Chapter 6.
Construction and Operating Costs

Methodology

Cost estimates are based on typical reconnaissance level procedures focusing the greatest attention on the largest cost components of the CRRP. For example, preliminary schematic drawings were prepared for water treatment alternatives, pumping stations, hydroelectric power plants and pipelines. These schematic drawings were used to generate cost estimates reflecting the size and complexity of the facility construction. Major cost items and constructability issues were reviewed with contractors specializing in construction of these facilities. In addition, manufacturers and local, state, and federal agencies provided data or commentary on the likely magnitude of electro-mechanical equipment prices and for power purchases and sales, materials, and equipment. Components of the alternative project configurations contributing small percentages of the total cost were estimated using data from other projects and industry cost estimating summaries. Presented below are the methods used to prepare cost estimates, including both the capital cost of construction and annual operating costs. Allowances for land acquisition, contingencies, and future planning, design, and administrative costs are as indicated in the cost summary section. All costs are based on 2003 US dollars.

Diversion Facilities

The selection of the type of diversion structure to be used if the CRRP advances will involve detailed consideration of the environmental effects of constructing a structure in a particular reach of the river. The most cost-efficient and reliable type of structure from an engineering perspective would likely be a low-head diversion dam across the river to create a pool from which the water would be diverted into a forebay reservoir for the first pumping station. Considering that the reach of river being considered is designated as critical habitat for four endangered fish species, this type of structure would need to incorporate appropriate fish passage features such as those that have been, or are being, constructed on existing diversion dams on the Colorado and Gunnison Rivers. The reach of river downstream of currently used diversions is an area adjoined by a wilderness study area, a national conservation area, and a state wildlife area. Therefore, while it may be possible to design some type of diversion dam with the requisite fish passage details, this study assumed that other types of diversion structures are preferable.

Infiltration galleries, consisting of perforated pipe buried in the river alluvium would eliminate any cross-channel barrier to fish migration. Unfortunately, high sediment loads, variable flows in the river and overall channel stability horizontally and vertically, do not lend themselves to this type of diversion, especially of this size.

A special type of infiltration gallery, known as a radial collector was also considered. Here, the perforated pipes extend radially outward under the river channel from a large diameter wet well. This type of structure should be considered further in future studies, if conducted.

The fourth type of diversion structure considered is a side channel inlet consisting of a concrete levee along one side of the river. The levee would contain covered screened inlets to exclude fish larger than the openings in the screens. The size of screen openings greatly affect the performance and annual maintenance costs. Screens with 3/32-inch openings have been installed in existing canals in the Grand Valley with similar flows. Since the structure's design is so dependent on the conditions in the specific reach where it would be constructed, and the overall cost is small in relation to the total cost of the CRRP, no design sketches were prepared for this study. Based on costs incurred on similar structures in the area, an allowance of $3,000/cfs (equal to the upper end of the cost range experienced to date) of diversion capacity was used. An additional contingency of 30% was also included since this is a specialty structure that would likely require hydraulic model studies, would have to be tailored to specific conditions at the site finally chosen, and would likely have special construction constraints given the environmental sensitivity of the area.

Operational Storage

Water storage can be an important component of long-distance water conveyance systems. It is especially important when there is great variability in the timing of water supplies available for diversion. Storage near the diversion point, or source of the water supply, allows the rest of the system, consisting of treatment plants, pumping stations, pipelines, and tunnels to be sized for flows approximately equal to the long-term average flow instead of short-term peak flows. Storage also provides operational flexibility. For example, if for an unexpected reason, there is a problem being able to divert water from the river, stored water can be delivered through the system instead of having to shut the system down until problems are resolved. For the purposes of this reconnaissance study, it is assumed that storage equal to five percent of the average annual deliveries is provided near the diversion point and that an additional five percent is distributed along the pipelines, likely near the pumping stations and hydropower facilities. Detailed layouts of these facilities were not prepared since the cost of this storage is estimated at less than 2 percent of the total construction costs. A cost allowance of $3,000 per acre-foot of storage was included based on a review of cost estimates for more than 100 new off-channel water storage sites prepared by Boyle Engineering in the past four years.

Water Treatment

Equipment cost data from manufacturer's representatives, and other literature were used to develop opinions of probable costs. Costs were developed for the 230-MGD, 460-MGD, and 690-MGD treatment plants for the four alternative treatment processes presented in the previous chapter. Tables 6-1 and Table 6-2 present reconnaissance-level opinions of probable capital and annual operations costs, respectively. These tables present costs for process equipment, buildings, electrical, instrumentation/controls, yard piping, basic site/civil work including roadways and stormwater retention. Operating costs include allowance for labor, chemicals, and power consumption ($0.05/kWh). Land costs are included in the overall project configuration summary costs.

Site considerations and plant hydraulics must be taken into account before any alternative is selected to ensure the required facilities can be constructed on-site. Some of the unit processes may require transfer pumps rather than the assumed gravity flow.

TABLE 6-1: Conceptual Water Treatment Alternatives Capital Cost Opinion

Treatment Alternative - 230 MGD				
PARAMETER	**1**	**2**	**3**	**4**
	UF/NF/UV	**C/S/LS/F/UV**	**C/S/F/NF/UV**	**LS/F/UV**
Pretreatment	$90,000,000	$21,000,000	$62,000,000	--
Advanced Treatment	$120,000,000	$92,000,000	$100,000,000	$65,000,000
Post Treatment	$29,000,000	$29,000,000	$29,000,000	$29,000,000
Residuals Handling	$1,000,000	$63,000,000	$21,000,000	$52,000,000
Facility Buildings	$9,000,000	$9,000,000	$9,000,000	$9,000,000
Yard Piping (10%)	$25,000,000	$21,000,000	$22,000,000	$16,000,000
Site Civil (15%)	$37,000,000	$32,000,000	$33,000,000	$23,000,000
Instrumentation & Controls (15%)	$37,000,000	$32,000,000	$33,000,000	$23,000,000
Electrical (15%)	$37,000,000	$32,000,000	$33,000,000	$23,000,000
Residuals Storage	$220,000,000	$4,000,000	$220,000,000	$4,000,000
SUBTOTAL	***$605,000,000***	***$335,000,000***	***$562,000,000***	***$244,000,000***
$/GPD*	***$2.63***	***$1.46***	***$2.44***	***$1.06***
Treatment Alternative - 460 MGD				
	1	**2**	**3**	**4**
	UF/NF/UV	**C/S/LS/F/UV**	**C/S/F/NF/UV**	**LS/F/UV**
Pretreatment	$160,000,000	$38,000,000	$120,000,000	--
Advanced Treatment	$200,000,000	$180,000,000	$180,000,000	$130,000,000
Post Treatment	$57,000,000	$57,000,000	$57,000,000	$57,000,000
Residuals Handling	$2,000,000	$117,000,000	$41,000,000	$103,000,000
Facility Buildings	$9,000,000	$9,000,000	$9,000,000	$9,000,000
Yard Piping (10%)	$43,000,000	$40,000,000	$41,000,000	$30,000,000
Site Civil (15%)	$64,000,000	$60,000,000	$61,000,000	$45,000,000
Instrumentation & Controls (15%)	$64,000,000	$60,000,000	$61,000,000	$45,000,000
Electrical (15%)	$64,000,000	$60,000,000	$61,000,000	$45,000,000
Residuals Storage	$440,000,000	$8,000,000	$440,000,000	$8,000,000
SUBTOTAL	***$1,103,000,000***	***$629,000,000***	***$1,071,000,000***	***$472,000,000***
$/GPD*	***$2.40***	***$1.37***	***$2.33***	***$1.03***
Treatment Alternative - 690 MGD				
	1	**2**	**3**	**4**
	UF/NF/UV	**C/S/LS/F/UV**	**C/S/F/NF/UV**	**LS/F/UV**
Pretreatment	$230,000,000	$48,000,000	$172,000,000	--
Advanced Treatment	$290,000,000	$271,000,000	$250,000,000	$190,000,000
Post Treatment	$85,000,000	$85,000,000	$85,000,000	$85,000,000
Residuals Handling	$3,000,000	$170,000,000	$54,000,000	$154,000,000
Facility Buildings	$9,000,000	$9,000,000	$9,000,000	$9,000,000
Yard Piping (10%)	$62,000,000	$58,000,000	$57,000,000	$44,000,000
Site Civil (15%)	$93,000,000	$87,000,000	$86,000,000	$66,000,000
Instrumentation & Controls (15%)	$93,000,000	$87,000,000	$86,000,000	$66,000,000
Electrical (15%)	$93,000,000	$87,000,000	$86,000,000	$66,000,000
Residuals Storage	$660,000,000	$12,000,000	$660,000,000	$12,000,000
SUBTOTAL	***$1,618,000,000***	***$914,000,000***	***$1,545,000,000***	***$692,000,000***
$/GPD*	***$2.34***	***$1.32***	***$2.24***	***$1.00***

* *$/GPD is the* cost in dollars per gallon per day of treatment capacity

TABLE 6-2: Conceptual Water Treatment Alternatives Operations and Maintenance Costs

Treatment Alternative - 230 MGD				
	1	**2**	**3**	**4**
PARAMETERS	**UF/NF/UV**	**C/S/LS/F/UV**	**C/S/F/NF/UV**	**LS/F/UV**
Pretreatment ($/yr)	$13,400,000	$12,500,000	$10,900,000	--
Advanced Treatment ($/yr)	$38,900,000	$26,000,000	$38,900,000	$28,100,000
Post Treatment ($/yr)	$14,900,000	$9,300,000	$14,900,000	$9,300,000
Residuals Handling ($/yr)	$700,000	$5,300,000	$2,200,000	$5,100,000
SUBTOTAL ($/yr)	***$67,900,000***	***$53,100,000***	***$66,900,000***	***$42,500,000***
SUBTOTAL ($/kgal)*	***$0.81***	***$0.63***	***$0.80***	***$0.51***
Treatment Alternative - 460 MGD				
	1	**2**	**3**	**4**
	UF/NF/UV	**C/S/LS/F/UV**	**C/S/F/NF/UV**	**LS/F/UV**
Pretreatment ($/yr)	$23,500,000	$24,700,000	$21,000,000	--
Advanced Treatment ($/yr)	$76,300,000	$51,800,000	$76,300,000	$55,900,000
Post Treatment ($/yr)	$29,000,000	$17,800,000	$29,000,000	$17,800,000
Residuals Handling ($/yr)	$1,400,000	$10,400,000	$4,300,000	$10,200,000
SUBTOTAL ($/yr)	***$130,200,000***	***$104,700,000***	***$130,600,000***	***$83,900,000***
SUBTOTAL ($/kgal)*	***$0.78***	***$0.62***	***$0.78***	***$0.50***
Treatment Alternative - 690 MGD				
	1	**2**	**3**	**4**
	UF/NF/UV	**C/S/LS/F/UV**	**C/S/F/NF/UV**	**LS/F/UV**
Pretreatment ($/yr)	$33,800,000	$37,000,000	$31,200,000	--
Advanced Treatment ($/yr)	$113,700,000	$77,700,000	$113,700,000	$83,800,000
Post Treatment ($/yr)	$43,000,000	$26,200,000	$43,000,000	$26,200,000
Residuals Handling ($/yr)	$2,000,000	$15,400,000	$6,300,000	$15,300,000
SUBTOTAL ($/yr)	***$192,500,000***	***$156,300,000***	***$194,200,000***	***$125,300,000***
SUBTOTAL ($/kgal)*	***$0.76***	***$0.62***	***$0.77***	***$0.50***

* $/Kgal is the cost of treatment operations in dollars per thousand gallons treated.

Capital cost opinions are based on preliminary identification of major equipment and conceptual flow diagrams. Residual storage ponds have been calculated assuming a 3.5 ft/yr evaporation rate and construction of 6' deep lined ponds at $5,200 per af. Capital costs listed in these tables include only direct construction costs. Indirect costs including engineering, legal, financial, are included in the overall project cost summary tables presented later in this chapter. The costs presented in this report are preliminary in nature because equipment selection and engineering design activities have not been performed.

Alternative 1 is the highest cost alternative and is used to compute total project cost in the rest of this chapter. This approach provides a potentially conservative estimate of treatment costs considering that one of the other alternatives or a completely different treatment process may be selected in future studies or in final design.

Pipelines

Alignment Alternatives

Multiple alignments were developed in each corridor between the diversion and delivery points. The following sections provide general descriptions of the alignments and the specific issues that affected the alignment development. The alignments are shown on Figures 6-1, 6-3 and 6-5.

North Corridor

Alignments in the north corridor head north from the diversion point towards the Demaree Canyon Wilderness Study Area. The alignments diverge around both the west and east side of the Wilderness Study Area. The alignments include tunnels through the ridge on both sides of Douglass Pass and then continue down drainage draws where they meet between Rangely and Meeker. The alignments in this corridor must travel as far north as Meeker in order to allow passage around the Flat Tops Wilderness area.

Once the alignments reach Meeker they generally follow a power transmission line east and slightly north. These alignments also stay just north of the White River and Routt National Forests, which was not a driving criteria of the alignment selection, but would offer some benefits in permitting.

Near Dunckley the alignments diverge and present several alternatives to get to Kremmling. Some of the alignments follow the railroad, highway and power transmission corridors, while others follow minor roads.

Once the alignments reach Kremmling they generally follow the State Highway 9 corridor past Green Mountain Reservoir to Silverthorne. The alignments then follow the State Highway 91 corridor to Climax over Fremont Pass. The alignments would branch at Climax traveling to both the South Platte Basin and to the Arkansas Basin.

The South Platte Basin alignment would tunnel through Mt. Democrat for delivery into Platte Gulch, which is a tributary to the South Platte River.

The Arkansas River Basin alignment would continue along the State Highway 91 corridor and discharge into the East Fork of the Arkansas River.

Central Corridor

Alignments in the central corridor begin at the diversion point and head generally east towards De Beque and remain north of the Little Bookcliffs Wilderness Study Area. The alignments vary from the I-70 corridor between the diversion point and De Beque. The Bookcliffs are the first major obstacle encountered. The topography generally rises in elevation to the east with increasingly deeper washes along the base of the Bookcliffs. The alignments include tunnels through the Bookcliffs and then continue towards De Beque where they meet up with the I-70 corridor again. The topography is decreasing in elevation from the Bookcliffs to De Beque. Near DeBeque the alignments diverge into a northern and southern set of alignments.

The northern set of alignments within the Central Corridor continue along the I-70 corridor toward the Grand Hogback between Silt and New Castle. At this point the alignments travel southeast to avoid the hogback and Glenwood Canyon. Alignments through Glenwood Canyon were not developed due to the rough terrain and congestion that would require extremely high construction costs. An alignment through Glenwood Canyon would not significantly reduce the length of pipe needed, but would allow a more gradual profile and eliminate the need for several tunnels. Future studies could consider an alignment through Glenwood Canyon, but a great deal of site investigation to quantify the impacts of congestion and geotechnical issues on the project cost would be required. Alignments to the north of Glenwood Canyon were not evaluated due to the rugged terrain in this area.

From a point south of Glenwood Canyon traveling in a straight line mostly east and a little south would take the alignment straight to the delivery points. However, this straight line would cross through the Holy Cross Wilderness Area. Therefore, to avoid the wilderness area, the alignments generally travel back to the I-70 corridor near Eagle.

East of Eagle the alignments vary from the I-70 corridor to allow passage through Bellyache Ridge. The alignments follow Brush Creek to a tunnel through Bellyache Mountain and then head back toward the I-70 corridor east of Edwards.

The alignments continue along the I-70 corridor to Minturn with relatively gradual rise in topography. At Minturn the alignments head southeast along the US Highway 24 corridor through Redcliff and Gillman to Eagle Park. The stretch between Gillman and Redcliff includes a very narrow canyon that would involve some difficult construction. An existing railroad grade that may not be in use may provide a possible alignment. A tunneling option may also be attractive to get through this area. Additional study would be required to optimize passage through this area.

At Eagle Park the alignments split heading southeast for delivery to the South Platte River Basin and south for delivery to the Arkansas River Basin. The South Platte Basin alignment would travel to the Climax Mine site and then tunnel through Mt. Democrat for Delivery into Platte Gulch which is a tributary to the South Platte River. The Arkansas River Basin alignment would continue along the US Highway 24 corridor with a tunnel through Tennessee Pass and deliver to East Tennessee Creek, which is a tributary to the Arkansas River.

The southern group of alignments in the central corridor generally follow Plateau Creek toward Carbondale. The alignments then generally follow the Roaring Fork River to Basalt. Some alignments continue along the Roaring Fork toward Aspen while others follow the Frying Pan River towards Ruedi Reservoir. Both groups come together and head east towards Leadville, where deliveries can be made into the Arkansas River basin. The alignments continue east through the Mosquito Range allowing delivery to the South Platte River basin.

South Corridor

Alignments in the south corridor travel southeast along the I-70 corridor from the diversion point to about five miles east of Grand Junction. The alignments then travel south toward the US Highway 50 corridor. The alignments follow the US Highway 50 corridor toward Delta staying north of the Dominguez Canyon Wilderness Study Area and south of the Adobe Badlands Wilderness Study area. The alignments diverge around the north and south of Delta.

The northern alignments travel along the State Highway 92 corridor to Paonia. The alignments then travel south of the Oh-Be-Joyful Wilderness Study Area and north of the Fossil Ridge Wilderness Study area toward Crested Butte. These alignments offer two basic passages around the north of the Fossil Ridge Wilderness with a northern alignment heading straight east just south of Taylor Park Reservoir. Two alternatives are identified for travel across the Sawatch Range. One includes tunneling and another option includes traveling over Cottonwood Pass.

From Crested Butte another alternative travels to the south, then up Taylor Canyon and tunnels through the Sawatch Range to join the other alignments described in the previous paragraph.

All of these alignments remain south of the Collegiate Peaks Wilderness Study Area and head toward Buena Vista. At Buena Vista the alignments would discharge into the Arkansas River and continue towards Antero Reservoir allowing delivery into the South Platte River Basin.

Back near Delta, the other southern alignment follows the US Highway 50 corridor to Blue Mesa Reservoir. Several alternatives are evaluated for passage around the south of Blue Mesa Reservoir. On the east side of Blue Mesa Reservoir the alignment diverges to the north and meets up with the previously described northern alignments in this corridor.

Other alternatives continue east along the US Highway 50 corridor south of the Fossil Ridge Wilderness Study Area and then travel northeast with delivery to the Arkansas River just south of Buena Vista and ultimately delivering to the South Platte basin near Antero Reservoir.

Hydraulics

Along each pipeline alignment approximate ground elevations were identified and a ground profile of the alignment was created. Pipeline diameters were chosen to maintain fluid velocities at approximately six feet per second. The rationale for the selected fluid velocity and the affect of reducing pipe diameter and increasing fluid velocity is discussed later in this report. Table 6-3 summarizes the pipe diameters and corresponding fluid velocities analyzed for each project delivery capacity.

