Chapter 2.
Alternative CRRP Configurations

Introduction

This chapter describes the three-phase process used to identify and evaluate alternative CRRP configurations and discusses major factors affecting the project configurations. Brief descriptions are then provided of the physical environment of the Colorado River basin as well as the tributary Gunnison and Yampa/White River basins in which CRRP facilities might be located. The chapter concludes with an overview of the decision support and geographic information systems developed by the State for these basins.

Three potential pipeline corridors, all of which begin on the Colorado River near the Utah State line are used in this study:

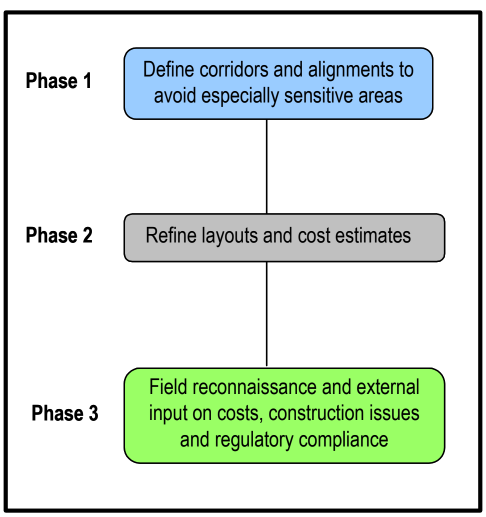
1) The Northern Corridor traverses the White/Yampa river basin before turning south into the upper Colorado River basin and on to the South Platte and Arkansas basins;

2) The Central Corridor extends up the Colorado River mainstem and its upper basin tributaries and on to the South Platte and Arkansas basins; and

3) The Southern Corridor traverses the Gunnison River basin before entering the Arkansas basin and extending on to the South Platte basin.

Three-Phase Evaluation Process

A three-phase process was used to formulate and evaluate CRRP infrastructure layouts for the three alternative delivery capacities.



The first phase of formulation and evaluation consisted of defining layout constraints and avoiding especially sensitive areas in locating facilities. These sensitive areas included existing Wilderness Areas, Wilderness Study Areas formally delineated in an on-going congressional process, and existing national parks and monuments. Other sensitive areas including national conservation areas and federal lands currently operated under special management restrictions were not eliminated from consideration in this first phase of formulation and evaluation. These areas were, however, considered in the subsequent phases as requiring special design considerations to minimize or avoid impacts or requiring further analysis in any studies subsequent to the CRRRS.

The second phase of formulation and evaluation consisted of refining the layouts considered in the first phase. These refinements included revisions to technologies being considered (e.g. alternative water treatment technologies); horizontal and vertical adjustment of the pipelines to improve the hydraulics and therefore, cost of construction; energy recovery (hydroelectric power production) and lessen environmental impacts. During this second phase, cost estimates for individual CRRP features were refined from the "rule-of-thumb" costs used in Phase I. In Phase II, costs per unit of construction (e.g. $ per million gallons per day of water treated, $ per inch-diameter per foot of pipeline construction, and $ per foot of tunnel construction) were supplemented with data from similar projects scaled to the potential sizes of the CRRP.

In the third phase of analysis, the alternatives were refined further. Technological considerations were considered in more detail and additional input was received independent of the consulting team formally retained by the state. This specialized input included the advice of contractors and manufacturers experienced in supplying and building major pumping stations, pipe and pipelines, tunnels, water treatment plants, and hydroelectric power plants.

In this phase, regulatory agency specialists were contacted to assure that the major issues have been identified and to solicit input on the required scope of any future studies.

Throughout the process, but especially for the third phase, members of the consulting team traveled the potential pipe alignments to the extent existing roads and public access permitted.

Factors Affecting CRRP Configurations

Presented below are major factors affecting the size, location, and type of facilities that would be required for the CRRP.

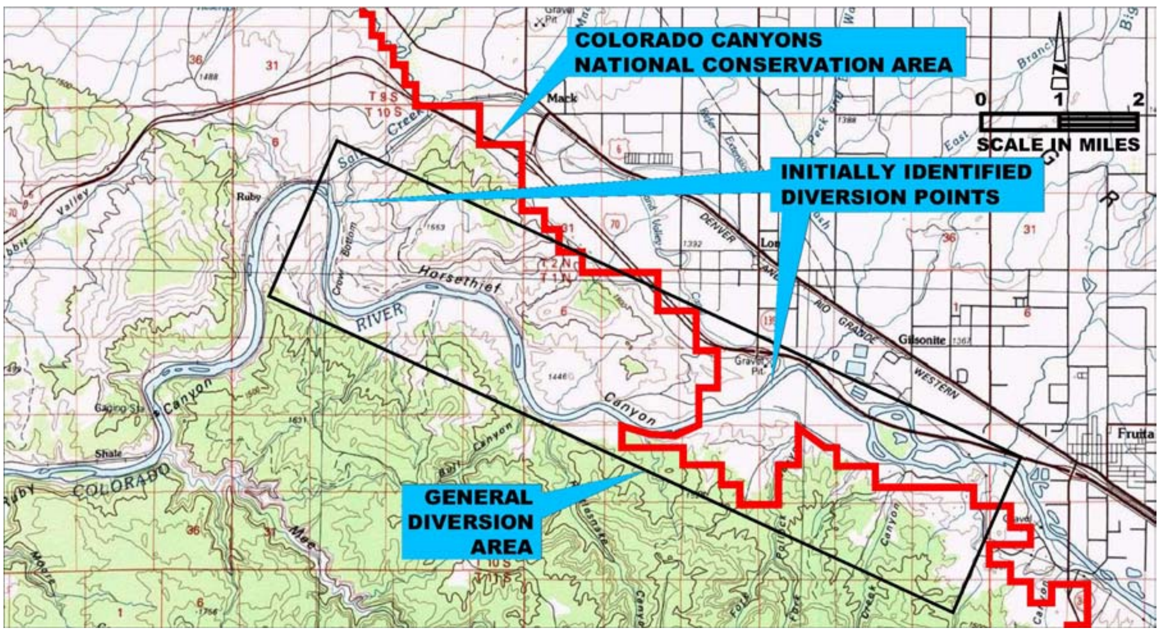
Delivery Capacity

Three annual average CRRP delivery capacities are evaluated in this study: 250,000, 500,000 and 750,000 af/yr. To deliver the full annual delivery capacity, the major facilities were planned to operate at slightly higher capacities to allow the facilities to be off-line for a period for routine maintenance and to account for unplanned outages, such as power failures. These higher design capacities would allow the CRRP to be out of service for a period of two weeks and still provide the full annual project delivery capacity. The following facilities were designed with this additional capacity: 1) Pumping stations; 2) Pipelines; 3) Tunnels and 4) Water Treatment Facilities.

Diversion Locations

It was determined by the state that the only diversion points to be considered at this time should be generally downstream of the last currently used water right on the Colorado River within the State of Colorado (downstream of Grand Junction). Based on this constraint, two potential diversion areas were identified for the CRRRS. The first diversion point is at the confluence of the Colorado River and Salt Creek in Horsethief Canyon. The second diversion point is located at the upstream end of Horsethief Canyon near the existing Loma Boat Launch. The area is shown in Figure 2-1. Diversion facilities are discussed later in Chapter 7. Any future studies should also consider other potential locations.

Figure 2-1: Diversion Areas



Existing Facilities

Opportunities may exist for reducing costs and/or enhancing performance of the CRRP through use of existing water storage and conveyance systems. However, the short duration of the CRRRS precludes analyzing the wide range of possibilities for integrating new facilities with existing facilities through revised operations. Furthermore, the scope of study did not allow face-to-face discussions between many potential operating partners and CWCB representatives, or review and comment on draft study findings. Initial discussions with owners of existing facilities indicated they are generally taking a wait and see approach to the CRRP. They typically want to see documentation on the CRRP's feasibility (namely this study) before they engage in discussions on how it may or may not compliment their water supply system.

Accordingly, this review of existing facilities suggests possibilities (and constraints) that can only be explored if the CRRP advances to more detailed analysis in future studies. Presented below are brief descriptions of major transmountain water conveyance projects. Awareness of these existing projects is helpful in conceptualizing future studies, if any are conducted.

- The **Colorado-Big Thompson Project's** main storage feature is Lake Granby, with an active capacity of approximately 466,000 acre-feet (af), supplemented by regulatory storage in Willow Creek Reservoir and Shadow Mountain/Grand Lake. Grand Lake is the site of the west portal of the Adams Tunnel, which has a capacity of 550 cubic feet per second (cfs). Water taken through the Adams Tunnel is delivered through a combination of natural channels, power penstocks, and pipelines to east slope storage or direct use. Natural channels used for delivery include the Cache La Poudre, Big Thompson, Little Thompson, and St. Vrain Rivers, as well as Boulder Creek and Left Hand Creek and the South Platte River. The Colorado-Big Thompson (C-BT) service area extends from Broomfield to north of Fort Collins, and as far east as the Colorado-Nebraska state line.

