Humid Continental Zones (Dfa, Dfb)** occur solely within the Northern Hemisphere. Although the name indicates a wet climate, there is not a copious amount of precipitation, but rather a modest amount with less evapotranspiration (McKnight, 1999). Often, this zone occurs upon the benches of the mountains and within the protected mountain valleys.

- **Structure**
  - **Precipitation** > Evapotranspiration
  - Occurs near mountain ranges and valleys
  - Hot summers and cold winters
  - Four distinct seasons

- **Function**
  - Premium agricultural and grazing lands
  - Desirable for human settlement
  - Provides excellent wild forage material and habitat
Function and Structure: Climate

*Tundra Climate Zones (ET)* occur high within the mountain ranges of the region. One excellent example of this climate zone happens to be within Rocky Mountain National Park. Within the park, this climate zone occurs at or above 11,000, but below 12,000, feet above sea level (National Park Service, 2007). The *Tundra* zone is the rarest climate zone within the study area.

- **Structure**
  - No summer season and cold temperatures year-round
  - Only exists at high elevations within the region
  - Ecosystems very sensitive to disturbances from human activity and climate change

- **Function**
  - Serves as critical habitat for high altitude species

![Image: Polar Tundra Climate, Rocky Mountain National Park](image_url)
Hydrology

The hydrologic system affects nearly every aspect of the UCRE, from historical development patterns to concerns over water management, water quantity and quality, and natural environments. The following brief summary of surface water, groundwater, and water policy is meant to illuminate the basic structure and function of the area’s hydrology and water use in order to inform regional policy and planning decision-making.

SURFACE WATER

Structure: Approximately 85% of the annual precipitation in the UCRE falls in the high mountains, 15% of the land area. As air masses are pushed up and over these mountains, water vapor condenses and falls as rain or snow. Winter snow accumulation in the mountains serves as a temporary reservoir for much of the UCRE’s annual precipitation. As the snow melts in the spring and early summer months, the region’s rivers and streams swell with the majority of annual runoff.

Function: Significant seasonal fluctuations in river flow within the UCRE conflict with the need for sources of water to support irrigated agriculture throughout the summer. This need for water compelled the construction of a comprehensive system of dams and reservoirs on the rivers of the UCRE in the second half of the 19th and first half of the 20th centuries.
Surface waters managed by the system of dams and reservoirs was historically, and is currently, used overwhelmingly for irrigated agriculture. This choice of water management and allocation facilitated the settlement of the region, but also created many problems. Some of these problems include water salinization, water pollution from fertilizers and pesticides, water loss due to reservoir evaporation, alterations of stream flows, and loss of riparian and riverine species’ habitats.

GROUND WATER

Structure: Significant groundwater resources exist in patterns that reflect precipitation and subsurface geology. Groundwater recharge and discharge zones are generally located at the base of mountain ranges and in contiguous valleys where runoff from precipitation and snowpack seeps into the ground and is held in aquifers formed by the subsurface geology.

Function: Most UCRE cities and towns use groundwater as the primary source of municipal and industrial (M&I) water. Groundwater is also of regional importance to ecosystems by
Function and Structure: Hydrology

supporting plant communities, stabilizing soils, and augmenting surface flow. Maintaining groundwater quantity and quality, therefore, is of obvious importance.

Prudent planning would manage groundwater quantity by protecting groundwater recharge areas and regulating pumping and for groundwater quality the management of pollution sources, transport, and attenuation factors.

Water Policy

Structure: The UCRE is not a unified political entity and, therefore, water policy varies somewhat by state and jurisdiction. However, interstate compacts do regulate water usage within the UCRE, namely the Colorado River Compact of 1922 and the Upper Colorado River Basin Compact of 1948. For further policy information on these documents, please see Appendix C and D.

The foundation of all UCRE water policies, however, is the doctrine of prior appropriation which has served as the guiding
principle of water law in the west since Euro-American settlement in the 19th century. The doctrine of prior appropriation, often summarized as “first in time, first in right,” grants the right to use water (water rights) to parties based upon the seniority of claims to continual beneficial use.

Under prior appropriation, beneficial use is defined by the rights-granting jurisdiction (states), and generally includes such activities as irrigation, stock watering, mining, domestic or industrial use, power generation, and others, including ecosystem uses. These ecosystem uses usually are in-stream flow that provide wildlife habitat, recreation, or maintains water quality. However, ecosystem beneficial uses depend upon state law, and are not ubiquitous in the west. After granting a water right, the water user can then use their granted water unobstructed for beneficial use, so long as all senior water rights are satisfied first, and there is still water in the stream.

**Function:** During the early Euro-American settlement of the west, the doctrine of prior appropriation allowed western states to provide settlers a measure of equitable rights-of-access to scarce and variable water sources. This allowed farmers to irrigate, miners to mine, and cities to grow with the ability to plan and manage for uncertainty and risk associated with access to water.

Today, the doctrine of prior appropriation still serves as the foundation of western water law. However, some view prior appropriation as an outdated system, which gives preference to inefficient, uneconomical irrigated agriculture at the expense of municipal, industrial, and in-stream use (Clyde, 1989).
**Wildlife**

The wildlife throughout the Upper Colorado River Ecosystem links directly to the unique and diverse habitat. The UCRE contains a high variance in species, both aquatic and terrestrial, and is a key feature of the landscape that many people strive to protect and maintain. Federal agencies like the Fish and Wildlife Service, National Park Service, Forest Service, and Bureau of Land Management supervise vast expanses of lands throughout the west and have federal mandates for wildlife and habitat management programs.

**Riparian Zones**

The riparian zones support a diverse amount of wildlife species ranging from birds to fish. This ecosystem provides many different habitat types, for instance: rivers, lakes, ponds, marshes, and wetlands. Riparian zones at high elevations also serve as migration corridors for species such as elk, deer, and moose. These migration corridors provide safe travel for species from the...
high altitude summer range down to the lowland winter range
and vice versa (Benyus, 1989)

The lowland riparian sub-zones primarily consist of slow
meandering rivers along with wetlands and marshes. The lowland
and aquatic species, unlike the large vertebrates in the upland
riparian areas, directly depend on the water quality and quantity
for their habitat. Fish species are a prime example of one of these
aquatic species, and water quality is a looming issue for popular
fish such as brown, rainbow, and cutthroat trout along with
salmon, bass, and walleye.

Wetlands throughout the west provide critical habitat for
many common migrating birds including geese, ducks, and cranes.
Wetlands also provide habitat for many sensitive species like the
Bobolink and Whooping Crane and the Greater Sandhill Crane.
However, wetlands are slowly diminishing due to human
interactions and, despite this continued decline, many efforts,
such as base flow regulations, sediment management, legal
actions, and establishing wildlife refuges, have been taken to
preserve this critical habitat. The refuges within the UCRE
are:

- Bear River NWR
- Fish Springs NWR
- Ouray NWR
- Cokeville Meadows NWR
- Seedskadee NWR
- Brown’s Park NWR
- Two Ponds NWR
- Arapaho NWR

Range and Intermountain Basins

A wide variety of fauna utilizes the habitat throughout the
range and basin ecosystem, both above and beneath the surface.
Many threatened and endangered burrowing species in Utah and
Colorado use the underground habitat for protection and evasion of predators, like the hawk. These species include the Burrowing Owl and both the White and Black Tailed Prairie Dog. Browsing wildlife, deer, elk, and pronghorn use much of the range and basin vegetation for winter forage. This zone is a very important food resource for those species that migrate down from the harsh winter conditions in the mountain.

This zone provides crucial habitat for many bird species of special interest such as the Plains Sharp-Tailed-Grouse, Gunnison Sage-Grouse, Greater Sage-Grouse, and Columbian Sharp-Tailed Grouse. Many birds enjoy the shrub cover this ecosystem provides. The eagle, falcon, and hawk are also common predatory birds that thrive by hunting mice, rabbits, and other small animals in the range and basin ecosystem.

American Pronghorn, Outside of Green River, Utah

© Louis Hurst
Function and Structure: Wildlife

Foothills and Transition Zones

The foothill and transition zones are interesting in that so many wildlife species utilize this habitat. The transitional landscapes encompass the edges of many shrubland species like the sage grouse. The foothills throughout this region act primarily as cover and mesic environments providing food and safety in crucial winter range for species like deer, elk, and antelope.

Montane Forests

Elevation, topography, and climate also dictate a wide variety of wildlife habitats in the UCRE. The high elevations and associated cool climate of the Montane forests provide important breeding grounds for large mammal species like deer and elk. Additionally, Montane forests provide the only habitat large enough to meet the privacy needs in the spring, summer, and fall for many of these larger species. Common predator species like the black bear and mountain lion roam for prey within these forests.

The bird species within the Montane zone are both diverse and aesthetically beautiful. Common birds throughout the ponderosa forests are bluebirds and nuthatches. Juncos and thrushes live in the Douglas-fir forests, warblers in the lodgepole pine forests, and blue grouse, solitaires, and woodpeckers are the most common in subalpine zones (Rennicke, 1990).
Function and Structure: Wildlife

Alpine Tundra

The short summer climate of the alpine tundra provides for a diverse range of wildlife. Large mammals including elk, mule deer, bighorn sheep, and mountain goats all forge here to escape the hot dry climate of the lowlands.

Threatened, Endangered, and Sensitive Species

The Endangered Species Act established by congress in 1973 was designated in order to protect, within reasonable means, any fish, wildlife, or plant species facing extinction due to their aesthetic, ecological, educational, historical, recreational, and scientific value (U.S. Fish and Wildlife Service, 1973). The Upper Colorado River Ecosystem contains numerous species listed as threatened, endangered, or sensitive by the United States Fish and Wildlife Service. Each state also has a separate list of state and even county species of special concern. These species are often the primary focus of state management agencies like the Utah Natural Heritage Program, Project WILD, and Habitat Counts in Wyoming. For full listings of threatened, endangered or species of concern, please see the websites listed below.

Federal


States

- Utah - [http://dwrcdc.nr.utah.gov/ucdc/ViewReports/SSL121407.pdf](http://dwrcdc.nr.utah.gov/ucdc/ViewReports/SSL121407.pdf)
- Colorado - [http://wildlife.state.co.us/WildlifeSpecies/](http://wildlife.state.co.us/WildlifeSpecies/)
- Wyoming - [http://gf.state.wy.us/wildlife/](http://gf.state.wy.us/wildlife/)
Vegetation

Much of the west’s landscape appears to have natural or semi-natural vegetation with little to no management. However, people have actively managed the west’s vegetation for hundreds, even thousands, of years. Vegetation often breaks down in subcategories; five such subcategories, eco-regions, divide the UCRE. These eco-regions illustrate the current vegetation and wildlife types throughout the UCRE.

Riparian zones

The riparian zones throughout the UCRE consist of many rivers, lakes, ponds, and wetlands within a wide range of elevations. Vegetation in the riparian eco-region commonly takes shape as marshes, meadows, shrublands, and trees. This distinct ecosystem is both dynamic and fragile. While riparian areas account for a very small percentage of the total area in the basin, stream banks and river edges contain a species variety that is two to three times higher than the surrounding landscapes.

Flora variation is a direct result of the diverse physical characteristics that riparian eco-regions possess. As a stream or river changes in elevation or topography, the gradient, sinuosity, and soil type changes which eventually dictates the changes in vegetation mosaics. The riparian eco-region separates into two main sub-regions: highland riparian and lowland riparian.
Function and Structure: Vegetation

Higher elevations, steeper stream gradients, and cooler temperatures define the highland riparian sub-region. The lowland riparian sub-regions have slower meandering rivers, along with still marshes and wetlands. These areas contain the more common riparian vegetation including cottonwoods, willows, dogwood, birch, cattails, bulrushes, sedges, and reed grasses.

Range and Intermountain Basins

The range and intermountain basin eco-region consists of the largest portion of the Upper Colorado River Ecosystem. With landscape characteristics including rolling hills, stunning mesas, and lower foothills, the range and basin makes up much of Utah, southwestern Wyoming, and western Colorado. This eco-region contains large amounts of biodiversity and provides very important habitat to many threatened and endangered species. Life is difficult in the range due to low precipitation, harsh winds, extreme temperatures, and poor soil conditions. The range and basin eco-region contains three sub-regions:

- **Desert shrublands**
- **Sagebrush basin and steppe**
- **Foothill shrublands**

Many different features like soil type, topography, and climate distinguish these sub-regions. They also encompass the majority of the plant communities throughout the Colorado Plateau, Central Basin, and Wyoming Basin.
Desert Shrublands

With a harsh, dry climate and soils that contain an abnormally large amount of salinity, the vegetation has become very adaptable to extreme growing conditions. Common species including Greasewood, Shadscale, Fourwing Saltbush, and Winterfat have evolved to limit their competition for resources to a seasonal pattern in order to survive.

Sagebrush Basins and Steppe

Much like the desert shrubland sub-region, water is scarce in the basin, and common sagebrush species like Big Basin Sagebrush and Wyoming Big Sagebrush, along with some grasses, have become very efficient in their water use. Many sagebrush species bore and extend their root system into a large diameter in order to find and retain the scarce water supply.

Foothill Shrublands

This rocky, visually rugged sub-region contains many mountain brush species like Mountain Mahogany, Cliffrose, Western Serviceberry, and some Bluebunch Wheatgrasses. The foothills often transition from mountain brush vegetation into a juniper woodland forest ecosystem depending on elevation, slope, soil type, and climate.
Function and Structure: Vegetation

**Foothills and Transition Zones**

Much like other ecosystems throughout the UCRE, the climate, topology, and soils depict the vegetation throughout the foothill and transition zones. The moderate climate within these transitional spaces is warmer than the mountains above and much cooler than the lands below. Additionally, these zones receive more annual precipitation than the dry ecosystems below. These conditions provide excellent habitat for many plant and animal species.

The climatic conditions often dictate one habitat type to another. The lower portions of the transitional eco-region consist of shrubland communities like Mountain Mahogany, Sumac, Sagebrush, and Gambel Oak, and they require less water and warmer temperatures. Transitioning to a slightly higher elevation and cooler climate, the woodland plant communities begin with common species including Juniper, Limber Pine, Ponderosa Pine, Aspen, Douglas-fir, and Pinyon Pine, which eventually transition into the montane eco-region.

**Montane Forests**

Much like the foothills, elevation, topography, and climate directly affects the vegetation distribution in the montane eco-region. Each holds influence on how vegetative communities are distributed throughout the landscape. For example, as elevation and topography increases, the temperature decreases, which dictates what certain forest types are suitable for that location.

Topography is another important example of how climate and elevation can affect plant communities. Southern aspects have warmer and dryer microclimates while northern
slopes are cooler and mesic. The general elevation distribution of plant communities follows as:

- **Low elevations – Ponderosa Pine and Douglas-Fir**
- **Mid elevations – Lodgepole Pine**
- **High elevations – Engelmann Spruce and Subalpine Fir**

Ponderosa pine forests generally grow on the warmer, dryer south-facing slopes while the Douglas-Fir forests tend to grow on the north facing cooler slopes (Rennicke, 1990). Aspen groves and mountain meadows are also interspersed throughout the different sub-regions within the specific landscape and habitat characteristics needed for establishment.

**Alpine Tundra**

The alpine tundra eco-region is one of the harshest landscapes for plant growth within the region. With elevation ranges of approximately 11,500 to over 14,000 ft. above sea level, the alpine tundra has an extremely windy, icy, and cold climate.

The vegetation mosaic throughout the upper alpine ecosystem has two different zones. The first would be the lower zone, just above the subalpine sub-region within the mountain eco-region, which consists of krummholz plants like Engelmann Spruce, Subalpine-Fir, Limber Pine, Bristlecone Pine, and Whitebark Pine. Krummholz is a form of plant that is short and wide to protect from the excessive wind in a harsh environment. The second alpine zone is above tree line and consists of many grasses, perennial herbs, low shrubs, mosses, and lichens.
History and Culture

The UCRE contains some of the most remote, rugged, and forbidding lands in the lower 48 states. Vast desert canyons cover southern Utah, northern Arizona, and New Mexico. Alpine mountain ranges cover western Colorado and run north-south through Utah, and the high desert covers Southwest Wyoming and the Uintah Basin. In this challenging environment, human cultures have adapted to and inhabited the UCRE for thousands of years, during which there have been changes in temperature, precipitation (Benson, Petersen, & Stein, 2007), land management choices, and resource use (Coltrain & Leavitt, 2002) (Kirsch, 2002) (Taylor, 2004).

Native American Societies

Two major agricultural societies arose in the UCRE prior to Euro-American settlement in the 19th and 20th centuries. Puebloan and Fremont societies flourished in southern and northern portions of the UCRE, respectively, developing advanced systems of irrigated agriculture and settlement reflective of complex, stratified societies (Varien, 2007) (Coltrain & Leavitt, 2002). The rapid abandonment of irrigated agriculture and permanent settlements around 1300 AD has been the subject of much debate. Leading theories attribute this change to
drought, environmental degradation, and climate change, as well
as cultural and religious factors (Varien, 2007) (Benson,
Petersen, & Stein, 2007) (Coltrain & Leavitt, 2002)
(Johnson, Kohler, & Cowan, 2005).

Later Native American groups in the UCRE,
Shoshone, Southern Paiute, Ute, Navajo, Goshute, and
others, developed unique cultural adaptations in their
respective regions (Kirsch, 2002) (Francaviglia, 2002)
(Johnson, Kohler, & Cowan, 2005) (VanHoak, 1999). Most
of these tribes were largely nomadic, with economies
based in varying degrees on hunting, gathering, animal
husbandry, and agriculture (VanHoak, 1999) (Wilkinson,

**Early European Exploration**

Early Euro-American exploration of the UCRE began in the
16th century with a variety of Spanish expedition. Notable among
them, Coronado’s search for a city of gold in the 1540’s and
Franciscan missionaries Escalante and Dominguez proselytizing
and mapping voyages through the Colorado Plateau in the late
18th century. Later, in the late 19th century, one-armed Civil War
veteran John Wesley Powell surveyed much of what is now Utah
for the U.S. Government (Kirsch, 2002) in a now famous three-
month journey down the Colorado River. Powell reported that the
arid lands of the West would require significantly different land
management frameworks than the humid lands of the East, as
many western lands were in a “present worthless state” (Kirsch,
2002) and had very limited agricultural capacities (Kirsch, 2002).
Though the Colorado Plateau remained mostly unpopulated, by
the early 19th century a trickle of explorers began to establish themselves in the Colorado Rockies, and to a lesser extent the Wasatch Mountains, in search of gold and silver, and profits from a burgeoning fur trade (Adler, 2007) (Wilkinson, 1992).

The 19th century saw the development of towns in the Colorado mountains, more comprehensive trapping and exploration of UCRE lands, and a series of conflicts between white settlers and Indian tribes (Miller, 2001) (Wilkinson, 1992) (Adler, 2007). The mid-19th century was also the setting for the migration of Mormons or Latter Day Saints (LDS) to what later became Utah (Garrett, 2005) (Vance, 2001).

Mormon Settlement

In the 1830’s and 1840’s, the development and persecution of the LDS movement in New York, Ohio, Illinois, and Missouri culminated in the lynching of LDS leader Joseph Smith in Illinois in 1844 (Brodie, 1945). What followed was the exodus of LDS faithful to the Salt Lake Valley, which was then outside the boundaries of the United States. Brigham Young led this migration

By the late 19th century, Mormons had successfully built towns throughout much of Utah (Garrett, 2005) (Meinig, 1996). After the U.S. acquired the UCRE from Mexico in the Treaty of Guadalupe Hidalgo in 1848, some federal authorities perceived the authoritarian Mormon theocracy as a threat to U.S. control of the territory (Meinig, 1996) (Krakauer, 2004). After several violent skirmishes between Mormons, U.S. troops, and settlers (Mackinnon, 2005), Mormon leaders and U.S. officials agreed that “Deseret” would submit to U.S. control.

Soon after, LDS leaders desired the full benefits of U.S. statehood for Utah and applied for it from Congress in 1873. Congress rejected the bid, citing the Mormon practice of polygamy as contrary to U.S. law. Seventeen years later, in 1890, LDS president Stewart Kimball instructed Mormons to abandon polygamy. Federal authorities then granted U.S. statehood to Utah in 1896, making it the 45th state (Krakauer, 2004) (Meinig, 1996) (Mackinnon, 2003). The confirmed federal authority gave
established Mormon settlements the benefits of trade with neighboring regions, federal assistance, and a voice in U.S. government (Mackinnon, 2003).