Table 6-3: Pipe Diameter and Fluid Velocity

Project Delivery Capacity (af/yr)	Inside Pipe Diameter (feet)	Fluid Velocity* (Feet per second)
250,000	8.5	6.3
500,000	12	6.4
750,000	15	6.1

*Based on providing project delivery capacity over 50 weeks during the year

Pump stations and hydropower facilities were added as discussed in Chapter 2. The pipeline alignments include large changes in elevation, which result in large variations in operating pressures ranging from 0-600 psi. For a given pipe diameter, the cost of the pipe varies with operating pressure. Hydraulic grade lines were computed to determine required lengths of pipe for each pressure rating. Headloss through the pipeline was calculated using Mannings equation with a friction coefficient of 0.011 which is a typical value for polyurethane lined pipeline. Lining alternatives are discussed later in this chapter. The operating pressure in each section of pipe was determined as the difference in elevation of the hydraulic grade line and the ground profile. A minimum pressure of 10 psi was maintained in the pipeline. The quantity of pipe in each operating class in 50-psi increments was summarized from the hydraulic calculations in order to allow costing of the pipe. Example profiles representative of alignments in each corridor are shown in Figures 6-2, 6-4, and 6-6.

Pipeline Materials

For the purposes of this reconnaissance study, the use of welded steel pipe has been assumed. Welded steel pipe is manufactured by shaping steel plate to form a cylinder and welding the plates together. The most efficient method of constructing steel pipe is with a machine that bends the steel plate in a spiral manner and welds the seams together. This method is currently utilized by most steel pipe manufacturers for pipe diameters up to twelve feet in diameter and steel plate thicknesses up to one-inch.

Several steel pipe suppliers were contacted during the study to identify manufacturing issues associated with this project. Most suppliers are currently capable of producing spiral welded steel pipe up to 12 feet diameter with thickness up to one inch. Most suppliers indicated they could likely build machines to spiral weld up to 15 feet diameter, thickness up to one inch.

Thickness over one-inch would have to be fabricated from steel plates and would require a greater amount of fabrication. The additional fabrication would cause slower production rates and handling issues resulting in increased cost and delivery times. During the development of the alignments effort was made to minimize the amount of pipe required that is greater than one-inch thick. This is accomplished by adding pumping stations and hydropower facilities in order to reduce the operating pressure.

Future analysis should be conducted to further reduce the amount of pipe with wall thickness greater than one inch. One possible method to accomplish this would be to utilize higher strength steels, which is a common practice in the design of oil and gas pipelines. However, this tends to reduce the ductility of the steel making the pipe stiffer and can degrade the longevity of the lining. The concept of installing two smaller parallel pipes should also be evaluated as an alternative for the thicker wall pipes. The installation costs of pipe would be higher, but the cost of the pipe itself may be lower. This analysis is discussed in later chapters.

The following assumptions were developed from data provided by the pipe suppliers and were used for calculating the cost of bare steel pipe including raw materials, fabrication and a small allowance for fittings, assuming alignments with mostly gradual direction changes.

- Calculate cost of steel using $0.20 per pound.
- Fabrication for spiral welded pipe equal to 2.2 times the cost of the steel.
- Fabrication of steel plate into “pipe cans” (thickness over one inch) equal to 2.7 times the cost of steel.

Lining and Coating Systems

There are several options for coating and lining steel piping for this application. Polyurethane linings are higher in cost than conventional cement mortar lining, but may result in lower friction losses and possibly reduced scaling potential. Reduced friction losses would reduce power consumption and/or pipe size that could have significant cost impacts. Cement mortar applied in the factory would add significant weight to the pipe, creating additional handling and shipping costs. Field application of cement mortar would be feasible and coal tar might be an option for lining as well. Analysis for this study is based on polyurethane lining and tape coating as a conservative estimate. More detailed cost-benefit analysis should be conducted to identify the best alternative. The following unit cost assumptions were utilized for the lining and coatings.

- Polyurethane lining (AWWA 222) - $1.75 per sq ft
- Tape coating system (AWWA C214) - $1.60 per sq ft

Pipe Shipping Costs

During discussions with steel pipe suppliers, freight was identified as a significant issue. For the larger diameter pipe, custom designed trucks would be needed to haul the pipe to allow proper clearances and permitting for travel.

Suppliers indicated that it may be cost effective to construct a pipe fabrication plant somewhere on the western slope to reduce the shipping distances of finished pipe. Timing would require about 18 months to get a new plant online. The new plant would require rail service to deliver steel and typical industrial 480 Volt, 3-phase power service.

Costs are based on shipping from less than 500 miles. This would allow pipe to be shipped from several existing suppliers or a new manufacturing facility. Pipe could be shipped from farther away, but may add cost to the project. The following assumptions were utilized for the unit costs for shipping pipe based on data provided by suppliers and are shown in Table 6-4.

Table 6-4: Pipe Shipping Costs

Diameter (Feet)	Shipping Cost per Foot based on Pressure		
	0 - 300 psi	**300 – 450 psi**	**450 – 600 psi**
8.5	$8	$10	$12
12	$13	$19	$25
15	$19	$27	$33

Appurtenances

Effort has not been made in this study to identify the appurtenance items that are typically required on this type of pipeline. These items would potentially include the following:

- Miscellaneous vaults
- In-line valves
- Air and vacuum valves
- Cathodic protection
- Piping identification

An allowance of five percent of the total pipeline construction cost has been added to each alternative to account for these items. Surge suppression systems for pipeline protection have been included with the pumping stations.

Installation

A baseline installation cost is initially calculated that would assume relatively easy pipeline construction. This would include enough access for construction, minimal rock, minimal groundwater and a cover depth not to exceed 10 feet. More challenging construction conditions are discussed in later sections of this chapter.

A typical unrestricted section showing the pipe trench and construction area is detailed in Figure 6-7. Construction easements for each pipe size are as follows:

- 8.5 feet diameter = 210 feet
- 12 feet diameter = 230 feet
- 15 feet diameter = 250 feet

Trench excavation assumes that sidewalls will be constructed at 1:1.5 slopes. Areas required for stockpiling have been calculated assuming the piles will hold at 1:1.5 slopes. Unit costs for installation were derived from industry standard data, and input received from several contractors. The following unit costs are estimated for each pipe size and comprise the total baseline installation cost estimated for the construction:

- Pipe excavation has been estimated at $3.20 per cubic yard
- In order to be conservative, it has been assumed that imported material will be required for pipe bedding. Import material (assuming a squeegee, sand and fine gravel, type material) placed and compacted has been estimated at $23.50 per cubic yard. Future studies, if conducted, should evaluate processing on-site materials which could reduce the material cost and reduce spoils disposal costs.
- Pipe installation, including setting and joint repair, has been estimated at $73/foot.
- Welding is a function of pipe thickness and diameter. The composite rate of $0.35/ft/inch diameter/inch thickness was utilized. This assumes an average length between joints of 40 feet.
- Backfill of the native material including compaction has been estimated at $1.80 per cubic yard.

Additional Installation Considerations

Due to the large number of alternatives and the long lengths of these alternatives, effort has not been made to identify the costs associated with conditions that differ from the baseline installation case. These conditions would consist of the following items:

- Construction area less than the typical
- Excavation of rock
- Groundwater
- Existing infrastructure (pavement replacement, surface restoration, etc.)
- Stream, canal or utility crossings

An allowance of fifteen percent of the pipeline construction cost has been allocated to account for these items. Future studies would need to perform site and geotechnical investigation to more accurately account for these items.

Pipeline Maintenance

An annual allowance for pipeline and appurtenance maintenance and replacement has been assumed to be one-half percent of the pipeline initial construction cost has been included in the operations and maintenance cost of each alternative.

Pumping Stations

Conceptual Layout

The pumping stations were located along the alignments as discussed previously. For each pumping station the total dynamic head was calculated based on the difference in elevation between the pump discharge hydraulic grade line at the pumping station and the ground elevation of the pumping station. This assumes a forebay will be utilized at each pumping station. Utilizing the total dynamic head and the flow rate for each flow scenario the required water horsepower needed was calculated. For planning purposes pumping equipment efficiency of 85 percent was utilized to determine the total motor horsepower required for each station. For calculating power use for operating costs a motor efficiency of 95 percent was utilized.

A conceptual plan was developed for a typical pumping station for the 500,000 af per year alternative, which is shown in Figure 6-8. The number of pumps installed in the pumping station should have sufficient capacity in the event one or more pumps are out of service. The level of redundancy increases with the number of pumps installed. However, the building size and level of maintenance also increases with the number of pumps installed. The minimum number of pumps considered was two pumps and the benefits of adding additional pumps diminish beyond sixteen. Ten pumps were utilized in each station for the purposes of this study. Therefore, if one pump were out of service, the pumping station could still operate at 90 percent capacity. Future studies should identify the optimal number of pumps that should be installed at each pumping station.

Construction Cost

Since the delivery capacity of the system has been assumed to be fairly constant, variable frequency drives or pressure/flow control valves would not be needed. Incremental flows could be obtained if needed by running fewer pumps, particularly since the friction losses are fairly small as compared to the static head.

A preliminary cost estimate was prepared for the conceptual pumping station layout shown in Figure 6-8 and 6-9. Manufacturers of pumping and electrical equipment were contacted in order to obtain the budgetary information used in this estimate. The cost estimate indicates a total cost of $72 million for a total pumping station horsepower of 140,000 HP. This results in a unit cost of $515/HP which is consistent with historical costs associated with large pumping station projects. This unit cost for pumping stations was utilized to identify the costs for each pumping station in each alternative.

Additional major items included in the conceptual pumping station include piping, valves, the building and support systems, controls and hydraulic transient mitigation measures. Piping in the pumping station was assumed to be welded steel pipe with polyurethane lining and painted on the exterior. Manufacture of the pipe would be similar to the rest of the piping on the project with the additional fabrication costs due to the large number of fittings such as tees and bends.

Valves would be needed for isolating pumps and preventing water from draining through the pumps when not operating. A combination of manual valves and power actuated valves would likely be utilized. Power actuated valves could be electrical or hydraulic and would be controlled by the pumping station control system. Manual valves would allow isolation in the event the actuated valves were not functioning properly or required maintenance. Valve types would likely be ball, spherical or metal seated butterfly valves. For the purposes of cost estimating, cone valves have been utilized. It should be noted that the piping and valves in and near the pumping station, to any points in the system where a valve could be shut while the pump(s) are operating, would have to be designed for the shutoff head of the pumps, which would be higher than the normal operating pressure in the piping.

General unit costs per square foot have been utilized to estimate the cost of the building based on the floor space developed in the conceptual plan.

The control system would be typical of municipal water pumping stations, consisting of instrumentation such as pressure transmitters and a flow meter to measure the total station flow. A programmable logic controller would be utilized to control the pumps and monitor status and alarms. The pumping stations would likely need to be controlled or at least monitored from a central facility, possibly the treatment plant. This would require some type of communication system either hard wired or transmitted such as radio. Since cabling could be efficiently installed along the pipeline route, this type of system has been assumed in the cost estimate.

As with most large pumping stations, a method for mitigating hydraulic transients will be required. It is likely that hydraulic transient mitigation measures would best be accomplished through the use of flywheels on the pumps used to store energy to be used during a power failure and/or surge chambers.

Operation and Maintenance Costs

Maintenance and replacement costs were estimated at 2% per year of initial construction cost. Operations costs are primarily comprised of power costs. Assuming the pumping station operates for a total period of 50 weeks per year, 24 hours per day, the total kWh was calculated and a cost of $0.05/kWh was used to calculate the power costs for each pumping station.

Tunnels

Preliminary engineering evaluations of construction along each of the three conveyance corridors were prepared. The evaluations include geologic reconnaissance based on literature review, construction methodology, and preliminary cost estimates for tunnel sections.

Data Collection and Review

Initial evaluations were made of 35 tunnels (7 tunnels in the North Corridor, 13 tunnels in the Central Corridor, and 15 tunnels in the South Corridor). Key elements of each proposed tunnel are summarized in Table 6-5 located at the end of the chapter. These initial tunnel layouts were later expanded with a second set of tunnels that involved longer and deeper alignments as a means of reducing pumping requirements at select locations (Table 6-6 located at the end of the chapter). Some of these subsequent tunnels would replace tunnels within the initial set of tunnels.

Upon initial review and discussion, the anticipated geologic conditions along the alignments were developed using, as a basis, information obtained from a review of published geologic maps (Tweto, 1976), geologic columns and descriptions of individual geologic units in the project area. In general, the tunnels located on the western slope of Colorado are expected to be situated in weak to moderately strong sedimentary rocks. These materials are predominantly shale and sandstone, with some siltstone, claystone, limestone and evaporate deposits. Tunnels that cross beneath the continental divide (eastern portion of corridors) are expected to encounter relatively strong igneous and metamorphic rock. Rock types include gneiss, schist, granite and intrusive igneous rock.

A rock classification system was developed to help characterize the anticipated geologic conditions for further assessment of tunneling conditions, ground support and associated costs. Three rock strength classes were selected for the geologic characterization:

- Class 1: Strong rock including gneiss, schist, granite, metamorphic rock and intrusive igneous rock.
- Class 2: Moderately strong rock including sandstone, limestone and shale.
- Class 3: Weak rock including shale, interbedded sandstone/siltstone/shale, volcanic ash and tuff.

Estimates were made to assess the percentage of each rock class anticipated to be encountered along each tunnel alignment. A review was also made to obtain additional relevant geologic information pertaining to geologic structure or other conditions that may impact tunnel construction. These conditions include faults, folding, intrusive contacts, paleo valleys, hot water, potential squeezing ground, etc. The rock classification and other relevant geologic information for each tunnel are summarized in Table 6-5 and Table 6-6.

Tunnel Configurations

Approximate tunnel lengths, range in tunnel elevations, and maximum and average ground cover were computed for each of 50 aforementioned tunnels. Tunnel lengths for the initial set of tunnels (35 tunnels) ranged between 0.75 and 16.7 miles and averaged 3.5 miles. Maximum ground cover ranged between 250 and 2,800 feet. Specific information for each tunnel is summarized in Table 6-5. Tunnel lengths for the second set of tunnels (15 tunnels) ranged between 4.5 and 32.8 miles and averaged 15.5 miles. Maximum ground cover is between 1,200 and 5,100 feet. Table 6-6 provides a summary of the information developed for this set of tunnels.

Preliminary Design Criteria

Tunnel geometries were set to accommodate final inside pipe diameters of 8.5 to 15 feet for either pressurized or gravity flow.

Anticipated Ground Conditions

A review of the anticipated geologic conditions and range in overburden cover indicates that a wide range in ground behavior can be expected. Rock types are expected to range from weak sedimentary rock (qu=500 to 1,500 psi) to strong metamorphic and igneous rock (qu=20,000 to 30,000+ psi). Furthermore, faulted/sheared ground is anticipated at some locations. Average overburden cover ranges between 150 and 2,070 feet, with maximums reaching 5,000+ feet.

Ground behavior during tunneling operations will be a function of the mass rock strength, nature and extent of rock mass, discontinuities (faults, shears, rock joints), in-situ stress conditions and groundwater conditions. Anticipated ground behavior may range from firm ground requiring no initial support to squeezing ground requiring significant and prompt support. Faulted/sheared ground may contain materials exhibiting raveling, flowing, squeezing or swelling behavior. Other post-tunneling ground behavior considerations may include the propensity for slaking and swelling of weaker clayey rocks.

The presence of weak shales and sandstones under high stress conditions for this project may present difficult ground conditions for tunneling. Overload factors (ratio of average tangential tunnel stress to vertical overburden stress, Deere, 1969) can be used to predict the potential for squeezing ground conditions in ductile rock. Overload factors between 1 and 3 are typically associated with mildly squeezing ground, while factors exceeding 3 often present moderately to highly squeezing behavior. Simple calculations suggest that the weakest rocks (qu=500 psi) could exhibit moderately squeezing conditions with ground cover around 1,000 feet and highly squeezing ground around 1,500 feet. Case histories of squeezing/raveling ground conditions in similar sedimentary rocks include the Navajo Tunnel 3 in New Mexico and the Stillwater Tunnel in Utah. In the Navajo Tunnel No. 3, extensive cracking, slabbing and spalling was observed in the 21-foot diameter tunnel, excavated in weak sandstone, siltstone, and shale (Sperry and Heur, 1972). The estimated overload factor was in the range of 1 to 2.5. Significant problems were encountered in the Stillwater Tunnel, where thinly bedded and sheared shale exhibited raveling and squeezing behavior (Phien-wej and Cording, 1991). Overburden cover for this tunnel was reported to be about 2,700 feet.

Overstressing of relatively moderate to strong rocks that exhibit brittle behavior can result in spalling or slabbing conditions. This can occur when overload factors exceed 1; however, Cording (1984) indicates that minor stress slabbing can occur in sedimentary rocks when the overload factor is as low as 0.5.

Excavation Methods

The tunnels on this project will generally require use of a Tunnel Boring Machine (TBM). TBMs utilizing a full-face rotating cutterhead are commonly being used in the tunneling industry today to excavate rock tunnels at relatively high advance rates through many types of rock. There are open TBMs and shielded TBMs. Open TBMs are used primarily for excavating hard rock formations with good stand-up time. The cutterhead of the open TBM is thrust forward with hydraulic rams supported by grippers which are mounted on either side of the frame of the machine and bear against the tunnel walls.

In weak rock or fault zones, the rock is not strong enough to withstand the bearing pressure of the grippers and a shielded TBM with thrust jacks may be better suited. A shielded TBM has a full circular shield that provides temporary ground support while the initial support system is erected in the tail of the shield. Shielded TBMs typically advance by thrusting against the tunnel's initial internal support system with hydraulic jacks. Such an approach requires an initial support system that can withstand both ground loads and TBM thrust forces. The cutterhead of either type of TBM can be equipped with disc cutters for excavating rock or drag teeth for excavating soil and soft rock. Squeezing ground and large groundwater flows are important factors to consider when selecting a TBM system.

TBM performance is critical when considering tunneling schedules and cost, particularly for long tunnels with difficult ground conditions. Other key factors include machine utilization and work schedule. Penetration rates are generally a function of tunnel geometry, rock mass characteristics, ground behavior and machine parameters.

Pressure Grouting

Tunnel construction for this project may require use of pressure grouting to reduce large groundwater inflows to manageable levels in fault/shear zones or other highly permeable formations. Probe holes drilled in advance of a tunnel excavation are often used as a means of checking the potential for large groundwater inflows and to identify where pre-excavation grouting is needed. Pressure grouting can be implemented depending on the amount of water encountered in the probe holes.