  Colorado-Big Thompson facilities have been used for storage and delivery of Windy Gap project water since the mid-1980's, on an "as available" basis. Yield to the Windy Gap project has been much more limited by the ability to move water to the east slope than by available water supply. Certain owners of Windy Gap supplies are considering various methods of enhancing their firm yield from their existing Windy Gap water rights. This would result in modifications to the timing of deliveries through the Adams Tunnel in order to realize the 48,000 af annual yield contemplated by the project's design, permitting, and water rights. With the development of the Windy Gap project, the Adams Tunnel began to run closer to capacity for longer periods than it did historically. It will do so even more when the storage project is completed, leaving little opportunity for delivering CRRP water. Furthermore, a delivery scenario involving the Colorado-Big Thompson project facilities only would not permit direct deliveries to the Arkansas basin. None of the entities that receive Windy Gap or C-BT water use Arkansas River water, so there are not opportunities for replacing or exchanging water to effectively increase supply in the Arkansas basin via the CRRP unless through more complicated exchanges likely involving major modifications to the current operations of the Moffat, Roberts, and/or Fryingpan-Arkansas projects discussed below. These "exchanges" would also likely require significant structural modifications.

- Denver's **Moffat Tunnel** system is unique among large transmountain systems in that it has almost no storage on the west slope that delivers directly to the tunnel. Meadow Creek Reservoir is physically connected to the tunnel and permits extension of deliveries after peak runoff, but its capacity is only 5,100 af. The Moffat Tunnel has a capacity of 1,360 cfs; however, it discharges to South Boulder Creek, which has a channel capacity of about 1,200 cfs. Water is stored in Gross Reservoir, from which it is delivered to Ralston Reservoir by way of South Boulder Creek and South Boulder Canal, and eventually to the Moffat Treatment Plant in Lakewood. Despite the channel limitations of South Boulder Creek, this delivery system has capacity to carry additional water during winter months, when neither the Moffat collection system nor South Boulder Creek flows are high. Since the potential delivery period is winter, when demands are low, seasonal storage would be required for CRRP water on the east slope. At this time, Denver Water is exploring additional east slope storage for water to which they currently have rights. In other words, the current Denver east slope storage would not be able to accommodate CRRP water.

- Denver's Blue River system diverts water to the **Roberts Tunnel** both directly and by way of storage in Dillon Reservoir. The decreed capacity for the tunnel is 788 cfs and the physical capacity is 1,020 cfs. The tunnel discharges to the natural channel of the North Fork of the South Platte River near Grant. From the east portal it flows to Strontia Springs

Reservoir on the South Platte mainstem, where it is taken into Denver Water's raw water delivery system for delivery to either Foothills or Marston water treatment plant. The practical limitation of the delivery system is channel capacity of the North Fork. It is 680 cfs at the east portal and increases to 980 cfs at the confluence with the main South Platte channel. Nonetheless, there is unused tunnel and channel capacity in fall and winter. East slope storage would be required if the CRRP was to deliver by way of the Roberts Tunnel.

A Roberts Tunnel delivery scenario does not allow for direct deliveries to the Arkansas basin. However, since Strontia Springs is also the site of Aurora's intake, and Aurora uses Arkansas River water, there is the possibility of exchanging water here. CRRP water could be delivered to Aurora in lieu of yield from their existing Arkansas projects. Average-year yield of Aurora's rights in the Arkansas basin is approximately 23,000 af. Aurora's yield in any given year represents an upper limit on what could be exchanged that year.

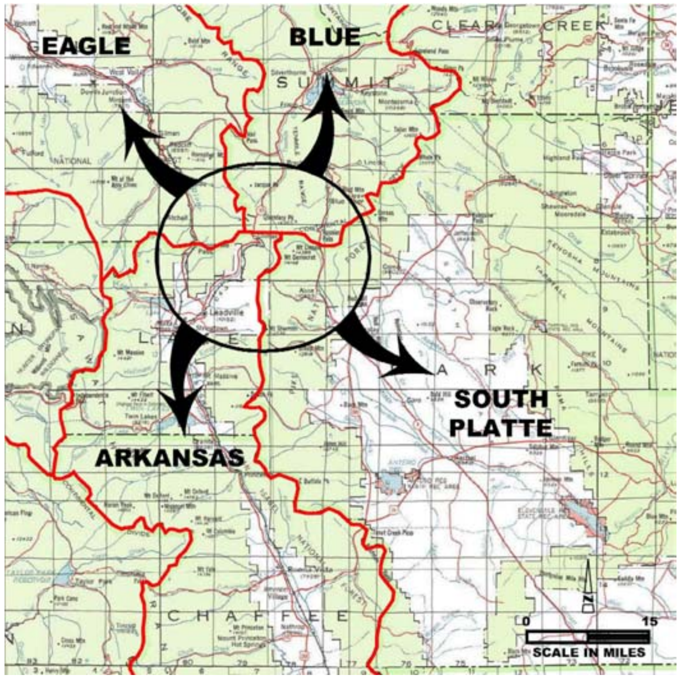
- The Colorado Springs Blue River (also known as **Continental Hoosier Project)** takes water from the upper Blue River drainage, very close to the Continental Divide, and delivers it to Colorado Springs by way of South Park, which is in the South Platte basin. Upper Blue Lake provides about 2,100 af of storage on the Blue River side. The Hoosier Tunnel, with a capacity of 360 cfs, delivers water to Montgomery Reservoir (capacity 5,100 af). From this point, water is delivered to Colorado Springs' storage facilities via the 70-mile long Montgomery Pipeline. Capacity of the pipeline is 30 cfs. The differences between the tunnel capacity and the pipeline capacity are regulated by Montgomery Lake. The Con-Hoosier Project has two sets of rights, one of which is senior to Green Mountain Reservoir, the other being junior to Green Mountain. The combination of some relatively senior rights and recent arrangements to divert ahead of Green Mountain under junior rights through a substitution agreement involving Wolford Mountain Reservoir means that the system generally operates at its 30-cfs capacity. There is little opportunity for using this infrastructure for delivering CRRP water to Colorado Springs and the Arkansas River below Fountain Creek, although the tunnel itself may have unused capacity during much of the year.
- The **Homestake Project** in the upper Eagle basin diverts from tributaries of Homestake Creek and conveys diversions to the Arkansas basin via the Homestake Tunnel. Homestake Reservoir (capacity 43,000 af) regulates flows between the diversions and the tunnel. The first phase of the project was developed in the 1960's; in the 1980's, the project's owners Aurora and Colorado Springs attempted to develop Phase II as contemplated in their water right decrees. They were unable to obtain Eagle County 1041 permitting, and the project has been in abeyance since then. Even though decrees allow tunnel flows up to 700 cfs, current carrying capacity of the structure is only 300 cfs. This is less than the smallest of three flow options considered in this study for the CRRP. Furthermore, access to the tunnel and its proximity to the Holy Cross Wilderness Area could be problematic.
- The **Fryingpan-Arkansas Project** diverts from the upper reaches of the Frying Pan and Roaring Fork Rivers, and delivers it to the upper Arkansas River, for municipal and irrigation use in the Arkansas basin. The project was designed for an average annual yield from the Colorado River basin of 69,200 af, with an upper limit in any single year of 120,000 af. As of the year 2000, annual diversions over the project history averaged approximately 49,000 af. There is no regulating storage on the west slope, so diversions occur only during the high runoff months. The Boustead Tunnel has a capacity of 945 cfs, which, based on perusal of

Annual Summaries of Operations for several recent years, is approached for short periods even when the total annual diversion is much below the design average. During most of the year, however, excess capacity exists. Upper Arkansas storage consists of Turquoise Lake and Twin Lakes, which have a combined capacity available to the Project of approximately 188,000 af. By contract, these facilities are also used by Aurora and Colorado Springs' Homestake Project. Both reservoirs are located above the Otero Pump station, which delivers water to the upper South Platte basin. In wet years, as in 1995, Fryingpan-Arkansas Project diversions can become limited by the available storage on the east slope. Use of the Fryingpan-Arkansas facilities by CRRP would allow deliveries to the Arkansas basin, although not during peak runoff, and probably not during certain wet years. Additional conveyance to reach the South Platte basin would be required, even if deliveries were being made to Aurora or Colorado Springs, as the Otero pumping pipeline is currently close to full utilization.

Delivery Areas

An advantageous termination point for the CRRP is the upper Eagle basin, where Eagle County, Summit County, Park County, and Lake County nearly meet, because, from this point, the CRRP could deliver water to the South Platte, Arkansas, and Colorado River basins (through deliveries to the Eagle and Blue River basins). Returning water into the Colorado system above Green Mountain Reservoir, Dillon Reservoir, and the rapidly growing population centers in Summit County offers the possibility of meeting both east and west slope needs in a variety of ways. Delivery alternatives that merit further study include the potential of making portions of the South Platte and Arkansas basin deliveries through existing facilities. With respect to the Denver metropolitan area, water could potentially be delivered both through the Roberts Tunnel and by way of the upper South Platte, offering redundancy and operational flexibility. The ability to move water into their large east slope reservoirs could be particularly valuable to the Denver area. Water could be delivered to the Arkansas basin via the river channel, with the possibility of Colorado Springs upgrading either their Montgomery pipeline or their Otero pump station and Homestake Pipeline.

Figure 2-2: Delivery Areas



In addition to the benefit of supplying several different areas, the ability to send the water several different directions from the termination point may resolve issues relating to conveyance capacity. For instance, capacity would probably be an issue even in the South Platte channel if the entire 1,000 cfs flow considered in the large CRRP option was directed there. Dealing with smaller flows creates the possibility of using natural channels and existing tunnels.

Finally, the Continental Divide swings west at the recommended area. In other words, the route from the Grand Valley to the upper Eagle basin is shorter than routes to the Continental Divide in the Colorado River headwaters, the upper Fraser River, or by way of the Blue River.