20th Century

By the turn of the 20th century, the American West had become politically unified, Native Americans had been pacified and relocated to reservations, and improved transportation, especially the Transcontinental Railroad completed in 1869, had connected the country (Jackson & Jackson, 2003) (Garrett, 2005) (Hafen, 1997) (Mackinnon, 2003).

In the first seventy years of the 20th century, development in the URCB was marked by efforts to “fully” exploit the resources of the region (Wilkinson, 1992). A set of 19th century laws designed to encourage the settlement and exploitation of western lands facilitated logging, dam building, road building, extensive ranching, and coal, uranium, copper, and silver mining (Wilkinson, 1992) (Adler, 2007). Oil and gas exploration and drilling became the economic backbone of UCRE communities in Wyoming and the Uintah Basin (Miller, 2001). Logging and mining expanded in the Colorado Rockies, also uranium, and coal mining expanded in parts of southern Utah, Colorado, and Wyoming (Wilkinson, 1992). Finally, an extensive system of major and minor dams and reservoirs stored the region’s swollen...
Function and Structure: History & Culture

springtime rivers for irrigated agriculture, industrial, and municipal uses (Adler, 2007).

The co-evolution of environmental values in the 1960’s and 1970’s and increased access to UCRE lands led to the UCRE becoming a destination for outdoor recreation, natural beauty, and new settlement. Additionally, the political climate during this time allowed new restrictions on the extractive economies of the region (Hafen, 1997) (Jackson & Jackson, 2003) (Taylor, 2004). Partly for these reasons, UCRE development in the latter decades of the 20th century has been significantly affected by new residents and visitors (Winkler, Field, Luloff, Krannich, & Williams, 2007) (Taylor, 2004). These new residents and visitors have been described as “New West,” which refers to changing values of residents within western populations such as recreation or amenity-based concerns on tourism, skiing, hiking, and aesthetic residential and lifestyle opportunities (Krumenaker, 2007) (Taylor, 2004). New West residents see significant regulation on extractive practices as important to the development of the UCRE and often have little connection to the traditional economies or lifestyles of the region beyond aesthetic appreciation, like farming and ranching (Taylor, 2004) (Winkler, Field, Luloff, Krannich, & Williams, 2007).
21st Century

At the beginning of the 21st century, the UCRE continues to have a diverse cultural and demographic composition (Sharkansky, 1997) (Taylor, 2004). The Colorado Rockies have been sold as the West’s playground, ideal for a variety of recreational activities and featuring towns and cities with many of the cultural amenities of more metropolitan areas of the east and west coasts (Taylor, 2004). Utah’s Wasatch Mountains have been similarly marketed, especially after the 2002 Winter Olympic Games in Salt Lake City. In Utah, Colorado, and other parts of the UCRE, traditional industries often remain important components of local economies. Growing tourism, recreation, service, and amenity-based industries reflect a changing of the west from that of twenty or thirty years ago. With so many different groups now sharing the western landscape, conflicts result from the divergent values on land use decisions, natural resource management, community and regional planning, and economic strategy (Winkler, Field, Luloff, Krannich, & Williams, 2007).
Satellite Imagery of the Upper Colorado River Ecosystem Study Area

Satellite Imagery from the National Agriculture Imagery Program (NAIP)
Analysis: Phase 1

The analysis of this study expands upon the research done in the pre-analysis phase on the biophysical and cultural aspects of the UCRE. Two primary phases make up the analysis: assessment modeling and alternative futures.

In phase 1, the study team created and developed assessment models stemming from the issues and concerns derived from discussions and lectures in the pre-analysis phase. This process entailed the initial model research, development of model criteria, data collection, peer review, and model creation. Assessment models are the backbone of the analysis because they many also contribute to the formulation of Alternative Futures. These models are tiered into different levels to provide decision-makers a greater array of options when implementing a new strategies or policies.

This tiered modeling approach was developed in previous Bioregional Planning Studios at Utah State University. The first attempt at tiering was accomplished by the 2004 Bioregional Planning Studio when they worked upon the Great Salt Lake Region Alternative Futures report (Toth, Edwards, & Lilieholm, 2004). Subsequently, other reports have developed and refined this technique, such as the Alternative Future Study: Little Bear Watershed (Toth, Covington, Curtis, & Luce, 2007).

Upon the next page, an example of the tiering process is presented. First, a the component table of the rangeland assessment model details what the tiers contain, and second is an illustration of the rangeland model with further information on tiering.
Example of the Tiering Process

This technique allows assessment models to contain several levels of objectives and allows different criteria to be used in the modeling process to affect the values of the model.

### Rangelands Assessment Model

<table>
<thead>
<tr>
<th>Tier One: Identifies those areas most suitable for rangeland use</th>
<th>Tier Two: Identifies areas at least somewhat suitable for rangeland use</th>
<th>Tier Three: Identifies areas at least marginally suitable for rangeland use</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Includes:</strong></td>
<td><strong>Includes:</strong></td>
<td><strong>Includes:</strong></td>
</tr>
<tr>
<td>• Areas with good wild forage materials - [StatsGo]</td>
<td>• Tier One lands</td>
<td>• Tier Two lands</td>
</tr>
<tr>
<td>o Wild Shrub or</td>
<td>• Areas with good and fair wild forage materials - [StatsGo]</td>
<td>• No lands excluded due to fire risk</td>
</tr>
<tr>
<td>o Wild Grass or</td>
<td>o Wild Shrub or</td>
<td></td>
</tr>
<tr>
<td>o Wild Rangeland or</td>
<td>o Wild Grass or</td>
<td></td>
</tr>
<tr>
<td>o Wild Open Space or</td>
<td>o Wild Rangeland or</td>
<td></td>
</tr>
<tr>
<td>o Wild Herbaceous Wetland</td>
<td>o Wild Open Space or</td>
<td></td>
</tr>
<tr>
<td>• Areas with greater than 1100 annual growing degree days after the last frost day - [Daymet]</td>
<td>o Wild Herbaceous Wetland</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Areas with greater than 520 annual growing degree days after the last frost day - [Daymet]</td>
<td></td>
</tr>
<tr>
<td><strong>Excludes:</strong></td>
<td><strong>Excludes:</strong></td>
<td><strong>Excludes:</strong></td>
</tr>
<tr>
<td>• Wetlands, Developed Lands, Barren Lands, Water - [National Land Cover Database]</td>
<td>• Wetlands, Developed Lands, Barren Lands, Water - [National Land Cover Database]</td>
<td>• Wetlands, Developed Lands, Barren Lands, Water - [National Land Cover Database]</td>
</tr>
<tr>
<td>• Slopes &gt; 25% - [National Elevation Dataset]</td>
<td>• Slopes &gt; 25% - [National Elevation Dataset]</td>
<td>• Slopes &gt; 25% - [National Elevation Dataset]</td>
</tr>
<tr>
<td>• Highest and medium fire occurrence density - [USGS, 2007]</td>
<td>• Highest fire occurrence density - [USGS, 2007]</td>
<td></td>
</tr>
</tbody>
</table>

**Tier 1**

**Essential**

This model contains the essential criteria in order to model the respective biophysical or cultural phenomena.

**Tier 2**

**Moderate**

This model contains less restrictive criteria and gives more flexibility when modeling the biophysical or cultural phenomena.

**Tier 3**

**Extensive**

This model typically uses the least restrictive criteria and results in the respective biophysical or cultural phenomena encompassing large areas.
After all the assessment models are developed, phase 2 begins with the creation of future models and scenarios. Future modeling combines key concerns from phase 1 and forces the planner to distribute a projected population onto the landscape given certain criteria from the assessment models. There are many ways to accomplish this modeling process and the study team decided to utilize the LUCIS Model (Carr & Zwick, 2007). Once each alternative future is developed, each assessment model can then evaluate the future scenario to determine the effects of that course of action.

The final component of phase 2 is the development of a conservation status model. This model compares biodiversity to that area’s current resource management status. This cross tabulation involves breaking down biodiversity in several categories in order to compare different sections of biodiversity and their status of protection. The conservation status model allows land management agencies to understand better where biodiversity needs further protection and where current areas provide high protection to biodiversity.

Additionally, throughout the analysis phase 1 and 2, several “windows” are inserted to help the reader discern what is shown in the maps. Due to the scale of the work in from this report it is often difficult to see the components within each assessment model or alternative future. These windows only appear as needed and are otherwise limited if they obscure more than that illuminate.
Assessment Models

Assessment modeling is the spatial representation of characteristics, both physical and cultural, that are important throughout the Upper Colorado River Ecosystem. These models serve as the backbone for future modeling processes such as the one for this study. The assessment model process begins with the realization of issues or concerns. The study team then researches these concerns, leading to full-scale analysis and identification of their function and structure. The information obtained from the analysis is then spatially mapped using Geographic Information Systems (GIS) data. The assessment models serve two functions:

- Provide a foundation for developing alternative futures
- Evaluate the potential of each alternative future

Assessment models have two categories: environmental evaluation models and activity allocation models. Explanations upon the differences follow below.

Environmental Assessment Models

Environmental Assessment models focus on the biophysical attributes of the landscape. The identification and creation of these models are crucial for planners to better understand the physical processes currently acting throughout the study area. The models developed in this category for the UCRE include:

- Biodiversity
- Air Quality
- Surface Water
- Public Health, Safety and Welfare
Biodiversity

The Upper Colorado River Ecosystem contains a very large number of terrestrial and aquatic species due to the size and uniqueness of the area. With this array of species, the study team determined that “species richness,” or biodiversity, would be the primary approach for the purpose of this model. Species richness simply is the total number of species present at one location during a certain time. Therefore, high species richness contains a large number of species, and low species richness equals a smaller number. The species richness approach also provides an interesting analysis tool in identifying the “hotspots” throughout the region where high species biodiversity exists. These “hotspots,” high species biodiversity, are important to this approach because they identify the areas that contain the greatest number of habitats and provide a starting point for future management strategies.

Dirty Devil River, Above Hite Marina, Lake Powell
Management agencies such as the United States Fish and Wildlife Service strive to conserve and maintain the ecological functions of single plant and animal species. The biodiversity approach presented here takes a different perspective, trying to accommodate the various habitat types represented throughout the study area. In contrast, an indicator or individual species approach typically conducted by the FWS would be unsuccessful in representing all the different habitat types simultaneously.

The Remote Sensing/Geographic Information Systems Laboratory (RS/GIS) at Utah State University was utilized to create the necessary files for this study. The data was obtained from the South West Regional Gap Analysis Project (SWReGAP) which developed Animal Habitat Models for all terrestrial vertebrate species in Arizona, Colorado, Nevada, New Mexico, and Utah. The Wyoming Gap Analysis (WYGAP) data represents the Wyoming richness since it was not included in the SWReGAP project. There is discrepancy in the way the two projects mapped the individual species distributions; however, both data sets are necessary in order to produce a contiguous representation of species richness.
## Biodiversity Assessment Model

<table>
<thead>
<tr>
<th>Tier One:</th>
<th>Tier Two:</th>
<th>Tier Three:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identifies the highest areas of species richness along with river buffers and designated conservation areas</td>
<td>Adds threatened and endangered aquatic species habitat along with medium level species richness</td>
<td>Adds low-level species richness</td>
</tr>
</tbody>
</table>

**Includes:**

- Species richness of 100 to 300+ (high) - [SWReGAP]
- Major river buffer of 100 meters - [National Hydrography Dataset]
- Wetlands - [National Land Cover Database]
- Riparian areas - [National Land Cover Database]
- Designated Wilderness Areas
- Wildlife refuges
- Wildlife conservation areas

**Includes:**

- Tier One Lands
- Species richness of 30 to 99 (medium) - [SWReGAP]
  - Bonytail Chub habitat 200 meter buffer
- Humpback Chub habitat 200 meter buffer
  - Colorado Pikeminnow habitat 200 meter buffer
- Razorback Chub habitat 200 meter buffer

**Includes:**

- Tier One Lands
- Tier Two Lands
  - Species Richness of 1 to 29 (low) - [SWReGAP]
Biodiversity – Tier 2

Model Criteria
- All Tier 1 Lands
- Species richness of 30-99
- Bonytail Chub habitat 200 m buffer
- Humpback Chub habitat 200 m buffer
- Colorado Pikeminnow habitat 200 m buffer
- Razorback Chub habitat 200 m buffer

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Logan, Utah

ENVS

0 25 50 100 Miles

1:4,500,000
Biodiversity – Tier 3

Model Criteria
- All Tier 1 Lands
- All Tier 2 Lands
- Species Richness of 1 - 29

ENVS

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Logan, Utah

0 25 50 100 Miles
Air Quality

Significant air quality problems exist in the UCRE due to development of urbanized areas in locations prone to temperature inversions. Three UCRE cities rank among the worst twelve cities nationally in short-term particulate pollution largely due the reasons stated above: Logan, UT (ranked 6th), Salt Lake City (7th), and Provo, UT (12th) (American Lung Association, 2008).

Temperature inversions occur when a higher layer of stable warm air traps a lower layer of cool air (Western Regional Climate Center). The normal temperature profile of the atmosphere decreases with height, so the reverse of this normal profile is an inversion. This atmospheric condition prevents air circulation and the dispersal of pollutants.

Many of the region’s valleys and basins are conducive to the development of temperature inversions as warmer stable air masses trap heavier cool air in valley bottoms. This model identifies developed (tier one) and undeveloped (tier two) areas susceptible to temperature inversions using the following criteria:

- **Areas of slopes less than one-degree** trap air flows in flat valley bottoms.
- **Concave lands** most effectively trap air masses and pollution.
- **Low wind speeds** reduce air circulation and are a proxy for stable air masses.
- **Developed areas** are a surrogate for pollution sources. Used in tier one only.
- **Areas with high road density** are a proxy for mobile pollution sources. Used in tier one only.
**Air Quality Risk (Inversion Susceptibility) Assessment Model**

<table>
<thead>
<tr>
<th>Tier One:</th>
<th>Tier Two:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identifies highly developed areas very susceptible to temperature inversions</td>
<td>Identifies all other areas very susceptible to temperature inversions</td>
</tr>
</tbody>
</table>

**Identifies lands with ALL of the following features:**

- Slope less than one degree - [National Elevation Dataset]
- Negative curvature of slope (concave areas) - [National Elevation Dataset]
- Wind speed less than 6 meters/second - [Wind Resource NREL]
- Developed areas - [National Land Cover Dataset]
- Road density greater than 2 roads/km² - [Census 2000 TIGER/Line File]

**Identifies lands with ALL of the following features:**

- Slope less than one degree - [National Elevation Dataset]
- Negative curvature of slope (concave areas) - [National Elevation Dataset]
- Wind speed less than 6 meters/second - [Wind Resource NREL]

---

Air pollution in Cache Valley, Utah
Air Quality – Tier 1

Model Criteria
- Air Quality
  - Slope less than one degree
  - Negative curvature of slope (concave areas)
  - Wind speed less than 6 meters/second
  - Developed areas
  - Road density greater than 2 roads/km²

Analysis
Public Health, Safety, and Welfare

The public health and safety assessment model identifies areas that are suitable for development based upon the exclusion of areas subject to public health and safety hazards. Public health and safety hazards are those biophysical factors that would significantly increase the potential for societal costs due to structural damages, injuries, or deaths associated with coexistent development. Hazards incorporated into the model include landslide risk, steep slopes, fire zones, fault lines, seismic zones, wetlands, and river areas.

Landslides are defined as “rock falls and topples, debris flows and debris avalanches, earth flows, mudflows, creep, and lateral spread of rock or soil” (United States Department of the Interior, 2008). Susceptibility factors include steep slopes, loss of vegetation, intense precipitation, and flooding. Landslide hazards are assessed as “high risk,” “medium risk,” “low risk,” and “no risk” from National Atlas rankings (National Atlas, 2007).

Steep slopes correlate with higher potential for landslides and increased fire hazard (Utah Governor’s Office of Planning and Budget). Slopes greater than 35% are considered a risk to public health and safety in tier one, slopes greater than 25% in tier two, and slopes greater than 15% in tier three.
Fire is part of the natural disturbance regime of most UCRE lands. Fire affects soils and understory plants, can cause major damage to homes and other structures, and can be difficult to control (Romme, et al.). Fire zones are assessed here based on two components: fire density (USGS, 2007) and mean fire return interval (USGS, 2006). *Fire density* is assessed by performing a point density analysis of fire occurrences from 1980 through 2006 from five federal agencies (BIA, BLM, FWS, NPS, USFS) to produce a continuous grid coverage of the UCRE (USGS, 2007). *Mean fire return interval* “quantifies the average period between fires under the presumed historical fire regime” (USGS, 2006). Relative levels of hazard posed by UCRE fire zones are then assessed by combining the fire density (high density is more hazardous) and mean fire return interval (shorter interval is more hazardous) grids. Areas with relatively high levels of fire hazard are then used as an exclusionary variable in tier three of the model.
Fault lines are fractures in the Earth’s crust along which there has been relative movement and are the source of earthquakes (United States Department of Interior, 2008). To reduce risks to public health and safety, a 50-meter buffer around fault lines is used as an exclusionary variable in tiers two and three of the model (USGS, 2008).

Seismic zones are areas susceptible to faulting, shaking, landslides, liquefaction, tectonic deformation, and seiches. Seismic zones are found throughout the Wasatch Mountains and other UCRE areas (United States Department of the Interior, 2008). Seismic zones with a 10% chance of exceeding a peak acceleration of 15 % g (the acceleration due to gravity) in 50 years are conceptualized as a threat to public health and safety in tier three of this model, and such lands are thus excluded.

Wetlands play a key role in ecosystems by protecting and improving water quality, providing fish and wildlife habitats, storing floodwaters, and maintaining surface water flow during
dry periods (US EPA, 2001). Wetlands are included in the public health and safety assessment model as a way to reduce the likelihood of damage to structures due to flooding, guard against erosion from waves and currents, boost quality of life, and protect attractive open spaces (US EPA, 1999).

River areas provide a set of essential services to UCRE communities and ecosystems. Rivers deliver water that is diverted and used for agricultural and municipal needs. Riparian areas stabilize riverbanks to reduce flooding and provide habitat for many species, and these areas contribute to recreation activities and visual amenities that add to the quality of life for UCRE residents and visitors. By applying a 300-meter buffer zone to UCRE rivers, these values can be protected; hazards associated with river areas, such as flooding and water quality impacts due to runoff from agricultural or residential lands, can be mitigated (USGS, 2008).
Public Health and Safety Assessment Model

<table>
<thead>
<tr>
<th>Tier One</th>
<th>Tier Two</th>
<th>Tier Three</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification lands suitable for development by excluding only those areas that present the greatest risks to public health and safety</td>
<td>Uses tighter restriction criteria to refine the lands deemed safe for development with regard to public health and safety</td>
<td>Uses even tighter restrictions to identify those lands that, if developed, would pose the fewest public health and safety risks</td>
</tr>
</tbody>
</table>

**Excludes:**

- Areas with slopes greater than 35% - [National Elevation Dataset]
- Areas of high landslide risk - [National Atlas]
- Wetlands - [National Land Cover Database]
- A 300-meter buffer zone around rivers - [National Hydrography Dataset]

**Tier Two Excludes:**

- Areas with slopes greater than 25% - [National Elevation Dataset]
- Areas with medium to high landslide risk - [National Atlas]
- Wetlands - [National Land Cover Database]
- A 300-meter buffer zone around rivers - [National Hydrography Dataset]
- A 50-meter buffer zone around fault lines

**Tier Three Excludes:**

- Areas with slopes greater than 15% - [National Elevation Dataset]
- Areas with any landslide risk - [National Atlas]
- Wetlands - [National Land Cover Database]
- A 300-meter buffer zone around rivers - [National Hydrography Dataset]
- A 50-meter buffer zone around fault lines
- Seismic Hazard Areas - [National Atlas]
- Hazardous Fire Zones - (USGS, 2007)
Public Health, Safety, & Welfare – Tier 1

Model Criteria
- Slopes greater than 35%
- Areas of high landslide risk
- Wetlands
- 300 m buffer zone around rivers

Risk
- Low
- High

Bioregional Planning
Utah State University
Logan, Utah

ENVS

1:4,500,000

0 25 50 100 Miles

Salt Lake City
Logan
Ezarston
Rock Springs
Steamboat Springs
Vernal
Glenwood Springs
Grand Junction
Moab
Farmington
Saint George

114°W 112°W 110°W 108°W 106°W
42°N 40°N 38°N
Surface Waters

Water is one, if not the most important resource within the UCRE. The waters that flow through the arid southern portions of the UCRE are an extremely critical resource. The water contained in the system that makes up the Colorado River gives life to local ecosystems, and external and internal human populations. The importance of this river system should not be downplayed (Schmidt, 2007).