Initial Support Systems

Requirements for initial support/stabilization systems are a function of anticipated ground behavior and loads, potential hydrostatic loads, compatibility with TBM excavation, design life and corrosion resistance, and timing of installation. Stabilization systems for rock tunnels generally consist of a number of elements, including rock dowels, welded wire fabric, shotcrete, steel sets and lagging. Massive to moderately blocky ground may only require spot rock dowels, while blocky and seamy ground may require pattern rock dowels and shotcrete. Faulted/sheared ground as well as squeezing ground often requires installation of steel sets on relatively tight spacing. Thick/robust stabilization systems (as well as final lining needs) must be considered when establishing the required excavated tunnel diameter.

Sequence and timing of initial support installation is critical, particularly for overstressed rock exhibiting raveling or squeezing behavior. Without timely installation of support, the rock can experience rapid deterioration and deformation, which in turn can result in unstable conditions and/or tunnel convergence.

Final Lining Systems

Final lining requirements for water conveyance tunnels are typically established based on hydraulic, groundwater infiltration/exfiltration, and erosion and corrosion protection criteria. Key hydraulic criteria impacting liner selection include internal pressures that must be resisted to avoid hydraulic fracturing or undue water loss into the surrounding rock mass. Conversely, watertight liners may be required to limit infiltration of groundwater into the tunnel and associated impacts to groundwater levels. Where potentially erodible rock conditions are present (soft sedimentary rock), liner systems will be required to prevent scour as a result of the anticipated maximum flow velocities.

Depending on the design criteria ultimately adopted, final lining systems for tunnels may include unlined, shotcrete, cast-in-place concrete, and/or welded steel or gasketed segmental lining systems with cast-in-place concrete. Welded steel lining is often employed in pressure tunnels where internal hydraulic pressures cannot be resisted by in-situ ground stresses (e.g. vicinity of portals or valley crossings). Gasketed, precast concrete segments are a one-pass system in which the liner is installed behind the TBM without the need for other primary stabilization methods. This system is generally employed where a watertight liner system is required and high external groundwater pressures are anticipated. State of the practice suggests that the liner system is capable of resisting external hydrostatic pressures up to 600 psi (about 1,400 of groundwater head).

Long Tunnels

Several of the proposed tunnels (especially those studied in Table 6-6) exceed 15 miles in length. As indicated in Table 6-5 and 6-6, these tunnels include, NCT06 (18.2 miles), NCT07 (24.2 miles), NCT12 (30 miles), CCT08 (16.7 miles) NCT13 (21.6 miles), CCT15 (18.9 miles) and SCT16 (32.8 miles). Drive lengths could be reduced substantially by implementing two drives from either end; however, tunnel lengths exceeding 15 miles will present several key issues that would require special consideration:

- Ability to meet ventilation requirements;
- Efficient muck removal to maintain desired TBM production rates;
- Groundwater removal under high inflows;
- Efficient transport of tunnel crews, equipment and construction materials to and from the heading; and
- Ability to provide the necessary large electric power sources in remote areas.

Extensive planning and detailed studies would be required to address the challenges presented by tunnel drives of this magnitude.

Cost Estimates

Tunnel cost estimates were developed to provide unit costs (per foot of tunnel) for use in developing the overall construction cost estimates for alternative pipeline alignments. The unit costs are intended to be used for reconnaissance level planning and screening of alternatives and will require more rigorous efforts upon selection of preferred conveyance corridors and pipeline alignments.

The unit costs were developed based on information obtained from a review of actual costs of previously constructed U.S. water conveyance tunnels. Cost information for several rigorous contractor estimates for proposed tunnels that involved long tunnel drives and high stress conditions were also included.

As a means of providing some level of consistency in the cost estimates, the following assumptions were made with respect to tunnel engineering considerations and assumptions:

- All tunnels will be constructed using a hard rock Tunnel Boring Machine (TBM);
- Initial support and final lining systems will be installed employing a two-pass system;
- Initial support will consist of rock reinforcement/welded wire fabric/shotcrete or steel sets and lagging;
- Final lining will consist of shotcrete or cast-in-place concrete; and
- Total lining thickness will range between 9 and 18 inches thick.

Although the following issues will be relevant for more detailed studies, estimated unit costs did not address the following:

- Provisions to accommodate high groundwater inflows during TBM operation (i.e. groundwater conditions and primary/secondary rock hydraulic conductivities are not known at this time);
- Requirements to limit long-term inflows into tunnels to avoid undesirable drawdown of groundwater levels (i.e. need for installing water-tight lining systems or grouting in advance of the TBM); and
- Employing steel lining in low-cover areas where internal pipeline pressures approach or exceed in-situ stresses.

Once the baseline range in unit costs was set, each proposed tunnel was assigned a unit cost based on a review of the following specific criteria:

- Excavated diameter;
- Tunnel length;
- Geologic conditions; and
- Anticipated ground behavior under the range in overburden cover (i.e. requirements for initial support).

Estimated unit costs and total costs for each tunnel are presented on Tables 6-5 and 6-6.

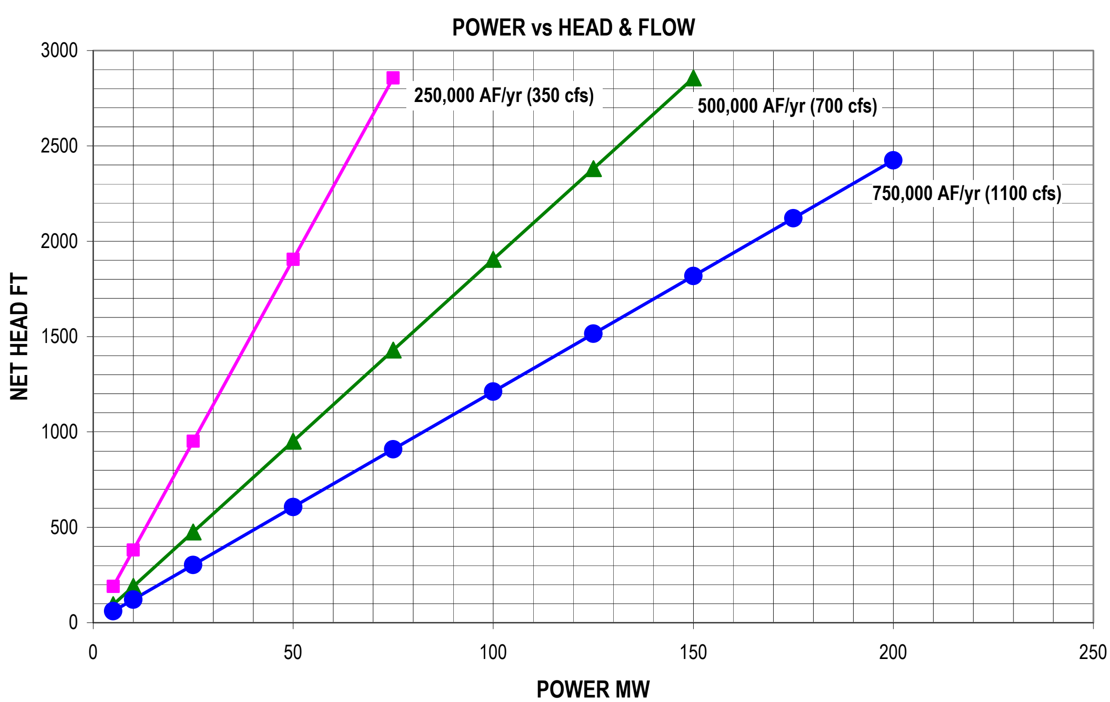
Hydropower Facilities

Capital Cost vs Capacity and Head

Hydroelectric powerhouse cost is governed largely by the physical size of the structure and the equipment cost which in turn are dependent on the dimensions of the power generating equipment, the turbine(s) and generator(s). Most of the installations being evaluated for the CRRRS will have a vertical shaft directly connecting the turbine and generator. In these arrangements the dimensions of the turbine water-passageways usually control the powerhouse foundation dimensions and strongly influence the footprint and powerhouse height. The turbine dimensions are governed by the water flow rate. The cost of the powerhouse is therefore also a function of flow rate, which is directly proportional to capacity and inversely proportional to head.

Figure 6-10 shows the potential installed capacities of the hydroelectric plants as a function of the three flow rates corresponding to the three project delivery capacities and available heads.

Figure 6-10: Hydropower Generation



Because power is directly proportional to head, when head increases, the turbine dimensions decrease with a constant capacity, and because the turbine speed increases, the generator also gets smaller. The powerhouse correspondingly decreases in size. Therefore powerhouse cost can be shown to be a function of Capacity/Head.

Reconnaissance-level cost estimates for hydroelectric power plants typically use generalized cost curves or formulas which have been developed based on actual costs of existing hydro plants. A sufficiently accurate expression has been developed using US Department of Energy and other, more recent, cost data from existing plants. Applying this approach and escalating costs to 2003 values yields these estimated costs for a range of potential hydro plants being considered at various flows and heads, as shown in Table 6-7.

Table 6-7: Hydropower Facility Costs

	1	2	3	4
FLOW cfs	**250,000 af/yr (350 cfs)**		**750,000 af/yr (1100 cfs)**	
HEAD ft (m)	100 ft (30.5m)	2500 ft (762m)	100 ft (30.5m)	2500 ft (762m)
CAPACITY MW	2.3 MW	66 MW	8.3 MW	208 MW
COST	$4,150,000	$19,500,000	$12,500,000	$46,200,000

Operation And Maintenance Cost

Operation and maintenance cost for a hydro plant can have many variables such as whether or not the plant is fully automated, the type and quality of equipment installed, the frequency of operation, frequency of overhaul etc. Statistical studies have been performed of some or all aspects of operation & maintenance costs. For example the USBR has developed the 'Replacements' Manual which predicts the service life of a large selection of hydroelectric equipment components and structures and assigns a relative cost to replace them. Another statistical study is that performed by Ontario Hydro using annual cost data published by the US Department of Energy entitled 'Historical Plant Cost and Annual Production Expenses for Selected Electric Plants. The data base was the 430 hydro plants regulated by the FERC and included as separate items maintenance, operation and capital expenditures. The cost items included; powerhouse mechanical, hydraulic and electric equipment; all structures; reservoirs, dams and waterways; supervision and engineering. The database included plant ages of up to 85 years. The operator cost would be significantly reduced for a hydro plant constructed today because it would be fully automated and there would be no need for operators in the plant. In the database there is a mix of fully attended, fully automated and semi-automated plants.

Future studies should consider this detailed analysis for operations cost, including revenue generation potential based on project power sales rates. However, to maintain consistency with other components of the study annual operations and maintenance costs have been assumed at 2% of construction costs. Power sales are assumed at $0.05 kwh. The following efficiencies are assumed in order to calculate power generation revenue, which are typical of similar facilities.

- Pelton turbine 91% at full load
- Generator 98% at full load
- Transformer 99% at full load

Typical layouts for the range of hydropower facilities are shown in Figures 6-11 through 6-14.

Power Supply

Energy Purchases

The electricity demands for the CRRP are a result of pumping a large volume of water (250,000 to 750,000 af per year) over major elevation changes (7,000 to 9,000 feet) and over a substantial distance (180 to 250 miles). There are, however, opportunities for hydroelectric generation along the corridors that would potentially offset a portion of the power requirements.

To complete this study, the following were addressed with respect to power:

- Pumping needs and related power generation requirements.
- Magnitude of power generation capacity available, and how the CRRP would procure this generation.
- Transmission lines to the pumping stations and from the hydrogeneration facilities into the existing power grid.
- Costs associated with providing power for the CRRP.

Total net power requirements range from 260 MW to 1164 MW depending on project delivery capacity and alignment. The CRRP's net pumping capacity requirements and annual energy needs for each alternative are projected in Table 6-8 as pumping requirements net the hydroelectric generation resulting from the project. This study assumes that all of the hydrogeneration coming out of this project will be used to help offset the power requirements so that net generation requirements by corridor and by delivery scenario become the focus of this evaluation. The number of pump stations and hydropower facilities for each alignment are listed in Tables 6-9 through 6-11.

Table 6-8. Net CRRP Pumping Capacity Requirements and Annual Energy Needs

	Annual Deliveries		
	250,000 af	500,000 af	750,000 af
<u>Northern Alignment (NO1)</u>			
Net Capacity Requirements	396 MW	779 MW	1,164 MW
Net Energy Requirements	3.3 BkWh*	6.5 BkWh*	9.8 BkWh*
<u>Central Alignment 1 (CO1)</u>			
Net Capacity Requirements	318 MW	630 MW	944 MW
Net Energy Requirements	2.7 BkWh*	5.3 BkWh*	7.9 BkWh*
<u>Central Alignment 5 (CO5)</u>			
Net Capacity Requirements	339 MW	689 MW	1,026 MW
Net Energy Requirements	2.8 BkWh*	5.8 BkWh*	8.6 BkWh*
<u>Southern Alignment 1 (S01)</u>			
Net Capacity Requirements	268 MW	520 MW	777 MW
Net Energy Requirements	2.3 BkWh*	4.4 BkWh*	6.5 BkWh*
<u>Southern Alignment 2 (SO2)</u>			
Net Capacity Requirements	261 MW	503 MW	751 MW
Net Energy Requirements	2.2 BkWh*	4.2 BkWh*	6.3 BkWh*

* BkwH=Billion Kilowatt hour (the use of one Billion Kilowatts of power for one hour duration

To place the power requirements of the CRRP in perspective, the 500,000 af delivery scenario would represent approximately 20 to 25 percent of current annual energy sales of Xcel Energy in Colorado and is roughly comparable to the combined annual sales of Fort Collins and Colorado Springs Utilities.

Capacity Requirements

The CRRP will need to obtain or contract for electric generation capacity ranging from approximately 300 to 1,200 megawatts, depending upon the delivery scenario and the corridor chosen. To put the generation capacity requirement in perspective, all Colorado residents and businesses together used slightly more than 8,000 megawatts of total generation capacity from all sources in 1999.[1] The 500,000 af delivery capacity would represent roughly six to eight percent of total generation capacity in the state.

As of Autumn 2003, there was not enough available generation capacity in western Colorado to supply this power, but initial research indicates that this amount of power could be obtained elsewhere within the Rocky Mountain Power Area or through the construction of a new plant. Substantial increases in generation capacity are planned in the near future; Xcel Energy is planning to increase capacity in the Rocky Mountain Power Area by more than 1,500 megawatts between 2000 and 2004, and other utilities are planning large increases as well. Regardless, no utilities are planning for the capacity load to serve CRRP at the present time, and a major effort would need to be undertaken collaboratively with area utilities to plan for such an addition to regional generation capacity.

From an efficiency standpoint, the project might be best served with the construction of a new base load facility in western Colorado. [2] Assuming the 500,000 af delivery scenario, such a plant might be about half the size of the Craig Generation Station.

Planning for new electricity generation of this magnitude will require a considerable period of time; perhaps 10 years or more may be needed to bring this base load generation capacity on line.[3]

Transmission Line Requirements

The three prospective pipeline corridors generally follow major electric transmission corridors. The Southern Corridor pipeline alignments are generally proximate to the 230 kV and 115 kV lines along the Gunnison River owned by the Western Area Power Administration. The Central Corridor alignment is, for the most part, proximate to the 230 kV line owned by Xcel Energy that follows the Colorado River. Much of the Northern Corridor alignment is parallel to the 230 and 345 kV lines owned by Western and Tri-State, though the transmission lines follow the Yampa Valley, approximately 10 to 20 miles north of the proposed pipeline alignment.

These major, high-voltage transmission lines are also likely to have available capacity to serve the 250,000 af and 500,000 af capacity delivery scenarios without major upgrades. The larger delivery scenario will probably require upgrading the high-voltage lines that transmit power in and out of these regions of Colorado.

Transmission lines will need to be constructed from the pumping stations and from the hydrogeneration facilities to the high-voltage transmission lines. Based upon an examination of the facility locations and the transmission lines, it is assumed that an average of 10 miles of transmission line will be needed for each pumping station, with the exception of the Northern Pipeline Alignment. For that alignment, between Meeker and Kremmling, it is assumed that the average transmission line connection would be about 20 miles.

Technical Feasibility And Cost

Based upon this preliminary evaluation, CRRP's power requirements can be met from a physical and technical standpoint. Environmental and permitting issues have not been addressed, and these might obviously be considerable, affecting feasibility, timelines and costs. Order of magnitude and environmental assessment costs

[1] U.S. Department of Energy, Energy Information Administration, 2003.

[2] Inez Dominguez, Engineer, Colorado Public Utilities Commission, October 1st, 2003.

[3] Inez Dominguez, Ibid.

were incorporated into the CRRP cost estimates. Without further study of alternative electricity supply approaches, a ten-year lead time should be assumed.

Costs associated with meeting the CRRP's electric power requirements would include the capital and annual costs of the pumping stations and hydroelectric generation facilities, the costs of transmission lines and other power features required to connect the project to the electric grid, and the annual energy costs used by the project. Capital and operating costs to build and maintain the pumping stations and hydroelectric generation facilities have been included in the overall project cost estimates.

Rough estimates of the costs of constructing lines needed for transmission can be derived using an assumed transmission line construction cost per mile. Guidelines developed by the Electric Power Research Institute and updated to current dollars using the Engineering News Record Cost Indices indicate a range of costs from about $215,000 to about $540,000 per mile for constructing single circuit, 230 kV transmission lines.[4] More recent guidelines, from the U.S. Department of Energy, indicate costs of about $440,000 to $650,000 per mile (updated to 2003 dollars) for 230 kV lines with rated capacities of 398 MW and 796 MW, exclusive of right of way costs.[5] Recent major transmission line construction projects, including the Navajo Transmission Project from the Four Corners area to Las Vegas and the Bonneville Power Administration's Shultz-Hanford Project have experienced or estimated costs of between $1 million and $2 million per mile, though both of these examples involve 500 kV lines that would likely not be required to provide power to individual CRRP pumping stations.

Factoring in the difficult terrain along much of the CRRP pipeline alignments, plus right-of-way costs, this study assumes an average cost of $1 million per mile for the necessary transmission connections. As shown in Tables 6-9, 6-10, and 6-11, general estimates of transmission line construction costs range from about $140 million for the Central Corridor pipeline alignment to about $250 million for the Northern Corridor pipeline alignment.

Electric utilities might recoup the costs of building generation capacity and the annual energy costs through a composite charge per kilowatt hour (kWh) of energy consumed by the CRRP. Ranges of kilowatt hour prices were obtained from the U.S. Department of Energy and the Western Area Power Administration for Colorado and for the Rocky Mountain Power Region. Price ranges were found from 3.9 cents per kWh to 5.6 cents per kWh; the most recent industrial electric price data for Colorado (1999) indicate 4.4 cents per kWh price. This study assumes 5 cents per kWh, recognizing the uncertainty of future fuel prices and other variables. Applying this assumption, estimated annual CRRP energy costs are included in the operations costs shown in Table 6-9, 6-10, and 6-11.