Alternatively, the Southern Corridor could deliver water from the diversion point near the Utah state line, traverse the Gunnison Basin, deliver water to the Arkansas Basin and continue on to the South Platte Basin. This would allow delivery to the Gunnison River, which is part of the Colorado River Basin, but would not allow physical delivery to the Upper Colorado River Basin.

Integration with Local Water Supply Projects

As noted above under “Existing Facilities”, coordination with water suppliers offers opportunities for reducing costs or otherwise enhancing CRRP’s ability to meet objectives efficiently, through non-structural options or elements within structural alternatives. This also holds true for local water supply projects on the West Slope as well as transmountain facilities. However, lacking the opportunity to involve project owners in this reconnaissance study, and given the typically complex operating rules, water right limitations, and agreements under which large projects operate, the CRRP alternatives identified in this chapter assume no integration with local water supply projects. Likewise, the technical and environmental analyses and estimates of probable cost presented in later chapters focus on the large scale structural options for utilizing Colorado's Colorado River Compact Entitlement. Chapter 8 presents concepts for future consideration under the assumption that any future arrangements would be between willing participants and facility owners only.

Conveyance Corridors

Once the diversion locations and the delivery locations were identified, the next step in the process was to identify routes between the two points. The shortest distance would obviously be a straight line between the two points and without considering other factors would result in the least construction cost. However, topography, obstacles (natural and manmade), environmental and other considerations can greatly increase the pipe length, unit cost of pipe fabrication and installation. These factors can make alternatives that vary from the straight line between the starting and ending point more economically attractive than the straight-line alternative.

Wilderness Areas preclude new construction and tunneling under these areas was not considered. All corridors considered in this CRRRS avoid currently designated Wilderness Areas.

Once the Wilderness Areas had been identified, the first corridor, identified as the Central Corridor was defined. This corridor generally follows Interstate I-70. The Central corridor includes the alignment that would be the straightest line from the diversion point to the delivery point.

Since the Central Corridor includes the potential obstacle of Glenwood Canyon, which is very narrow and heavily congested, additional corridors were identified in order to avoid this area. The North Corridor travels from the diversion points to an area just north of the Flat Tops Wilderness Area. Once past the Flat Tops Wilderness Area, the corridor travels south to the delivery points. While avoiding Eagles Nest Wilderness Area, the North Corridor provides for alternative routes around Glenwood Canyon and includes the farthest northward alternative that would meet the CRRP goals and provide reasonable comparison to the Central Corridor Alternatives.

The South Corridor was identified to also provide a reasonable alternative to Central Corridor Alternatives. The South Corridor travels south of the Little Bookcliffs Wilderness Area, before continuing east. The corridor stays south of the Oh-Be-Joyful and Collegiate Peaks Wilderness Areas and is mostly divided into two corridors by several Wilderness Areas in the middle of the corridor.

The locations of the North, Central, and South Corridors are shown in Figure 2-3.

Factors Affecting Pipeline Alignments

Within each corridor, a variety of specific alignments were evaluated. The alignments were identified with only enough detail to allow hydraulic and other calculations to be performed so that the corridors could be generally characterized. It is recognized that all of these alignments would be adjusted in future studies, if any are performed, to improve or optimize the alignment, considering technical, economic, environmental, land ownership, future uses, and other factors.

For each alignment, the major infrastructure components were identified. They include diversion structures, operational storage, treatment facilities, pipelines, tunnels, pumping stations, hydropower facilities, power transmission facilities, and ancillary facilities.

The following key principles have significant effects on the cost of the overall project and were considered during the initial identification of alignments:

Minimization of Pipeline Length

This principle is simply stated, without considering the impact of the other principles, that the longer the length of pipe, the more expensive the project cost. Therefore, alternatives that vary from the shortest distance between the diversion and delivery point were not considered unless specifically developed due to one of the other principles listed below.

Minimization of Total Pumping Lift

The minimum elevation difference between the diversion point at approximate 4,500 feet Mean Sea Level (MSL) and the point to which the water must be pumped would consist of a straight line in profile. However, the ground profiles rise and fall along all of the potential alignments. Decreases in elevation require either higher pressure pipe or additional pumping stations that increase the cost of the CRRP. Alignments were developed to minimize total pumping lift.

Proximity To Major Power Transmission Facilities

Multiple pumping stations are required along the alignments and opportunities for energy recovery through hydropower generation are present. These facilities require connection to major power transmission facilities. Major power transmission facilities were located, and the proximity to existing power transmission facilities was considered during alignment development.

Proximity To Major Roadways

Constructing pipelines in existing major highways or immediately adjacent to them can slow the construction progress resulting in additional costs and impacts to traffic flows. However, roadways are beneficial to construction as they provide routes for delivery of heavy construction equipment and materials, particularly pipe and pipe bedding material. Major roadways also aid in the transport of spoil materials from construction. Pipelines constructed in remote areas require additional costs to construct temporary or permanent roadways. Therefore, routes were identified that are relatively near to existing roadways, but do not assume that existing rights-of-way could be used.

Infrastructure Congestion

Construction of a pipeline this large requires large excavations and a large amount of space for construction activities. Pipeline routes that pass through developed areas will require demolition and reconstruction of infrastructure, including roads, structures and other utilities. Effort was made during route development to avoid congested areas.

Environmental Constraints

Areas that are known to be very environmentally sensitive to new construction were avoided, such as Wilderness Areas.

Maximum Tunnel Lengths and Cover

Based on observation of the topographic maps, relatively simple tunnels without major construction challenges were added to the alignments to minimize the pumping energy required and to avoid tight construction areas. Initially, tunnels were limited in length to 10 miles and in depth to 3,000 feet. During later stages of the CRRS longer and deeper tunnels were considered.

Maximum Single Stage Pump Lifts

Based on a survey of several pump manufacturers, a maximum practical total dynamic pumping head for each pump station at the capacities required was identified at approximately 1500 feet. Pumping equipment is available, or can be developed to deliver higher heads, however, there are additional costs for the higher pressures. Therefore, the total dynamic head of each pump station was limited to 1500 feet for this reconnaissance study.

Using 1500 feet as a maximum total dynamic head, the minimum number of pumping stations was included along the alignments. Each alternative was then reviewed and pumping stations were moved or added in obvious locations that would reduce the cost of the pipe. The same amount of effort during this process was expended on each alternative in order to provide a balanced improvement of each alternative. It should be noted that this process is a very cursory improvement of alternatives due to the large number of alternatives evaluated and short duration of the study. Within each alternative, additional pumping stations could be included that may result in a decrease in the overall project cost.

The cost of constructing additional pumping stations with smaller lifts would result in slightly higher costs. However, the cost of a single pump station is much less than the cost of pipe for the CRRP, and future studies, if performed, should optimize the number and size of the pump-stations for each alignment being studied.

Colorado Mainstem Basin

Basin Geography

The Colorado mainstem basin within the State of Colorado extends from its headwaters in Rocky Mountain National Park to the Colorado-Utah State line, about 30 miles west of the City of Grand Junction. The drainage basin at this point is approximately 17,700 square miles, of which approximately 7,800 square miles are attributable to the Colorado's largest tributary within Colorado, the Gunnison River. This section describes the physical setting of the remaining 9,900 square mile area.

The Colorado mainstem is approximately 230 miles long, flowing generally southwestward from the Continental Divide where numerous peaks and ridges exceed 13,000 feet in elevation. Resistant gneisses, schists, and granites form the core of these mountains, which are flanked by steeply dipping sedimentary rock. All the major tributaries join the Colorado from the south: in downstream order, the Fraser, Williams Fork, Blue, Eagle, Roaring Fork, and finally Gunnison Rivers. The basin is bounded on the north by the Rabbit Ears Range, dividing it from the North Platte River headwaters, and the Gore Range and Flattops, which delineate the White and Yampa basins. A little below the confluence of the Roaring Fork, the river crosses from the Southern Rocky Mountain physiographic province to the Colorado Plateau, and the mountains give way to plateau country. This part of the basin and west to the State Line is characterized by sandstones and siltstones, which have formed distinctive mesas bounded by steep cliffs. Some of the geologic layers here are of marine origin, featuring both bedded and disseminated sodium chloride, calcium sulfate, and clays with exchangeable magnesium and sodium. These salts are delivered to the river at mineral springs, and through runoff from high-energy thunderstorms.

The Gunnison River joins the Colorado at Grand Junction, so named for this confluence of the Gunnison and the river once referred to as the “Grand River” above this site. Elevation here is 4,500 feet. The alluvial plain forms the relatively broad Grand Valley, which slopes gently toward the State Line. The Colorado River leaves the state at an elevation of 4,325 feet.

The elevation difference from top to bottom of the basin – on the order of 10,000 feet – is responsible for great differences in climate across the region. The climate is alpine on the eastern and southeastern fringes of the basin, with perennial snowfields and annual precipitation above 40 inches. Prevailing air currents come from the west, losing much of their moisture on west-facing slopes and mountaintops as they are forced to rise. Most of this precipitation occurs in the winter, and above 8,000 feet, snow generally accumulates without melting until spring or summer. The high valleys and parks can experience strong temperature inversions on calm, clear winter nights. Temperatures below -30˚ F occur several times each winter in the Fraser and upper Eagle Valleys, and subfreezing temperatures are possible in every month of the year.

The Grand Valley’s climate, by contrast, has been described as semiarid to arid. Winter temperatures are mild with many sunny days, and from 1974 to 1996, Grand Junction averaged 175 days above freezing during the growing season. These factors account for the fruit-growing established here a little after the turn of the century. June is the driest month, and near the Utah border, summer and early autumn can be the wettest time of the year. In some places, contrasts in climate occur across an extremely small distance. Annual precipitation atop the Grand Mesa at 10,000 feet averages over 40 inches, while 30 miles away in Grand Junction; average annual precipitation is about 8 inches.