This assessment model attempts to model several water-related processes simultaneously: infiltration, snow pack runoff, open channel sediment dynamics, rivers and wetland dynamic, and dust mobilization. Additionally, these features were modeled on both the basin and sub-basin scale.

In the UCRE, the behavior of surface waters are tightly coupled with snow pack dynamics. To display this, areas with high precipitation receive weights based on the percentage of basin and sub-basin total precipitation. These two scales combine to identify critical water production zones.

The snow pack has two principle stressors: melting speed and infiltration speed. To model changes in infiltration speed, the model displays reductions in the infiltration capacity of soils by measuring impervious surfaces. Quantifying changes in snowmelt is very
Surface Waters

difficult and often leads to global connections. However, dust deposited in snow packs actually can accumulate to such an extent as to increase the amount of solar energy that is absorbed, thereby leading to snow packs melting earlier in the spring season and with greater magnitude (USGS, 2007).

The primary regional sources of dust are the Colorado Plateau and Great Salt Lake/Sevier Deserts. The soils in these areas vary in their susceptibility to wind erosion and received weight accordingly. Furthermore, regional, national, and global dusts accumulate on the snows of UCRE mountains and are acknowledged here, but not modeled.

To model floodplains, three criteria substituted for actual maps: soils flooded regularly, distance to channels, and the wetland plant communities. Finally, in each tier of this model distances from rivers is modeled to help protect this sensitive area.

Cub River, Franklin County, Idaho
# Surface Water Assessment Model

<table>
<thead>
<tr>
<th>Tier 1:</th>
<th>Tier 2:</th>
<th>Tier 3:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identifies those lands and surface waters of highest quality for water production</td>
<td>Identifies those lands and surface waters of moderate to high quality for water production</td>
<td>Identifies those lands and surface waters of low to high quality for water production</td>
</tr>
</tbody>
</table>

**Includes**

<table>
<thead>
<tr>
<th>Tier 1</th>
<th>Tier 2</th>
<th>Tier 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>5% of the land receiving the highest amount of the basin’s total precipitation - [Daymet]</td>
<td>10% of the land receiving the highest amount of the basin’s total precipitation - [Daymet]</td>
<td>15% of the land receiving the highest amount of the basin’s total precipitation - [Daymet]</td>
</tr>
<tr>
<td>Wind erodability group 1 - [Statsgo]</td>
<td>Wind erodability groups 1 – 3 - [Statsgo]</td>
<td>Wind erodability groups 1 – 5 - [Statsgo]</td>
</tr>
<tr>
<td>Soils classified as frequently flooded - [Statsgo]</td>
<td>Soils classified as frequently- occasional flooded - [Statsgo]</td>
<td>Soils classified as frequently- rare flooded - [Statsgo]</td>
</tr>
<tr>
<td>30 m buffer of surface water - [National Hydrography Dataset]</td>
<td>100 m buffer of surface water - [National Hydrography Dataset]</td>
<td>300 m buffer of surface water - [National Hydrography Dataset]</td>
</tr>
</tbody>
</table>
Surface Waters – Tier 1

Model Criteria
- Flooded Soils
- Precipitation
- Soil Erodability
- 5% of the highest total precipitation
- Wind erodability group 1
- Soils classified as frequently flooded
- Wetlands
- 30 m buffer of surface water
Activity Assessment Models

Activity assessment models represent current and potential land-uses that exist throughout the UCRE. These models use GIS data, much like the environmental evaluation models, to locate the existing and future land-uses given specific criteria. The criterion within these models ranges broadly from land cover to climate data. These models are important in representing the human dimension of planning and policy decisions in order to relate areas to the environmental assessment models. The activity models developed for this study include:

- Farmland
- Rangeland
- Extractive Energy
- Solar Energy
- Wind Energy
- Outdoor Recreation
Farmland

In the past, communities in the Upper Colorado River Ecosystem relied upon local farms to produce the majority of their food. More recently, however, local farms have lost their importance as subsistence patterns have shifted. Communities no longer grow their own food. Instead, they rely upon food grown regionally, nationally, and internationally to be shipped to local grocery stores. These shifts in subsistence changed the value of farmland which often resulted in farmlands growing homes instead of food.

Farmlands require a combination of many factors: soils, topography, hydrology, water, and climate. The Natural Resource Conservation Service (NRCS) has developed a list of criteria to determine “prime” farmlands (NRCS, 2007). “Prime” farmlands are those lands most appropriate for cultivation and productive plant growth, without serious land degradation. The NRCS “prime farmland” criteria is found within the National Soil Survey Handbook (NRCS, 2007). This handbook cannot explicitly list every
data source or metric needed to identify these “prime” farmlands; however, it provides an excellent professional and practical resource.

For farmland productivity within the UCRE, many serious issues must be overcome. The UCRE contains many areas, mountain valleys and desert canyons, which provide excellent opportunities for soil buildup and water availability. Many of these areas also provide an excellent growing season and protection from the harsh climate. However, the UCRE is still extremely arid, and farming often requires irrigation. As well, soil compaction and erosion are problems that farmers must combat.

This assessment model attempts to identify suitable farmland through the combination of “prime” farmland indicators. A three-tiered assessment model showing farmland suitability resulted from the modeling process.
## Farmland Assessment Model

<table>
<thead>
<tr>
<th>Tier One:</th>
<th>Tier Two:</th>
<th>Tier Three:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identifies those areas most suitable for farmland use</td>
<td>Adds somewhat less desirable farmland areas to Tier One lands</td>
<td>Adds marginally suitable farmland areas to Tier One and Tier Two lands</td>
</tr>
</tbody>
</table>

**Includes:**

- Growing degree days > 500 after last frost day - [Daymet]
- Slope < 10 degrees - [National Elevation Dataset]
- Soil temperature regimes - [StatsGo]
  - Frigid
  - Hyperthermic
  - Isohyperthermic
  - Mesic
  - Thermic
- Soil drainage class - [StatsGo]
  - Well drained
  - Moderately well drained
  - Somewhat well drained
- Proximity to canal infrastructure 1000 meters - [National Hydrography Dataset]
- Existing agricultural croplands - [National Land Cover Database]

**Excludes:**

- Excludes all water - [National Land Cover Database]
- Excludes all developed land - [National Land Cover Database]
Farmlands – Tier 1

Analysis

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Utah State University
Logan, Utah

Model Criteria
- GDD > 500 After Last Frost Day
- Slope < 10 degrees
- Soil Temperature Regimes
- Soil Drainage Class
- Proximity to Canal Infrastructure 1000 M

ENVS

0 25 50 100 Miles

1:4,500,000
Farmlands – Tier 2

Model Criteria
- All Tier 1 Lands
- Proximity to Canal Infrastructure 1500 M
- Existing Agricultural Croplands

Bioregional Planning
Utah State University
Logan, Utah

ENVS

0 25 50 100 Miles

1:4,500,000
Rangeland

Western rangelands are iconic American open spaces that often remind people of bygone times and lifestyles. Rangeland environments are diverse landscapes extending from high mountain meadows to low desert basins (Committee on Rangeland Classification, Board on Agriculture, National Research Council, 1994, p. 18).
Vast tracts of the UCRE are used as rangelands, defined here as minimally managed lands used seasonally or year-round as grazing areas for domesticated animals. Most rangelands are public lands managed by federal agencies such as the Bureau of Land Management and US Forest Service, though some are privately owned.

Rangelands play important roles in the economic, social, and ecological processes of the UCRE. Livestock and other rangeland animals help support local economies by providing jobs and a sustainable food source on a regional level (Holechek & Hawkes, 2007). Rangelands also provide ecological services such as providing wildlife habitat (Knight, 2007), development buffers (Huntsinger & Hopkinson, 1996), and vegetation propagation (Knight, 2007).

This assessment model identifies rangeland areas by defining a series of topological, climatic, human, and vegetation variables. A three-tiered assessment of the suitability of areas for rangeland use results.
## Rangelands Assessment Model

<table>
<thead>
<tr>
<th>Tier One:</th>
<th>Tier Two:</th>
<th>Tier Three:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identifies those areas most suitable for rangeland use</td>
<td>Identifies areas at least somewhat suitable for rangeland use</td>
<td>Identifies areas at least marginally suitable for rangeland use</td>
</tr>
</tbody>
</table>

### Tier One: Includes:
- Areas with good wild forage materials - [StatsGo]
  - Wild Shrub or
  - Wild Grass or
  - Wild Rangeland or
  - Wild Open Space or
  - Wild Herbaceous Wetland
- Areas with greater than 1100 annual growing degree days after the last frost day - [Daymet]

### Tier Two: Includes:
- Tier One lands
- Areas with good and fair wild forage materials - [StatsGo]
  - Wild Shrub or
  - Wild Grass or
  - Wild Rangeland or
  - Wild Open Space or
  - Wild Herbaceous Wetland
- Areas with greater than 520 annual growing degree days after the last frost day - [Daymet]

### Tier Three: Includes:
- Tier Two lands
- No lands excluded due to fire risk

### Excludes:
- Wetlands, Developed Lands, Barren Lands, Water - [National Land Cover Database]
- Slopes > 25% - [National Elevation Dataset]
- Highest and medium fire occurrence density - (USGS, 2007)
- Wetlands, Developed Lands, Barren Lands, Water - [National Land Cover Database]
- Slopes > 25% - [National Elevation Dataset]
- Highest fire occurrence density - (USGS, 2007)
Extractive Energy

The UCRE has significant deposits of oil, natural gas, coal, and oil shale. Oil and natural gas development has played an important role in the economies of the Uinta Basin, western Wyoming, and other areas in the UCRE. Coal mining has likewise been prevalent in the above-mentioned areas, as well as in portions of southern Utah. Large-scale development of oil shale resources has been proposed as one major means to increase domestic production of oil, and several major oil companies including Chevron and Shell have been granted leases in areas of Colorado and Utah to study the feasibility of large-scale oil shale development. The United States has massive deposits of oil shale, mostly in the Green River Formation of Utah, Wyoming, and Colorado, equivalent to 1.5 trillion barrels of oil, or several times the reserves of Saudi Arabia.

The extractive energy assessment model combined tiered assessments of (1) oil and natural gas reserves, (2) coal deposits, and (3) oil shale to render a region-wide assessment of cumulative extractive energy resources.

Tiering Process for Oil and Gas Reserves

GIS data representing reserves of crude oil, natural gas, and natural gas liquids were retrieved from the US Department of Energy’s Energy Information Administration (EIA) website (US Department of Energy). The data contained attributes describing the sizes of proved 2001 reserves of crude oil, natural gas, and natural gas liquids.
liquids. An assessment of the data provided cumulative oil and natural gas information that went into creating this model. Reserves for each of the three categories of energy reserves (crude oil, natural gas, and natural gas liquids) were retrieved based on an already classified EIA rubric.

**EIA Rubric or Oil, Natural Gas, and Natural Gas Liquids**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 0=0 MBO, 1=0-10, 2=10-100, 3=100-1000, 4=1000-10,000, 5=10,000-100,000, 6= greater than 100,000 MBO.</td>
<td>Class 0=0 MMCFG, 1=0-10, 2=10-100, 3=100-1000, 4=1000-10,000, 5= 10,000-100,000, 6= Greater than 100,000 MMCFG.</td>
<td>Class 0=0 MBO, 1=0-10, 2=10-100, 3=100-1000, 4=1000-10,000, 5=10,000-100,000, 6= Greater than 100,000 MBO.</td>
</tr>
</tbody>
</table>

For each area, the three energy categories were summed, providing a point total measure of the total oil and natural gas reserves for that area. For example, where crude oil reserves are class 3, natural gas reserves are class 2, and natural gas liquids are class 5, this would have an oil and natural gas reserve total 10 based upon EIA classes.

The data was then categorized into tiers dependent upon the size of their reserves, resulting in approximately one-third of the oil and natural gas reserves belonging to each of the tiers:
Extractive Energy

- Tier 1: cumulative reserves of 9-17 total points, classified as having large reserves
- Tier 2: 5-8 total points, classified as having medium reserves
- Tier 3: 1-4 points, classified as having small reserves

**Tiering Process for Coal Deposits**

The data for the extent and type of coal deposits were acquired from the USGS (USGS, 2003). Coal deposits were classified into three tiers according to the quality of the coal. Tier 1 contained the best coals, tier 2 all moderately good coals, and tier 3 all inferior and “of doubtful value” coals.

- **Tier 1:** Anthracite, Low Volatile Bituminous, and Medium and High Volatile Bituminous Coals
- **Tier 2:** Lignite and Sub-Bituminous Coals
- **Tier 3:** Bituminous and Sub-Bituminous Coals that are “of doubtful value”

![Coal Power Plant, North of Ephraim, Utah](image)

(C) Louis Hurst
**Tiering Process for Oil Shale**

The data on oil shale deposits were obtained and created from the BLM’s “Oil Shale and Tar Sands Programmatic EIS Information Center” website (BLM, 2008). Areas underlain by oil shale deposits were placed into four tiers: tier 1 being areas underlain by the most accessible or promising deposits and tier 4 areas being underlain by only marginally exploitable oil shale resources.

- **Tier 1:** BLM-granted preference right lease areas (leased to energy companies exploring oil shale development) in geologically prospective areas
- **Tier 2:** Geologically prospective areas where the overburden to oil shale is less than 500 feet
- **Tier 3:** Geologically prospective areas for oil shale development
- **Tier 4:** Maximum extent of the Green River Formation of oil shale deposits

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Coal Power Plant, North of Ephraim, Utah
**Extractive Energy**

**Combining Tiered Assessments of Oil and Natural Gas, Coal, and Oil Shale into a Cumulative Extractive Energy Assessment**

Tiers for each of the three energy resources (oil and natural gas, coal, and oil shale) were reclassified through reverse coding to reflect the value of energy resources. For example, a tier 1 coal cell was reclassified so that it would contain a raster value of three (high value coal), while a tier three coal cell was reverse coded so that it would contain a raster value of one (low value coal).

The resulting reclassified data were summed to produce one model reflective of a cumulative assessment of the extractive energy resources available. For example, if an area had tier 1 resources in oil and natural gas, coal, and oil shale, then in the final cumulative extractive energy assessment, that area would have a value of 3+3+4=10. In contrast, if a given area had only tier 3 resources in oil and natural gas, and neither coal nor oil shale resources, then that area’s value in the final cumulative extractive energy assessment model would be 1+0+0=1.

In this way, the energy resources of the entire UCRE study area were assessed on a scale from zero (no extractive energy resources extant) to ten (high quality energy resources of all three categories available).
Solar Energy

The solar energy assessment model examines the suitability of UCRE areas for regional solar energy development. Extensive areas suitable for solar energy development exist throughout the UCRE, particularly in areas west of the Wasatch Mountains and in the southwestern part of Wyoming.

The model assesses solar energy development suitability in three tiers of declining suitability. Tier 1 identifies areas that are most suitable, tier 2 identifies areas that are somewhat less suitable, and tier 3 identifies marginally suitable areas. Model criteria are shown in the table on the subsequent page.

Measurements of solar radiation are based on average annual values from 1980 to 1997, measured in megajoules per square meter per day (MJ/m²day), calculated by averaging yearly mean total daily incident shortwave radiation flux from 1980 to 1997, then dividing by 365 (Thornton, Running, & White, 1997).
Solar Energy Assessment Model

<table>
<thead>
<tr>
<th>Tier One</th>
<th>Tier Two</th>
<th>Tier Three</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identifies those lands most suitable for solar energy production</td>
<td>Identifies those lands less suitable for solar energy production</td>
<td>Identifies those lands least suitable for solar energy production</td>
</tr>
</tbody>
</table>

**Included Lands:**
- solar radiation 16 MJ/m²/day or greater - [Daymet]
- slopes less than one percent - [National Elevation Dataset] (Kustscher, 2008)

**Included Lands:**
- solar radiation 13 MJ/m²/day or greater - [Daymet]
- slopes less than five percent - [National Elevation Dataset]

**Included Lands:**
- solar radiation 10 MJ/m²/day or greater - [Daymet]
- slopes less than ten percent - [National Elevation Dataset]

**Excluded Lands (All Tiers):**
- Wetlands and Water bodies - [National Land Cover Database]
- Developed lands - [National Land Cover Database]
- Forested areas - [National Land Cover Database]
Solar Energy – Tier 2

Analysis

Excludes
Wetlands
Water bodies
Developed lands
Forested areas

Model Criteria
All Tier 1 Lands
Solar radiation 13 MJ/m²/day or greater
Slopes less than five percent

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1:4,500,000

0 25 50 100 Miles

Upper Colorado River Ecosystem – Alternative Future Study
Solar Energy – Tier 3

Excludes:
- Wetlands
- Water bodies
- Developed lands
- Forested areas

Model Criteria:
- All Tier 1 Lands
- All Tier 2 Lands
- Solar radiation 10 MJ/m²/day or greater
- Slopes less than ten percent

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Wind Energy

The wind energy assessment model looks at the suitability of UCRE areas for wind turbine placement through a three-tiered suitability assessment. Tier 1 shows lands with the most suitable conditions for wind power development, tier 2 shows those areas that are somewhat less suitable, and tier 3 those areas that are only marginally suitable. The model considers wind speed, slope, conservation lands, developed lands, and land cover type in its assessment of suitable areas for wind turbine placement.

The US Department of Energy (DOE) has a scale for ranking wind power potential based upon wind speed. On the scale, one (the minimum rank) corresponds to areas with low wind speeds and frequency, and seven (the maximum rank) to areas with high wind speeds and frequency. Suitable wind speeds for turbine placement are those considered “marginal” (three on the Department of Energy scale) through “superb” (seven on the DOE scale) (U.S. Department of Energy, 2003). The DOE wind power rank is the criteria used to separate the three tiers of suitability.
Wind Energy Assessment Model

<table>
<thead>
<tr>
<th>Tier One:</th>
<th>Tier Two:</th>
<th>Tier Three:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identifies those areas most suitable for wind energy production</td>
<td>Identifies those areas less suitable for wind energy production</td>
<td>Identifies those areas least suitable for wind energy production</td>
</tr>
</tbody>
</table>

**Included:**
- Areas with slope <20% - [National Elevation Dataset] - (National Renewable Energy Laboratory, 2007)
- US Department of Energy wind classes 6 and 7 - [Wind Resource NREL]

**Included:**
- Areas with slope <20% - [National Elevation Dataset]
- US Department of Energy wind classes 4 and 7 - [Wind Resource NREL]

**Included:**
- Areas with slope <20% - [National Elevation Dataset]
- US Department of Energy wind classes 3 and 7 - [Wind Resource NREL]

**Excluded Lands (all tiers):**
- 100 meter buffer zone around major roads (turbine “fall zone”) - [Census 2000 TIGER/Line File]
- Conservation lands with 1000 meter buffer zone (Lindquist, 2006):
  - Wilderness areas
  - National Parks
  - Fish and Wildlife refuges
- Water - [National Land Cover Database]
- Wetlands - [National Land Cover Database]
- Developed Lands (for aesthetic and safety reasons) - [National Land Cover Database]
Wind Energy – Tier 1

Excludes:
- 100 m buffer around major roads
- 1000 m buffer conservation lands
- Water, Wetlands
- Developed Lands

Model Criteria:
- Areas with slope < 20%
- US Department of Energy wind classes 5 and 7

Analysis
Wind Energy – Tier 3

Excludes
- 100 m buffer around major roads
- 1000 m buffer conservation lands
- Water, Wetlands
- Developed Lands

Model Criteria
- Wind Energy
- All Tier 1 Lands
- All Tier 2 Lands
- Areas with slope<20%
- US Department of Energy wind classes 3 and 7
Outdoor Recreation

Outdoor recreation is a very important part of the lifestyle, economy, and identity of the west. This is especially true for the Upper Colorado River Ecosystem. The stunning landscapes of Zion, Bryce Canyon, and Arches National Parks set off the southern extent of the UCRE and compare beautifully to the resort towns of Aspen, Vail, and Breckenridge in Colorado. These destinations are world-renowned venues and are not the exception, but rather the norm, for outdoor recreation the region.
The recreation assessment model uses three tiers to identify UCRE areas suitable for winter and summer recreation activities.

*Summer recreation* is conceptualized as camping, hiking, OHV use, water activities, and wilderness areas. Tier 1 identifies lands most suitable for summer recreation, and tier 2 identifies those lands marginally suitable for summer recreation.