Power Supply Conclusions

Based upon preliminary research, it appears that sufficient electric power can be provided for the CRRP. The 750,000 af delivery capacity scenario might be problematic from both a transmission line and generation standpoint. Hydrogeneration from the project can be used to partially offset power requirements. New generation capacity will likely be needed in western Colorado or elsewhere in the Rocky Mountain region to provide the base load power requirements for the CRRP. Transmission lines will need to be built from the project to nearby high-voltage transmission lines that currently cross western Colorado.

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[4] Electric Power Research Institute, Technical Assessment Guide: Electric Supply, 1989, Vol. 1, Revision 6, p. B-4. Updated to current dollars by BBC Research & Consulting using ENR Index.

[5] *Upgrading Transmission Capacity for Wholesale Electric Power Trade*. U.S. Department of Energy, Energy Information Administration. Table FE2. Accessed by Internet, file last updated on June 6, 2003.

Capital costs will be required to construct transmission lines from the pipeline to the high-voltage transmission lines that already exist. These costs are anticipated to range from $140 million to $250 million in up-front 2003 dollar requirements. Annual energy costs to pay for generation capacity and production will range from $110 million to $490 million, depending upon the alignment corridor and the water delivery scenario.

The size of such a project is not unprecedented. The annual pumping energy requirements for the California State Water Project are roughly comparable with the range of the CRRP pumping energy requirements.

Land and Easements

Land purchases will be required for facilities such as the water treatment plants, pumping stations, hydropower facilities, and storage reservoirs. Easements will also be needed for the pipeline

Advertisements for undeveloped land on the west slope of 5 acres or more ranged from $2000 to $20,000 per acre. This data was used to develop an average land value of $13,000 per acre that is used in the cost estimates for the water treatment plant, pump stations and hydropower facilities. Easement costs assumed to be 30% of the value of the land. Further studies would require additional research on land value that could result in modification of the alignments.

Ancillary Facilities

The costs of constructing and operating ancillary facilities not specifically discussed above including, but not limited to, access roads and their maintenance, are provided by the 30 percent cost contingency applied to all project configurations.

Sensitivity Analyses

The components of the CRRP can be grouped in five broad categories: 1) Diversion; 2) Operational storage; 3) Water treatment; 4) Conveyance; and 5) Energy recovery. The largest cost component of the CRRP is the conveyance system, including pipe, tunneling and pump stations. The conveyance system is also the largest contributor to annual operating costs, primarily due to pumping. Evaluation of the costs and benefits of these three components were conducted together because the sizing and operational characteristics of one component affects the sizing and operational requirements of the rest of the components in the system. It was determined during the layout of the alternative pipeline alignments that the cost and performance of the CRRP could be significantly affected by the length and depth of the tunnels (longer tunnels can reduce the magnitude of pumping along any given alignment) and the velocity of the water in the pipeline (the higher the velocity of flow, the smaller the pipe diameter will need to be, but more pumping energy is required). Therefore, analyses were made to test how sensitive the construction and operating costs are to the following two issues:

- Utilization of longer and deeper tunnels
- Reductions in pipeline diameter

Longer and Deeper Tunnels

By incorporating longer tunnels with greater overburden, the total pumping lift can be minimized, resulting in lower capital and operating cost for pumping and reduced pipe costs due to lower operating pressures. However, the unit cost of these tunnels is higher than shorter, shallower tunnels and may result in higher total capital costs.

To characterize the net effects of longer and deeper tunnels, they were incorporated into two of the alignments, one in the Central Corridor (C01) and one in the Southern Corridor (S02). Compared to the original C01 alignment, the net increase in capital (including tunneling, pipe, pump stations, and hydropower) after the inclusion of longer tunnels is on the order of $180 Million, with a net annual operating savings of $16 Million. This would offer direct pay back in a period of approximately eleven years. A greater benefit was seen in the sensitivity analysis for the southern alignment S02. With the inclusion of longer and deeper tunnels in alignment S02, the capital costs decrease by approximately $35 Million due to the decrease in amount of high pressure pipe. The annual operating costs are smaller as well, by approximately $42 Million. Should further studies be performed on the CRRP, the concept of longer and deeper tunnels should be considered.

Reductions in Pipeline Diameter

A reduction in pipe diameter reduces the unit cost of the pipeline, but increases the velocity in the pipeline. Increased fluid velocity results in higher friction along the pipe walls requiring higher head pumping pressures which increase the pumping station capital and operations cost. A cursory evaluation was performed to characterize the effect of a change in pipeline diameter on the Central Corridor alignment (C01) for the middle project delivery capacity of 500,000 af/yr.

The pipe diameter was reduced from 12-feet to 8.5-feet, approximately doubling the velocity in the pipe. It is recognized that the resulting velocity is on the higher end of the acceptable range, but was chosen to bracket the lowest potential pipe cost, and thus the greatest potential for savings. This resulted in a greater pumping capital cost, higher annual operating costs, and reduction in hydropower recovery. The net reduction in capital costs including pipe, pump stations, and hydropower is on the order of $400 million. The increase in net annual operating costs in on the order of $75 million. In this case the capital savings is utilized in a period just over 5 years, which is probably not justified. However, there may be some benefit to a smaller pipeline diameter reduction that should be evaluated further if future studies are conducted.

Additional Sensitivity Analyses

The two sensitivity analyses presented above are only starting points to consider in any future improvements in the layout of the CRRP alternatives. If further studies are conducted, these and other sensitivity studies should be performed including, but not limited to, the following:

- Utilization of longer and deeper tunnels
- Optimization of pipeline diameter
- Multiple pipes installed in the same trench instead of single large diameter pipe
- Additional pump stations and hydropower facilities along the alignment
- Use of above ground pipelines for portions of the alignment

- Use of gravity-flow canals to reduce project cost (note this concept may have water quality constraints if treatment facilities are sited ahead of the canal sections)

- Use of cast in place concrete conduits for portions of the alignment

Cost Summary

The data discussed in previous sections was used to compile opinions of probable costs for 31 alignments representing all three corridors. The results for each of the three delivery capacities are shown on Tables 6-9 through 6-11.

Total capital costs including construction, easements, engineering, administration and contingencies for the least costly alternatives are as follows:

- For 250,000 af/yr – approximately $3.7 billion or about $14,700 per acre foot[6]

- For 500,000 af/yr – approximately $6.0 billion or about $12,000 per acre foot[6]

- For 750,000 af/yr – approximately $8.7 billion or about $11,600 per acre foot[6]

For purposes of comparison, Colorado-Big Thompson Project water purchases are currently $21,000 to $24,000 per af of firm yield.

Total annual operation and maintenance costs including net energy purchases and operation of physical facilities are as follows:

- For 250,000 af/yr – approximately $220 million or about $890 per acre foot

- For 500,000 af/yr – approximately $420 million or about $840 per acre foot

- For 750,000 af/yr – approximately $620 million or about $820 per acre foot

The following general conclusions were reached:

1. Economy of Scale – for all 31 alignments, the estimated capital cost of per acre-foot of water delivered decreases with increasing delivery capacities, that is, at 750,000 af/yr, the CRRP is more cost effective per unit of water delivered than for 500,000 or 250,000 af/yr.

2. Most Cost-Effective Alignments within each Corridor - at this reconnaissance level of study, there are no significant differences in costs between the alignments in each corridor. Therefore, there is flexibility in future selection of specific alignments.

3. Most Cost-Effective Corridors – at this reconnaissance level of study, there are no significant differences in capital costs between the Central and South corridors. There is, however, a significant difference (approximately a 50% capital cost penalty) between the North Corridor and the other two corridors due to the increased length of pipe. Annual operating costs are also higher for the North Corridor. Comparing the least cost alignments in each corridor based on annual costs indicates that the North Corridor is

[6] Cost per acre foot is equal to the project cost divided by the project delivery capacity. Operating costs are discussed in Chapter 7.

almost 20% more expensive than the Central and almost 40% more expensive than the Southern. Environmental impacts and the differences between each corridor are discussed in the next chapter.

The affordability of the capital and annual operating costs, and their competitiveness with other sources of supply are discussed in the financial and economic sections of the next chapter.

Table 6-5 Initial Tunnel Alternatives Data

Conveyance Corridor	Tunnel Designation	Alignment Segment	Location	Tunnel Length miles	Tunnel Length feet	Tunnel Elevation (feet)	Maximum Ground Elevation	Maximum Cover (feet)	Average Cover (feet)	Rock Classification Class 1 (%)	Rock Classification Class 2 (%)	Rock Classification Class 3 (%)	Geology Comments	Estimated Cost/foot 10-foot I.D.	Estimated Cost/foot 12-foot I.D.	Estimated Cost/foot 15-foot I.D.
North	NCT01	NC3	Douglas Pass	2.26	11,933	7,500	8,500	1,000	610	0	80	20	Oil Shale	$1,700	$2,020	$2,500
	NCT02	NC2	Douglas Pass	0.9	4,752	8,150	8,700	550	320	0	80	20	Oil Shale	$1,750	$2,070	$2,550
	NCT03	NC2	Cathedral Bluffs	3.3	17,424	7,300	8,200	900	490	0	100	0	Sandstone	$1,600	$1,920	$2,400
	NCT04a	NC4	Good Spring Creek	4.3	22,704	7,250	8,500	1,250	775	0	0	100	Complex folded shale and sandstone	$1,950	$2,270	$2,750
	NCT04b	NC4	Good Spring Creek	3	15,840	7,200	8,300	1,100	630	0	0	100	Complex folded shale and sandstone	$1,900	$2,220	$2,700
	NCT05a	NC14	Henderson Tunnel	4.25	22,440	9,000-9,600	11,000	1,800	1,360	100	0	0	Crosses 4 large faults, wide squeezing ground	$1,600	$1,920	$2,400
	NCT05b	NC14	Henderson Tunnel	3.9	20,592	9,900-10,300	12,300	2,200	1,240	100	0	0	Crosses 4 large faults, wide squeezing ground	$1,600	$1,920	$2,400
Central	CCT01	CC2	Kimball Creek	11.4	60,192	6,300	8,600	2,300	710	0	80	20	Sandstone and shale	$1,700	$2,020	$2,500
	CCT02	CC11	Hunter Canyon/Corcorah Wash	3.7	19,536	6,100-6,500	6,900	600	430	0	90	10	Sandstone with possible coal and shale beds	$1,700	$2,020	$2,500
	CCT03	CC12	Corcoran Point	1.75	9,240	6,500	7,000	500	250	0	90	10	Sandstone with possible coal and shale beds	$1,750	$2,070	$2,550
	CCT04	CC3	Cottonwood Creek	1.5	7,920	7,250	7,700	450	230	0	80	20	Sandstone	$1,750	$2,070	$2,550
	CCT05a	CC2	De Beque	3.3	17,424	5,230	5,480	250	150	0	70	30	Shale and sandstone	$1,700	$2,020	$2,500
	CCT05b	CC15	De Beque	1.1	5,808	5,060-5,120	5,460	370	240	0	70	30	Shale and sandstone	$1,750	$2,070	$2,550
	CCT06	CC6	Garfield Creek	1.15	6,072	6,100	6,700	600	380	0	30	70	Shale and sandstone	$1,750	$2,070	$2,550
	CCT07	CC3	Glenwood Springs	8	42,240	6,400-6,900	9,150	2,600	1,450	0	25	75	Soft shale, coal, gypsum, hot water, crosses 4 large faults. Bedding dips at 45 deg.	$2,700	$3,020	$3,500
	CCT08	CC3	Cottonwood Divide	16.7	88,176	6,800	8,500	1,700	1,010	0	20	80	Gypsum, soft shale, volcanics	$2,700	$3,020	$3,500
	CCT09	CC3	Bellyache Mountain	9.7	51,216	7,550	9,550	2,000	1,000	0	60	40	Limestone, crosses 1 large fault	$2,000	$2,320	$2,800
	CCT10	CC3	Battle Mountain	1.95	10,296	8,750	9,550	800	510	30	60	10	Sandstone	$1,650	$1,970	$2,450
	CCT11	CC8	Tennessee Pass	0.85	4,488	10,200	10,500	300	150	80	10	10	Parallel to fault	$1,700	$2,020	$2,500
	CCT12	CC4	Mount Democrat	2.5	13,200	11,500	13,300	1,800	900	80	20	0	Intrusive contacts, crosses 1 large fault	$1,600	$1,920	$2,400
South	SCT01	SC3	Fitzpatrick Mesa	2.65	13,992	8,400	9,350	950	650	70	0	30	Crosses 1 large fault and 1 small fault	$1,600	$1,920	$2,400
	SCT02a	SC6	Blue Mesa	0.85	4,488	8,600	9,000	400	200	90	0	10	Crosses 1 large fault.	$1,750	$2,070	$2,550
	SCT02b	SC6	Blue Mesa	1.9	10,032	8,600	9,000	400	270	90	0	10	Crosses small fault	$1,700	$2,020	$2,500
	SCT02c	SC6	Blue Mesa	2.9	15312	8,500	8,900	400	230	90	0	10	Crosses small fault	$1,500	$1,820	$2,300
	SCT03	SC8	Carpenter Ridge	1.6	8448	8,300	8,800	500	350	70	0	30	Buried paleo valley filled with weak volcanic rock.	$1,750	$2,070	$2,550
	SCT04	SC18	Kebler Pass	0.75	3960	9,850	10,100	250	130	40	20	40	Intrusive contacts.	$1,850	$2,170	$2,650
	SCT05	SC28	Cement Mountain	4.6	24288	9,500	11,320	1,820	800	20	50	30	Complex geology, limestone, numerous intrusive contacts, crosses 4 large faults.	$1,900	$2,220	$2,700
	SCT06	SC25	Matchless Mountain	2.1	11088	9,700	12,140	2,440	1000	60	30	10	Numerous intrusive contacts	$1,600	$1,920	$2,400
	SCT07	SC21	Bertha Gulch	2.05	10824	10,250	10,700	450	250	80	20	0	Limestone, intrusive contacts	$1,450	$1,770	$2,250
	SCT08	SC21	Mount Kreutzer	2.95	15576	11,500	12,800	1,300	750	100	0	0	Intrusive contacts	$1,450	$1,770	$2,250
	SCT09	SC26	Lost Lake	1.65	8712	11,550	12,600	1,050	530	100	0	0	Intrusive contacts	$1,500	$1,820	$2,300
	SCT10	SC12	Wausita Pass	2.75	14520	9,800	10,700	900	460	100	0	0	Intrusive contacts	$1,450	$1,770	$2,250
	SCT11	SC13	Continental Divide	7.5	39600	10,000	12,800	2,800	1,580	100	0	0	Intrusive contacts	$1,600	$1,920	$2,400
	SCT12a	SC24	San Isabel Forest	1.45	7656	10,100	10,100	550	270	30	20	50	Limestone, evaporites (salt and gypsum)	$1,750	$2,070	$2,550
	SCT12b	SC24	Pike Forest	1.65	8712	10,000	10,000	500	250	30	20	50	Intrusive contact, crosses 3 large faults	$1,850	$2,170	$2,650

Notes:

1. Rock Classification:

Class 1: Strong rock including gneiss, schist, granite, metamorphic rock, intrusive igneous rock.

Class 2: Moderately strong rock including sandstone, limestone and hard shale.

Class 3: Weak rock including shale, interbedded sandstone/siltstone/shale, volcanic ash and tuff.

Table 6-6 Subsequent Tunnel Alternatives Data

Conveyance Corridor	Tunnel Designation	Alignment Segment	Location	Tunnel Length miles	Tunnel Length feet	Tunnel Elevation (feet)	Maximum Ground Elevation	Maximum Cover (feet)	Average Cover (feet)	Rock Classification Class 1 (%)	Rock Classification Class 2 (%)	Rock Classification Class 3 (%)	Geology Comments	Estimated Cost/foot 10-foot I.D.	Estimated Cost/foot 12-foot I.D.	Estimated Cost/foot 15-foot I.D.
North	NCT06	NC2	Pike Ridge	18.2	96,096	6,100-6,300	8,800	2,600	1,210	0	90	10	Sandstone	$2,400	$2,720	$3,200
	NCT07	NC2	Cathedral Bluffs	24.2	127,776	6,600-6,000	8,400	1,800	625	0	75	25	Sandstone, shale, oil shale	$2,300	$2,620	$3,100
	NCT08	NC4	White River	8.2	43,296	6,000	7,200	1,200	460	0	70	30	Sandstone, shale	$2,200	$2,520	$3,000
	NCT09	NC4	Yellowjacket Pass	12.3	64,944	8,150	8,350	1,600	780	0	0	100	Shale	$2,700	$3,020	$3,500
	NCT10	NC4	Iles Mountain	11.6	61,248	6,900-7,100	8,500	1,500	910	0	0	100	Shale	$2,700	$3,020	$3,500
	NCT11	NC4	Beaver Creek	5.8	30,624	7,050-7,200	8,300	1,200	780	0	0	100	Shale	$2,600	$2,920	$3,400
	NCT12	NC5 to NC13	Morrison Creek	30	158,400	7,400	10,350	2,950	1,650	60	20	20	Sandstone, 5 large faults	$2,800	$3,120	$3,600
Central	CCT13	CC11	South Shale Ridge	21.6	114,048	5,000-5,100	7,800	2,750	1,350	0	60	40	Shale, sandstone	$2,800	$3,120	$3,600
	CCT14	CC3	Roaring Fork River	14.7	77,616	6,000	8,700	2,700	1,150	0	20	80	Shale, gypsum, hot water	$2,700	$3,020	$3,500
	CCT15	CC3	Cottonwood Divide	18.9	99,792	6,050-6,600	9,200	2,950	1,670	0	20	80	Shale, gysum, salt, hot water	$2,800	$3,120	$3,600
	CCT16	CC3	Bellyache Mountain	9.6	50,688	7,200-7,300	9,300	2,050	970	0	40	60	Complex structure, faults, shale, evaporites	$2,600	$2,920	$3,400
South	SCT13	SC2	Cimmaron	7.4	39,072	7,000-6,950	8,300	1,300	840	10	20	70	Shale	$2,400	$2,720	$3,200
	SCT14	SC2 to SC7	Fitzpatrick/Blue/ Pine Mesas	12.8	67,584	7,100-7,850	9,350	1,950	1,050	80	10	10	Crosses 2 large faults and 3 small faults	$1,900	$2,220	$2,700
	SCT15	SC7 to SC8	Carpenter Ridge	4.5	23,760	7,600	8,800	1,200	740	90	0	10	Faults, Buried paleo valley filled with weak volcanic rock	$1,900	$2,220	$2,700
	SCT16	SC11 to SC14	Continental Divide	32.8	173,184	8,100-8,200	13,300	5,100	2,070	80	10	10	Intrusive Contacts, Faults	$2,800	$3,120	$3,600

Notes:

1. Rock Classification:

Class 1: Strong rock including gneiss, schist, granite, metamorphic rock, intrusive igneous rock.