Vegetation types in the Colorado River basin reflect variations in elevation and climate. Generally, alpine communities are present above 11,500 feet, along the Continental Divide and Elk Mountains on the southeastern edge of the basin. The mixed coniferous forest ranges from 6,000 feet to treeline, although composition and appearance changes with elevation. Englemann spruce and subalpine firs predominate above 9,000 feet, while Douglas fir and, to a lesser extent, ponderosa pine predominates below 9,000 feet. Lodge pole pine thrives from 7,500 feet to 11,000 feet where fire, wind, or avalanche has disturbed the forest. The basin represents more or less the southern limit of the lodgepole pine’s expansive natural range. Aspen also appears through wide elevation ranges, occurring in extensive forests, small groves within the coniferous forest, along riparian corridors, or in transitional zones between forest and shrub or meadowland.

Middle Park, the mountain valley that occupies much of Grand County, lies within the elevation ranges listed for forest, but hosts a mountain grassland ecosystem. Grasslands and meadows tend to develop where low precipitation, cold temperatures, and fine-textured soils discourage growth of trees. The herbaceous communities give way to sagebrush shrublands as one moves down the basin, including the lower Blue River and Muddy Creek valleys. Conspicuously missing from Middle Park are Gambel oak and mountain mahogany which generally thrive between 7,000 and 8,500 feet. They appear along the walls of Glenwood Canyon, however, in the Roaring Fork Valley, and on the western slopes of the Grand Mesa.

At their lower limit the mountain shrublands interface with pinon-juniper woodlands and semi-desert scrub. Pinon pine dominates higher elevation forests, while the more drought-tolerant juniper dominates at lower elevations. Greasewood and/or saltbush is the primary species of the semi-desert scrub community which predominates the Grand Valley below Grand Junction.

Land Use and Resources

According to the USGS, 85 percent of the combined Colorado and Gunnison River drainages are forest and rangeland. Most of this is under federal management. Livestock production is the main use of this land.

Recreation, especially represented by ski areas on National Forest tracts, is an economically significant land use of the “forest” category. Eight major ski areas attract destination visitors from the remainder of Colorado as well as out-of-state, and several smaller areas serve more local visitors. Boating, fishing, hunting, whitewater sports, mountain biking, and scenery and wildlife viewing attract summer and fall visitors as well. According to a recent study, 38 percent of total income in Summit County is directly related to tourism and recreation (Goldsmith, et. al., 2001). The hot springs at Glenwood Springs draws visitors throughout the year.

Cropland is concentrated in the lower basin below Palisade, where the combination of water supply, long growing season, and alluvial soil provide favorable growing conditions for fruit, vineyards, alfalfa, beans, corn, oats, barley, potatoes, and wheat. According to the Bureau of Reclamation, the Grand Valley Project serves approximately 42,000 acres in this area. The more senior Grand Valley Irrigation Company serves 27,000 acres and Redlands Canal serves 2,900 acres (Boyle Engineering Corporation, 2000. [CDSS]), for a total of 72,000 irrigated acres below Palisade. Numerous irrigated lowlands in the mountain parks and alluvial valleys of the upper basin are devoted to hay crops, which support ranching.

The Blue, Eagle, and Roaring Fork Rivers drain metal-mining regions that figured prominently in the history of white settlement of Colorado. In addition to the traditional precious metals, molybdenum, vanadium, copper, nickel, uranium, lead, and zinc have been mined in the basin. The sedimentary formations of the central and western side contain oil, coal, oil shale, and natural gas. Federal oil shale reserves are located along Parachute Creek near Rifle and are recognized as the largest reserves of that type in the world. Mining is cyclical and currently represents a relatively minor portion of the basin economy

Urban land constitutes a very small land use in the basin.

Water Resources

Hydrology of the Colorado River is snowmelt-driven, with most of the annual flow occurring in two to three months of the year. During the remainder of the year, flows are relatively stable, although thunderstorm runoff from the western plateaus contributes spikes to the summer hydrograph. Late summer flows are sustained by reservoir releases from the Aspinall Unit of the Colorado River Storage Project, delayed return flows from irrigation use, and melting of perpetual snow fields. Annual flow at the state line averages 4.6 million af per year (Colorado Division of Water Resources, based on 1999 United States Geological Survey (USGS) and Department of Water Resources (DWR) Water Data Reports).

Water quality in the basin is generally good but degrades in a downstream direction. The river is subject to elevated salinity levels due to naturally occurring springs and agricultural use on saline soils. It has been estimated that mineral hot springs contribute 15 percent of the total salinity in the basin (USGS 1996). Diversion of large volumes of high quality water in the headwaters removes their diluting potential, resulting in higher salinity in the lower basin than there would otherwise be. Mining activity in the upper Eagle River is responsible for metals contamination in that tributary. The Colorado Water Quality Control Division in 1989 identified contamination of the alluvial supply immediately below Rifle, related to now inactive uranium processing. Phosphorus is generally low throughout the basin. Nitrates are also low except in the Grand Valley. The combination of erodible sedimentary geology and high-energy thunderstorms in the western part of the basin results in large sediment loads (USGS, 2001).

The most significant groundwater reserves lie in unconsolidated deposits in the river valley bottom and adjacent, higher terraces. These are most extensive north of Granby (the Kawuneeche Valley), near Kremmling, near Rifle, and in the Grand Valley from Palisade to Fruita. The Kawuneeche Valley's status as National Park land and the rural character of the land outside the park have precluded its development. Generally, alluvial well depths range from 25 to 150 feet, with yields of 10 to 800 gallons per minute (gpm). Large alluvial well yields have been reported at Silt and at DeBeque. The Colorado Groundwater Atlas identifies the geologic basins underlying Middle Park and the Eagle Basin as containing significant bedrock aquifers. To date they have been tapped primarily for stock, domestic, and commercial uses. Well yields range from five to several hundred gpm, but this variability reflects wide variation in well depth as well as aquifer characteristics. Groundwater plays a modest role in the Colorado mainstem basin's water supply. Both the ready availability of good quality surface water and the lack of highly transmissive aquifers worked against development of the groundwater resource. On the other hand the resource has long been important for rural domestic use and more recently for municipal use, as most of the cities located on the river have wells in the alluvium.

The basin's water resources, and primarily the surface water, supports an internal population of approximately 234,000 (http://cwcb.state.co.us/Fact_Sheets/Colorado/Page 0001.htm), and contributes to agricultural production and municipal needs of 3.5 million people on the Front Range. From 450,000 to 600,000 af of water are diverted to the East Slope each year (http://cwcb.state.co.us/Fact_Sheets/Colorado/Page 0001.htm). Agricultural use accounts for approximately 90 percent of water consumption within the basin, irrigating approximately 266,500 acres of land (CDSS, based on 1993 imagery). Non-consumptive diversions for hydropower generation at the Shoshone, Grand Valley, and Molina Power Plants average about 1 million af/yr (Boyle Engineering Corporation, 2000 [CDSS]). Other commercial uses of water include snowmaking, stock watering, and recreation.

Average annual consumptive use in the Colorado basin was estimated as follows for the period 1986-1990. The investigation was done under CDSS, following the Bureau of Reclamation's approach and reporting periods for their 5-year consumptive uses and losses reports are shown below in Table 2-1 (http://cdss.state.co.us/ftp/products/cu/data/culoss/culossapp.pdf):

Table 2-1: Consumptive Use (CU) and Loss for the Colorado basin

Use Category	Annual CU (1000 af)
Reservoir evaporation	45
Irrigation[1]	403
Stockpond evaporation and livestock use	1.9
Mineral resources	0.8
Thermal electric power generation	0
Other [2]	9.2
Exports	491
TOTAL	951

[1] based on 266,500 acres for reporting period

[2] includes municipal, domestic, and other industrial uses

Probable future uses of water in the Colorado basin reflect the basin's growth and recreational economy, and the East Slope's continuing development of their West Slope water rights. For instance, the Municipal Subdistrict of the Northern Colorado Water Conservancy District is currently pursuing storage in order to "firm" supply diverted by the Windy Gap project. Historically, diversions have been limited by available capacity in Granby Reservoir and the conveyance facilities to the East Slope. The Windy Gap Firming Project seeks to realize the 48,000 af/yr they have been decreed and for which permits have been issued.

Similarly, Denver Water is exploring possible methods to improve the reliability of their Moffat Collection system, and to more fully use existing rights. For the purposes of the Upper Colorado River Basin Study (UPCO), Denver Water estimated that, with the new storage and full use of their system, Roberts Tunnel diversions would increase from 70,500 af/yr to 118,600 af/yr, and Moffat Tunnel diversions would rise from 63,600 af/yr to 67,400 af/yr.

The scope of the UPCO study was Grand and Summit Counties, and water providers throughout the area were active participants in the project. Collectively, they estimated additional annual demands of 21,000 af at full buildout of their service areas. Computer modeling indicated there would be shortages of approximately 1,600 af/yr to the municipal suppliers under full buildout on the West Slope and the Denver and Windy Gap demands described above. The UPCO participants also identified a need for minimum instream flows to maintain the quality of recreation experience that attracts tourists and visitors to the area. Under future scenarios, these minima could not be met in the Colorado mainstem below Windy Gap and the Blue River below Dillon during parts of many years (Hydrosphere Resources Consultants, Inc., 2003).