*Winter recreation* is conceptualized as skiing and water related activities. This model spatially identifies areas suitable for ski resort development and winter fishing. Tier 3 identifies areas suitable for winter recreation.
# Recreation Assessment Model

<table>
<thead>
<tr>
<th>Tier One (Summer):</th>
<th>Tier Two (Summer):</th>
<th>Tier Three (Winter):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identifies lands most suitable for summer recreation</td>
<td>Adds somewhat less desirable trail and OHV areas to Tier One lands</td>
<td>Identifies lands most suitable for current and potential winter recreation</td>
</tr>
</tbody>
</table>

**Includes:**

- Designated wilderness areas
- Open water - [National Land Cover Database]
  - Rivers
  - Lakes
- Camping
  - ½ Mile from existing paved or weathered roads - [Census 2000 TIGER/Line File]
  - slope less than 5% - [National Elevation Dataset]
  - 50% vegetation cover
  - 50% open canopy
- Trails (Basch, Duffy, Giordanengo, & Seabloom, 2007)
  - Elevation - [National Elevation Dataset]
    - 3,300’ to 9,000’
  - Aspect - [National Elevation Dataset]
    - W, SW, S, SE, E
  - Slope - [National Elevation Dataset]
    - 20% to 40%
- Off highway vehicle areas
  - Current status: open (BLM)

**Includes:**

- Tier One lands
- Trails (Wingle, 1994)
  - Elevation - [National Elevation Dataset]
    - 7,000’ to 10,000’
  - Aspect - [National Elevation Dataset]
    - W, SW, S, SE, E
  - Slope - [National Elevation Dataset]
    - 40% to 60%
- Off highway vehicle areas
  - Current status: restricted (BLM)

**Includes:**

  - Federal Lands
  - Slope - [National Elevation Dataset]
    - 12% to 80%
  - Aspect - [National Elevation Dataset]
    - N, NE
- Open water - [National Land Cover Database]
  - Lakes
**Analysis: Phase 2**

Phase 2 of the analysis began with the team developing population projections based upon the counties contained entirely within the study area. Instead of relying upon one projection, the team bound the future population by using both a low and high extrapolation.

The development of future models was the next step in phase 2. Future modeling combines key concerns from phase 1 and forces the planner to distribute a projected population onto the landscape given certain criteria from the assessment models. There are many ways to accomplish this modeling process, and the study team decided to utilize the LUCIS Model (Carr & Zwick, 2007). Once each alternative future is developed, each assessment model can then evaluate it to determine the effects of that course of action.

The final component of phase 2 is the development of a conservation status model. This model utilizes data from the earlier biodiversity assessment model and compares it to resource management data upon different levels of conservation status. This model operates at several levels by breaking down biodiversity into sub-categories such as vegetation and wildlife, and then goes into more depth by separating the data once again. This model allows wildlife managers to understand biodiversity in the context of current protection levels based upon conservation status. Finally, this model could help to identify “hotspots” of biodiversity, if that were an intended management decision.
Population Projections

The pressures of population growth upon biophysical resources, infrastructure, quality of life, and public health and safety are a major justification for regional and local planning efforts. An important contribution to improved decision-making, then, is accurate population projections.

Population projections are usually made using one of two general approaches: direct, and indirect. Direct projections forecast population based upon current rates of birth and death, migration, disease, and other factors. This technique is labor intensive and requires extensive knowledge from the current population. Indirect projections use historical rates of growth or decline, derived from equations, to extrapolate future population figures. This technique requires a less comprehensive understanding of the current population and is the method used here.

In order to bound the UCRE population projections by a likely minimum and maximum, a linear growth equation and an exponential growth equation were used, respectively, based upon rates of growth from 1970 to 2000 for each county. The equations used for this are found upon the following page, and the table on the subsequent page shows the upper and lower bound projections created by the study team.

The ever growing Moab, Utah

The ever growing Moab, Utah

The ever growing Moab, Utah
### Linear Regression

\[ Y = a + bX \]

\[ b = \frac{N \sum XY - (\sum X)(\sum Y)}{N \sum X^2 - (\sum X)^2} \]

\[ a = \frac{\sum Y - b \sum X}{N} \]

- \( N \) = number of observed years
- \( X \) = a year index (each decade)
- \( Y \) = population size for a given year

### Exponential

\[ P_{t+n} = P_t (1 + r)^n \]

\[ r = \frac{1}{m} \sum \frac{P_t - P_{t-1}}{P_{t-1}} \]

- \( P_{t+n} \) = population at future date in time
- \( P_t \) = last census taking
- \( P_{t-1} \) = prior census taking
- \( m \) = number of historic intervals
- \( r \) = rate of change
## State Population Projections

<table>
<thead>
<tr>
<th>States</th>
<th>Historic Population Figures</th>
<th>Linear Regression Population Figures</th>
<th>Exponential Population Figures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Colorado (20 of 64 Counties)</strong></td>
<td>189,892</td>
<td>288,697</td>
<td>330,613</td>
</tr>
<tr>
<td></td>
<td>646,165</td>
<td>938,853</td>
<td>1,413,467</td>
</tr>
<tr>
<td><strong>Idaho (3 of 44 Counties)</strong></td>
<td>16,038</td>
<td>19,084</td>
<td>18,808</td>
</tr>
<tr>
<td></td>
<td>24,451</td>
<td>27,400</td>
<td>30,763</td>
</tr>
<tr>
<td><strong>New Mexico (1 of 33 Counties)</strong></td>
<td>52,517</td>
<td>81,433</td>
<td>91,605</td>
</tr>
<tr>
<td></td>
<td>148,617</td>
<td>194,084</td>
<td>253,462</td>
</tr>
<tr>
<td><strong>Utah (29 of 29 Counties)</strong></td>
<td>1,059,273</td>
<td>1,461,037</td>
<td>1,722,850</td>
</tr>
<tr>
<td><strong>Wyoming (4 of 23 Counties)</strong></td>
<td>37,886</td>
<td>71,469</td>
<td>74,996</td>
</tr>
<tr>
<td></td>
<td>105,115</td>
<td>142,691</td>
<td>194,638</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1,355,606</td>
<td>1,921,720</td>
<td>2,238,872</td>
</tr>
</tbody>
</table>

The light blue is historic population figures
The darker blue is the lower bound, linear population projections
The red is the upper bound, exponential population projections
Alternative Futures: Overview

The development of alternative futures was a very contentious and difficult process for the study team. Team members suggested many ideas and conducted research on many different alternative future-modeling techniques. In the end, the team selected a “Land-Use Conflict Identification Strategy” or LUCIS (Carr & Zwick, 2007) and developed two futures.

- Development Future
- Conservation Future

The LUCIS process relies upon two key terms: “suitability” and “preference.” Suitability describes the fitness of a “land-use” for a given area. Preference is the overall desire for a “land-use” in an area. With these two terms established, this process is a competition between “land-uses” on the combined basis of suitability and preference. First, land-uses were established based on suitability: to do this, the team used seven of their assessment models as land-uses:

- Farmland
- Rangeland
- Extractive Energy
- Biodiversity
- Outdoor Recreation
- Solar Energy
- Wind Energy

In addition, the team developed an eighth land-use, “development”; this process was based upon the following eight categories:

- Air Quality Risk
- Slope
- Distance from Roads
- Distance from Development
- Seismic Hazard
- Fire Hazard
- Distance from Faults
- Landslide Risk
- Distance from Rivers
- Distance from Wetlands
Once the eight land-uses’ suitability were established, which do not change, the team applied individual preference values to each land-use to determine how desired each land-use was in a particular future. After assigning these values, each land-use was then put into competition against the others to develop a future land-use map for the UCRE. Finally, after the competition of land-uses, the team distributed the “future population” across the landscape.

The study team accomplished this by using the previously discussed population projections. Since the projections occurred at the county level, the allocation took place at that same level. However, in order to do this, the team had to assume densities for the future distribution which they took from the largest city currently within each county and applied that city’s density to the future population, so the team used 57 different densities, one for each county. Additionally, the study team had to distribute population twice due to the team attempting to show the possible range in growth in the UCRE.

Finally, this process is a speculative one, showing what may occur and not what will occur. The LUCIS model embraces subjective values and then shows spatially how these values could manipulate land-uses in the future. Furthermore, this modeling shows only the primary land-use and does not speak to dual land-uses such as farmlands and wind energy occurring on the same tract of land. In the real world, those types of dual land-uses have many benefits and should be encouraged, but the team did not address alternative futures in that sense for this phase of the study. Following on the next page is a simple methodological diagram depicting this process.
LUCIS Methodology

Step 1: Assessment Models & Suitability Rankings

Step 2: Development Suitability & Preference

Step 3: Preference Ranking (8 Land-use models)

Step 4: Compete Development Against 7 other Land-use Models

Step 5: Compete Each Land-use Against 6 other Land-use Models (No Development)

Step 6: Land Consumed Equation & Population Projections

Step 7: Remove Developed Lands (Step 6) from “Winning” Land-use Models (Step 5)

Step 8: Combine Outputs (Step 7) and Developed Land Consumed (Step 6)

Alternative Futures

Development Future

This alternative future scenario’s intent is to favor development over all other land uses within the UCRE. Development in this future does not have many constraints, as well, other potential disruptive land-uses like extractive energy exploration and outdoor recreation have very high preference in this scenario. The four highest preferred land-uses within this future follow as:

1. Development
2. Extractive Energy
3. Outdoor Recreation
4. Farmland

Development Model

Additionally, the development model associated with this future has little emphasis on ecological integrity and minimally for public safety. The highest priority is distance from development, followed next by distance from existing roads. The top four preferred components of this model for the development future are:

1. Distance from Development
2. Distance from Roads
3. Slope
4. Landslide Risk

Development, extractive energy, and outdoor recreation play critical roles within this future. Furthermore, biodiversity is minimized when compared to the Conservation Alternative Future. Lastly, agricultural lands (farmlands and rangelands) have a limited role in this future.
Development Future: Composite Map

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Land-Uses

Population Projection
- Linear
- Exponential

Wind Energy
Solar Energy
Outdoor Recreation
Biodiversity
Farmlands
Extractive Energy
Rangelands

1:4,500,000
Development Future: Wind Energy

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Development Future
Pink Wind Energy

0 30 60 120 Miles

14,500,000
Development Future: Solar Energy

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Utah State University
Logan, Utah

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Development Future
- Solar Energy
Development Future: Rangelands
Development Future: Biodiversity

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Utah State University
Logan, Utah

ENVS

Development Future
Biodiversity

14,500,000
Conservation Future

The intent of the conservation alternative future was to promote land-uses near or close to their natural or semi-natural states. Wildlands, farms, and rangelands would all have very high values within this future. The four highest preferred land-uses within this future follow as:

1. Biodiversity
2. Rangeland
3. Farmland
4. Development

Development Model

The development model for the conservation future is drastically different from that seen in the development future. The top priority is distance from rivers and wetlands, meaning the further away the better for likelihood of development. Additionally, this development model attempts to limit sprawl and keep development tightly together. The top four preferred components of this model are:

1. Distance from Rivers
2. Distance from Wetlands
3. Distance from Roads
4. Distance from Development

This future values biodiversity as the top priority within the Upper Colorado River Ecosystem. When looking through the following maps, it is apparent that a large area within the site is set aside for ecological concerns. Again, notice the differences in development patterns between the two futures. Development in this future is ecologically conscious and has more concern for public health, safety, and welfare.
Conservation Future: Outdoor Rec

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Conservation Future
Outdoor Recreation

0 30 60 120 Miles

143,500,000
Conservation Future: Farmlands

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Conservation Future
Farmlands

Upper Colorado River Ecosystem – Alternative Future Study
Alternative Futures: Summary

The two alternative futures for this study, Development and Conservation, relied upon the previously created assessment models. These models functioned as the basis for suitability modeling within the LUCIS methodology. Given the methodology behind creating the alternative futures, evaluation of each future is relatively straightforward. This evaluation occurs based upon the total area of the assessment model and the area of the land-use in the future scenario. Given the size of the Upper Colorado River Ecosystem, approximately 170,000 square miles, the square mile unit of measurement will most appropriately reflect these statistics.

Following on the next page is the summary of the evaluation for the two alternative future scenarios. The table displays eight different land-uses’ areas in square miles, as well as the percentage of the land-use compared to the area within the assessment model. Of importance is the fact that the total areas of the different land-uses in the future do not need to equal the entire UCRE area. Land-uses within the alternative future scenarios are only assigned when they are a better fit than all other uses. Certain areas are not assigned a land-use when no clear land-use winner exists; this means competing land-uses are both suitable and preferred for that given area. To resolve these types of conflict between land-uses, decisions-makers would have to alter their preference values and then make a decision. The development future has roughly 10% of the available land un-assigned, meaning a great deal of conflict exists based upon the preference values; compare that to 99.5% of land within the conservation future.
### Alternative Future Comparison Tables

#### Development Alternative Future

<table>
<thead>
<tr>
<th>Assessment Model/Land-use</th>
<th>Assessment Model Areas (sq. miles)</th>
<th>Future Land Use Area (sq. miles)</th>
<th>Future Land Use % Compared to Original Assessment Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind Energy</td>
<td>10489</td>
<td>418</td>
<td>3.9%</td>
</tr>
<tr>
<td>Solar Energy</td>
<td>48760</td>
<td>10358</td>
<td>21.2%</td>
</tr>
<tr>
<td>Outdoor Recreation</td>
<td>103355</td>
<td>86420</td>
<td>83.6%</td>
</tr>
<tr>
<td>Rangeland</td>
<td>57220</td>
<td>7243</td>
<td>12.6%</td>
</tr>
<tr>
<td>Farmland</td>
<td>81368</td>
<td>1762</td>
<td>2.1%</td>
</tr>
<tr>
<td>Extractive Energy</td>
<td>57305</td>
<td>1969</td>
<td>3.4%</td>
</tr>
<tr>
<td>Biodiversity</td>
<td>164665</td>
<td>40063</td>
<td>24.33</td>
</tr>
<tr>
<td>Population Allocation Linear</td>
<td>38854*</td>
<td>2916</td>
<td>7.5%</td>
</tr>
<tr>
<td>Population Allocation Exponential</td>
<td></td>
<td>5077</td>
<td>13%</td>
</tr>
<tr>
<td>Totals UCRE Area</td>
<td>170009</td>
<td>153307 (Summed)</td>
<td>90.1%</td>
</tr>
</tbody>
</table>

#### Conservation Alternative Future

<table>
<thead>
<tr>
<th>Assessment Model/Land-use</th>
<th>Assessment Model Areas (sq. miles)</th>
<th>Future Land Use Area (sq. miles)</th>
<th>Future Land Use % Compared to Original Assessment Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind Energy</td>
<td>10489</td>
<td>274</td>
<td>2.6%</td>
</tr>
<tr>
<td>Solar Energy</td>
<td>48760</td>
<td>12000</td>
<td>24.6%</td>
</tr>
<tr>
<td>Outdoor Recreation</td>
<td>103355</td>
<td>31699</td>
<td>30.6%</td>
</tr>
<tr>
<td>Rangeland</td>
<td>57220</td>
<td>5538</td>
<td>9.6%</td>
</tr>
<tr>
<td>Farmland</td>
<td>81368</td>
<td>18250</td>
<td>22.4%</td>
</tr>
<tr>
<td>Extractive Energy</td>
<td>57305</td>
<td>648</td>
<td>1.1%</td>
</tr>
<tr>
<td>Biodiversity</td>
<td>164665</td>
<td>95551</td>
<td>58%</td>
</tr>
<tr>
<td>Population Allocation Linear</td>
<td>38854*</td>
<td>2923</td>
<td>7.5%</td>
</tr>
<tr>
<td>Population Allocation Exponential</td>
<td></td>
<td>5199</td>
<td>13.3%</td>
</tr>
<tr>
<td>Totals UCRE Area</td>
<td>170009</td>
<td>169159 (Summed)</td>
<td>99.5%</td>
</tr>
</tbody>
</table>
Conservation Status Model Overview

The final analysis within this report focuses on two concepts: arbitrary synthetic boundaries and natural systems of biodiversity. Within this juxtaposition, the study team created a model which identifies previously delineated conservation statuses within the UCRE and then cross-tabulates biodiversity against each different status area. This analysis considers both terrestrial vertebrates and plant species, and models them independently.

The Regional Gap Analysis Program (GAP) created the conservation status data used for this analysis. The GAP aims to provide a regional assessment of the conservation status of native vertebrate species and natural land cover types and then to facilitate the application of this information to land management activities (USGS National Gap Analysis Program, 2007).

The premise behind this conservation status data is the segregation of conservation lands into their four primary categories with each representing a different level or strategy for conservation. Descriptions of these four categories are outlined below (USGS National Gap Analysis Program, 2007):

**Conservation Status 1:** An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a natural state within which disturbance events are allowed to proceed without interference or are mimicked through management.

**Conservation Status 2:** An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a primarily natural state, but which may receive uses or
management practices that degrade the quality of existing natural communities, including the suppression of natural disturbances.

**Conservation Status 3:** An area having permanent protection from conversion of natural land cover for the majority of the area, but subject to extractive uses of either a broad, low-intensity type (e.g., logging) or localized intense type (e.g., mining). It also confers protection to federally listed endangered and threatened species throughout the area.

**Conservation Status 4:** There are no known public or private institutional mandates, legally recognized easements, or deed restrictions held by the managing entity to prevent conversion of natural habitat types to anthropogenic habitat types. The area generally allows conversion to unnatural land cover throughout.

The major goal of the analysis between biodiversity and conservations status is to improve the way land management agencies address issues related to overall ecosystem health and holistic management. This model provides information to land management agencies on how they are currently managing areas of high conservation status and low conservation status, and ultimately could locate areas known as “hot spots” or areas with high biodiversity. In addition, this model may be expanded to include other wildlife characteristics or subcategories.

**Models**

The two separate models, vegetation and wildlife, will develop the ideas in this introduction further and list in detail what was pursued and accomplished.
Conservation Status: Map
Vegetation Conservation

The vegetation conservation status model for plant communities (United States Forest Service, 2006) contains two sections. The first section categorizes plant communities based on the percentage of the study area occupied by a given community. The second section deals with areas that hold a high variety of communities.

### Plant Categories by Area Designation

<table>
<thead>
<tr>
<th>Category</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abundant</td>
<td>Occupies more than 5.0% of UCRE</td>
</tr>
<tr>
<td>Common</td>
<td>Occupies between 1.0 &amp; 5.0% of UCRE</td>
</tr>
<tr>
<td>Ecotone</td>
<td>Occupies less than 1.0% of the UCRE &amp; over 90% of the community exists outside the UCRE</td>
</tr>
<tr>
<td>Rare</td>
<td>Occupies less than 1.0% of the UCRE &amp; less than 90% of the community exists outside the UCRE</td>
</tr>
</tbody>
</table>

For both calculations, category and variety, a table presents cross-tabulated information on the proportion of communities in each conservation status and the areas of cover within the UCRE.

The vegetation map utilized for this analysis is the Landfire Existing Vegetation Type (United States Forest Service, 2006). The biotic resolution is on the association level, following the terrestrial ecological system classification developed by NatureServe. The map is in grid format with a spatial resolution of 30 meters. For the UCRE study area, there are 81 community types covering 472,301,875 grid cells (excluding developed, agriculture, invasive, and water classes).
Abundant Communities

The three most abundant plant communities, Mixed Salt Desert Scrub, Pinyon-Juniper Woodland, and Big Sagebrush, cover over 35% of the UCRE study area. The inter-mountain basin’s mixed salt desert scrub dominates the Bonneville Basin lowlands, where salts remained behind after the Pleistocene Lake Bonneville receded. The Colorado plateau Pinyon-Juniper woodland dominates the plateaus and foothills of the Colorado plateau and is scattered across the lowlands and foothills of the study area. The inter-mountain basin’s Big Sagebrush shrubland occupies vast expanses of the Wyoming basin, as well as the foothills across much of the study region.

All three exist primarily in the low lands and plateaus. These areas are primarily under the management of the Bureau of Land Management, which is reflected in the conservation status 3.

<table>
<thead>
<tr>
<th>Existing Vegetation Type</th>
<th>Percent of UCRE</th>
<th>status 1</th>
<th>status 2</th>
<th>status 3</th>
<th>status 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inter-Mountain Basin’s Mixed Salt Desert Scrub</td>
<td>7.58</td>
<td>0.17</td>
<td>0.86</td>
<td>74.88</td>
<td>24.08</td>
</tr>
<tr>
<td>Colorado Plateau Pinyon-Juniper Woodland</td>
<td>10.92</td>
<td>1.48</td>
<td>4.43</td>
<td>65.30</td>
<td>28.79</td>
</tr>
<tr>
<td>Inter-Mountain Basin’s Big Sagebrush Shrubland</td>
<td>16.58</td>
<td>0.49</td>
<td>1.59</td>
<td>56.35</td>
<td>41.56</td>
</tr>
</tbody>
</table>
Conservation Status: Abundant

Bioregional Planning
Utah State University
Logan, Utah

Abundant Communities
**Common Communities**

Communities are designated as common if they occupy between 1.0 and 5.0% of the UCRE. The communities comprising this section cover most landforms in the study area and include forests, woodlands, and shrub-steppe. Most common communities have approximately 50% of their area in conservation status 3, which often is BLM or USFS. The forests generally have 10% or more of their areas in conservation status 2.