Class 2: Moderately strong rock including sandstone, limestone and hard shale.

Class 3: Weak rock including shale, interbedded sandstone/siltstone/shale, volcanic ash and tuff.

Table 6-9 - Total Project Costs - 250,000 acre-feet per year Delivery Capacity ($ in Millions)

	Capital Costs																					Annual Operations			
	Infrastructure										Contingencies		Land								Summary				
Alternative	Pipe	Appurts.	Const. Cond.	Tunnels	Pump Stat.	Hydro	Diver. Struc.	Water Treatment	Storage	Power Trans	Total Capital	General 30%	E&A 20%	WTP Land Cost	# of PS	PS Land Cost	# of Hydro	Hydro Land Cost	Pipe Length (miles)	Pipe Ease. Cost	Total L & E Costs	Total Project Cost	Pump & Hydro	WTP	Pipeline	Total O&M
N01	$ 2,090	$ 104	$ 313	$ 147	$ 355	$ 87	$ 0.9	$ 605	$ 75	$ 250	$ 4,027	$ 1,208	$ 805	$ 92	14	$ 0.4	7	$ 0.09	260	$ 26	$ 118	$ 6,159	$ 175	$ 68	$ 13	$ 257
N02	$ 1,997	$ 100	$ 300	$ 147	$ 365	$ 88	$ 0.9	$ 605	$ 75	$ 250	$ 3,929	$ 1,179	$ 786	$ 92	15	$ 0.4	7	$ 0.09	253	$ 25	$ 118	$ 6,011	$ 178	$ 68	$ 13	$ 259
N03	$ 2,054	$ 103	$ 308	$ 147	$ 357	$ 87	$ 0.9	$ 605	$ 75	$ 250	$ 3,986	$ 1,196	$ 797	$ 92	14	$ 0.4	7	$ 0.09	257	$ 26	$ 118	$ 6,098	$ 175	$ 68	$ 13	$ 257
N04	$ 2,015	$ 101	$ 302	$ 147	$ 341	$ 75	$ 0.9	$ 605	$ 75	$ 250	$ 3,912	$ 1,174	$ 782	$ 92	14	$ 0.4	6	$ 0.08	253	$ 25	$ 118	$ 5,986	$ 194	$ 68	$ 13	$ 275
N05	$ 2,051	$ 103	$ 308	$ 147	$ 371	$ 104	$ 0.9	$ 605	$ 75	$ 250	$ 4,015	$ 1,204	$ 803	$ 92	15	$ 0.4	9	$ 0.12	260	$ 26	$ 118	$ 6,140	$ 178	$ 68	$ 13	$ 259
N06	$ 2,108	$ 105	$ 316	$ 147	$ 363	$ 103	$ 0.9	$ 605	$ 75	$ 250	$ 4,073	$ 1,222	$ 815	$ 92	14	$ 0.4	9	$ 0.12	264	$ 26	$ 119	$ 6,229	$ 175	$ 68	$ 13	$ 256
N07	$ 2,146	$ 107	$ 322	$ 147	$ 361	$ 102	$ 0.9	$ 605	$ 75	$ 250	$ 4,116	$ 1,235	$ 823	$ 92	14	$ 0.4	9	$ 0.12	268	$ 27	$ 119	$ 6,293	$ 175	$ 68	$ 13	$ 256
N08	$ 2,070	$ 104	$ 311	$ 147	$ 347	$ 90	$ 0.9	$ 605	$ 75	$ 250	$ 3,999	$ 1,200	$ 800	$ 92	14	$ 0.4	8	$ 0.10	260	$ 26	$ 118	$ 6,118	$ 173	$ 68	$ 13	$ 254
C01	$ 734	$ 37	$ 110	$ 392	$ 244	$ 33	$ 0.9	$ 605	$ 75	$ 140	$ 2,371	$ 711	$ 474	$ 92	11	$ 0.3	3	$ 0.04	184	$ 18	$ 111	$ 3,667	$ 140	$ 68	$ 13	$ 221
C02	$ 738	$ 37	$ 111	$ 403	$ 235	$ 29	$ 0.9	$ 605	$ 75	$ 140	$ 2,374	$ 712	$ 475	$ 92	11	$ 0.3	3	$ 0.04	184	$ 18	$ 111	$ 3,671	$ 139	$ 68	$ 13	$ 220
C03	$ 816	$ 41	$ 122	$ 377	$ 256	$ 36	$ 0.9	$ 605	$ 75	$ 140	$ 2,469	$ 741	$ 494	$ 92	11	$ 0.3	3	$ 0.04	193	$ 19	$ 112	$ 3,815	$ 143	$ 68	$ 13	$ 224
C04	$ 725	$ 36	$ 109	$ 223	$ 297	$ 63	$ 0.9	$ 605	$ 75	$ 200	$ 2,336	$ 701	$ 467	$ 92	15	$ 0.4	5	$ 0.07	168	$ 17	$ 109	$ 3,613	$ 150	$ 68	$ 13	$ 231
C05	$ 730	$ 37	$ 110	$ 260	$ 295	$ 63	$ 0.9	$ 605	$ 75	$ 200	$ 2,375	$ 713	$ 475	$ 92	15	$ 0.4	5	$ 0.07	168	$ 17	$ 109	$ 3,672	$ 149	$ 68	$ 13	$ 230
S01	$ 961	$ 48	$ 144	$ 150	$ 258	$ 78	$ 0.9	$ 605	$ 75	$ 180	$ 2,500	$ 750	$ 500	$ 92	12	$ 0.3	6	$ 0.08	195	$ 19	$ 112	$ 3,862	$ 120	$ 68	$ 13	$ 201
S02	$ 1,078	$ 54	$ 162	$ 74	$ 226	$ 46	$ 0.9	$ 605	$ 75	$ 150	$ 2,472	$ 741	$ 494	$ 92	11	$ 0.3	4	$ 0.05	217	$ 22	$ 114	$ 3,821	$ 115	$ 68	$ 13	$ 196
S03	$ 973	$ 49	$ 146	$ 155	$ 275	$ 78	$ 0.9	$ 605	$ 75	$ 180	$ 2,537	$ 761	$ 507	$ 92	12	$ 0.3	6	$ 0.08	198	$ 20	$ 112	$ 3,918	$ 118	$ 68	$ 13	$ 200
S04	$ 1,001	$ 50	$ 150	$ 127	$ 276	$ 73	$ 0.9	$ 605	$ 75	$ 180	$ 2,537	$ 761	$ 507	$ 92	13	$ 0.3	5	$ 0.07	202	$ 20	$ 113	$ 3,918	$ 121	$ 68	$ 13	$ 202
S05	$ 990	$ 49	$ 148	$ 121	$ 277	$ 72	$ 0.9	$ 605	$ 75	$ 180	$ 2,519	$ 756	$ 504	$ 92	13	$ 0.3	5	$ 0.07	199	$ 20	$ 112	$ 3,891	$ 121	$ 68	$ 13	$ 203
S06	$ 1,027	$ 51	$ 154	$ 100	$ 246	$ 63	$ 0.9	$ 605	$ 75	$ 180	$ 2,502	$ 751	$ 500	$ 92	11	$ 0.3	5	$ 0.07	202	$ 20	$ 112	$ 3,866	$ 112	$ 68	$ 13	$ 194
S07	$ 1,057	$ 53	$ 158	$ 71	$ 247	$ 58	$ 0.9	$ 605	$ 75	$ 180	$ 2,505	$ 751	$ 501	$ 92	12	$ 0.3	4	$ 0.05	206	$ 21	$ 113	$ 3,870	$ 114	$ 68	$ 13	$ 195
S08	$ 1,001	$ 50	$ 150	$ 119	$ 217	$ 48	$ 0.9	$ 605	$ 75	$ 150	$ 2,415	$ 725	$ 483	$ 92	11	$ 0.3	4	$ 0.05	215	$ 21	$ 114	$ 3,737	$ 107	$ 68	$ 13	$ 188
S09	$ 979	$ 49	$ 147	$ 141	$ 220	$ 53	$ 0.9	$ 605	$ 75	$ 150	$ 2,421	$ 726	$ 484	$ 92	11	$ 0.3	5	$ 0.07	216	$ 22	$ 114	$ 3,745	$ 108	$ 68	$ 13	$ 189
S10	$ 997	$ 50	$ 150	$ 126	$ 272	$ 89	$ 0.9	$ 605	$ 75	$ 150	$ 2,514	$ 754	$ 503	$ 92	12	$ 0.3	8	$ 0.10	214	$ 21	$ 114	$ 3,885	$ 119	$ 68	$ 13	$ 200
S11	$ 1,016	$ 51	$ 152	$ 97	$ 267	$ 86	$ 0.9	$ 605	$ 75	$ 150	$ 2,500	$ 750	$ 500	$ 92	12	$ 0.3	8	$ 0.10	218	$ 22	$ 114	$ 3,864	$ 119	$ 68	$ 13	$ 200
S12	$ 1,059	$ 53	$ 159	$ 96	$ 228	$ 52	$ 0.9	$ 605	$ 75	$ 150	$ 2,479	$ 744	$ 496	$ 92	11	$ 0.3	5	$ 0.07	218	$ 22	$ 114	$ 3,832	$ 114	$ 68	$ 13	$ 195
S13	$ 1,078	$ 54	$ 162	$ 81	$ 280	$ 88	$ 0.9	$ 605	$ 75	$ 150	$ 2,573	$ 772	$ 515	$ 92	12	$ 0.3	8	$ 0.10	216	$ 22	$ 114	$ 3,974	$ 125	$ 68	$ 13	$ 206
S14	$ 1,097	$ 55	$ 165	$ 52	$ 275	$ 86	$ 0.9	$ 605	$ 75	$ 150	$ 2,560	$ 768	$ 512	$ 92	12	$ 0.3	8	$ 0.10	220	$ 22	$ 114	$ 3,954	$ 125	$ 68	$ 13	$ 207
S15	$ 1,030	$ 52	$ 155	$ 120	$ 206	$ 42	$ 0.9	$ 605	$ 75	$ 150	$ 2,435	$ 731	$ 487	$ 92	10	$ 0.3	4	$ 0.05	213	$ 21	$ 114	$ 3,767	$ 105	$ 68	$ 13	$ 187
S16	$ 1,013	$ 51	$ 152	$ 142	$ 210	$ 48	$ 0.9	$ 605	$ 75	$ 150	$ 2,447	$ 734	$ 489	$ 92	10	$ 0.3	5	$ 0.07	214	$ 21	$ 114	$ 3,785	$ 107	$ 68	$ 13	$ 188
S17	$ 1,032	$ 52	$ 155	$ 126	$ 264	$ 84	$ 0.9	$ 605	$ 75	$ 150	$ 2,544	$ 763	$ 509	$ 92	11	$ 0.3	8	$ 0.10	212	$ 21	$ 114	$ 3,929	$ 119	$ 68	$ 13	$ 200
S18	$ 1,053	$ 53	$ 158	$ 98	$ 258	$ 81	$ 0.9	$ 605	$ 75	$ 150	$ 2,531	$ 759	$ 506	$ 92	11	$ 0.3	8	$ 0.10	217	$ 22	$ 114	$ 3,911	$ 119	$ 68	$ 13	$ 200

Table Heading Legend and Descriptions (for a more detailed description of the assumptions see the Chapter 6 Text)

Alternative - alternative name

Capital Costs

- **Pipe** - the baseline installed construction cost for the pipeline
- **Appurts.** - allowance for pipe appurtenances such as valves and misc. items (5% of the baseline pipe cost)
- **Const. Cond.** - allowance for difficult construction conditions such as rock, limited access, etc. (15% of baseline)
- **Tunnels** - total construction cost for all of the tunnels included in the alternative
- **Pump Stat.** - total construction cost for all of the pump stations included in the alternative
- **Hydro** - total construction cost for all of the hydropower facilities included in the alternative
- **Diver. Struc.** - construction cost of the diversion structure
- **Water Treatment** - Construction cost of the water treatment plant
- **Storage** - construction cost of the operational storage include in the alternative
- **Power Trans** - Construction cost of installing power transmission
- **Total Capital** - total cost of construction for the infrastructure items listed above

General 30% - allowance of the 30% of the Total Capital cost for unaccounted for items and contingency

E&A 20% - allowance of 20% for engineering, legal, administration and permitting

Land

- **WTP Land Cost** - cost of land required for the treatment plant
- **# of PS** - number of pump stations included in the alternative
- **PS Land Cost** - cost of the land required for all of the pump stations
- **# of Hydro** - number of hydro power facilities included in the alternative
- **Hydro Land Cost** - cost of the land required for all of the hydropower facilities
- **Pipe Length (miles)** - total length of pipe
- **Pipe Ease. Cost** - cost of the pipeline easement
- **Total L & E Cost** - total cost of the land purchases and easement acquisition

Total Project Cost - Includes the total Capital Cost, Contingency, E & A, and Land and Easement Acquisition

Annual Operations

- **Pump & Hydro** - total operations cost for pump stations and hydropower facilities (including hydropower revenue)
- **WTP** - operations cost for the water treatment plant
- **Pipeline** - maintenance cost of the pipeline and tunnels (0.5% of the total pipeline and tunnel construction cost)
- **Total O&M** - total annual operations cost for the above items

Table 6-10 - Total Project Costs - 500,000 acre-feet per year Delivery Capacity ($ in Millions)

	Capital Costs: Infrastructure											Capital Costs: Contingencies		Capital Costs: Land								Capital Costs: Summary	Annual Operations			
Alternative	Pipe	Appurts.	Const. Cond.	Tunnels	Pump Stat.	Hydro	Diver. Struc.	Water Treatment	Storage	Power Trans	Total Capital	General 30%	E&A 20%	WTP Land Cost	# of PS	PS Land Cost	# of Hydro	Hydro Land Cost	Pipe Length (miles)	Pipe Ease. Cost	Total L & E Costs	Total Project Cost	Pump & Hydro	WTP	Pipeline	Total O&M
N01	$ 3,392	$ 170	$ 509	$ 168	$ 707	$ 152	$ 2	$ 1,103	$ 150	$ 250	$ 6,602	$ 1,981	$ 1,320	$ 185	14	$ 1	7	$ 0.09	260	$ 28	$ 214	$ 10,117	$ 345	$ 130	$ 13	$ 488
N02	$ 3,228	$ 161	$ 484	$ 168	$ 728	$ 155	$ 2	$ 1,103	$ 150	$ 250	$ 6,429	$ 1,929	$ 1,286	$ 185	15	$ 1	7	$ 0.09	253	$ 28	$ 213	$ 9,857	$ 351	$ 130	$ 13	$ 494
N03	$ 3,339	$ 167	$ 501	$ 168	$ 711	$ 153	$ 2	$ 1,103	$ 150	$ 250	$ 6,544	$ 1,963	$ 1,309	$ 185	14	$ 1	7	$ 0.09	257	$ 28	$ 214	$ 10,030	$ 346	$ 130	$ 13	$ 489
N04	$ 3,257	$ 163	$ 489	$ 168	$ 678	$ 132	$ 2	$ 1,103	$ 150	$ 250	$ 6,393	$ 1,918	$ 1,279	$ 185	14	$ 1	6	$ 0.08	253	$ 28	$ 213	$ 9,802	$ 381	$ 130	$ 13	$ 525
N05	$ 3,308	$ 165	$ 496	$ 168	$ 739	$ 183	$ 2	$ 1,103	$ 150	$ 250	$ 6,565	$ 1,969	$ 1,313	$ 185	15	$ 1	9	$ 0.12	260	$ 28	$ 214	$ 10,061	$ 349	$ 130	$ 13	$ 493
N06	$ 3,416	$ 171	$ 512	$ 168	$ 721	$ 181	$ 2	$ 1,103	$ 150	$ 250	$ 6,674	$ 2,002	$ 1,335	$ 185	14	$ 1	9	$ 0.12	264	$ 29	$ 215	$ 10,225	$ 345	$ 130	$ 13	$ 489
N07	$ 3,470	$ 174	$ 521	$ 168	$ 717	$ 180	$ 2	$ 1,103	$ 150	$ 250	$ 6,735	$ 2,020	$ 1,347	$ 185	14	$ 1	9	$ 0.12	268	$ 29	$ 215	$ 10,317	$ 345	$ 130	$ 13	$ 488
N08	$ 3,341	$ 167	$ 501	$ 168	$ 691	$ 160	$ 2	$ 1,103	$ 150	$ 250	$ 6,533	$ 1,960	$ 1,307	$ 185	14	$ 1	8	$ 0.10	260	$ 28	$ 214	$ 10,014	$ 338	$ 130	$ 13	$ 481
C01	$ 1,242	$ 62	$ 186	$ 445	$ 484	$ 59	$ 2	$ 1,103	$ 150	$ 140	$ 3,873	$ 1,162	$ 775	$ 185	11	$ 1	3	$ 0.04	184	$ 20	$ 206	$ 6,016	$ 276	$ 130	$ 13	$ 419
C02	$ 1,225	$ 61	$ 184	$ 465	$ 466	$ 53	$ 2	$ 1,103	$ 150	$ 140	$ 3,849	$ 1,155	$ 770	$ 185	11	$ 1	3	$ 0.04	184	$ 20	$ 206	$ 5,979	$ 272	$ 130	$ 13	$ 415
C03	$ 1,378	$ 69	$ 207	$ 454	$ 537	$ 63	$ 2	$ 1,103	$ 150	$ 140	$ 4,102	$ 1,231	$ 820	$ 185	11	$ 1	3	$ 0.04	193	$ 21	$ 207	$ 6,360	$ 301	$ 130	$ 13	$ 445
C04	$ 1,245	$ 62	$ 187	$ 256	$ 592	$ 111	$ 2	$ 1,103	$ 150	$ 200	$ 3,909	$ 1,173	$ 782	$ 185	15	$ 1	5	$ 0.07	168	$ 18	$ 204	$ 6,067	$ 296	$ 130	$ 13	$ 439
C05	$ 1,244	$ 62	$ 187	$ 297	$ 600	$ 110	$ 2	$ 1,103	$ 150	$ 200	$ 3,955	$ 1,187	$ 791	$ 185	15	$ 1	5	$ 0.07	168	$ 18	$ 204	$ 6,137	$ 302	$ 130	$ 13	$ 445
S01	$ 1,654	$ 83	$ 248	$ 171	$ 544	$ 135	$ 2	$ 1,103	$ 150	$ 180	$ 4,271	$ 1,281	$ 854	$ 185	12	$ 1	6	$ 0.08	195	$ 21	$ 207	$ 6,613	$ 232	$ 130	$ 13	$ 375
S02	$ 1,840	$ 92	$ 276	$ 89	$ 442	$ 81	$ 2	$ 1,103	$ 150	$ 150	$ 4,225	$ 1,267	$ 845	$ 185	11	$ 1	4	$ 0.05	217	$ 24	$ 209	$ 6,546	$ 222	$ 130	$ 13	$ 365
S03	$ 1,675	$ 84	$ 251	$ 178	$ 541	$ 135	$ 2	$ 1,103	$ 150	$ 180	$ 4,300	$ 1,290	$ 860	$ 185	12	$ 1	6	$ 0.08	198	$ 22	$ 207	$ 6,656	$ 229	$ 130	$ 13	$ 372
S04	$ 1,718	$ 86	$ 258	$ 150	$ 542	$ 125	$ 2	$ 1,103	$ 150	$ 180	$ 4,313	$ 1,294	$ 863	$ 185	13	$ 1	5	$ 0.07	202	$ 22	$ 208	$ 6,678	$ 233	$ 130	$ 13	$ 377
S05	$ 1,698	$ 85	$ 255	$ 143	$ 545	$ 125	$ 2	$ 1,103	$ 150	$ 180	$ 4,285	$ 1,285	$ 857	$ 185	13	$ 1	5	$ 0.07	199	$ 22	$ 207	$ 6,634	$ 236	$ 130	$ 13	$ 379
S06	$ 1,777	$ 89	$ 267	$ 114	$ 483	$ 110	$ 2	$ 1,103	$ 150	$ 180	$ 4,274	$ 1,282	$ 855	$ 185	11	$ 1	5	$ 0.07	202	$ 22	$ 208	$ 6,619	$ 217	$ 130	$ 13	$ 361
S07	$ 1,822	$ 91	$ 273	$ 85	$ 484	$ 100	$ 2	$ 1,103	$ 150	$ 180	$ 4,290	$ 1,287	$ 858	$ 185	12	$ 1	4	$ 0.05	206	$ 22	$ 208	$ 6,642	$ 222	$ 130	$ 13	$ 365
S08	$ 1,698	$ 85	$ 255	$ 143	$ 424	$ 83	$ 2	$ 1,103	$ 150	$ 150	$ 4,092	$ 1,228	$ 818	$ 185	11	$ 1	4	$ 0.05	215	$ 23	$ 209	$ 6,347	$ 206	$ 130	$ 13	$ 349
S09	$ 1,658	$ 83	$ 249	$ 170	$ 433	$ 94	$ 2	$ 1,103	$ 150	$ 150	$ 4,090	$ 1,227	$ 818	$ 185	11	$ 1	5	$ 0.07	216	$ 24	$ 209	$ 6,345	$ 208	$ 130	$ 13	$ 351
S10	$ 1,699	$ 85	$ 255	$ 146	$ 536	$ 157	$ 2	$ 1,103	$ 150	$ 150	$ 4,283	$ 1,285	$ 857	$ 185	12	$ 1	8	$ 0.10	214	$ 23	$ 209	$ 6,633	$ 248	$ 130	$ 13	$ 391
S11	$ 1,722	$ 86	$ 258	$ 117	$ 525	$ 152	$ 2	$ 1,103	$ 150	$ 150	$ 4,265	$ 1,279	$ 853	$ 185	12	$ 1	8	$ 0.10	218	$ 24	$ 209	$ 6,607	$ 230	$ 130	$ 13	$ 374
S12	$ 1,814	$ 91	$ 272	$ 116	$ 449	$ 91	$ 2	$ 1,103	$ 150	$ 150	$ 4,237	$ 1,271	$ 847	$ 185	11	$ 1	5	$ 0.07	218	$ 24	$ 209	$ 6,565	$ 220	$ 130	$ 13	$ 364
S13	$ 1,846	$ 92	$ 277	$ 92	$ 554	$ 158	$ 2	$ 1,103	$ 150	$ 150	$ 4,423	$ 1,327	$ 885	$ 185	12	$ 1	8	$ 0.10	216	$ 24	$ 209	$ 6,843	$ 240	$ 130	$ 13	$ 384
S14	$ 1,868	$ 93	$ 280	$ 63	$ 543	$ 153	$ 2	$ 1,103	$ 150	$ 150	$ 4,404	$ 1,321	$ 881	$ 185	12	$ 1	8	$ 0.10	220	$ 24	$ 210	$ 6,816	$ 241	$ 130	$ 13	$ 385
S15	$ 1,770	$ 89	$ 266	$ 144	$ 403	$ 74	$ 2	$ 1,103	$ 150	$ 150	$ 4,150	$ 1,245	$ 830	$ 185	10	$ 1	4	$ 0.05	213	$ 23	$ 209	$ 6,433	$ 203	$ 130	$ 13	$ 347
S16	$ 1,735	$ 87	$ 260	$ 170	$ 414	$ 85	$ 2	$ 1,103	$ 150	$ 150	$ 4,156	$ 1,247	$ 831	$ 185	10	$ 1	5	$ 0.07	214	$ 23	$ 209	$ 6,443	$ 208	$ 130	$ 13	$ 351
S17	$ 1,766	$ 88	$ 265	$ 146	$ 519	$ 151	$ 2	$ 1,103	$ 150	$ 150	$ 4,341	$ 1,302	$ 868	$ 185	11	$ 1	8	$ 0.10	212	$ 23	$ 209	$ 6,720	$ 228	$ 130	$ 13	$ 371
S18	$ 1,791	$ 90	$ 269	$ 118	$ 508	$ 146	$ 2	$ 1,103	$ 150	$ 150	$ 4,325	$ 1,297	$ 865	$ 185	11	$ 1	8	$ 0.10	217	$ 24	$ 209	$ 6,697	$ 230	$ 130	$ 13	$ 374