Recreational use as identified in the UPCO study has a peculiar character with respect to water rights. While use of instream flows for boating may be an important component of the local economy, recreational users have not had water rights protection in the past. In 1992 the Colorado Supreme Court held that entities may obtain instream flow rights if they control the water to serve that purpose. Subsequently, several municipalities have filed for water rights for boat chutes and kayak courses, including Breckenridge, Vail, and Aspen. These uses of water would have been unanticipated a decade ago, but now represent potential limitations on future development in local areas.

Finally, numerous conditional rights for oil shale development in the lower basin remain in good standing. The largest oil shale reserves in the world are believed to be beneath the White and

Colorado River basins, and their processing will require water. The future rate of consumptive use associated with that industry is highly uncertain, as it will depend on economics and political trends which are global in scope.

Gunnison River Basin

Basin Geography

The Gunnison River basin is approximately 7,800 square miles in area, and ranges in elevation from over 14,000 feet to 4,550 feet at Grand Junction. The Gunnison River begins at the confluence of the East and Taylor Rivers, about 10 miles upstream from the City of Gunnison. These tributaries have their headwaters in the Elk and West Elk Mountains to the north and the Sawatch Range to the east. Cochetopa and Tomichi Creeks, flowing out of the Cochetopa Hills and San Juan Mountains to the south, join the river at Gunnison. Shortly downstream, the river has carved the narrow, steep-sided Black Canyon, a 53-mile long feature, through the Precambrian basement rocks of the Gunnison Uplift. The upper end of the canyon contains the reservoirs of the Aspinall Unit, but below this feature of the Colorado River Storage Project, 14 miles of the canyon are preserved as the Black Canyon of the Gunnison National Park.

Below the canyon, the river crosses into the Colorado Plateau physiographic province, characterized by sedimentary geology, broader valleys, and erodible soils. Here the North Fork of the Gunnison joins the mainstem which turns west, skirting the south side of the Grand Mesa, one of the largest “flat-topped” mountains in the world. Separating the Gunnison basin from the mainstem Colorado, the Grand Mesa rises a vertical mile to 11,000 feet, providing dramatic variation in climate and vegetation over a short distance.

The Uncompahgre River is the last major tributary to the Gunnison. It rises among 13- and 14,000-foot peaks in the vicinity of Ouray and flows nearly due north. Near the small town of Colona, the river valley opens up forming a relatively broad alluvial plain that extends about 35 miles to the confluence with the Gunnison. The Uncompahgre Plateau, a 70-mile long geologic uplift formation running southeast to northwest, bounds the Uncompahgre valley and lower Gunnison basin on the west.

Climate varies greatly across the Gunnison basin, because of the great variation in elevation. The high mountain headwater areas receive over 40 inches of precipitation annually, mostly as winter snowfall. Precipitation on the Uncompahgre Plateau and Grand Mesa ranges from 25 to 40 inches per year. The lower Uncompahgre Valley near Delta receives as little as 8 inches per year with that precipitation predominately as summer thundershowers. The upper Gunnison and Uncompahgre basins experience cold winters, with the City of Gunnison being subject to temperature inversions and nighttime temperatures below –30 degrees Fahrenheit. Temperatures as low as –60 degrees Fahrenheit have been recorded at Taylor Reservoir. The lower basin, however, is characterized by mild winters, hot summers, low humidity, and plenty of sunshine. The growing season ranges from approximately 70 days at Gunnison to 175 days at Grand Junction.

Vegetation in the Gunnison basin, like climate, varies with elevation. The highest headwater regions are above treeline and are therefore either barren or support only tundra. Above 8,000 feet, mixed conifer forest can be found. Generally, Douglas fir dominates at lower elevations and gives way to subalpine fir and Engelmann spruce at higher elevations. Aspen occurs across a wide range of elevations, and forests of lodgepole pine are common in the northern half of the basin. Mountain grasslands, composed of abundant perennial bunchgrasses mixed with forbs, are generally found between 7,500 and 8,500 feet in elevation. While grasslands occur in uplands, mountain meadows occur in drainages, and are characterized by herbaceous plants, grasses, sedges and rushes.

The sagebrush-steppe community is prevalent from 7,500 feet to 9,000 feet elevation in the upper Gunnison basin, where the lack of pinon-juniper woodlands is notable. This latter community, including several species of sagebrush, is abundant between 6,000 and 7,500 feet on the Uncompahgre Plateau. It can also be found on isolated mesas and on the valley fringes in the Lower Gunnison valley. Below this zone, semi-desert and desert shrubs (saltbush, greasewood, and rabbitbrush) are predominant, although riparian woodlands line natural and irrigation drainages.

Land Use and Resources

The USGS reports the following land use categories for the Upper Gunnison basin, defined as the basin above Crystal Reservoir (USGS, 2002):

Forest	57 percent
Rangeland	32 percent
Tundra	7.8 percent
Agriculture	2.3 percent
Urban	0.14 percent

Considering the entire Gunnison basin, forest and rangeland are still predominant, as the lower basin includes large tracts of the Uncompahgre, Grand Mesa, and Gunnison National Forests as well as lands managed by Bureau of Land Management (BLM). However, agriculture is a much larger land use in the lower basin. It is reported that 38 percent of Delta County is in agricultural use (Hammer, Siler, George Associates, 2003). This includes lands under the Uncompahgre Project, which irrigates 76,000 acres in Montrose and Delta counties combined . The fruit-growing area near Hotchkiss and approximately 14,000 acres of irrigated hay, fruit, corn, and small grains in the Tongue and Surface Creek drainages (PRC Engineering, 1986) lie outside the Uncompahgre Project. Irrigated area varies by year and has been variously estimated for the entire Gunnison basin between 235,000 (http://cdss.state.co.us/ftp/products/cu/data/culoss/culossapp.pdf) and 270,000 acres (CDSS unpublished data for 1993, personal communication with Erin Wilson, Leonard Rice Consulting Water Engineers). Urban land represents only a small portion of land use in the Gunnison basin.

Silver mining first drew permanent populations of white settlers to the upper Gunnison basin in the mid-to-late 1800's. Silver mining in the basin is currently dormant, but coal mining represents a small but viable part of the basin's economy. Mines are located in the North Fork valley near the communities of Somerset and Paonia. Subject to economic cycles, coal-mining activity has been generally increasing since the early 1990's (Hammer, Siler, George Associates, 2003).

Recreational resources of the Gunnison basin include the river itself, which attracts anglers, kayakers, and rafters to the upper tributaries particularly. The Curecanti National Recreation Area, which encompasses Blue Mesa, Morrow Point, and Crystal Reservoirs, and Black Canyon of the Gunnison National Park are federal recreational destinations. Visitation in 2002 is given by the National Park Service as over 892,000 for the Curecanti NRA and 174,000 for the Black Canyon. Crested Butte ski area has contributed greatly to Gunnison County's winter economy and growth of tourism in general. According to the ski area website, Crested Butte had approximately 340,000 skier days in each of the 2001-2002 and 2002-2003 ski seasons. The mountains around Ouray offer incomparable scenery and backcountry for photographers, hikers, and other outdoor enthusiasts. Thus recreation and tourism represent a significant part of the basin's economy. According to the USGS, recreation is the major employer in Gunnison County, followed by education (Western State College), and then ranching (USGS 2002).

Water Resources

Hydrology of the Gunnison River is snowmelt-driven, with most of the annual flow occurring in two to three months of the year. Late summer flows are sustained by reservoir releases, delayed return flows from irrigation use, and melting of perpetual snow fields. Annual flow at the confluence with the Colorado River averages 1.9 million af/yr, or 41 percent of the State Line flows. (Colorado Division of Water Resources, based on 1999 USGS and DWR Water Data Reports).

Water quality in the upper Gunnison basin (i.e., above Crystal Reservoir) is generally good, with temperature, dissolved oxygen, and pH within Colorado stream standards. Ammonia and nitrate concentrations are generally low, although below Crested Butte and Mount Crested Butte, ammonia concentrations rose between 1995 and 1999. Cadmium, copper, lead, manganese, and zinc concentrations have exceeded stream standards near the town of Crested Butte and above Lake City on Henson Creek. These elevated levels have been attributed to the effects of historical mining. (USGS, 2002).

Compared with the upper Gunnison basin, the lower basin exhibits more water quality issues from both natural and human causes. Red Mountain Creek, an upstream tributary of the Uncompahgre River, is affected by acid mine drainage (http://water.usgs.gov/pubs/of/ofr94-102/pdf/ofr-94-102.pdf). High concentrations of selenium arise from naturally occurring sources, but heavy irrigation in the Uncompahgre Valley exacerbates the problem. Selenium concentrations in the Gunnison and Uncompahgre Rivers exceed United States Environmental Protection Agency (USEPA) criteria for protection of aquatic life, and may be of concern for fish and water fowl. Irrigation and related agricultural activity in the Uncompahgre valley are also responsible for elevated levels of nitrates in that area. The combination of erodible soils and summer storm precipitation in the lower basin produces high suspended sediment as well as salts. These generally increase in a downstream direction from the eastern edge of the Colorado Plateau to the Gunnison River's mouth (http://water.usgs.gov/pubs/of/ofr94-102/pdf/ofr-94-102.pdf).