### Common Communities

<table>
<thead>
<tr>
<th>Existing Vegetation Type</th>
<th>Percent of UCRE</th>
<th>status 1</th>
<th>status 2</th>
<th>status 3</th>
<th>status 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland</td>
<td>0.75</td>
<td>0.35</td>
<td>12.81</td>
<td>59.35</td>
<td>27.48</td>
</tr>
<tr>
<td>Inter-Mountain Basin’s Semi-Desert Shrub-Steppe</td>
<td>0.76</td>
<td>0.21</td>
<td>2.01</td>
<td>68.24</td>
<td>29.55</td>
</tr>
<tr>
<td>Inter-Mountain Basin’s Montane Sagebrush Steppe</td>
<td>0.77</td>
<td>0.42</td>
<td>2.05</td>
<td>58.65</td>
<td>38.87</td>
</tr>
<tr>
<td>Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland</td>
<td>0.84</td>
<td>0.95</td>
<td>9.19</td>
<td>57.19</td>
<td>32.67</td>
</tr>
<tr>
<td>Rocky Mountain Lower Montane-Foothill Shrubland</td>
<td>0.92</td>
<td>0.65</td>
<td>6.37</td>
<td>51.67</td>
<td>41.30</td>
</tr>
<tr>
<td>Colorado Plateau Mixed Low Sagebrush Shrubland</td>
<td>1.04</td>
<td>0.20</td>
<td>1.40</td>
<td>72.86</td>
<td>25.54</td>
</tr>
<tr>
<td>Southern Rocky Mountain Ponderosa Pine Woodland</td>
<td>1.25</td>
<td>0.39</td>
<td>4.41</td>
<td>45.92</td>
<td>49.27</td>
</tr>
<tr>
<td>Rocky Mountain Lodgepole Pine Forest</td>
<td>1.36</td>
<td>2.10</td>
<td>24.57</td>
<td>60.98</td>
<td>12.35</td>
</tr>
</tbody>
</table>
### Conservation Status: Common

#### Existing Vegetation Type

<table>
<thead>
<tr>
<th>Vegetation Type</th>
<th>Percent of UCRE</th>
<th>status 1</th>
<th>status 2</th>
<th>status 3</th>
<th>status 4</th>
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</thead>
<tbody>
<tr>
<td>Southern Colorado Plateau Sand Shrubland</td>
<td>1.42</td>
<td>0.13</td>
<td>1.89</td>
<td>39.42</td>
<td>58.55</td>
</tr>
<tr>
<td>Rocky Mountain Montane Riparian Systems</td>
<td>1.44</td>
<td>0.88</td>
<td>5.98</td>
<td>55.31</td>
<td>37.81</td>
</tr>
<tr>
<td>Inter-Mountain Basin’s Mat Saltbush Shrubland</td>
<td>1.66</td>
<td>0.26</td>
<td>1.41</td>
<td>76.14</td>
<td>22.19</td>
</tr>
<tr>
<td>Inter-Mountain Basin’s Semi-Desert Grassland</td>
<td>1.78</td>
<td>0.64</td>
<td>1.81</td>
<td>40.26</td>
<td>57.28</td>
</tr>
<tr>
<td>Inter-Mountain Basin’s Big Sagebrush Steppe</td>
<td>1.78</td>
<td>0.13</td>
<td>0.74</td>
<td>64.50</td>
<td>34.62</td>
</tr>
<tr>
<td>Great Basin Xeric Mixed Sagebrush Shrubland</td>
<td>1.96</td>
<td>0.00</td>
<td>0.92</td>
<td>83.95</td>
<td>15.13</td>
</tr>
<tr>
<td>Inter-Mountain Basin’s Sparsely Vegetated Systems</td>
<td>2.06</td>
<td>0.28</td>
<td>3.80</td>
<td>30.20</td>
<td>65.72</td>
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<tr>
<td>Quercus gambelii Shrubland Alliance</td>
<td>2.20</td>
<td>0.38</td>
<td>3.92</td>
<td>41.03</td>
<td>54.67</td>
</tr>
<tr>
<td>Inter-Mountain Basin’s Aspen-Mixed Conifer Forest and Woodland</td>
<td>2.27</td>
<td>0.32</td>
<td>17.35</td>
<td>63.25</td>
<td>19.09</td>
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<tr>
<td>Great Basin Pinyon-Juniper Woodland</td>
<td>2.41</td>
<td>0.01</td>
<td>2.72</td>
<td>82.12</td>
<td>15.14</td>
</tr>
<tr>
<td>Inter-Mountain Basin's Greasewood Flat</td>
<td>2.63</td>
<td>0.50</td>
<td>1.66</td>
<td>39.92</td>
<td>57.92</td>
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<td>Artemisia tridentata ssp. vaseyana Shrubland Alliance</td>
<td>2.93</td>
<td>0.65</td>
<td>2.15</td>
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<td>45.36</td>
</tr>
<tr>
<td>Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland</td>
<td>3.53</td>
<td>1.80</td>
<td>41.07</td>
<td>49.84</td>
<td>7.29</td>
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<tr>
<td>Coleogyne ramosissima Shrubland Alliance</td>
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<td>0.27</td>
<td>7.38</td>
<td>67.63</td>
<td>24.72</td>
</tr>
<tr>
<td>Rocky Mountain Aspen Forest and Woodland</td>
<td>3.86</td>
<td>0.21</td>
<td>10.97</td>
<td>54.59</td>
<td>34.22</td>
</tr>
</tbody>
</table>
Conservation Status: Common
Ecotone Communities

Ecotone communities are those which have small areas in the study area because the core of their distribution lies elsewhere. For this analysis, they were identified as occupying less than 1.0% of the UCRE and having over 90% of their area outside the UCRE. The protection afforded these communities varies, with those having the most protection existing in the USFS boundaries of the high elevations or in the National Parks of southern Utah.

### Ecotone Communities

<table>
<thead>
<tr>
<th>Existing Vegetation Type</th>
<th>Percent of UCRE</th>
<th>status 1</th>
<th>status 2</th>
<th>status 3</th>
<th>status 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Madrean Encinal</td>
<td>&lt;0.01</td>
<td>50.00</td>
<td>0.00</td>
<td>0.00</td>
<td>50.00</td>
</tr>
<tr>
<td>Juniperus occidentalis Woodland Alliance</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.00</td>
<td>87.34</td>
<td>12.66</td>
</tr>
<tr>
<td>Madrean Lower Montane Pine-Oak Forest and Woodland</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.00</td>
<td>6.48</td>
<td>93.52</td>
</tr>
<tr>
<td>Madrean Pinyon-Juniper Woodland</td>
<td>&lt;0.01</td>
<td>4.37</td>
<td>0.00</td>
<td>33.98</td>
<td>61.65</td>
</tr>
<tr>
<td>Sonora-Mojave Mixed Salt Desert Scrub</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.00</td>
<td>50.93</td>
<td>49.07</td>
</tr>
<tr>
<td>Sonoran Mid-Elevation Desert Scrub</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>12.63</td>
<td>79.12</td>
<td>8.25</td>
</tr>
<tr>
<td>Apacherian-Chihuahuan Mesquite Upland Scrub</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.09</td>
<td>14.10</td>
<td>85.81</td>
</tr>
<tr>
<td>Rocky Mountain Poor-Site Lodgepole Pine Forest</td>
<td>&lt;0.01</td>
<td>0.86</td>
<td>0.02</td>
<td>97.02</td>
<td>2.11</td>
</tr>
<tr>
<td>Columbia Plateau Low Sagebrush Steppe</td>
<td>&lt;0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>59.48</td>
<td>40.50</td>
</tr>
</tbody>
</table>
## Existing Vegetation Type

<table>
<thead>
<tr>
<th>Existing Vegetation Type</th>
<th>Percent of UCRE</th>
<th>status 1</th>
<th>status 2</th>
<th>status 3</th>
<th>status 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern Rocky Mountain Mesic Montane Mixed Conifer Forest</td>
<td>&lt;0.01</td>
<td>64.55</td>
<td>0.00</td>
<td>35.02</td>
<td>0.44</td>
</tr>
<tr>
<td>Northwestern Great Plains Mixed Grass Prairie</td>
<td>&lt;0.01</td>
<td>0.06</td>
<td>2.26</td>
<td>73.90</td>
<td>23.74</td>
</tr>
<tr>
<td>Columbia Plateau Steppe and Grassland</td>
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<td>&lt;0.01</td>
<td>0.97</td>
<td>33.88</td>
<td>65.04</td>
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<tr>
<td>Western Great Plains Depressional Wetland Systems</td>
<td>0.01</td>
<td>5.94</td>
<td>3.21</td>
<td>25.43</td>
<td>65.41</td>
</tr>
<tr>
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<td>0.63</td>
<td>66.68</td>
<td>30.17</td>
</tr>
<tr>
<td>Apacherian-Chihuahuan Semi-Desert Grassland and Steppe</td>
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<td>1.53</td>
<td>2.22</td>
<td>12.35</td>
<td>83.89</td>
</tr>
<tr>
<td>Southern Rocky Mountain Juniper Woodland and Savanna</td>
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<td>0.15</td>
<td>1.79</td>
<td>54.98</td>
<td>43.08</td>
</tr>
<tr>
<td>Southern Rocky Mountain Ponderosa Pine Savanna</td>
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<td>0.02</td>
<td>4.38</td>
<td>52.92</td>
<td>42.69</td>
</tr>
<tr>
<td>North American Warm Desert Sparsely Vegetated Systems</td>
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<td>0.00</td>
<td>0.01</td>
<td>90.24</td>
<td>9.75</td>
</tr>
<tr>
<td>Mogollon Chaparral</td>
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<td>0.38</td>
<td>9.37</td>
<td>73.95</td>
<td>16.30</td>
</tr>
<tr>
<td>Northern Rocky Mountain Montane-Foothill Deciduous Shrubland</td>
<td>0.02</td>
<td>2.99</td>
<td>0.30</td>
<td>65.02</td>
<td>31.66</td>
</tr>
<tr>
<td>Quercus turbinella Shrubland Alliance</td>
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<td>0.01</td>
<td>5.92</td>
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<td>11.75</td>
</tr>
<tr>
<td>North American Warm Desert Riparian Systems</td>
<td>0.03</td>
<td>&lt;0.01</td>
<td>0.45</td>
<td>67.26</td>
<td>32.29</td>
</tr>
<tr>
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<td>58.15</td>
<td>9.95</td>
<td>27.22</td>
<td>4.67</td>
</tr>
</tbody>
</table>
## Conservation Status: Ecotone

<table>
<thead>
<tr>
<th>Existing Vegetation Type</th>
<th>Percent of UCRE</th>
<th>status 1</th>
<th>status 2</th>
<th>status 3</th>
<th>status 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern Rocky Mountain Subalpine Deciduous Shrubland</td>
<td>0.04</td>
<td>56.87</td>
<td>0.04</td>
<td>41.83</td>
<td>1.26</td>
</tr>
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<td>Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland</td>
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<td>0.66</td>
<td>0.90</td>
<td>63.26</td>
<td>35.17</td>
</tr>
<tr>
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<td>67.56</td>
<td>0.00</td>
<td>31.42</td>
<td>1.01</td>
</tr>
<tr>
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<td>0.04</td>
<td>4.00</td>
<td>0.56</td>
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<td>7.31</td>
</tr>
<tr>
<td>Sonora-Mojave Semi-Desert Chaparral</td>
<td>0.04</td>
<td>0.59</td>
<td>5.89</td>
<td>32.56</td>
<td>60.96</td>
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<td>Southern Rocky Mountain Pinyon-Juniper Woodland</td>
<td>0.05</td>
<td>0.06</td>
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<td>3.13</td>
<td>0.24</td>
<td>82.65</td>
<td>13.97</td>
</tr>
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<td>Inter-Mountain Basins Montane Riparian Systems</td>
<td>0.08</td>
<td>0.00</td>
<td>3.79</td>
<td>54.75</td>
<td>41.31</td>
</tr>
<tr>
<td>Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland</td>
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<td>1.91</td>
<td>42.19</td>
<td>48.01</td>
<td>7.89</td>
</tr>
<tr>
<td>Sonora-Mojave Creosotebush-White Bursage Desert Scrub</td>
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<td>&lt;0.01</td>
<td>0.31</td>
<td>74.06</td>
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<td>Southern Rocky Mountain Montane-Subalpine Grassland</td>
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<td>62.32</td>
<td>15.52</td>
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<tr>
<td>Northern Rocky Mountain Subalpine Woodland and Parkland</td>
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<td>0.01</td>
<td>45.61</td>
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<td>1.31</td>
<td>47.59</td>
<td>49.74</td>
</tr>
</tbody>
</table>
## Conservation Status: Ecotone

<table>
<thead>
<tr>
<th>Existing Vegetation Type</th>
<th>Percent of UCRE</th>
<th>status 1</th>
<th>status 2</th>
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<th>status 4</th>
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<tr>
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<td>0.33</td>
<td>10.90</td>
<td>67.57</td>
<td>21.19</td>
</tr>
</tbody>
</table>

©Louis Hurst

Independence Pass, Continental Divide, Colorado
Rare Communities

Rare communities are defined as occupying less than 1.0% of the UCRE and having less than 90% of their total area outside the region. Rare communities primarily fall into conservation status 3 and 4. Alpine communities are among the most protected as the high mountains have a relatively high coverage of wilderness areas and National Parks. Lower elevation communities tend to occur in the BLM administered lands and private lands.

<table>
<thead>
<tr>
<th>Existing Vegetation Type</th>
<th>Percent of UCRE</th>
<th>status 1</th>
<th>status 2</th>
<th>status 3</th>
<th>status 4</th>
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</thead>
<tbody>
<tr>
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<td>&lt;0.01</td>
<td>0.01</td>
<td>53.93</td>
<td>40.89</td>
<td>5.17</td>
</tr>
<tr>
<td>Inter-Mountain Basin’s Subalpine Limber-Bristlecone Pine Woodland</td>
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<td>0.00</td>
<td>52.28</td>
<td>40.28</td>
<td>7.44</td>
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<tr>
<td>Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland</td>
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<td>0.34</td>
<td>18.91</td>
<td>63.09</td>
<td>17.66</td>
</tr>
<tr>
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<td>&lt;0.01</td>
<td>4.93</td>
<td>73.22</td>
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<tr>
<td>Arctostaphylos patula Shrubland Alliance</td>
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<td>0.04</td>
<td>11.69</td>
<td>56.65</td>
<td>31.61</td>
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<td>Colorado Plateau Blackbrush-Mormon-tea Shrubland</td>
<td>0.05</td>
<td>0.17</td>
<td>1.69</td>
<td>81.84</td>
<td>16.30</td>
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<td>Inter-Mountain Basin’s Juniper Savanna</td>
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<td>2.40</td>
<td>70.31</td>
<td>27.12</td>
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<tr>
<td>Rocky Mountain Foothill Limber Pine-Juniper Woodland</td>
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<td>0.57</td>
<td>5.32</td>
<td>58.04</td>
<td>35.98</td>
</tr>
<tr>
<td>Existing Vegetation Type</td>
<td>Percent of UCRE</td>
<td>status 1</td>
<td>status 2</td>
<td>status 3</td>
<td>status 4</td>
</tr>
<tr>
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<td>----------</td>
<td>----------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>Great Basin Semi-Desert Chaparral</td>
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<td>2.61</td>
<td>76.70</td>
<td>20.54</td>
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<td>Rocky Mountain Alpine/Montane Sparsely Vegetated Systems</td>
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<td>0.12</td>
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<td>0.53</td>
<td>0.24</td>
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<tr>
<td>Rocky Mountain Alpine Turf</td>
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</table>
Conservation Status: Rare

Analysis: Phase 2

Upper Colorado River Ecosystem – Alternative Future Study
Conservation Status: Variety

*Community Variety*

Community variety for this analysis came from a calculation based upon the variety of community types existing within a given search radius of each grid cell. The calculation was made twice using a 180 m radius and a 1 km radius to reflect two spatial scales, which for convenience are referred to as local and landscape, respectively. Developed land cover types, barren areas, and invasive plant communities were excluded from this analysis.

The areas of highest variety occur in the same general landscape positions for both the localized and landscape calculation. These are generally areas of high topographic relief.

<table>
<thead>
<tr>
<th>Variety within 180m</th>
<th>Area (ha)</th>
<th>Percent of UCRE</th>
<th>status 1</th>
<th>status 2</th>
<th>status 3</th>
<th>status 4</th>
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## Conservation Status: Variety

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## Conservation status of landscape variety

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<tr>
<td>Variety within 1km</td>
<td>Area (ha)</td>
<td>Percent of UCRE</td>
<td>status 1</td>
<td>status 2</td>
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</tr>
<tr>
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<td>&lt;0.01</td>
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<td>83.33</td>
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</table>
**Discussion**

Overall, the conservation status of all communities reflects the proportions of conservation status across the study area. Very few communities have significant proportions in full conservation status. Understand the quality of any given community in any particular conservation status will require additional analysis.

Improvement to this analysis could occur by refining the area-based categories, addressing the spatial distribution and context of each community, and by expanding the variety analysis to include a larger, i.e. ~10km, calculation radius. The common and ecotone communities are particularly large, and it seems worthwhile to search for meaningful divisions within these groups. The proportion of a community in a given conservation status would offer a more complete story if the spatial distribution and context of each community were analyzed with respect to the quality of the community under each status. The variety analysis scratches the surface by considering two spatial scales, but a more complete picture would be obtained by considering variety at the next order of spatial magnitude, ~10km or greater.
Wildlife Conservation

The wildlife portion of the conservation status model spatially examines biodiversity hotspots throughout each status section, 1 through 4. This model then locates where hotspots or high richness areas will serve various purposes for the wildlife and land management agencies within the Upper Colorado River Ecosystem. By cross tabulating these hotspots and their associated conservation status, the agencies will then be able to modify their current management strategies in order to preserve the areas with highest diversity.

The wildlife biodiversity models represented in this section are total terrestrial vertebrates, birds, mammals, and amphibians. Additionally, the bird wildlife model is segmented by animal form to provide more detail and includes gallinaceous birds (upland), raptors, and waterfowl. Finally, the mammals model contains expanded categories by animal form detailing carnivores and hooved browsers.