Table Heading Legend and Descriptions (for a more detailed description of the assumptions see the Chapter 6 Text)

Alternative - alternative name

Capital Costs

- **Pipe** - the baseline installed construction cost for the pipeline
- **Appurts.** - allowance for pipe appurtenances such as valves and misc. items (5% of the baseline pipe cost)
- **Const. Cond.** - allowance for difficult construction conditions such as rock, limited access, etc. (15% of baseline)
- **Tunnels** - total construction cost for all of the tunnels included in the alternative
- **Pump Stat.** - total construction cost for all of the pump stations included in the alternative
- **Hydro** - total construction cost for all of the hydropower facilities included in the alternative
- **Diver. Struc.** - construction cost of the diversion structure
- **Water Treatment** - Construction cost of the water treatment plant
- **Storage** - construction cost of the operational storage include in the alternative
- **Power Trans** - Construction cost of installing power transmission
- **Total Capital** - total cost of construction for the infrastructure items listed above

General 30% - allowance of the 30% of the Total Capital cost for unaccounted for items and contingency

E&A 20% - allowance of 20% for engineering, legal, administration and permitting

Land

- **WTP Land Cost** - cost of land required for the treatment plant
- **# of PS** - number of pump stations included in the alternative
- **PS Land Cost** - cost of the land required for all of the pump stations
- **# of Hydro** - number of hydro power facilities included in the alternative
- **Hydro Land Cost** - cost of the land required for all of the hydropower facilities
- **Pipe Length (miles)** - total length of pipe
- **Pipe Ease. Cost** - cost of the pipeline easement
- **Total L & E Cost** - total cost of the land purchases and easement acquisition

Total Project Cost - Includes the total Capital Cost, Contingency, E & A, and Land and Easement Acquisition

Annual Operations

- **Pump & Hydro** - total operations cost for pump stations and hydropower facilities (including hydropower revenue)
- **WTP** - operations cost for the water treatment plant
- **Pipeline** - maintenance cost of the pipeline and tunnels (0.5% of the total pipeline and tunnel construction cost)
- **Total O&M** - total annual operations cost for the above items

Table 6-11 - Total Project Costs - 750,000 acre-feet per year Delivery Capacity ($ in Millions)

	Capital Costs																						Annual Operations			
	Infrastructure											Contingencies		Land								Summary				
Alternative	Pipe	Appurts.	Const. Cond.	Tunnels	Pump Stat.	Hydro	Diver. Struc.	Water Treatment	Storage	Power Trans	Total Capital	General 30%	E&A 20%	WTP Land Cost	# of PS	PS Land Cost	# of Hydro	Hydro Land Cost	Pipe Length (miles)	Pipe Ease. Cost	Total L & E Costs	Total Project Cost	Pump & Hydro	WTP	Pipeline	Total O&M
N01	$ 5,237	$ 262	$ 786	$ 205	$ 1,060	$ 211	$ 3	$ 1,618	$ 225	$ 250	$ 9,856	$ 2,957	$ 1,971	$ 277	14	$ 1	7	$ 0.09	260	$ 31	$ 309	$ 15,093	$ 515	$ 193	$ 13	$ 721
N02	$ 4,978	$ 249	$ 747	$ 205	$ 1,092	$ 215	$ 3	$ 1,618	$ 225	$ 250	$ 9,581	$ 2,874	$ 1,916	$ 277	15	$ 1	7	$ 0.09	253	$ 30	$ 309	$ 14,680	$ 523	$ 193	$ 13	$ 730
N03	$ 5,146	$ 257	$ 772	$ 205	$ 1,066	$ 212	$ 3	$ 1,618	$ 225	$ 250	$ 9,754	$ 2,926	$ 1,951	$ 277	14	$ 1	7	$ 0.09	257	$ 30	$ 309	$ 14,941	$ 516	$ 193	$ 13	$ 722
N04	$ 5,029	$ 251	$ 754	$ 205	$ 1,018	$ 183	$ 3	$ 1,618	$ 225	$ 250	$ 9,537	$ 2,861	$ 1,907	$ 277	14	$ 1	6	$ 0.08	253	$ 30	$ 309	$ 14,613	$ 570	$ 193	$ 13	$ 777
N05	$ 5,108	$ 255	$ 766	$ 205	$ 1,109	$ 254	$ 3	$ 1,618	$ 225	$ 250	$ 9,793	$ 2,938	$ 1,959	$ 277	15	$ 1	9	$ 0.12	260	$ 31	$ 310	$ 14,999	$ 521	$ 193	$ 13	$ 727
N06	$ 5,271	$ 264	$ 791	$ 205	$ 1,082	$ 251	$ 3	$ 1,618	$ 225	$ 250	$ 9,959	$ 2,988	$ 1,992	$ 277	14	$ 1	9	$ 0.12	264	$ 31	$ 310	$ 15,248	$ 513	$ 193	$ 13	$ 719
N07	$ 5,365	$ 268	$ 805	$ 205	$ 1,076	$ 250	$ 3	$ 1,618	$ 225	$ 250	$ 10,064	$ 3,019	$ 2,013	$ 277	14	$ 1	9	$ 0.12	268	$ 32	$ 310	$ 15,407	$ 512	$ 193	$ 13	$ 718
N08	$ 5,163	$ 258	$ 774	$ 205	$ 1,036	$ 223	$ 3	$ 1,618	$ 225	$ 250	$ 9,755	$ 2,927	$ 1,951	$ 277	14	$ 1	8	$ 0.10	260	$ 31	$ 309	$ 14,942	$ 505	$ 193	$ 13	$ 711
C01	$ 1,890	$ 94	$ 283	$ 531	$ 726	$ 82	$ 3	$ 1,618	$ 225	$ 140	$ 5,592	$ 1,677	$ 1,118	$ 277	11	$ 1	3	$ 0.04	184	$ 22	$ 300	$ 8,687	$ 412	$ 193	$ 13	$ 618
C02	$ 1,919	$ 96	$ 288	$ 554	$ 699	$ 74	$ 3	$ 1,618	$ 225	$ 140	$ 5,615	$ 1,685	$ 1,123	$ 277	11	$ 1	3	$ 0.04	184	$ 22	$ 300	$ 8,723	$ 407	$ 193	$ 13	$ 613
C03	$ 2,111	$ 106	$ 317	$ 544	$ 761	$ 87	$ 3	$ 1,618	$ 225	$ 140	$ 5,910	$ 1,773	$ 1,182	$ 277	11	$ 1	3	$ 0.04	193	$ 23	$ 301	$ 9,167	$ 421	$ 193	$ 13	$ 627
C04	$ 1,893	$ 95	$ 284	$ 320	$ 889	$ 154	$ 3	$ 1,618	$ 225	$ 200	$ 5,680	$ 1,704	$ 1,136	$ 277	15	$ 1	5	$ 0.07	168	$ 20	$ 298	$ 8,818	$ 443	$ 193	$ 13	$ 649
C05	$ 1,879	$ 94	$ 282	$ 297	$ 900	$ 153	$ 3	$ 1,618	$ 225	$ 200	$ 5,650	$ 1,695	$ 1,130	$ 277	15	$ 1	5	$ 0.07	168	$ 20	$ 299	$ 8,773	$ 452	$ 193	$ 13	$ 658
S01	$ 2,498	$ 125	$ 375	$ 209	$ 816	$ 186	$ 3	$ 1,618	$ 225	$ 180	$ 6,234	$ 1,870	$ 1,247	$ 277	12	$ 1	6	$ 0.08	195	$ 23	$ 301	$ 9,653	$ 360	$ 193	$ 13	$ 567
S02	$ 2,801	$ 140	$ 420	$ 111	$ 664	$ 112	$ 3	$ 1,618	$ 225	$ 150	$ 6,243	$ 1,873	$ 1,249	$ 277	11	$ 1	4	$ 0.05	217	$ 26	$ 304	$ 9,669	$ 331	$ 193	$ 13	$ 537
S03	$ 2,527	$ 126	$ 379	$ 218	$ 812	$ 186	$ 3	$ 1,618	$ 225	$ 180	$ 6,275	$ 1,883	$ 1,255	$ 277	12	$ 1	6	$ 0.08	198	$ 23	$ 302	$ 9,714	$ 342	$ 193	$ 13	$ 548
S04	$ 2,601	$ 130	$ 390	$ 184	$ 813	$ 173	$ 3	$ 1,618	$ 225	$ 180	$ 6,317	$ 1,895	$ 1,263	$ 277	13	$ 1	5	$ 0.07	202	$ 24	$ 302	$ 9,778	$ 349	$ 193	$ 13	$ 555
S05	$ 2,572	$ 129	$ 386	$ 176	$ 817	$ 172	$ 3	$ 1,618	$ 225	$ 180	$ 6,277	$ 1,883	$ 1,255	$ 277	13	$ 1	5	$ 0.07	199	$ 24	$ 302	$ 9,718	$ 353	$ 193	$ 13	$ 559
S06	$ 2,687	$ 134	$ 403	$ 141	$ 724	$ 151	$ 3	$ 1,618	$ 225	$ 180	$ 6,266	$ 1,880	$ 1,253	$ 277	11	$ 1	5	$ 0.07	202	$ 24	$ 302	$ 9,702	$ 323	$ 193	$ 13	$ 529
S07	$ 2,764	$ 138	$ 415	$ 107	$ 725	$ 137	$ 3	$ 1,618	$ 225	$ 180	$ 6,312	$ 1,893	$ 1,262	$ 277	12	$ 1	4	$ 0.05	206	$ 24	$ 303	$ 9,770	$ 331	$ 193	$ 13	$ 538
S08	$ 2,593	$ 130	$ 389	$ 160	$ 636	$ 114	$ 3	$ 1,618	$ 225	$ 150	$ 6,018	$ 1,805	$ 1,204	$ 277	11	$ 1	4	$ 0.05	215	$ 26	$ 304	$ 9,331	$ 308	$ 193	$ 13	$ 514
S09	$ 2,515	$ 126	$ 377	$ 194	$ 649	$ 130	$ 3	$ 1,618	$ 225	$ 150	$ 5,987	$ 1,796	$ 1,197	$ 277	11	$ 1	5	$ 0.07	216	$ 26	$ 304	$ 9,285	$ 310	$ 193	$ 13	$ 517
S10	$ 2,565	$ 128	$ 385	$ 181	$ 805	$ 217	$ 3	$ 1,618	$ 225	$ 150	$ 6,276	$ 1,883	$ 1,255	$ 277	12	$ 1	8	$ 0.10	214	$ 25	$ 304	$ 9,718	$ 370	$ 193	$ 13	$ 576
S11	$ 2,602	$ 130	$ 390	$ 147	$ 788	$ 211	$ 3	$ 1,618	$ 225	$ 150	$ 6,264	$ 1,879	$ 1,253	$ 277	12	$ 1	8	$ 0.10	218	$ 26	$ 304	$ 9,700	$ 344	$ 193	$ 13	$ 550
S12	$ 2,752	$ 138	$ 413	$ 145	$ 673	$ 127	$ 3	$ 1,618	$ 225	$ 150	$ 6,243	$ 1,873	$ 1,249	$ 277	11	$ 1	5	$ 0.07	218	$ 26	$ 304	$ 9,668	$ 329	$ 193	$ 13	$ 536
S13	$ 2,779	$ 139	$ 417	$ 113	$ 830	$ 218	$ 3	$ 1,618	$ 225	$ 150	$ 6,493	$ 1,948	$ 1,299	$ 277	12	$ 1	8	$ 0.10	216	$ 26	$ 304	$ 10,044	$ 359	$ 193	$ 13	$ 565
S14	$ 2,817	$ 141	$ 422	$ 79	$ 814	$ 212	$ 3	$ 1,618	$ 225	$ 150	$ 6,481	$ 1,944	$ 1,296	$ 277	12	$ 1	8	$ 0.10	220	$ 26	$ 305	$ 10,025	$ 360	$ 193	$ 13	$ 567
S15	$ 2,697	$ 135	$ 405	$ 179	$ 604	$ 103	$ 3	$ 1,618	$ 225	$ 150	$ 6,118	$ 1,835	$ 1,224	$ 277	10	$ 1	4	$ 0.05	213	$ 25	$ 303	$ 9,481	$ 304	$ 193	$ 13	$ 510
S16	$ 2,632	$ 132	$ 395	$ 216	$ 621	$ 118	$ 3	$ 1,618	$ 225	$ 150	$ 6,110	$ 1,833	$ 1,222	$ 277	10	$ 1	5	$ 0.07	214	$ 25	$ 304	$ 9,468	$ 311	$ 193	$ 13	$ 517
S17	$ 2,659	$ 133	$ 399	$ 185	$ 779	$ 209	$ 3	$ 1,618	$ 225	$ 150	$ 6,359	$ 1,908	$ 1,272	$ 277	11	$ 1	8	$ 0.10	212	$ 25	$ 303	$ 9,842	$ 340	$ 193	$ 13	$ 546
S18	$ 2,703	$ 135	$ 405	$ 151	$ 762	$ 203	$ 3	$ 1,618	$ 225	$ 150	$ 6,355	$ 1,906	$ 1,271	$ 277	11	$ 1	8	$ 0.10	217	$ 26	$ 304	$ 9,836	$ 341	$ 193	$ 13	$ 547

Table Heading Legend and Descriptions (for a more detailed description of the assumptions see the Chapter 6 Text)