The most prolific aquifers in the Gunnison basin are Quaternary alluvial and glacial deposits. Significant alluvial deposits occur in limited reaches along the streams above Blue Mesa Reservoir, in the Uncompahgre River valley, and in the drainages of the Grand Mesa. Glacial, landslide, and slope talus deposits can be found in the mountainous fringes of the basin, as in Taylor Park. Alluvial deposits range in thickness from 10 to 200 feet, although thicknesses less than 100 feet are typical along the major streams. Potential well yield is characterized as 5 to 100 gpm in the alluvial aquifers, with yields between 20 and 40 gpm being more common. Where alluvial deposits overlie less permeable formations, the aquifers discharge to the surface as springs. The Towns of Crawford and Paonia get their water supplies from springs; the Crawford spring is reported to flow at over 100 gpm (Colorado Ground-Water Association, 2000). Quality of water from the alluvial aquifers is generally good, although there are limited areas where human activity has degraded the aquifers. For instance, irrigation returns in the Uncompahgre valley have raised nitrate levels in the area, and high radium concentrations associated with uranium mining and milling have occurred in shallow aquifers in Montrose County (http://co.water.usgs.gov/nawqa/ucol/Intro.html).

Bedrock aquifers underlying the Gunnison River basin include the Mesa Verde aquifer, the Mancos shale, the Dakota, Morrison, and Entrada aquifers, and Precambrian crystalline bedrock. There has been limited development of these sources, as they generally produce less water and are more prone to quality issues than the alluvial aquifers. Iron and manganese in bedrock groundwater often exceed Colorado drinking water quality standards. Mineralized areas in the upper basin may contribute trace metals to groundwater, and pyrite in the Mancos shale is known to contribute selenium to the groundwater. Water in the Mancos shale is also very high in dissolved solids.

Alluvial and bedrock aquifers in the Gunnison basin provide only 1 percent of the water use in the basin. In addition to Crawford and Paonia mentioned above, Gunnison, Lake City, Orchard City, and Ridgeway, rely on ground water for public supply, but the majority of public supply is from surface water (Colorado Ground-Water Association, 2000). As in the Colorado River basin, the ready availability of surface water and its lower total dissolved solids (TDS) has relegated groundwater to a minor role.

Surface and groundwater resources support a population of approximately 79,300 (http://cwcb.state.co.us/Fact_Sheets/Gunnison/page0001.htm). Exports from the basin are not significant if one discounts the Redlands Canal. The Redlands diversion is two miles from the mouth of the Gunnison River, and delivers water to nearby lands which technically lie in the Colorado mainstem basin. To date, there are no major headwater diversions across the Continental Divide although several projects have been contemplated. Agricultural use accounts for the majority of water consumption within the basin. Over 25 percent of the irrigated lands are served by the Gunnison Tunnel, which diverts over 300,000 af/yr out of the Gunnison River and into the tributary Uncompahgre basin.

Average annual consumptive use in the Gunnison basin was estimated as follows for the period 1986-1990. The investigation was done under CRDSS, following the Bureau of Reclamation’s approach and reporting periods for their 5-year consumptive uses and losses reports are shown in Table 2-2 (http://cdss.state.co.us/ftp/products/cu/data/culoss/culossapp.pdf):

Table 2-2: Consumptive Use and Loss in the Gunnison basin

Use Category	Annual CU (1000 af)
Reservoir evaporation (excludes Curecanti Unit)	13.0
Irrigation[1]	343.1
Stockpond evaporation and livestock use	3.4
Mineral resources	0.3
Thermal electric power generation	0.
Other [2]	4.1
Exports	0.
TOTAL	363.9

[1] based on 235,600 acres for reporting period

[2] includes municipal, domestic, and other industrial uses

Yampa/White River basins

Basin geography

The Yampa River basin within Colorado is approximately 7,660 square miles in size, ranging in elevation from 12,200 feet in the headwaters near the town of Yampa to 5,600 feet in the vicinity of Dinosaur National Monument. The Yampa River begins at the confluence of the Bear River, which drains the Flattops to the west, and Chimney Creek, which comes out of the northern end of the Gore Range to the east. Headwater elevations are 11,000 to 12,000 feet, somewhat lower than elevations characteristic of the Colorado and Gunnison basins. The Flattops comprise the northern extent of the White River Plateau. Volcanic activity followed uplift of the plateau, and enormous basalt deposits have protected the plateau from erosion. From the Bear River/Chimney Creek confluence, the Yampa River flows generally northward through irrigated valley farmland until it reaches Steamboat Springs. Here the river turns west, gathering flows from Elk River, Elkhead Creek, the Williams Fork River, and the Little Snake River. The Little Snake River is a significant tributary which rises in southern Wyoming and Colorado, near the Wyoming border. The lower end of the Yampa River passes through dry rangeland and into Dinosaur National Monument, where it becomes a meandering desert river. It flows through a scenic sandstone gorge of its own making and joins the Green River at Echo Park, a grassy meadow set among sandstone cliffs.

The White River basin lies between the Colorado River and Yampa basins. Like the Yampa River, the White River is part of the larger Green River drainage, but does not reach the Green until it has traveled into Utah. The basin within Colorado is approximately 2,600 square miles. The North and South Forks each begin in the highlands of the Flattops formation at about 11,000 feet, and flow west, meeting near Buford shortly outside the White River National Forest. The valley opens up here and continues west, picking up Piceance Creek and Yellow Creek, which rise on the Roan Plateau to the south. At Rangely, the White River is on the fringe of the Colorado Plateau physiographic province. Here the terrain is typical of that province, with impressive mesas, cliffs, and rims. The White River enters Utah about 20 miles west of Rangely.

The Northern Corridor for CRRP coincides with the southern portion of the White River basin, encompassing the Piceance Creek basin and skirting the Flattops on their northwest and north sides. The corridor includes a relatively small part of the Yampa basin, all above Steamboat Springs, and re-enters the Colorado basin east of this area, at Egeria and Muddy Creeks.

Climate in the Yampa and White basins is similar to the other western Colorado basins, varying with elevation. Average annual rainfall varies from more than 60 inches near Rabbit Ears Pass, and over 40 inches in the Flat Tops, to approximately 10 inches near the State line. Temperatures generally vary inversely with elevation, and variations in the growing season follow a similar trend. Steamboat Springs has an average growing season of 86 days, while the growing season at Craig, Hayden, and Maybell has been estimated at approximately 120 days (Smith, et. al., 1998). Winter brings snow and cold temperatures at the higher elevations but mild, sunny days in the west.

Lacking elevations over 12,500 feet, the upper Yampa and White River basins have little land above treeline. The upper limits of the northern Gore Range and the White River Plateau are instead parklike, with large open meadows interspersed with aspen or coniferous forests. Engelmann spruce and subalpine fir are the dominant forest cover at higher elevations, while lodgepole pine and Douglas-fir are conspicuous at lower elevations. Between 7,500 and 9,000 feet, as on the western flanks of the Flat Tops and in the Piceance basin, mountain shrubland typified by Gambel oak and sagebrush-steppe communities dominate.

Land Use and Resources

In contrast to the Colorado and Gunnison basins, precious metals mining has never been a significant activity in the Yampa and White basins. As a result, fewer roads penetrate the back country, and the tailings piles and diggings scars evident elsewhere in Colorado are not seen in these basins. Mineral resources are present, however, in the form of coal, gas, and oil. The Roan Creek Plateau and Piceance Creek basin host some of the largest oil shale deposits known, and received a great deal of attention in the early 1980's during Colorado's "energy boom." In this basin, so many conditional rights are held for oil shale use that some concern has been expressed about the impact of their eventual development on more junior CWCB instream flow rights.

Traditional methods of extracting oil and gas have been used in the White River basin for decades, and BLM routinely grants permits to drill on land they administer within the White River Resource Area. In 1997, mining and extraction industries accounted for 36 percent of Total Personal Income in Rio Blanco County, and 14 percent of employment (www.wilderness.org/library/documents/economicprofile_coloradocounties.cfm). Coal mining has been an important activity in the Yampa basin for the last century. In 1996, the Yampa basin produced 60 percent of all the coal produced in Colorado. At that time mines were located near Oak Creek, in the upper Yampa basin, and in the vicinity of Craig. Mining employment has remained stable even as productivity has increased, due to new efficiencies in mining methods (BBC Research & Consulting, 1998). Availability of coal in the Yampa basin gave rise to two thermal electric generating plants, at Craig and at Hayden. These two plants account for a significant portion of the consumptive use of water in the Yampa basin.

Recreational assets are abundant in the Yampa and White River basins. Since the 1970's, the dominant tourist draw in Routt County has been the Steamboat Ski Area. Skier visits over the last nine years have averaged 1.0 million (http://www.coloradoski.com/Media/01_02SV.pdf), and have brought both out-of-state and international visitors to the area. Summertime tourism has been successfully marketed in the last decade, with fishing, rafting, bicycling, camping, boating, and horseback riding drawing visitors. The City of Steamboat Springs recently opened the Haymaker golf course to complement other summertime activities, and summer weekend festivals and events fill the calendar. Recreation in the lower Yampa basin (Moffat County) and the White River basin attracts a somewhat different kind of tourist. Hunting and fishing are primary draws, as this area includes some of Colorado's best elk hunting (BBC Research & Consulting, 1998). The Town of Meeker's website asserts that their population doubles during hunting season, and the Colorado Division of Wildlife estimated that in 1996, out-of-state hunters and anglers spent $9.7 million in Rio Blanco County (www.wilderness.org/library/documents/economicprofile_coloradocounties.cfm). Dinosaur National Monument on the lower Yampa River, reported 300,000 recreational visitors in 2002 (http://www.nps.gov/dino/pphtml/facts.html).