For the full list of species mapped throughout this project, see the table below. Following the species lists are maps containing different aspects of the biodiversity model cross tabulated against conservation status areas. These maps provide the information of which areas of biodiversity fall into different conservation status, and under further analysis would lead to changes in management status or techniques.
## UCR Terrestrial Vertebrate List

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
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<td>Bucephala albeola</td>
<td>bufflehead</td>
<td>Chen caerulescens</td>
<td>snow goose</td>
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<td>Accipiter gentilis</td>
<td>northern goshawk</td>
<td>Bucephala clangula</td>
<td>common goldeneye</td>
<td>Chlidonias niger</td>
<td>black tern</td>
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<td>sharp-shinned hawk</td>
<td>Bucephala islandica</td>
<td>barrow's goldeneye</td>
<td>Chondestes grammacus</td>
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<td>Bufo boreas</td>
<td>western toad</td>
<td>Chordeiles minor</td>
<td>common nighthawk</td>
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<td>Bufo cognatus</td>
<td>great plains toad</td>
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<td>Bufo woodhousei</td>
<td>woodhouse's toad</td>
<td>Circus cyaneus</td>
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<td>Buteo jamaicensis</td>
<td>red-tailed hawk</td>
<td>Cistothorus palustris</td>
<td>marsh wren</td>
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<td>boreal owl</td>
<td>Buteo lagopus</td>
<td>rough-legged hawk</td>
<td>Cletiramomys gapperi</td>
<td>southern red-backed vole</td>
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<td>white-throated swift</td>
<td>Buteo platypterus</td>
<td>broad-winged hawk</td>
<td>Chremonidoborus sexlineatus</td>
<td>six-lined racerunner</td>
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<td>red-winged blackbird</td>
<td>Buteo regalis</td>
<td>ferruginous hawk</td>
<td>Coccothraustes vespertinus</td>
<td>evening grosbeak</td>
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<tr>
<td>Aix sponsa</td>
<td>wood duck</td>
<td>Buteo swainsoni</td>
<td>swainson's hawk</td>
<td>Coccyzus americana</td>
<td>yellow-billed cuckoo</td>
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<td>moose</td>
<td>Calamospiza melanocorys</td>
<td>lark bunting</td>
<td>Coccyzus erythropthalmus</td>
<td>black-billed cuckoo</td>
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<td>Colaptes auratus</td>
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<td>mccoyn's longspur</td>
<td>Colius virginianus</td>
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**Analysis:**

**Phase 2:**

- **Status:**
  - **Upper Colorado River Ecosystem – Alternative Future Study**
  - Page 172
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<td>Tachycineta bicolor</td>
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<td>Tachycineta thalassina</td>
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<td>Tamias umbrinus</td>
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<td>Selasphorus platycercus</td>
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<td>northern pocket gopher</td>
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<td>Sialia currucoides</td>
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<td>Thyromanes bewickii</td>
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<td>Tymanuthus phasianellusjamesi</td>
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<td>Sorex monticolus</td>
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<td>Sorex ranus</td>
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<td>Tyrranusscyrtus</td>
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<td>Sorex palustris</td>
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<td>Tyrranuss vociferans</td>
<td>cassin’s kingbird</td>
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<td>Sorex preblei</td>
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<td>Spermannus armatus</td>
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<td>Ursus americanus</td>
<td>american black bear</td>
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<td>Spermannus elegans</td>
<td>wyoming ground squirrel</td>
<td>Ursus arctos</td>
<td>brown bear</td>
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<td>Spermannus lateralis</td>
<td>golden-mantled ground squirrel</td>
<td>Vermivora celata</td>
<td>orange-crowned warbler</td>
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<td>Spermannus splissoma</td>
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<tr>
<td>Spermannus tridecemlineatus</td>
<td>thirteen-lined ground squire</td>
<td>Vermivora ruficapilla</td>
<td>nashville warbler</td>
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<td></td>
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<tr>
<td>Sphyrapicus nuchalis</td>
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<td>Vermivora virginiae</td>
<td>virginia’s warbler</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sphyrapicus thyroideus</td>
<td>williamson’s sapucker</td>
<td>Vireo solitarius</td>
<td>warbling vireo</td>
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<td></td>
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<tr>
<td>Spizella gracilis</td>
<td>western spotted skunk</td>
<td>Vireo olivaceus</td>
<td>red-eyed vireo</td>
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<td></td>
</tr>
<tr>
<td>Spizella pusilla</td>
<td>eastern spotted skunk</td>
<td>Vulpes velox</td>
<td>swift fox</td>
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<tr>
<td>Spiza americana</td>
<td>dickcissel</td>
<td>Vulpes vulpes</td>
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<td>Spizella arborea</td>
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<td>Wilsonia pusilla</td>
<td>wilson’s warbler</td>
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<td>Xanthocephalus xanthocephalus</td>
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<td>Spizella passeroa</td>
<td>chipping sparrow</td>
<td>Zapus hudsonius</td>
<td>meadow jumping mouse</td>
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<td>field sparrow</td>
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<tr>
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<td>northern rough-winged swallow</td>
<td>Zena rixella</td>
<td>mourning dove</td>
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<td></td>
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<tr>
<td>Stellula calliope</td>
<td>calliope hummingbird</td>
<td>Zonotrichia leucophrys</td>
<td>white-crowned sparrow</td>
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</table>
As previously mentioned, the premise behind this conservation status data is the segregation of conservation lands into their four primary categories with each representing a different level or strategy for conservation. The table below outlines and explains each of the four primary categories (USGS National Gap Analysis Program, 2007).

### Conservation Status Overview

<table>
<thead>
<tr>
<th>Conservation Status</th>
<th>Description</th>
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</thead>
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<tr>
<td><strong>1</strong></td>
<td><strong>Conservation Status 1:</strong> An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a natural state within which disturbance events are allowed to proceed without interference or are mimicked through management.</td>
</tr>
<tr>
<td><strong>2</strong></td>
<td><strong>Conservation Status 2:</strong> An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a primarily natural state, but which may receive uses or management practices that degrade the quality of existing natural communities, including the suppression of natural disturbances.</td>
</tr>
<tr>
<td><strong>3</strong></td>
<td><strong>Conservation Status 3:</strong> An area having permanent protection from conversion of natural land cover for the majority of the area, but subject to extractive uses of either a broad, low-intensity type (e.g., logging) or localized intense type (e.g., mining). It also confers protection to federally listed endangered and threatened species throughout the area.</td>
</tr>
<tr>
<td><strong>4</strong></td>
<td><strong>Conservation Status 4:</strong> There are no known public or private institutional mandates, legally recognized easements, or deed restrictions held by the managing entity to prevent conversion of natural habitat types to anthropogenic habitat types. The area generally allows conversion to unnatural land cover throughout.</td>
</tr>
</tbody>
</table>
Conservation Status: Terrestrial Vertebrates

Analysis: Phase 2
Conservation Status: Hooved Browsers

Hooved Browser Richness

Status 1
- High: 7
- Low: 1

Status 2
- High: 7
- Low: 1

Status 3
- High: 9
- Low: 1

Status 4
- High: 9
- Low: 1
Conservation Status: Carnivories

Analysis: Phase 2

Bioregional Planning
Utah State University
Logan, Utah

Carnivore Richness

<table>
<thead>
<tr>
<th>Status</th>
<th>High</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Status 1</td>
<td>18</td>
<td>1</td>
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<tr>
<td>Status 2</td>
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<td>Status 3</td>
<td>21</td>
<td>1</td>
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<tr>
<td>Status 4</td>
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</table>
Conservation Status: Birds

Analysis: Phase 2

Bird Richness

<table>
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<th>Low</th>
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<td>169</td>
<td>1</td>
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<tr>
<td>4</td>
<td>207</td>
<td>1</td>
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</tbody>
</table>
Conservation Status: Gallinaceous Birds

Gallinaceous (Upland) Bird Richness

- Status 1: High: 5, Low: 1
- Status 2: High: 5, Low: 1
- Status 3: High: 6, Low: 1
- Status 4: High: 8, Low: 1

Bioregional Planning
Utah State University
Logan, Utah

ENVS

0 30 60 120 Miles
Conservation Status: Raptors

Raptor Richness

- Status 1: High: 16, Low: 1
- Status 2: High: 15, Low: 1
- Status 3: High: 17, Low: 1
- Status 4: High: 26, Low: 1

Bioregional Planning
Utah State University
Logan, Utah

ENVS

Analysis: Phase 2

Upper Colorado River Ecosystem – Alternative Future Study
**Conclusions**

This report has been a collaborative work which attempted to examine in a more holistic approach the Upper Colorado River Ecosystem as defined by the United States Fish and Wildlife Service and Utah State University. Both political borders and watershed boundaries define this area. The area’s expansiveness has challenged the study team to look at the UCRE through a broad “lens.” This broad-level landscape lens has allowed the study team to notice trends within the regions and concurrently examine the benefits of the methodology, process, and scale of the study.

The study team cannot predict the future, despite their best attempt to do so. However, through all of the research on the UCRE, the team can state several things will help define the future of the region. Four major land-uses of critical importance for the region are outdoor recreation/tourism, energy agricultural working lands, and human development. Currently, these land-uses all play critical roles in the region, and their impacts will increase in the future. All of these land-uses share a common driver that influences them which is human population growth.

Outdoor Recreation at all levels is a vastly popular activity within the Upper Colorado River Ecosystem and as population-growth continues over the next twenty years. Visitor usage and impacts on natural resource areas within the study area will continue to increase as the urban population centers expand, and their residents visit the surrounding environments.

Energy extraction and production will continue within the region due to rich reserves of coal, natural gas, and oil shale. Renewable energy production such as solar power and wind
power generation will also continue to increase in popularity, and both renewable and carbon based energy will push help to the economic development regionally over the next twenty years.

Although agriculture within the Upper Colorado River Ecosystem does not compare to the production of the “bread basket” in America, it still tributes to the region’s economy, character, and history. Several areas of high agricultural value do exist within the site, such as Cache Valley in northern Utah, agricultural lands near the Gunnison and Colorado Rivers in Colorado, and the cattle areas found around the Yampa-White Sub-watershed in northern Colorado. Over the next twenty to thirty years, the importance of local agricultural may again regain importance as an American ideal.

Human developments within the UCRE will also continue to expand as growth continues. The area has stunning natural resources and many amenities that help bring new residents to the area. There will continue to be a mixture of ever-expanding urban centers, suburbs, and rural developments within the region. However, local and regional organizations must address questions on “smart” growth if they wish to preserve areas of pristine ecological and aesthetic value.

As mentioned previously, the study team often struggled with the scale of the area. The sheer size presented several challenges from the onset. The three most pressing concerns for this study were data, scale, and taking on such a large physiographic diverse area. The study team found in their research and data collection that political boundaries often present large obstacles to finding contiguous and complete data. Ecosystems, geology, soils, wildlife, vegetation, climate,
hydrology, history, and cultures do not stop at political boundaries, yet information and data from a wide range of organizations surely does. This will surely change in the future, but until then these issues are large for regional level work.

The issue of scale is very important for the study team to address and mention as both a strength and weakness of this report. At a finer resolution, many of the issues associated with the study would have been effectively eliminated; however, the strengths within the report and the modeling would have also been excluded, such as the conservation status analysis and biodiversity models.

The diversity and “abstractness of the region” caused uncertainty within the study team about speculation and the impacts of such on land-use decisions. In order to develop models, a certain amount of generalization and speculation had to occur. For instance, to model farmland within the study site, the team had to ask what was ubiquitous for farming throughout the region and then how can the team map farmland. The team did not explicitly state all of the assumptions within their models, but listed all of the components in order that others can improve on this work in the future.

In conclusion, the study team hopes that further work will continue to advance responsible planning within the UCRE. This report will hopefully open and invigorate debate within the region on what are appropriate land-uses and how to manage for a complex future. There are no easy solutions, but with critical examination and continued hard work, this region can provide for both human growth and development and simultaneously protect the biodiversity and beauty of the natural landscape.
Appendix A

Bibliography


References


References

http://nationalatlas.gov/articles/geology/a_geohazards.html

http://nationalatlas.gov/mld/seihazp.html


http://www.epa.gov/r02earth/water/wetlands/dryfact.pdf


References

USGS. (2007, August 7). National Elevation Dataset (NED) 1 Arc Second. Sioux Falls, SD, U.S.A.


USGS. (2003, September 1). National Land Cover Database. Sioux Falls, South Dakota, U.S.A.


Appendix B

Overview:

To initialize the formation of a Geographic Information System (GIS) for the Upper Colorado River Ecosystem (UCRE), basic parameters were defined and basic existing geographic datasets were acquired. A brief overview of the GIS database parameters follows, with a bibliography of the datasets acquired.

Parameters:

Coordinate System

Projection and Datum

The Albers Equal Area Conic projection, based on the North American Datum of 1983, is used for all calculations and displays. The standard parallels and the central meridian have been selected to minimize distortion of the Upper Colorado River Ecosystem. This projection is referred to as the UCRE_Equal_Area_Conic, and is defined in the following table and figure.

---

**UCRE_Equal_Area_Conic Parameters**

<table>
<thead>
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<th>Central Meridian</th>
<th>110°W</th>
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<td>Standard Parallel 1</td>
<td>38°N</td>
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<tr>
<td>Standard Parallel 2</td>
<td>41°N</td>
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<tr>
<td>Latitude of Origin</td>
<td>39°N</td>
</tr>
</tbody>
</table>

---

[Map showing the UCRE_Equal_Area_Conic parameters and the projection area]
Context Area

In order to consider neighboring influences on the UCRE, a contextual area was defined. This will be used for the extent of the UCRE GIS, as shown in the picture on the previous page. It is roughly 1,000 by 1,000 kilometers.

Boundary

The FWS UCRE boundary is a composite of biophysical and political boundaries. Adjustment to this boundary was made to include the hydrologic sub-basins, which have their center of mass inside the administrative boundary, referred to as the UCRE composite boundary and shown below.
Sources:

**Climate** Three datasets on climate have been collected, one for the current climatic regime, another for climate change scenarios over the coming century, and one on the wind energy throughout the region.

**Current Climate:** Current climatic conditions (precipitation, temperature, and solar radiation for 1980 - 1997) come from DAYMET:


**Climate Change Forecasts:** Climate change scenarios (in terms of temperature and precipitation) for the coming century come from the World Climate Research Programme’s (WCRP’s) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset, projections downscaled by the Lawrence Livermore National Laboratory -Reclamation-Santa Cruz University, stored and served at the Lawrence Livermore National Laboratory Green Data Oasis.

**Wind:**

GIS References

Ecoregions


Physiographic Regions

Fenneman, N. M., & Johnson, D. W. (1946), Physiographic divisions of the conterminous U. S.

Cultural/ Historical

Agriculture


Cities and Towns


County Boundaries:

GIS References

Federal Lands


Place Names


Population


State Boundaries


Geology

Surface Geology


Faults


Hydrology

Floodplains

FEMA (Federal Emergency Management Agency) flood plain boundaries.

National Hydrologic Dataset (includes surface waters and watersheds)


Principle Aquifers


Oil and Gas

Oil and Gas wells by quarter mile


Oil and Gas Assessment Plays


Oil and Gas Assessment Assessment Province Boundaries

GIS References

Soils

States Soil Geographic Database (STATSGO): U.S. Department of Agriculture, Natural Resources Conservation Service, July 5th 2006

Soil Survey Geographic Database (SSURGO): level 3 Soil Surveys may be utilized from this source, but specific ones have not been selected.

Topography


Vegetation/Landcover


GAP Landcover

Arizona: USGS Southwest Biological Science Center, Colorado Plateau Field Station, Northern Arizona University, P.O. Box 5614, Flagstaff, AZ 86011-5614, Principle Investigator: Kathryn Thomas, Landcover Analysts: Sarah Falzarano, Cynthia Wallace, Keith Pohs.


Idaho: Landscape Dynamics Lab, 19990210, Gap Analysis of Idaho Land Cover, Moscow, Idaho, Idaho Cooperative Fish and Wildlife Research Unit.


New Mexico: New Mexico Cooperative Fish & Wildlife Research Unit, New Mexico State University, P.O. Box 30003, MSC 4901, Las Cruces, NM 88003, Principle Investigators: Bruce Thompson, Ken Boykin, Landcover Analyst: Scott Schrader.

Utah: RS/GIS Laboratory, College of Natural Resources, UMC 5275, Utah State University, Logan, UT 84322-5275, Principle Investigators: Doug
GIS References

Ramsey, John Lowry, Landcover Analysts: Jessica Kirby, Lisa Langs, Gerald Manis.


USGS/EROS Data Center: EROS Data Center, USGS, Sioux Falls, SD 57198, Deputy Science Department Manager: Collin Homer.

USGS/Biological Resources Discipline: P.O. Box 30003, MSC 4901, Las Cruces, NM 88003, SWReGAP Project Coordinator: Julie Prior-Magee.

Landfire Landcover
United States Forest Service, 2006. Landfire Existing Vegetation Type. USDA Forest Service, Missoula MT.

Wildlife

30m resolution Terrestrial Vertebrate Models from the GAP analysis program, summarized in the following table:

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<thead>
<tr>
<th>Group</th>
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<tr>
<td>Amphibians</td>
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<td>Birds</td>
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<tr>
<td>Mammals</td>
<td>212</td>
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<tr>
<td>Reptiles</td>
<td>39</td>
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</table>
Appendix C

This document came from the Bureau of Reclamations website (Bureau of Reclamation, 2008).

Colorado River Compact, 1922

The States of Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming, having resolved to enter into a compact under the Act of the Congress of the United States of America approved August 30, 1921 (42 Statutes at Large, page 711), and the Acts of the Legislatures of the said States, have through their Governors appointed as their Commissioners:

W.S. Norvid for the State of Arizona,
W.F. McClure for the State of California,
Delph E. Carpenter for the State of Colorado,
J.G. Seraphim for the State of Nevada,
Stephen B. Davis, Jr., for the State of New Mexico,
R.E. Caldwell for the State of Utah,
Frank C. Emerson for the State of Wyoming,

who, after negotiations participated in by Herbert Hoover appointed by The President as the representative of the United States of America, have agreed upon the following articles:

ARTICLE I

The major purposes of this compact are to provide for the equitable division and apportionment of the use of the waters of the Colorado River System, to establish the relative importance of different beneficial uses of water, to promote interstate comity, to remove causes of present and future controversies, and to secure the expeditious agricultural and industrial development of the Colorado River Basin, the storage of its waters, and the protection of life and property from floods. To these ends the Colorado River Basin is divided into two Basins, and an apportionment of the use of part of the water of the Colorado River System is made to each of them with the provision that further equitable apportionments may be made.

ARTICLE II

As used in this compact-
(a) The term “Colorado River System” means that portion of the Colorado River and its tributaries within the United States of America.
(b) the term “Colorado River Basin” means all of the drainage area of the Colorado River System and all other territory within the United States of America to which the waters of the Colorado River System shall be beneficially applied.
(c) The term “States of the Upper Division” means the States of Colorado, New Mexico, Utah, and Wyoming.
(d) The term “States of the Lower Division” means the States of Arizona, California, and Nevada.
(e) The term “Lee Ferry” means a point in the main stream of the Colorado River one mile below the mouth of the Paria River.
(f) The term “Upper Basin” means those parts of the States of Arizona, Colorado, New Mexico, Utah, and Wyoming within and from which waters naturally drain into the Colorado River System above Lee Ferry, and also all parts of said States located without the drainage area of the Colorado River System which are now or shall hereafter be beneficially served by waters diverted from the System above Lee Ferry.
(g) The term “Lower Basin” means those parts of the States of Arizona, California, Nevada, New Mexico, and Utah within and from which waters naturally drain into the Colorado River System below Lee Ferry, and also all parts of said States located without the drainage area of the Colorado River System which are now or shall hereafter be beneficially served by waters diverted from the System below Lee Ferry.
(h) The term “domestic use” shall include the use of water for household, stock, municipal, mining, milling, industrial, and other like purposes, but shall exclude the generation of electrical power.
ARTICLE III

(a) There is hereby apportioned from the Colorado River System in perpetuity to the Upper Basin and to the Lower Basin, respectively, the exclusive beneficial consumptive use of 7,500,000 acre-feet of water per annum, which shall include all water necessary for the supply of any rights which may now exist.

(b) In addition to the apportionment in paragraph (a), the Lower Basin is hereby given the right to increase its beneficial consumptive use of such waters by one million acre-foot per annum.

(c) If, as a matter of international comity, the United States of America shall hereafter recognize in the United States of Mexico any right to the use of any waters of the Colorado River System, such waters shall be supplied first from the waters which are surplus over and above the aggregate of the quantities specified in paragraphs (a) and (b); and if such surplus shall prove insufficient for this purpose, then, the burden of such deficiency shall be equally borne by the Upper Basin and the Lower Basin, and whenever necessary the States of the Upper Division shall deliver at Lee Ferry water to supply one-half of the deficiency so recognized in addition to that provided in paragraph (d).

(d) The States of the Upper Division will not cause the flow of the river at Lee Ferry to be depleted below an aggregate of 75,000,000 acre-feet for any period of ten consecutive years reckoned in continuing progressive series beginning with the first day of October next succeeding the ratification of this compact.

(e) The States of the Upper Division shall not withhold water, and the States of the Lower Division shall not require the delivery of water, which cannot reasonably be applied to domestic and agricultural uses.

(f) Further equitable apportionment of the beneficial uses of the waters of the Colorado River System unapportioned by paragraphs (a), (b), and (c) may be made in the manner provided in paragraph (g) at any time after October first, 1963, if and when either Basin shall have reached its total beneficial consumptive use as set out in paragraphs (a) and (b).

(g) In the event of a desire for a further apportionment as provided in paragraph (f) any two signatory States, acting through their Governors, may give joint notice of such desire to the Governors of the other signatory States and to The President of the United States of America, and it shall be the duty of the Governors of the signatory States and of The President of the United States of America forthwith to appoint representatives, whose duty it shall be to divide and apportion equitably between the Upper Basin and Lower Basin the beneficial use of the unapportioned water of the Colorado River System as mentioned in paragraph (f), subject to the legislative ratification of the signatory States and the Congress of the United States of America.

ARTICLE IV

(a) Inasmuch as the Colorado River has ceased to be navigable for commerce and the reservation of its waters for navigation would seriously limit the development of its Basin, the use of its waters for purposes of navigation shall be subordinated to the uses of such waters for domestic, agricultural, and power purposes. If the Congress shall not consent to this paragraph, the other provisions of this compact shall nevertheless remain binding.