Alternative - alternative name

Capital Costs

- **Pipe** - the baseline installed construction cost for the pipeline
- **Appurts.** - allowance for pipe appurtenances such as valves and misc. items (5% of the baseline pipe cost)
- **Const. Cond.** - allowance for difficult construction conditions such as rock, limited access, etc. (15% of baseline)
- **Tunnels** - total construction cost for all of the tunnels inlcuded in the alternative
- **Pump Stat.** - total construction cost for all of the pump stations included in the alternative
- **Hydro** - total construction cost for all of the hydropower facilities included in the alternative
- **Diver. Struc.** - construction cost of the diversion structure
- **Water Treatment** - Construction cost of the water treatment plant
- **Storage** - construction cost of the operational storage include in the alternative
- **Power Trans** - Construction cost of installing power transmission
- **Total Capital** - total cost of construction for the infrastructure items listed above

General 30% - allowance of the 30% of the Total Capital cost for unaccounted for items and contingency

E&A 20% - allowance of 20% for engineering, legal, administration and permitting

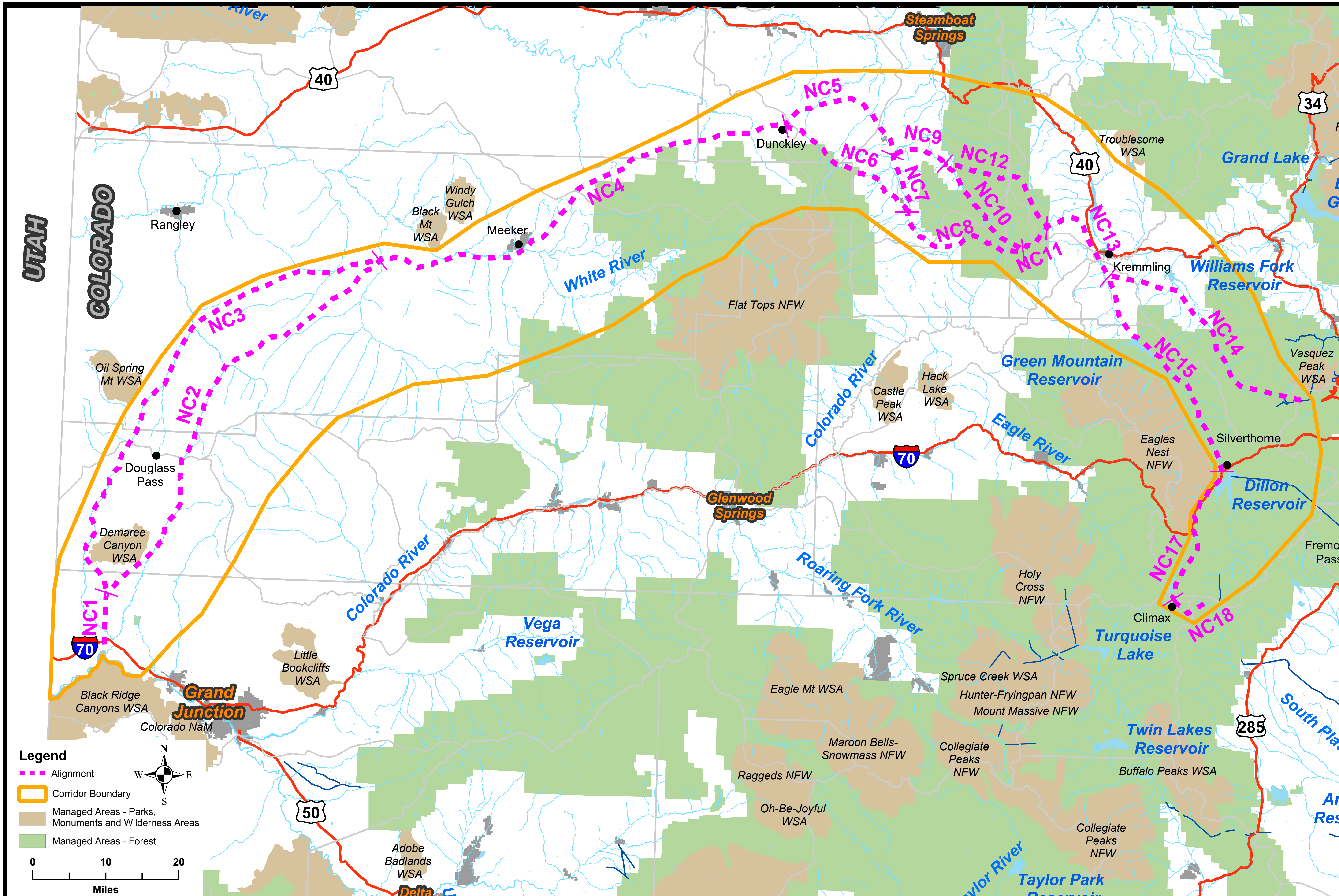
Land

- **WTP Land Cost** - cost of land required for the treatment plant
- **# of PS** - number of pump stations included in the alternative
- **PS Land Cost** - cost of the land required for all of the pump stations
- **# of Hydro** - number of hydro power facilities included in the alternative
- **Hydro Land Cost** - cost of the land required for all of the hydropower facilities
- **Pipe Length (miles)** - total length of pipe
- **Pipe Ease. Cost** - cost of the pipeline easement
- **Total L & E Cost** - total cost of the land purchases and easement acquisition

Total Project Cost - Includes the total Capital Cost, Contingency, E & A, and Land and Easement Acquisition

Annual Operations

- **Pump & Hydro** - total operations cost for pump stations and hydropower facilities (including hydropower revenue)
- **WTP** - operations cost for the water treatment plant
- **Pipeline** - maintenance cost of the pipeline and tunnels (0.5% of the total pipeline and tunnel construction cost)
- **Total O&M** - total annual operations cost for the above items



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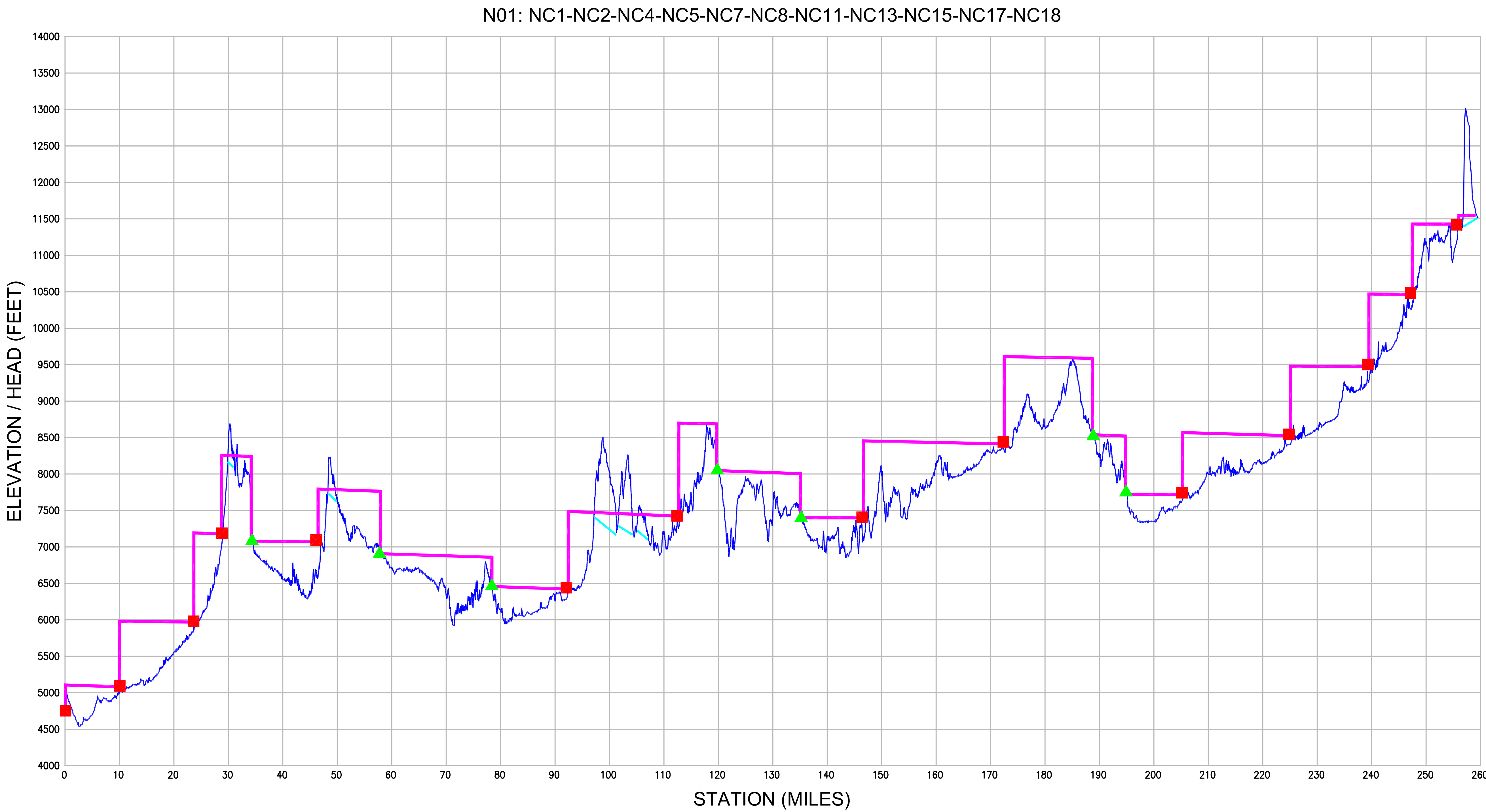
COLORADO RIVER RETURN RECONNAISSANCE STUDY

NORTH CORRIDOR ALIGNMENTS

FIGURE
6-1



LEGEND

- PUMP STATION
- HYDRO POWER STATION
- TUNNEL
- HYDRAULIC GRADE LINE
- GROUND SURFACE (PIPE ELEVATION NEAR GROUND SURFACE EXCEPT AT TUNNELS)

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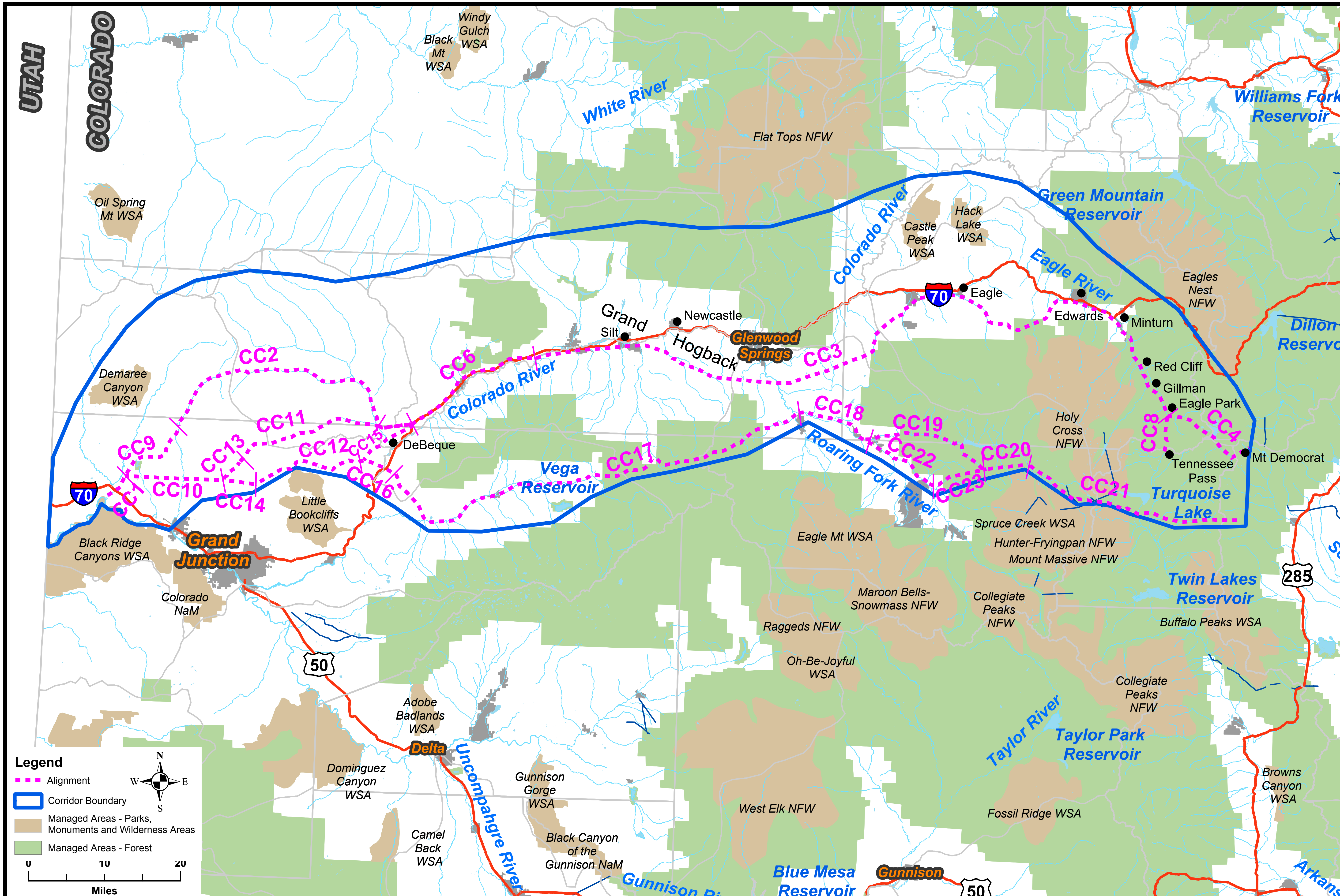
COLORADO RIVER RETURN RECONNAISSANCE STUDY

TYPICAL NORTH CORRIDOR PROFILE

FIGURE 6-2

DWG: Z:_DENVER PROJECTS\C72\501\CAD\PLAN SET\PROFILES.dwg USER: mrau
DATE: Nov 14, 2003 2:08pm XREFS: IMAGES: CENTRAL_PROF.jpg NORTH_PROF.jpg SOUTH_PROF.jpg



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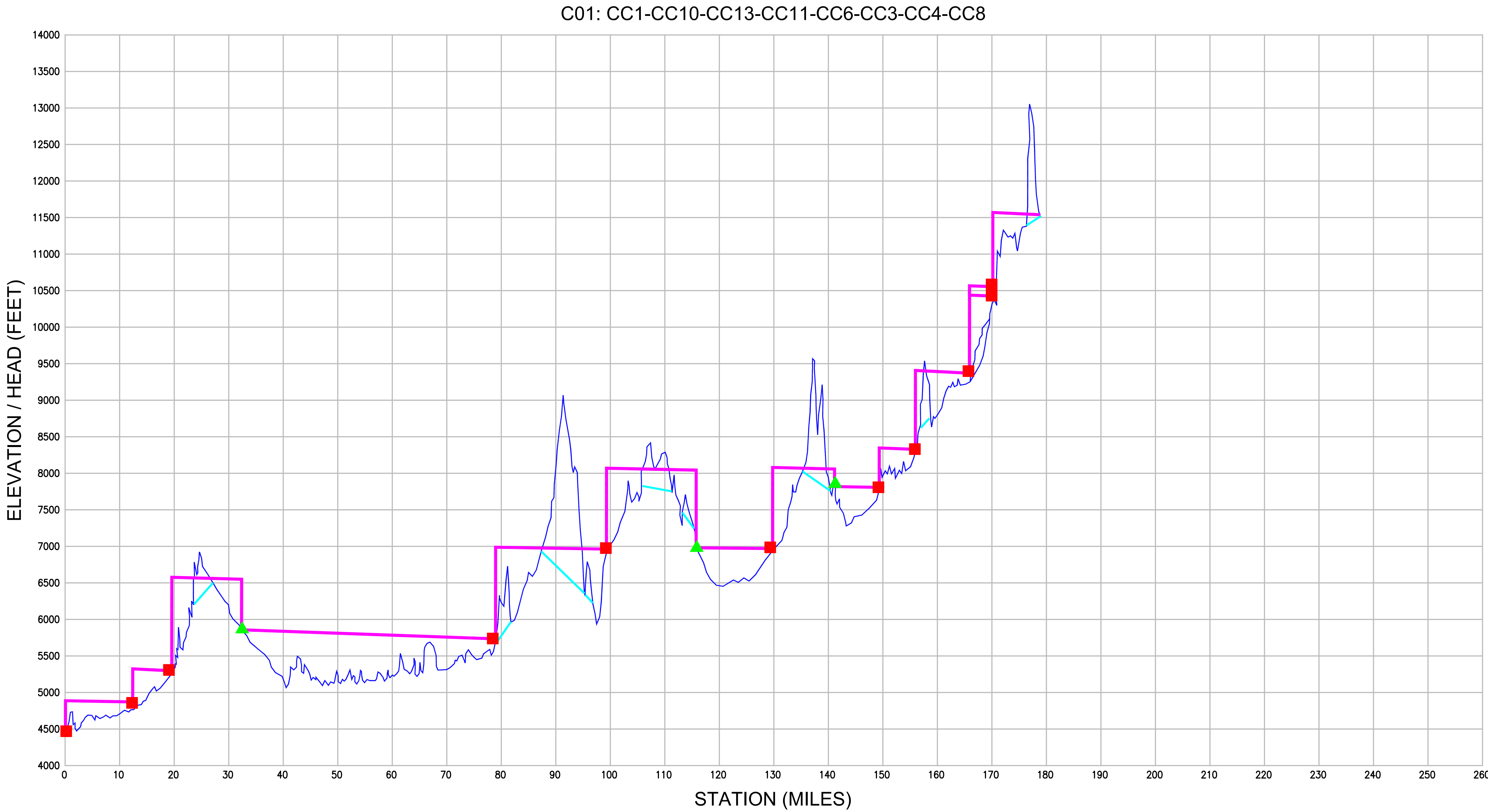
COLORADO RIVER RETURN RECONNAISSANCE STUDY

CENTRAL CORRIDOR ALIGNMENTS

FIGURE 6-3



LEGEND

- PUMP STATION
- HYDRO POWER STATION
- TUNNEL
- HYDRAULIC GRADE LINE
- GROUND SURFACE (PIPE ELEVATION NEAR GROUND SURFACE EXCEPT AT TUNNELS)