Agriculture has long been a staple of the Yampa basin economy, with an estimated 1.8 million acres in farming and ranching in 1992. Livestock production is the primary activity. Irrigated acreage was estimated under CDSS as 80,600 acres in the Yampa basin (Boyle Engineering Corporation, 2003 [CDSS]) based on 1993 photo imagery. As of the mid 1990's, however, irrigated lands comprised only 38 percent of the harvested crop acreage in the Yampa basin. Dry land farming produces primarily hay and wheat, with small amounts of oats and barley being produced as well (BBC Research & Consulting, 1998). Area of irrigated land in the White River basin has been estimated under CDSS as 25,200 acres (Colorado Division of Water Resources, 1999 [CDSS]).

Urban use of land in this largely rural part of Colorado is extremely small.

Water Resources

Most of the water yield in the Yampa and White basins is attributable to snowmelt from the higher elevation areas. Average annual streamflow for the upper Yampa River (USGS gage near Stagecoach Reservoir) is approximately 62,000 af, which increases to an annual average of 1,623,000 af at Dinosaur Monument (USGS gage near Deerlodge Park) (Boyle Engineering Corporation, 200 0 [CDSS]). Flow at the State Line for the White River averages 595,000 af (Colorado Division of Water Resources, 1999 [CDSS]).

There is no National Water-Quality Assessment (NAWQA) Program in the Yampa and White River basins, as there are in the Colorado and Gunnison mainstem basins, to provide general information on quality issues in those rivers. From the limited information readily available to CRRRS, water quality in the Yampa River appears to be generally good. Non-point source pollution related to construction, urbanization in general, and agriculture are of concern in the upper Yampa Valley. Active local citizens groups in Steamboat Springs include the Yampa River Basin Partnership and the Yampa Valley Water Quality Committee, which is provided support by the Routt County Department of Environmental Health. These groups have been involved in developing local erosion and sediment control guidelines and regulations, and integrating 208 plans for Routt and Moffat Counties into one plan. The City of Steamboat Springs recently embarked on development of a Yampa River Plan to, among other things, protect the health of the river. Meeker Dome in the White River basin is the site of a Colorado River Salinity Control Program project undertaken in the 1980's. Abandoned oil and gas wells were discovered to be discharging highly saline (19,200 mg/L) water into the White River east of Meeker. The wells were plugged, resulting in an estimated reduction of 57,000 tons of salt annually, and continue to be monitored (www.usbr.gov/dataweb/html/meeker.html).

Groundwater is not used extensively in the Yampa and White River basins, although Steamboat Springs, Phippsburg, Hayden, Yampa, and Meeker are all known to get at least part of their supply from alluvial wells. Well yields are reported in the range of 100 to 900 gpm. Two sedimentary aquifers in the Piceance Creek have been tapped for irrigation use, and well yields are in the range of 100 to several hundred gpm. TDS in waters from the upper aquifer ranges from 400 to 2,000 Milligrams per Liter (mg/L), and is considerably higher in the lower aquifer (Colorado Groundwater Association 2000).

Except for a few irrigation ditches that cross the divide into the Colorado basin, there are no exports of water out of the Yampa and White Rivers, and no imports into the basin. Municipal and domestic needs for water relate to a current population of approximately 42,000 (http://cwcb.state.co.us/Fact_Sheets/Yampa/page0001.htm), most of which is located in the Yampa basin. Irrigation use is the largest consumer of water in both basins. Average annual consumptive use in the White and Yampa basins was estimated as follows for the period 1986-1990. The investigation was done under CRDSS, following the Bureau of Reclamation's approach and reporting periods for their 5-year consumptive uses and losses reports as shown in Table 2-3 (http://cdss.state.co.us/ftp/products/cu/data/culoss/culossapp.pdf).

Table 2-3: Consumptive Use and Loss in the Yampa/White basin

Use Category	Yampa Basin Annual CU (1000 af)	White Basin Annual CU (1000 af
Reservoir evaporation	8.3	2.5
Irrigation	92.2[1]	32.4[2]
Stockpond evaporation and livestock use	3.6	0.5
Mineral resources	1.6	1.3
Thermal electric power generation	16.4	0.
Other [3]	1.5	0.5
Exports	0.	0.
TOTAL	123.7	37.2

[1] based on 82,700 acres for reporting period

[2] based on 25,200 acres for reporting period

[3] includes municipal, domestic, and other industrial uses

Decision Support Systems And Geographic Information Systems

Colorado's Decision Support Systems (CDSS) are computer-based water management systems being developed by the Colorado Water Conservation Board and the Colorado Division of Water Resources. The systems are defined by basin, and thus the Colorado River Decision Support System (CRDSS) includes the entire West Slope. The goal of this system is to assist in making informed decisions regarding historical and future use of water.

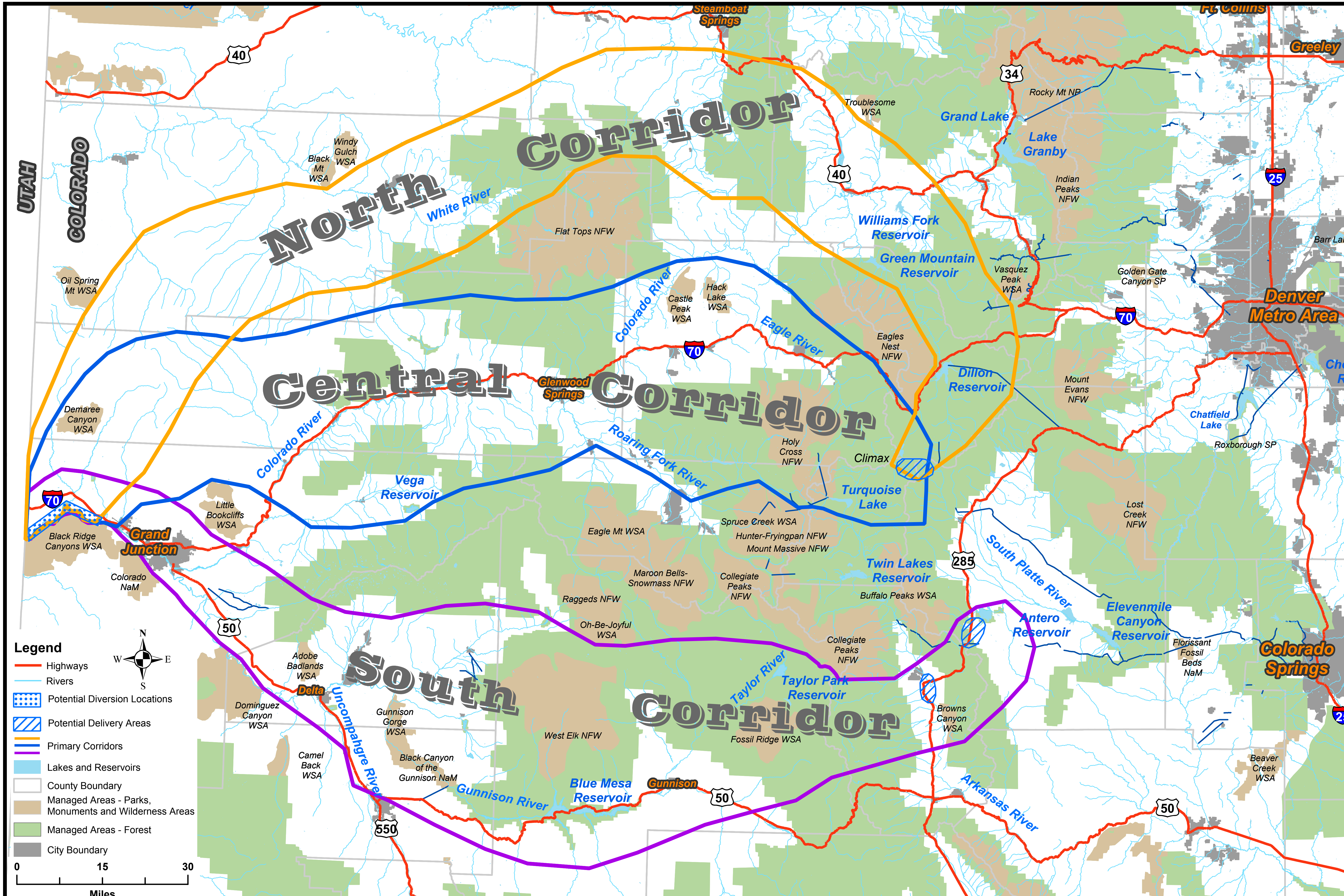
CRDSS consists of several analytical tools or models and the extensive databases that support them. Relational data tables include hydrologic and climate data, water rights data, historical diversion records, irrigated acreage, physical characteristics of reservoirs and diversion structures, and historical reservoir contents. These are generally data collected by the Division of Water Resources but include other agency data such as the USGS daily streamflows. There is also a spatial data component consisting of geographic data and coverages to allow map-based displays and analysis. In addition to a viewing tool for reviewing, summarizing, and retrieving data, the system includes a consumptive use model and water resources planning models for the San Juan/Dolores system, Gunnison, upper Colorado, White, and Yampa Rivers. Data management interfaces automate the process of retrieving data from the database and assembling it for input to the models.