(b) Subject to the provisions of this compact, water of the Colorado River System may be impounded and used for the generation of electrical power, but such impounding and use shall be subordinated to the use and consumption of such water for agricultural and domestic purposes and shall not interfere with or prevent use for such dominant purposes.

(c) The provisions of this article shall not apply to or interfere with the regulation and control by any State within its boundaries of the appropriation, use, and distribution of water.

ARTICLE V

The chief official of each signatory State charged with the administration of water rights, together with the Director of the United States Reclamation Service and the Director of the United States Geological Survey shall cooperate, ex-officio:

(a) To promote the systematic determination and coordination of the facts as to flow, appropriation, consumption, and use of water in the Colorado River Basin, and the interchange of available information in such matters.

(b) To secure the ascertainment and publication of the annual flow of the Colorado River at Lee Ferry.

(c) To perform such other duties as may be assigned by mutual consent of the signatories from time to time.
ARTICLE VI

Should any claim or controversy arise between any two or more of the signatory States: (a) with respect to the waters of the Colorado River System not covered by the terms of this compact; (b) over the meaning or performance of any of the terms of this compact; (c) as to the allocation of the burdens incident to the performance of any article of this compact or the delivery of waters as herein provided; (d) as to the construction or operation of works within the Colorado River Basin to be situated in two or more States, or to be constructed in one State for the benefit of another State; or (e) as to the diversion of water in one State for the benefit of another State; the Governors of the States affected, upon the request of one of them, shall forthwith appoint Commissioners with power to consider and adjust such claim or controversy, subject to ratification by the Legislatures of the States so affected.

Nothing herein contained shall prevent the adjustment of any such claim or controversy by any present method or by direct future legislative action of the interested States.

ARTICLE VII

Nothing in this compact shall be construed as affecting the obligations of the United States of America to Indian tribes.

ARTICLE VIII

Present perfected rights to the beneficial use of waters of the Colorado River System are unimpaired by this compact. Whenever storage capacity of 5,000,000 acre-feet shall have been provided on the main Colorado River within or for the benefit of the Lower Basin, then claims of such rights, if any, by appropriators or users of water in the Lower Basin against appropriators or users of water in the Upper Basin shall attach to and be satisfied from water that may be stored not in conflict with Article III.

All other rights to beneficial use of waters of the Colorado River System shall be satisfied solely from the water apportioned to that Basin in which they are situate.

ARTICLE IX

Nothing in this compact shall be construed to limit or prevent any State from instituting or maintaining any action or proceeding, legal or equitable, for the protection of any right under this compact or the enforcement of any of its provisions.

ARTICLE X

This compact may be terminated at any time by the unanimous agreement of the signatory States. In the event of such termination all rights established under it shall continue unimpaired.

ARTICLE XI

This compact shall become binding and obligatory when it shall have been approved by the Legislatures of each of the signatory States and by the Congress of the United States. Notice of approval by the Legislatures shall be given by the Governor of each signatory State to the Governors of the other signatory States and to the President of the United States, and the President of the United States is requested to give notice to the Governors of the signatory States of approval by the Congress of the United States.

IN WITNESS WHEREOF, the Commissioners have signed this compact in a single original, which shall be deposited in the archives of the Department of State of the United States of America and of which a duly certified copy shall be forwarded to the Governor of each of the signatory States.
DONE at the City of Santa Fe, New Mexico, this twenty-fourth day of November, A.D. One Thousand Nine Hundred and Twenty-two.

W. S. NORVIEL
W. F. McCIJRE
DELPH E. CARPENTER
J. G. SCRUGHAM
STEPHEN G. DAVIS, JR.
R. E. CALDWELL
FRANK C. EMERSON

Approved:
HERBERT HOOVER
Appendix D

Upper Colorado River Basin Compact, 1948

The State of Arizona, the State of Colorado, the State of New Mexico, the State of Utah and the State of Wyoming, acting through their Commissioners,

Charles A. Carson for the State of Arizona,
Clifford H. Stone for the State of Colorado,
Fred E. Wilson for the State of New Mexico,
Edward H. Watson for the State of Utah, and
L. C. Bishop for the State of Wyoming,

after negotiations participated in by Harry W. Bashore, appointed by the President as the representative of the United States of America, have agreed, subject to the provisions of the Colorado River Compact, to determine the rights and obligations of each signatory State respecting the uses and deliveries of the water of the Upper Basin of the Colorado River, as follows:

Article I

(a) The major purposes of this Compact are to provide for the equitable division and apportionment of the use of the waters of the Colorado River System, the use of which was apportioned in perpetuity to the Upper Basin by the Colorado River Compact; to establish the obligations of each State of the Upper Division with respect to the deliveries of water required to be made at Lee Ferry by the Colorado River Compact; to promote interstate comity; to remove causes of present and future controversies; to secure the expeditious agricultural and industrial development of the Upper Basin, the storage of water and to protect life and property from floods.

(b) It is recognized that the Colorado River Compact is in full force and effect and all of the provisions hereof are subject thereto.

Article II

As used in this Compact:

(a) The term "Colorado River System" means that portion of the Colorado River and its tributaries within the United States of America.

(b) The term "Colorado River Basin" means all of the drainage area of the Colorado River System and all other territory within the United States of America to which the waters of the Colorado River System shall be beneficially applied.

(c) The term "States of the Upper Division" means the States of Colorado, New Mexico, Utah and Wyoming.

(d) The term "States of the Lower Division" means the States of Arizona, California and Nevada.

(e) The term "Lee Ferry" means a point in the main stream of the Colorado River one mile below the mouth of the Pena River.

(f) The term "Upper Basin" means those parts of the States of Arizona, Colorado, New Mexico, Utah, and Wyoming within and from which waters naturally drain into the Colorado River System above Lee Ferry, and also parts of said States located without the drainage area of the Colorado River System which are now or shall hereafter be beneficially served by waters diverted from the Colorado River System above Lee Ferry.

(g) The term "Lower Basin" means those parts of the States of Arizona, California, New Mexico and Utah within and from which waters naturally drain into the Colorado River System below Lee
Ferry, and also all parts of said States located without the drainage area of the Colorado River System which are now or shall hereafter be beneficially served by waters diverted from the Colorado River System below Lee Ferry.

(h) The term "Colorado River Compact" means the agreement concerning the apportionment of the use of the waters of the Colorado River System dated November 24, 1922, executed by Commissioners for the States of Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming, approved by Herbert Hoover, representative of the United States of America, and proclaimed effective by the President of the United States of America, June 25, 1929.

(i) The term "Upper Colorado River System" means that portion of the Colorado River System above Lee Ferry.

(j) The term "Commission" means the administrative agency created by Article VII of this Compact.

(k) The term "water year" means that period of twelve months ending September 30 of each year.

(l) The term "acre-foot" means the quantity of water required to cover an acre to the depth of one foot and is equivalent to 43,560 cubic feet.

(m) The term "domestic use" shall include the use of water for household, stock, municipal, mining, milling, industrial and other like purposes, but shall exclude the generation of electrical power.

(n) The term "virgin flow" means the flow of any stream undepleted by the activities of man.

**Article III**

(a) Subject to the provisions and limitations contained in the Colorado River Compact and in this Compact, there is hereby apportioned from the Upper Colorado River System in perpetuity to the States of Arizona, Colorado, New Mexico, Utah and Wyoming, respectively, the consumptive use of water as follows:

(1) To the State of Arizona the consumptive use of 50,000 acre-feet of water per annum.

(2) To the States of Colorado, New Mexico, Utah and Wyoming, respectively, the consumptive use per annum of the quantities resulting from the application of the following percentages to the total quantity of consumptive use per annum apportioned in perpetuity to and available for use each year by Upper Basin under the Colorado River Compact and remaining after the deduction of the use, not to exceed 50,000 acre-feet per annum, made in the State of Arizona.

State of Colorado, 51.75 per cent; State of New Mexico, 11.25 per cent; State of Utah, 23.00 per cent; State of Wyoming, 14.00 per cent.

(b) The apportionment made to the respective States by paragraph (a) of this Article is based upon, and shall be applied in conformity with, the following principles and each of them:

(1) The apportionment is of any and all man-made depletions;

(2) Beneficial use is the basis, the measure and the limit of the right to use;

(3) No State shall exceed its apportioned use in any water year when the effect of such excess use, as determined by the Commission, is to deprive another signatory State of its apportioned use during that water year; provided, that this subparagraph (b) (3) shall not be construed as:

(i) Altering the apportionment of use, or obligations to make deliveries as provided in Articles XI, XII, XIII or XIV of this Compact;

(ii) Purporting to apportion among the signatory States such uses of water as the Upper Basin may be entitled to under paragraphs (l) and (g) of Article III of the Colorado River Compact; or

(iii) Countenancing average uses by any signatory State in excess of its apportionment.

(4) The apportionment to each State includes all water necessary for the supply of any rights which now exist.

(c) No apportionment is hereby made, or intended to be made, of such uses of water as the Upper
Basin may be entitled to under paragraphs (f) and (g) of Article III of the Colorado River Compact.

(d) The apportionment made by this Article shall not be taken as any basis for the allocation among the signatory States of any benefits resulting from the generation of power.

ARTICLE IV

In the event curtailment of use of water by the States of the Upper Division at any time shall become necessary in order that the flow at Lee Ferry shall not be depleted below that required by Article III of the Colorado River Compact, the extent of curtailment by each State of the consumptive use of water apportioned to it by Article III of this Compact shall be in such quantities and at such times as shall be determined by the Commission upon the application of the following principles:

(a) The extent and times of curtailment shall be such as to assure full compliance with Article III of the Colorado River Compact;

(b) If any State or States of the Upper Division, in the ten years immediately preceding the water year in which curtailment is necessary, shall have consumptively used more water than it was or they were, as the case may be, entitled to use under the apportionment made by Article III of this Compact, such State or States shall be required to supply at Lee Ferry a quantity of water equal to its, or the aggregate of their, overdraft of the proportionate part of such overdraft, as may be necessary to assure compliance with Article III of the Colorado River Compact, before demand is made on any other State of the Upper Division;

(c) Except as provided in subparagraph (b) of this Article, the extent of curtailment by each State of the Upper Division of the consumptive use of water apportioned to it by Article III of this Compact shall be such as to result in the delivery at Lee Ferry of a quantity of water which bears the same relation to the total required curtailment of use by the States of Upper Division as the consumptive use of Upper Colorado River System water which was made by each such State during the water year immediately preceding the year in which the curtailment becomes necessary bears to the total consumptive use of such water in the States of the Upper Division during the same water year; provided, that in determining such relation the uses of water under rights perfected prior to November 24, 1922, shall be excluded.

ARTICLE V

(a) All losses of water occurring from or as the result of the storage of water in reservoirs constructed prior to the signing of this Compact shall be charged to the State in which such reservoir or reservoirs are located. Water stored in reservoirs covered by this paragraph (a) shall be for the exclusive use of and shall be charged to the State in which the reservoir or reservoirs are located.

(b) All losses of water occurring from or as the result of the storage of water in reservoirs constructed after the signing of this Compact shall be charged as follows:

(1) If the Commission finds that the reservoir is used, in whole or in part, to assist the States of the Upper Division in meeting their obligations to deliver water at Lee Ferry imposed by Article III of the Colorado River Compact, the Commission shall make findings, which in no event shall be contrary to the laws of the United States of America under which any reservoir is constructed, as to the reservoir capacity allocated for that purpose. The whole or that portion, as the case may be, of reservoir losses as found by the Commission to be reasonably and properly chargeable to the reservoir or reservoir capacity utilized to assure deliveries at Lee Ferry shall be charged to the States of the Upper Division in proportion which the consumptive use of water in each State of the Upper Division during the water year in which the charge is made bears to the total consumptive use of water in all States of the Upper Division during the same water year. Water stored in reservoirs or reservoir capacity covered by this subparagraph (b) (1) shall be for the common benefit of all of the States of the Upper Division.

(2) If the Commission finds that the reservoir is used, in whole or in part, to supply water for use in a State of the Upper Division, the Commission shall make findings, which in no event shall be contrary
to the laws of the United States of America under which any reservoir is constructed, as to the reservoir or reservoir capacity utilized to supply water for use and the State in which such water will be used. The whole or that proportion, as the case may be, of reservoir losses as found by the Commission to be reasonably and properly chargeable to the State in which such water will be used shall be borne by that State. As determined by the Commission, water stored in reservoirs covered by this subparagraph (b) (2) shall be earmarked for and charged to the State in which the water will be used.

(c) In the event the Commission finds that a reservoir site is available both to assure deliveries at Lee Ferry and to store water for consumptive use in a State of the Upper Division, the storage of water for consumptive use shall be given preference. Any reservoir or reservoir capacity hereafter used to assure deliveries at Lee Ferry shall be ordered of the Commission be used to store water for consumptive use in a State, provided the Commission finds that such storage is reasonably necessary to permit such State to make the use of the water apportioned to it by this Compact.

ARTICLE VI

The Commission shall determine the quantity of the consumptive use of water, which use is apportioned by Article III hereof, for the Upper Basin and for each State of the Upper Basin by the inflow-outflow method in terms of man-made depletions of the virgin flow at Lee Ferry, unless the Commission, by unanimous action, shall adopt a different method of determination.

ARTICLE VII

The consumptive use of water by the United States of America or any of its agencies, instrumentalities or wards shall be charged as use by the State in which the use is made; provided, that such consumptive use incident to the diversion, impounding, or conveyance of water in one State for use in another shall be charged to such latter State.

ARTICLE VIII

(a) There is hereby created an interstate administrative agency to be known as the "Upper Colorado River Commission." The Commission shall be composed of one Commissioner, representing each of the States of the Upper Division, namely, the States of Colorado, New Mexico, Utah and Wyoming, designated or appointed in accordance with the laws of each such State and, if designated by the President, one Commissioner representing the United States of America. The President is hereby requested to designate a Commissioner. If so designated the Commissioner representing the United States of America shall be the presiding officer of the Commission and shall be entitled to the same powers and rights as the Commissioner of any State. Any four members of the Commission shall constitute a quorum.

(b) The salaries and personal expenses of each Commissioner shall be paid by the Government which he represents. All other expenses which are incurred by the Commission incident to the administration of this Compact, and which are not paid by the United States of America, shall be borne by the four States according to the percentage of consumptive use apportioned to each. On or before December 1 of each year, the Commission shall adopt and transmit to the Governors of the four States and to the President a budget covering an estimate of its expenses for the following year, and of the amount payable by each State. Each State shall pay the amount due by it to the Commission on or before April 1 of the year following. The payment of the expenses of the Commission and of its employees shall not be subject to the audit and accounting procedures of any of the four States; however, all receipts and disbursement of funds handled by the Commission shall be audited yearly by a qualified independent public accountant and the report of the audit shall be included in and become a part of the annual report of the Commission.

(c) The Commission shall appoint a Secretary, who shall not be a member of the Commission,
or an employee of any signatory State or of the United States of America while so acting. He shall serve for such term and receive such salary and perform such duties as the Commission may direct. The Commission may employ such engineering, legal, clerical and other personnel as, in its judgment, may be necessary for the performance of its functions under this Compact. In the hiring of employees, the Commission shall not be bound by the civil service laws of any State.

(d) The Commission, so far as consistent with this Compact, shall have the power to:

(1) Adopt rules and regulations;
(2) Locate, establish, construct, abandon, operate and maintain water gaging stations;
(3) Make estimates to forecast water run-off on the Colorado River and any of its tributaries;
(4) Engage in cooperative studies of water supplies of the Colorado River and its tributaries;
(5) Collect, analyze, correlate, preserve and report on data as to the stream flows, storage, diversions and use of the waters of the Colorado River, and any of its tributaries;
(6) Make findings as to the quantity of water of the Upper Colorado River System used each year in the Upper Colorado River Basin and in each State thereof;
(7) Make findings as to the quantity of water deliveries at Lee Ferry during each water year;
(8) Make findings as to the necessity for and the extent of the curtailment of use, required, if any, pursuant to Article IV hereof;
(9) Make findings to the quantity of reservoir losses and as to the share thereof chargeable under Article V hereof to each of the States;
(10) Make findings of fact in the event of the occurrence of extraordinary drought or serious accident to the irrigation system in the Upper Basin, whereby deliveries by the Upper Basin of water which it may be required to deliver in order to aid in fulfilling obligations of the United States of America to the United Mexican States arising under the Treaty between the United States of America and the United Mexican States, dated February 3, 1944 (Treaty Series 994) become difficult, and report such findings to the Governors of the Upper Basin States, the President of the United States of America, the United States Section of the International Boundary and Water Commission, and such other Federal officials and agencies as it may deem appropriate to the end that the water allotted to Mexico under Division III of such treaty may be reduced in accordance with the terms of such Treaty;
(11) Acquire and hold such personal and real property as may be necessary for the performance of its duties hereunder and to dispose of the same when no longer required;
(12) Perform all functions required of it by this Compact and do all things necessary, proper or convenient in the performance of its duties hereunder, either independently or in cooperation with any state or federal agency;
(13) Make and transmit annually to the Governors of the signatory States and the President of the United States of America, with the estimated budget, a report covering the activities of the Commission for the preceding water year.

(e) Except as otherwise provided in this Compact the concurrence of four members of the Commission shall be required in any action taken by it.

(f) The Commission and its Secretary shall make available to the Governor of each of the signatory States any information within its possession at any time, and shall always provide free access to its records by the Governors of each of the States, or their representatives, or authorized representatives of the United States of America.

(g) Findings of fact made by the Commission shall not be conclusive in any court, or before any agency or tribunal, but shall constitute prima facie evidence of the facts found.

(h) The organization meeting of the Commission shall be held within four months from the effective date of Compact.
ARTICLE IX

(a) No State shall deny the right of the United States of America and, subject to the conditions hereinafter contained, no State shall deny the right of another signatory State, any person, or entity of any signatory State to acquire rights to the use of water, or to construct or participate in the construction and use of diversion works and storage reservoirs with appurtenant works, canals and conduits in one State for the purpose of diverting, conveying, storing, regulating and releasing water to satisfy the provisions of the Colorado River Compact relating to the obligation of the States of the Upper Division to make deliveries of water at Lee Ferry, or for the purpose of diverting, conveying, storing or regulating water in an upper signatory State for consumptive use in a lower signatory State, when such use is within the apportionment to such lower State made by this Compact. Such rights shall be subject to the rights of water users, in a State in which such reservoir or works are located, to receive and use water, the use of which is within the apportionment to such State by this Compact.

(b) Any signatory State, any person or any entity of any signatory State shall have the right to acquire such property rights as are necessary to the use of water in conformity with this compact in any other signatory State by donation, purchase or through the exercise of the power of eminent domain. Any signatory State, upon the written request of the Governor of any other signatory State, for the benefit of whose water users property is to be acquired in the State to which such written request is made, shall proceed expeditiously to acquire the desired property either by purchase at a price satisfactory to the requesting State, or, if such purchase cannot be made, then through the exercise of its power of eminent domain and shall convey such property to the requesting State or such entity as may be designated by the requesting State; provided, that all costs of acquisition and expenses of every kind and nature whatsoever incurred in obtaining the requested property shall be paid by the requesting State at the time and in the manner prescribed by the State requested to acquire the property.

(c) Should any facility be constructed in a signatory State by any for the benefit of another signatory State or States or the water users thereof, as above provided, the construction, repair, replacement, maintenance and operation of such facility shall be subject to the laws of the State in which the facility is located, except that, in the case of a reservoir constructed in one State for the benefit of another State or States, the water administration officials of the State in which the facility is located shall permit the storage and release of any water which, as determined by findings of the Commission, falls within the apportionment of the State or States for whose benefit the facility is constructed. In the case of a regulating reservoir for the joint benefit of all States in making Lee Ferry deliveries, the water administration officials of the State in which the facility is located, in permitting the storage and release of water, shall comply with the findings and orders of the Commission.

(d) In the event property is acquired by a signatory State in another signatory State for the use and benefit of the former, the users of water made available by such facilities, as a condition precedent to the use thereof, shall pay to the political subdivisions of the State in which such works are located, each and every year during which such rights are enjoyed for such purposes, a sum of money equivalent to the average annual amount of taxes levied and assessed against the land and improvements thereon during the ten years preceding the acquisition of such land. Said payments shall be in full reimbursement for the loss of taxes in such political subdivisions of the State, and in lieu of any and all taxes on said property, improvements and rights. The signatory States recommend to the President and the Congress that, in the event the United States of America shall acquire property in one of the signatory States for the benefit of another signatory State, or its water users, provision be made for like payment in reimbursement of loss of taxes.