The water resources planning models are water allocation models that simulate diversions, reservoirs, and instream flow rights according to the actual administrative priority of each right. The models explicitly operate every consumptive right in the system, so that basinwide consumptive use can be estimated for Compact analysis. The model is capable of simulating protected reservoir releases to downstream uses, diversions under exchange rights, off-stream reservoir storage, releases to off stream demands, minimum bypasses, multiple-gated collection systems, and so on. Engineers, planners, and managers can use the models to test efficacy and reliability of proposed operations or projects, to support structure design, or to develop negotiating positions in conflict resolution.

The CDSS products and extensive documentation for their use are available at the Colorado Water Conservation Board's website (www.cwcb.state.co.us).

Geographic Information System (GIS) coverages for various features and delineations are available from a variety of public agency websites. A sample list is included here:

- Colorado Department of Local Affairs (www.dola.stat.co.us/oem/cartography) - municipal boundaries and county boundaries
- Colorado Department of Transportation (www.dot.state.co.us/App_DTD_DataAccess/GeoData/index.cfm?fuseaction=StatewideDataset&menuType=GeoData) - highways and major roads
- Colorado National Heritage Program (www.cnhp.colostate.edu/gis.html) – species of concern and potential conservation areas
- U.S. Geologic Survey (http://water.usgs.gov/lookup/getspatial?huc250k) - hydrologic unit codes
- Bureau of Land Management (ftp.co.blm.gov/pub/) - land ownership
- U.S. Fish & Wildlife Service (www.nwi.fws.gov/downloads.htm) - National Wetlands Inventory mapping



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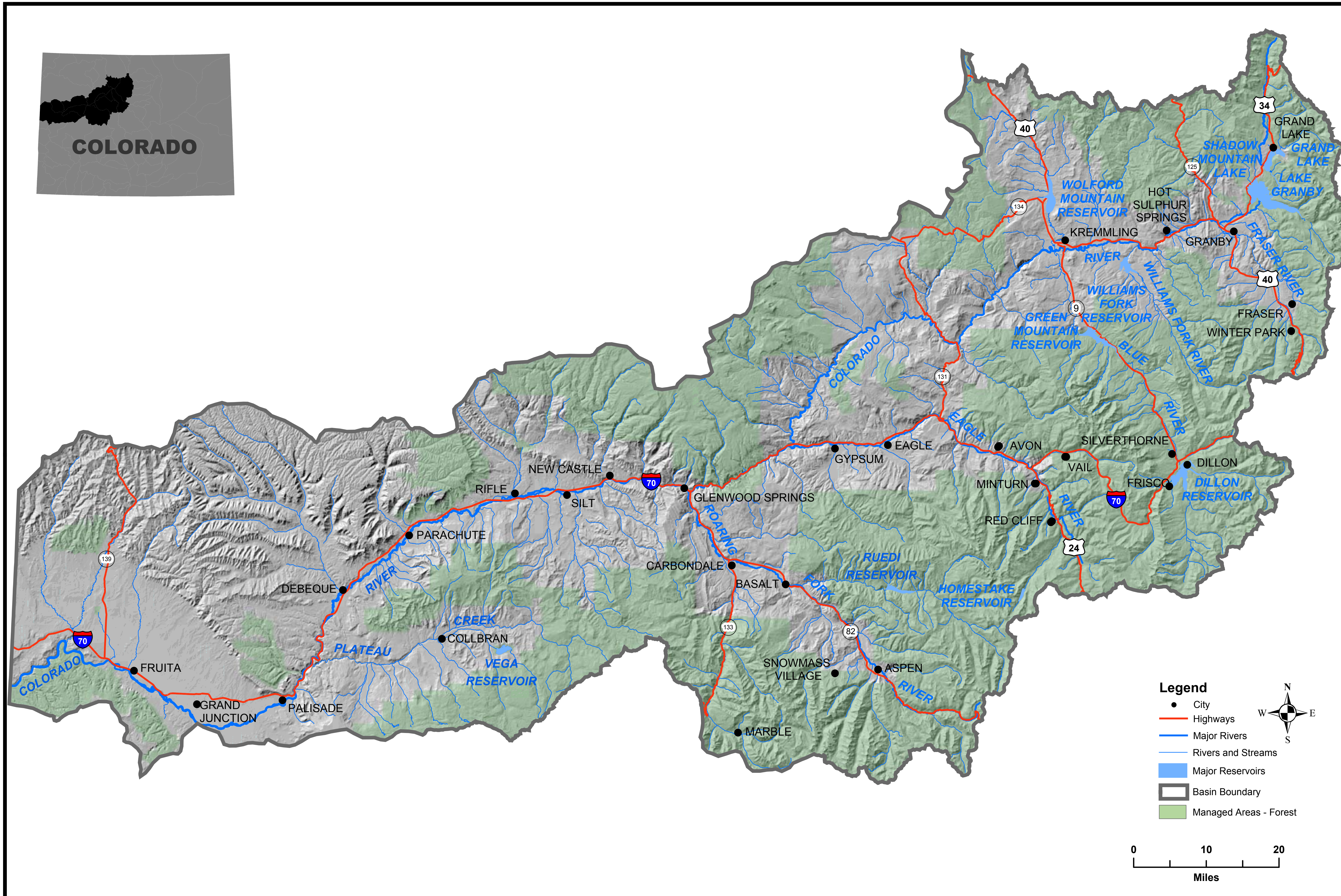
BEC PROJECT NO.
DN-C72-501-01

COLORADO RIVER RETURN RECONNAISSANCE STUDY

CONVEYANCE CORRIDORS

FIGURE
2-3



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COLORADO RIVER RETURN RECONNAISSANCE STUDY

COLORADO RIVER BASIN

FIGURE
2-4

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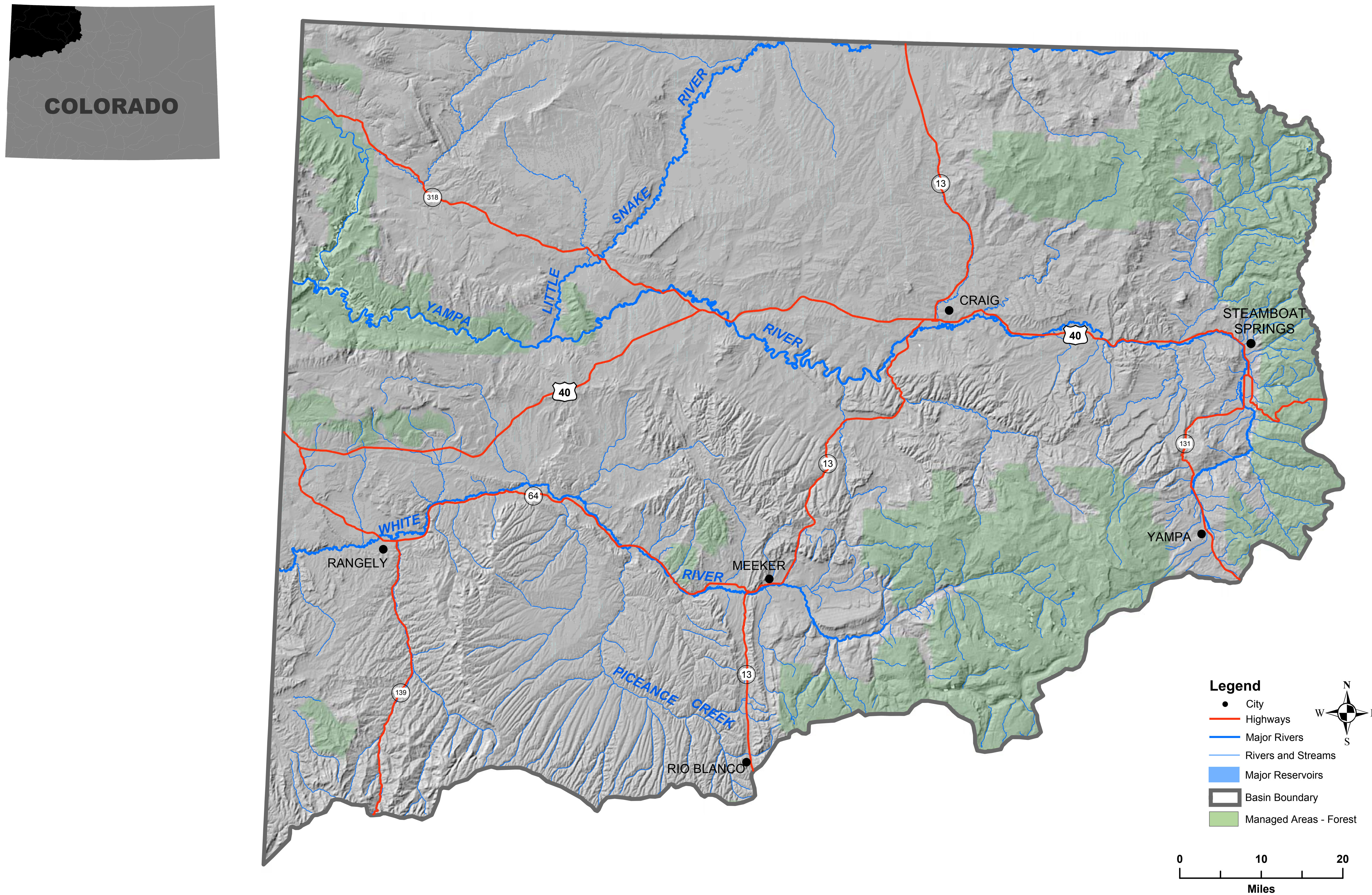
GUNNISON RIVER BASIN

FIGURE

2-5



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WHITE AND YAMPA RIVER BASIN

FIGURE 2-6