ARTICLE X

(a) The signatory States recognize the La Plata River Compact entered into between the States of Colorado and New Mexico, dated November 27, 1922, approved by the Congress on January 29, 1925 (43
Stat. 796), and this Compact shall not affect the apportionment therein made.

(b) All consumptive use of water of La Plata River and its tributaries shall be charged under the apportionment of Article III hereof to the State in which the use is made; provided, that consumptive use incident to the diversion, impounding or conveyance of water in one State for use in the other shall be charged to the latter State.

ARTICLE XI

Subject to the provisions of this Compact, the consumptive use of the water of the Little Snake River and its tributaries is hereby apportioned between the States of Colorado and Wyoming in such quantities as shall result from the application of the following principles and procedures:

(a) Water used under rights existing prior to the signing of this Compact.

(1) Water diverted from any tributary of the Little Snake River or from the main stem of the Little Snake River above a point one hundred feet below the confluence of Savery Creek and the Little Snake River shall be administered without regard to rights covering the diversion of water from any downstream points.

(2) Water diverted from the main stem of the Little Snake River below a point one hundred feet below the confluence of Savery Creek and the Little Snake River shall be administered on the basis of an interstate priority schedule prepared by the Commission in conformity with priority dates established by the laws of the respective States.

(b) Water used under rights initiated subsequent to the signing of this Compact.

(1) Direct flow diversions shall be so administered that, in time of shortage, the curtailment of use on each acre of land irrigated thereunder shall be as nearly equal as may be possible in both of the States.

(2) The storage of water by projects located in either State, whether of supplemental supply or of water used to irrigate land not irrigated at the date of the signing of this Compact, shall be so administered that in times of water shortage the curtailment of storage of water available for each acre of land irrigated thereunder shall be as nearly equal as may be possible in both States.

(c) Water uses under the apportionment made by this Article shall be in accordance with the principle that beneficial use shall be the basis, measure and limit of the right to use.

(d) The States of Colorado and Wyoming each assent to diversions and storage of water in one State for use in the other State, subject to compliance with Article IX of this Compact.

(e) In the event of the importation of water to the Little Snake River Basin from any other river basin, the State making the importation shall have the exclusive use of such imported water unless by written agreement, made by the representatives of the States of Colorado and Wyoming on the Commission, it is otherwise provided.

(f) Water use projects initiated after the signing of this Compact, to the greatest extent possible, shall permit the full use within the Basin in the most feasible manner of the waters of the Little Snake River and its tributaries, without regard to the state line; and, so far as is practicable, shall result in an equal division between the States of the use of water not used under rights existing prior to the signing of this Compact.

(g) All consumptive use of the waters of the Little Snake River and its tributaries shall be charged under the apportionment of Article III hereof to the State in which the use is made; provided, that consumptive use incident to the diversion, impounding or conveyance of water in one State for use in the other shall be charged to the latter State.

ARTICLE XII

Subject to the provisions of this Compact, the consumptive use of the waters of Henry's Fork, a tributary of Green River originating in the State of Utah and flowing into the State of Wyoming and thence into the Green River in the State of Utah; Beaver Creek, originating in the State of Utah and flowing into Henry's Fork in the State of Wyoming; Burnt Fork, a tributary of Henry's Fork, originating in the State of
Utah and flowing into Henry's Fork in the State of Wyoming; Birch Creek, a tributary of Henry's Fork, originating in the State of Utah and flowing into Henry's Fork in the State of Wyoming; and Sheep Creek, a tributary of Green River in the State of Utah, and their tributaries are hereby apportioned between the States of Utah and Wyoming in such quantities as will result from the application of the following principles and procedures:

(a) Waters used under rights existing prior to the signing of this Compact. Waters diverted from Henry's Fork, Beaver Creek, Bonne Fork, Birch Creek and their tributaries, shall be administered without regard to the State line on the basis of an interstate priority schedule to be prepared by the States affected and approved by the Commission in conformity with the actual priority of right of use, the water requirements of the land irrigated and the acreage irrigated in connection therewith.

(b) Waters used under rights from Henry's Fork, Beaver Creek, Bonne Fork, Birch Creek and their tributaries, initiated after the signing of this Compact shall be divided fifty percent to the State of Wyoming and fifty percent to the State of Utah and each State may use said waters as and where it deems advisable.

(c) The State of Wyoming assigns to the exclusive use by the State of Utah of the water of Sheep Creek, except that the lands, if any, presently irrigated in the State of Wyoming from the water of Sheep Creek shall be supplied with water from Sheep Creek in order of priority and in such quantities as are in conformity with the laws of the State of Utah.

(d) In the event of the importation of water to Henry's Fork, or any of its tributaries, from any other river basin, the State making the importation shall have the exclusive use of such imported water unless by written agreement made by the representatives of the States of Utah and Wyoming on the Commission, it is otherwise provided.

(e) All consumptive use of waters of Henry's Fork, Beaver Creek, Bonne Fork, Birch Creek, Sheep Creek, and their tributaries shall be charged under the apportionment of Article III hereof to the State in which the use is made; provided, that consumptive use incident to the diversion, impounding or conveyance of water in one State for use in the other shall be charged to the latter State.

(f) The States of Utah and Wyoming each assign to the diversion and storage of water in one State for use in the other State, subject to compliance with Article IX of this Compact. It shall be the duty of the water administrative officials of the State where the water is stored to release said stored water to the other State upon demand. If either the State of Utah or the State of Wyoming shall construct a reservoir in the other State for use in its own State, the water users of the State in which said facilities are constructed may purchase at cost a portion of the capacity of said reservoir sufficient for the irrigation of their lands thereunder.

(g) In order to measure the flow of water diverted, each State shall cause suitable measuring devices to be constructed, maintained and operated at or near the point of diversion into each ditch.

(h) The State Engineers of the two States jointly shall appoint a Special Water Commissioner who shall have authority to administer the water in both States in accordance with the terms of this Article. The salary and expense of such Special Water Commissioner shall be paid, thirty percent by the State of Utah and seventy percent by the State of Wyoming.

ARTICLE XIII

Subject to the provisions of this Compact, the rights to the consumptive use of the water of the Yampa River, a tributary entering the Green River in the State of Colorado, are hereby apportioned between the States of Colorado and Utah in accordance with the following principles:

(a) The State of Colorado will not cause the flow of the Yampa River at the Maybell Gaging Station to be depleted below an aggregate of 5,000,000 acre-feet for any period of ten consecutive years reckoned in continuing progressive series beginning with the first day of October next succeeding the ratification and approval of this Compact. In the event any diversion is made from the Yampa River or from tributaries entering the Yampa River above the Maybell Gaging Station for the benefit of any water use project in the State of Utah, then the gross amount of all such diversions for use in the State of Utah, less any returns from such diversions to the River above Maybell, shall be added to the actual flow at the Maybell...
Gaging Station to determine the total flow at the Maybell Gaging Station.

(b) All consumptive use of the waters of the Yampa River and its tributaries shall be charged under the apportionment of Article III hereof to the State in which the use is made; provided, that consumptive use incident to the diversion, impounding or conveyance of water in one State for use in the other shall be charged to the latter State.

**ARTICLE XIV**

Subject to the provisions of this Compact, the consumptive use of the waters of the San Juan River and its tributaries is hereby apportioned between the States of Colorado and New Mexico as follows:

The State of Colorado agrees to deliver to the State of New Mexico from the San Juan River and its tributaries which rise in the State of Colorado a quantity of water which shall be sufficient, together with water originating in the San Juan Basin in the State of New Mexico, to enable the State of New Mexico to make full use of the water apportioned to the State of New Mexico by Article III of this Compact, subject, however, to the following:

(a) A first and prior right shall be recognized as to:

(1) All uses of water made in either State at the time of the signing of this Compact; and

(2) All uses of water contemplated by projects authorized, at the time of the signing of this Compact, under the laws of the United States of America whether or not such projects are eventually constructed by the United States of America or by some other entity.

(b) The State of Colorado assents to diversions and storage of water in the State of Colorado for use in the State of New Mexico, subject to compliance with Article IX of this Compact.

(c) The uses of the waters of the San Juan River and any of its tributaries within either State which are dependent upon a common source of water and which are not covered by (a) hereof, shall in times of water shortages be reduced in such quantity that the resulting consumptive use in each State will bear the same proportionate relation to the consumptive use made in each State during times of average water supply as determined by the Commission, provided, that any preferential uses of water to which Indians are entitled under Article XIX shall be excluded in determining the amount of curtailment to be made under this paragraph.

(d) The curtailment of water use by either State in order to make deliveries at Lee Ferry as required by Article IV of this Compact shall be independent of any and all conditions imposed by this Article and shall be made by each State, as and when required, without regard to any provision of this Article.

(e) All consumptive use of the waters of the San Juan River and its tributaries shall be charged under the apportionment of Article III hereof to the State in which the use is made, provided, that the consumptive use incident to the diversion, impounding or conveyance of water in one State for use in the other shall be charged to the latter State.

**ARTICLE XV**

(a) Subject to the provisions of the Colorado River Compact and of this Compact, water of the Upper Colorado River System may be impounded and used for the generation of electrical power, but such impounding and use shall be subservient to the use and consumption of such water for agricultural and domestic purposes and shall not interfere with or prevent use for such dominant purposes.

(b) The provisions of this Compact shall not apply to or interfere with the right or power of any signatory State to regulate within its boundaries the appropriation, use and control of water, the consumptive use of which is apportioned and available to such State by this Compact.

**ARTICLE XVI**

The failure of any State to use the water, or any part thereof, the use of which is apportioned to it under the terms of this Compact, shall not constitute a relinquishment of the right to such use to the Lower Basin or to any other State, nor shall it constitute a forfeiture or abandonment of the right to such use.
ARTICLE XVII

The use of any water now or hereafter imported into the natural drainage basin of the Upper Colorado River System shall not be charged to any State under the apportionment of consumptive use made by this Compact.

ARTICLE XVIII

(a) The State of Arizona reserves its rights and interests under the Colorado River Compact as a State of the Lower Division and as a State of the Lower Basin.
(b) The State of New Mexico and the State of Utah reserve their respective rights and interests under the Colorado River Compact as States of the Lower Basin.

ARTICLE XIX

Nothing in this Compact shall be construed as:
(a) Affecting the obligations of the United States of America to Indian tribes;
(b) Affecting the obligations of the United States of America under the Treaty with the United Mexican States (Treaty Series 994);
(c) Affecting any rights or powers of the United States of America, its agencies or instrumentalities, in or to the waters of the Upper Colorado River System, or its capacity to acquire rights in and to the use of said waters;
(d) Subjecting any property of the United States of America, its agencies or instrumentalities, to taxation by any State or subdivision thereof, or creating any obligation on the part of the United States of America, its agencies or instrumentalities, by reason of the acquisition, construction or operation of any property or works of whatever kind, to make any payment to any State or political subdivision thereof, State agency, municipality or entity whatsoever, in reimbursement for the loss of taxes;
(e) Subjecting any property of the United States of America, its agencies or instrumentalities, to the laws of any State to any extent other than the extent to which such laws would apply without regard to this Compact.

ARTICLE XX

This Compact may be terminated at any time by the unanimous agreement of the signatory States. In the event of such termination, all rights established under it shall continue unimpaired.

ARTICLE XXI

This Compact shall become binding and obligatory when it shall have been ratified by the legislatures of each of the signatory States and approved by the Congress of the United States of America. Notice of ratification by the legislatures of the signatory States shall be given by the Governor of each signatory State to the Governor of each of the other signatory States and to the President of the United States of America, and the President is hereby requested to give notice to the Governor of each of the signatory States of approval by the Congress of the United States of America.

In WITNESS WHEREOF, the Commissioners have executed six counterparts hereof, each of which shall be and constitute an original, one of which shall be deposited in the archives of the Department of State of the United States of America, and one of which shall be forwarded to the Governor of each of the signatory States.

Done at the City of Santa Fe, State of New Mexico, this 11th day of October 1948.

CHARLES A. CARSON
Commissioner for the State of Arizona
Upper Colorado River Basin Compact of 1948

Appendix D

CLIFFORD H. STONE  
Commissioner for the State of Colorado

FRED E. WILSON  
Commissioner for the State of New Mexico

EDWARD H. WATSON  
Commissioner for the State of Utah

L. C. BISHOP  
Commissioner for the State of Wyoming

GROVER A. GILES  
Secretary

Approved:

HARRY W. BASHORE  
Representative of the United States of America

NOTES

Congressional consent to negotiations. --Section 19 of the Boulder Canyon Project Act (45 Stat. 1057, 1065), gave the Congress' consent 'to the States of Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming to negotiate and enter into compacts or agreements, supplemental to and in conformity with the Colorado River compact and consistent with this Act for a comprehensive plan for the development of the Colorado River and providing for the storage, diversion, and use of the waters of said river.' The consent was given "upon condition that a representative of the United States, to be appointed by the President, shall participate in the negotiations and shall make report to Congress of the proceedings and of any compact or agreement entered into." It was also provided that no such compact should be effective until "approved" by the legislatures of the States and by the Congress. See also Article VI of the Colorado River compact, p. 55 ante.


Congressional consent to compact. --Act of April 6, 1949 (63 Stat. 31, from which text of the Compact above set out is taken. For legislative history, see S. 790 and H.R. 2325, 81st Congress; Senate Report 39 (Committee on Interior and Insular Affairs) and House Report 270 (Committee on Public Lands), 81st Congress; 95 Cong. Rec. 2758-2762, 3036-3041 (1949); Public Law 37, 81st Congress. Printed hearings on H.R. 2325.

Related documents. --The report of the Federal representative is printed in Senate Document 8, 81st Congress. The Upper Colorado River Basin Compact Commission published, in mimeographed form, an undated three-volume Official Record of its proceedings, including the final report of its Engineering Advisory Committee and that Committee's "Inflow-Outflow Manual."


Animas-La Plata Project Compact. --Section 501, subsection (b), of the Act of September 30, 1968 (82 Stat. 885), which provides for construction of the Animas-La Plata Federal reclamation project, also provides that construction work shall not be begun until the States of Colorado and New Mexico have ratified a compact reading as follows:
"The State of Colorado and the State of New Mexico, in order to implement the operation of the Animas-La Plata Federal Reclamation Project, Colorado-New Mexico, a proposed participating project under the Colorado River Storage Project Act (70 Stat. 105), and being moved by considerations of Interstate comity, have resolved to conclude a compact for these purposes and have agreed upon the following articles:

"ARTICLE I"

"A. The right to store and divert water in Colorado and New Mexico from the La Plata and Animas River systems, including return flow to the La Plata River from Animas River diversions, for uses in New Mexico under the Animas-La Plata Federal Reclamation Project shall be valid and of equal priority with those rights granted by decree of the Colorado state courts for the uses of water in Colorado for that project, providing such uses in New Mexico are within the allocation of water made to that state by articles III and XIV of the Upper Colorado River Basin Compact (63 Stat. 31).

"B. The restrictions of the last sentence of Section (a) of Article IX of the Upper Colorado River Basin Compact shall not be construed to validate paragraph A of this article.

"ARTICLE II"

"This Compact shall become binding and obligatory when it shall have been ratified by the legislatures of each of the signatory States."

Neither State has yet (September 1968) taken the action required by this provision.
Appendix E

Alternative Futures Modeling Techniques:
A Futures Study on the Upper Colorado River Basin
Bioregional Planning Studio 2007-2008

Overview

- Project Work
  - Our team’s work began in June 2007 with data collection
  - Followed by Function and Structure of critical elements in Fall semester 2007
    - Three issues arose from Fall (biodiversity, Water, Energy)
  - Assessment models derived from primary issues Spring 2008
  - Alternative Futures occurring in late Spring 2008 (currently)
Basics on Assessment Models

- Tiered assessment models
  - Hierarchical tiered system (Tier 1, Tier 2, and Tier 3)
  - 12 assessment models total
  - Models developed through several techniques (contributory, dominance, and interaction rules)
- Assessment models form the backbone of our study
  - These models provide the foundation from which we create our future alternatives

Steps In The Process

1. Build all appropriate assessment models (land-use & other) and develop suitability raster grids for 7 land-uses
2. Create a “development” suitability and preference raster grids
3. Assign preference rankings for 8 land-use models
4. Compete “development” preference against 7 other land-use models
5. Compete each land-use model against the other 6 land-use models (excluding “development”) (7 competitions)
6. Determine the amount of “developed land” needed (57 counties)
7. Remove “developed land” from the output raster grids in “step 5”
8. Combine “developed lands” (step 6) with the other 7 land-use models (step 7)
9. Reiterate model with different preference values to create different alternative future scenarios (steps 2, 3, and 6)
LUCIS Modeling Technique: Power Point

Suitability Rankings:

**Step 1**
- Land-use assessment models (top right)
- Suitability (bottom right)
  - 0 – 5 ranking
  - Our tiered modeling system becomes re-ranked
    - Tier 1 = 5 (best)
    - Tier 2 = 3 (med.)
    - Tier 3 = 1 (low)
    - When no tier exists = 0 (not suitable)

This process is completed for seven Land-use assessment models
LUCIS Modeling Technique: Power Point

Appendix E

Development Suitability/Preference:

Step 2

- "Development" model combines suitability rankings and preference values
  - Suitability derived from 10 component maps
  - Rankings from 1 - 5
  - Coefficient values for all component sum to 1
- The output is a future specific "development" preference raster grid

Model Preference Rankings Land-use:

Step 3

- Preference rankings
  - A module to control priorities between differing future alternatives
- Eight suitability raster grids form components
  - Comes from step 1 & step 2: 7 land-uses & development
- Preference values sum to 1
- Assign land-use ID
  - Arbitrary, but unique, 1 – 8 value for tracking purposes

Example 3
Compete Development:

Step 4

- Compare the preference raster of “development” against seven other preference raster grids (cell to cell)
- At any cell where development’s preference value is greater than another grid’s cell preference value, substitute Land-use ID (ID)
- Sum “winning” development raster grids to produce a development “win” raster
  - Values only intervals of 7’s
  - Values 99 identifies where development never lost a competition

Compete Remaining Land-use Models:

Step 5

- Compete 7 remaining land-uses against each other
  - Excludes development from this competition
  - At any cell where the competing land-use preference value is greater than another cell’s preference value substitute in the competing land-use ID (6, 8)
  - Sum competed raster grids to produce a land-use specific “win” raster
  - Highest grid value chooses where land-use continually maintained a winning value and won each competition
Determining Land Consumed for Development:
Step 6 A
- Population projections
  - 57 Counties
  - Calculated three separate population projections
    - Linear Regression Projection (lowest)
    - Linear Projection (low)
    - Exponential Projection (high)
  - Indirect population projections from 1970-2000
- Current population: 2.9 million
- 2030 population
  - Linear Regression: 4.3 million
  - Exponential: 7.1 million

Determining Land Consumed for Development:
Step 6 B
- Simple equation for land area consumed
  - Land consumed = Population Projection/Density
- Calculated land area consumed from population projection for the 57 counties
- Equation gives total number of existing cells needed to accommodate 2030 population projections
- Population Allocation
  - Based on the needed cells from the linear regression population projection and the exponential population projection
Removal of Developed Lands:
Step 7
- Removal of developed land (step 6) from the 7 competed "winning" raster grids (step 5)
- Resulting output is land-use "winning" raster grids with no developed land
- This step gives us the 7 "winning" raster grids minus developed land, so that no overlap exists between land-use grids and the development grid

Combining Developed Lands and 7 Land-uses:
Step 8
- Simply combining the seven land-use minus development raster grids with the development raster grid
- No overlap is present within this raster grid
- Additionally, this method identifies conflict areas, where no land-use obtains a "winning" values against all other land-uses
Reiteration:
Step 9

- Reiteration is a critical component of this alternative future modeling process
  - Step 2: Changing the development preference values allows exploration of different development scenarios
  - Step 3: Changing the land-use preference values results in a different pattern of land-use
  - Step 6: Movement of population centers and changing density allows different land area consumption

- Changing these 3 steps provides an entirely different scenario

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Upper Colorado River Ecosystem – Alternative Future Study

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Conclusion

Pros

- Allows comparisons between futures
  - All land-use components are present in every future
  - Each assessment model provides a way to evaluate each future
- Determines primary land-use preference for each specific future
- Our approach is systematic and repeatable
- Identifies conflict areas where no land-use "wins" every competition

Cons

- Currently shows only primary land-use, i.e., no two land-use appear on the same ground
- Assumptions in population projections (indirect projections)
- Development land consumed currently does not distinguish between different residential types
- Scale limitations upon details