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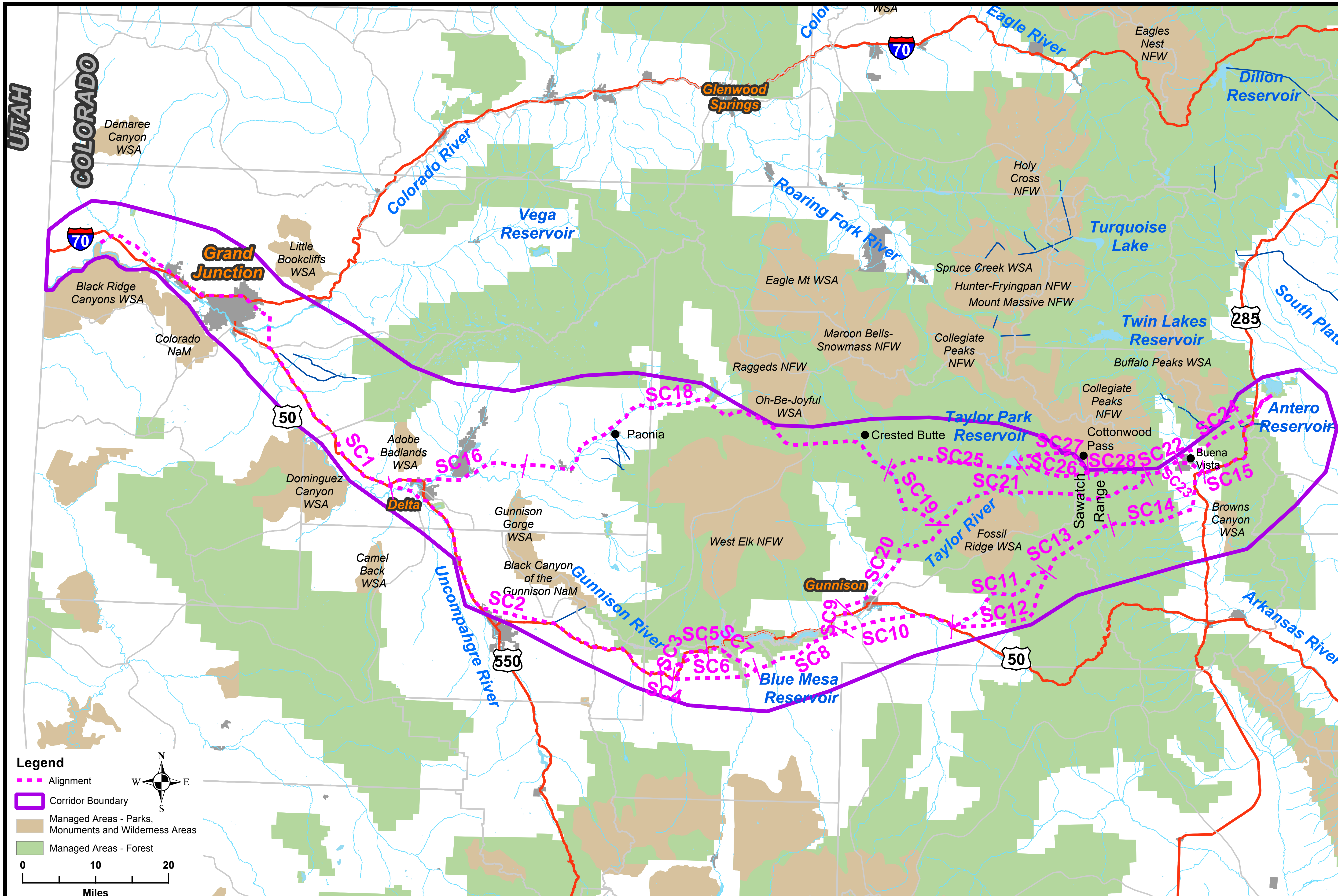
COLORADO RIVER RETURN RECONNAISSANCE STUDY

TYPICAL CENTRAL CORRIDOR PROFILE

FIGURE 6-4

DWG: Z:_DENVER PROJECTS\C72\501\CAD\PLAN SET\PROFILES.dwg USER: mrau
DATE: Nov 14, 2003 2:09pm XREFS: IMAGES: CENTRAL_PROF.jpg NORTH_PROF.jpg SOUTH_PROF.jpg



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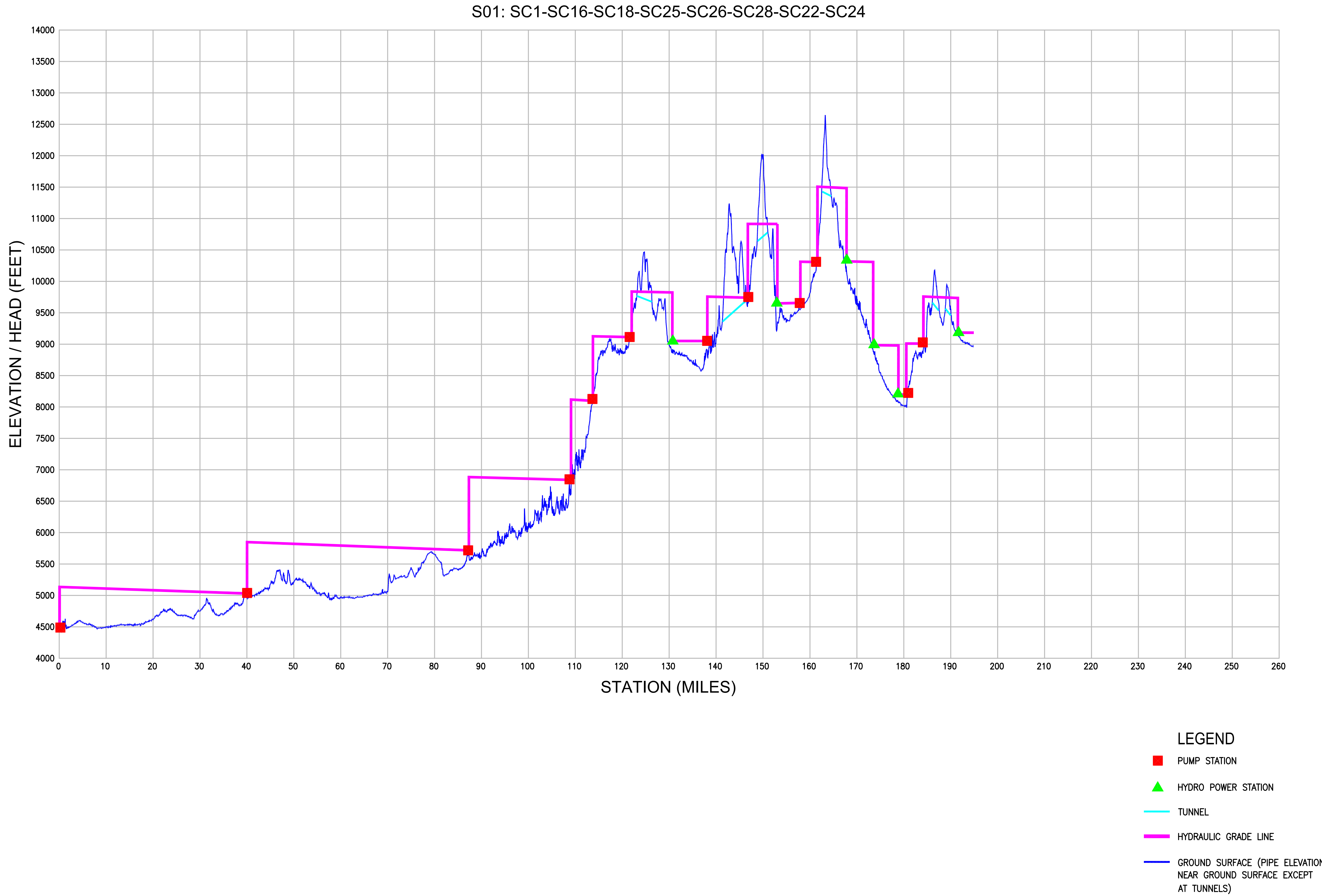
SOUTH CORRIDOR ALIGNMENTS

FIGURE
6-5



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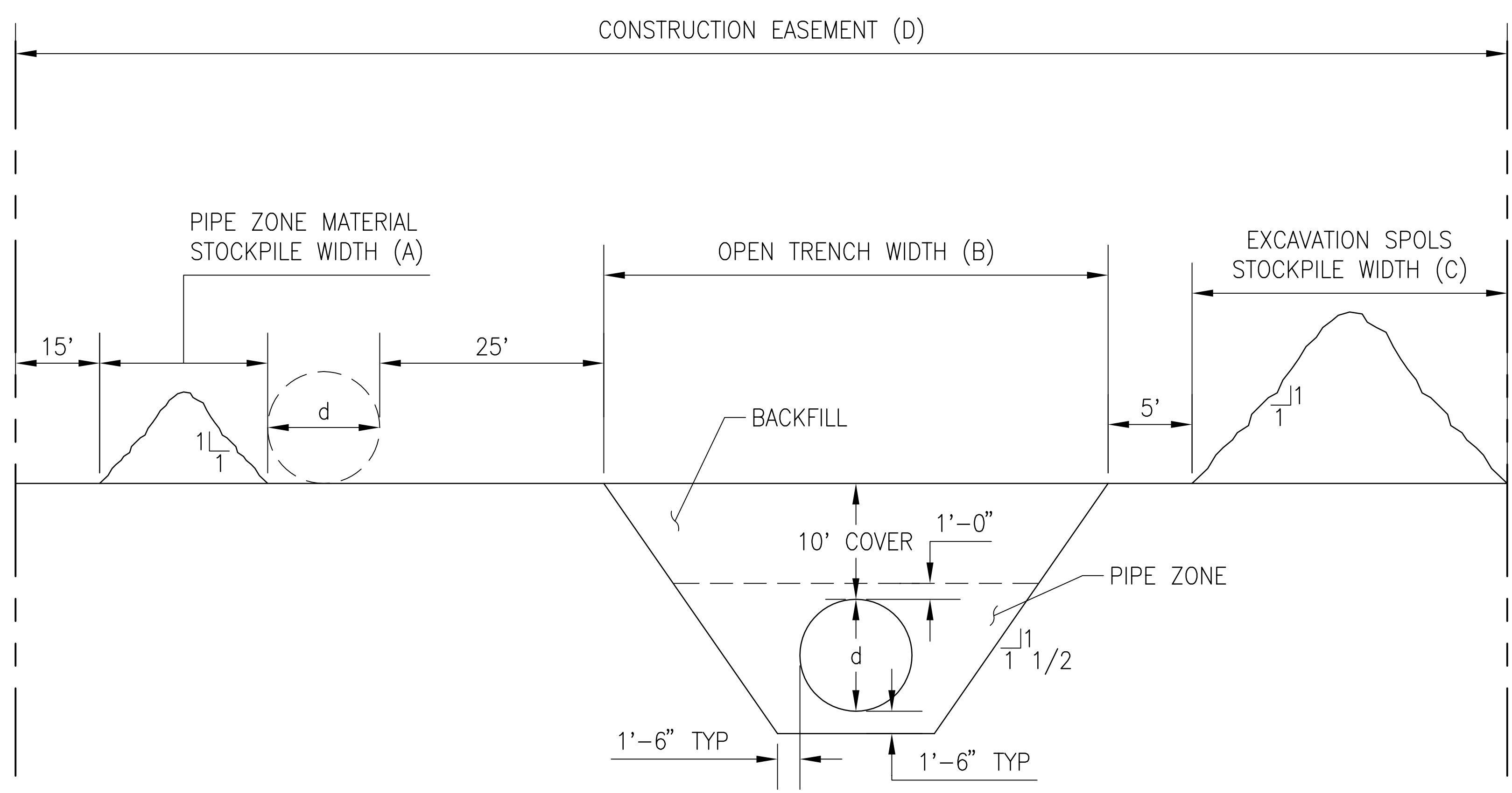
TYPICAL SOUTH CORRIDOR PROFILE

FIGURE 6-6

DWG: Z:_DENVER PROJECTS\C72\501\CAD\PLAN SET\PROFILES.dwg USER: mrau
DATE: Nov 14, 2003 2:10pm XREFS: IMAGES: CENTRAL_PROF.jpg NORTH_PROF.jpg SOUTH_PROF.jpg

DWG: Z:_DENVER PROJECTS\C72\501\CAD\PLAN SET\CJ301.dwg USER: mrau
DATE: Nov 14, 2003 2:12pm XREFS: IMAGES:



PIPE DIAMETER(d)	A	B	C	D
8.5'	31	75	50	210
12'	34	85	54	230
15'	35	100	55	250

TYPICAL SECTION

N.T.S.

FIGURE **6-7**

COLORADO RIVER RETURN RECONNAISSANCE STUDY

TYPICAL TRENCH SECTION
AND CONSTRUCTION EASEMENT

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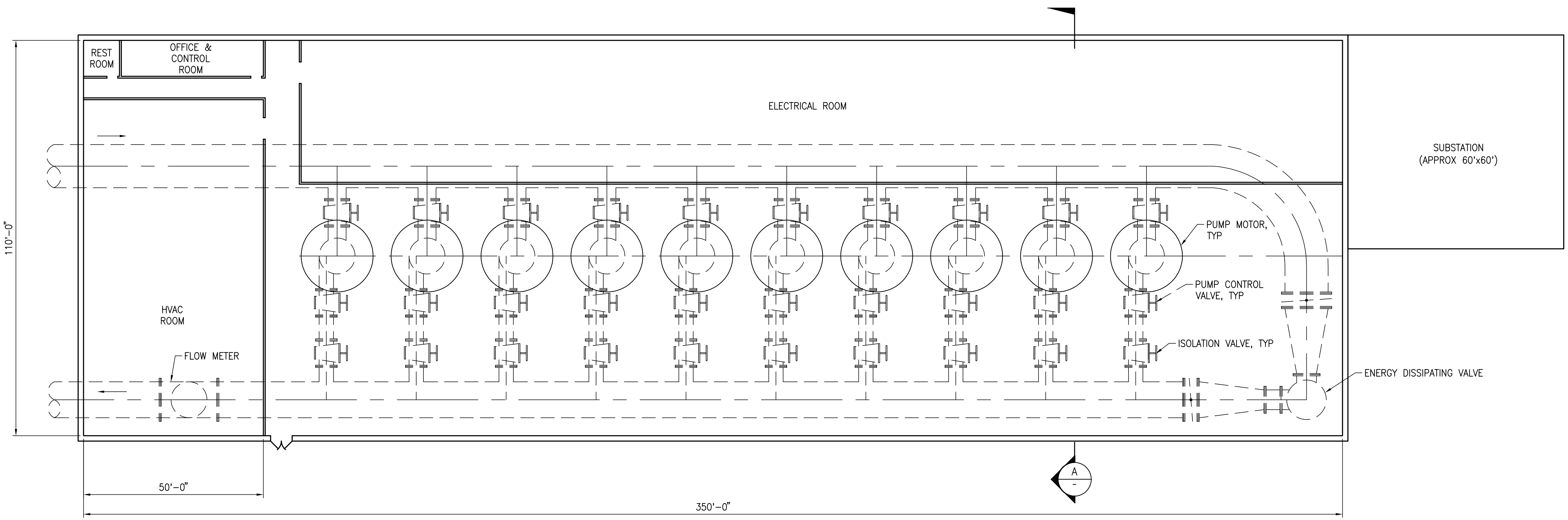

PUMP STATION PLAN

SCALE: 1" = 20'

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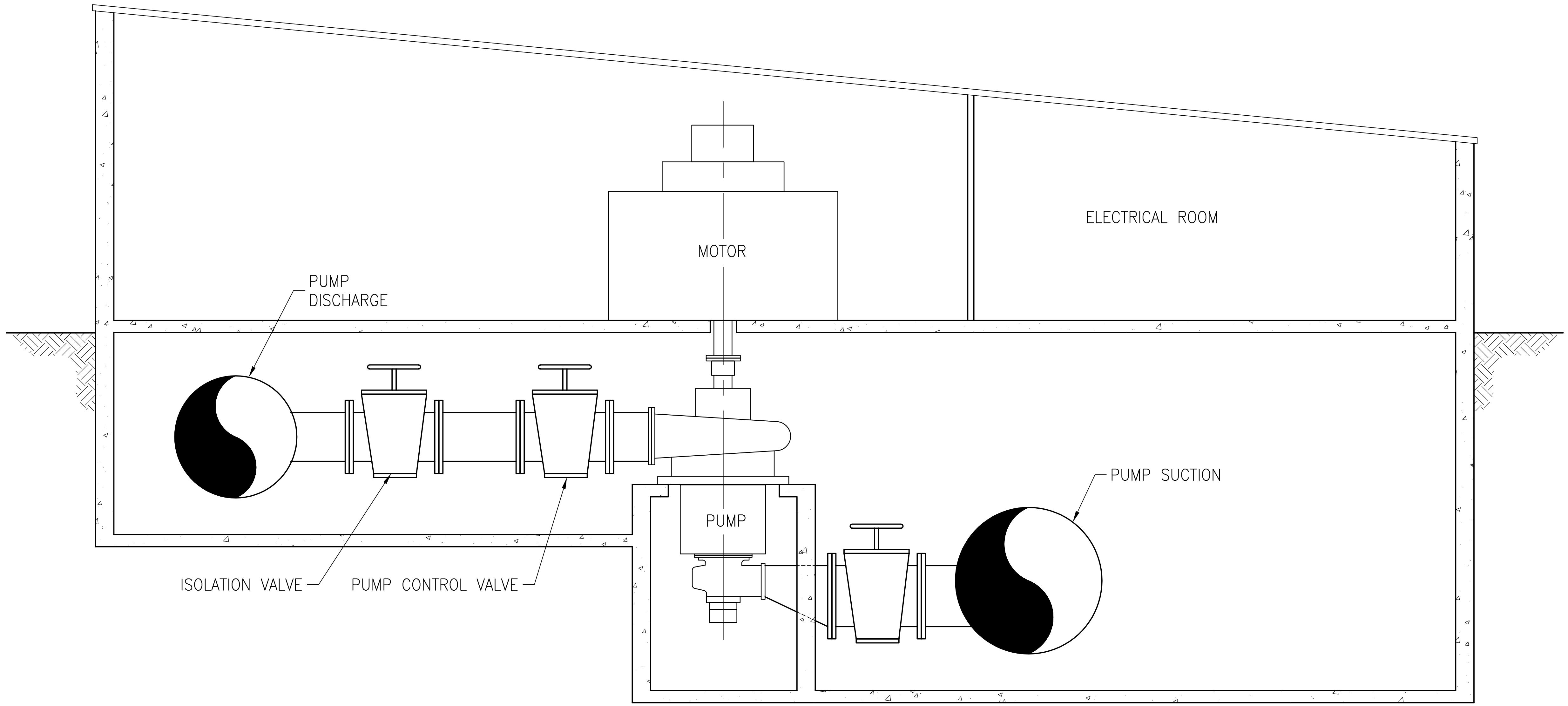
COLORADO RIVER RETURN RECONNAISSANCE STUDY

1400-FT 720 CFS PUMP STATION PLAN

FIGURE 6-8

DWG: Z:_DENVER PROJECTS\C72\501\CAD\PLAN SET\PUMPSTATION.dwg USER: mrau
DATE: Nov 14, 2003 2:13pm XREFS: IMAGES:



SECTION A
SCALE: 1" = 10'

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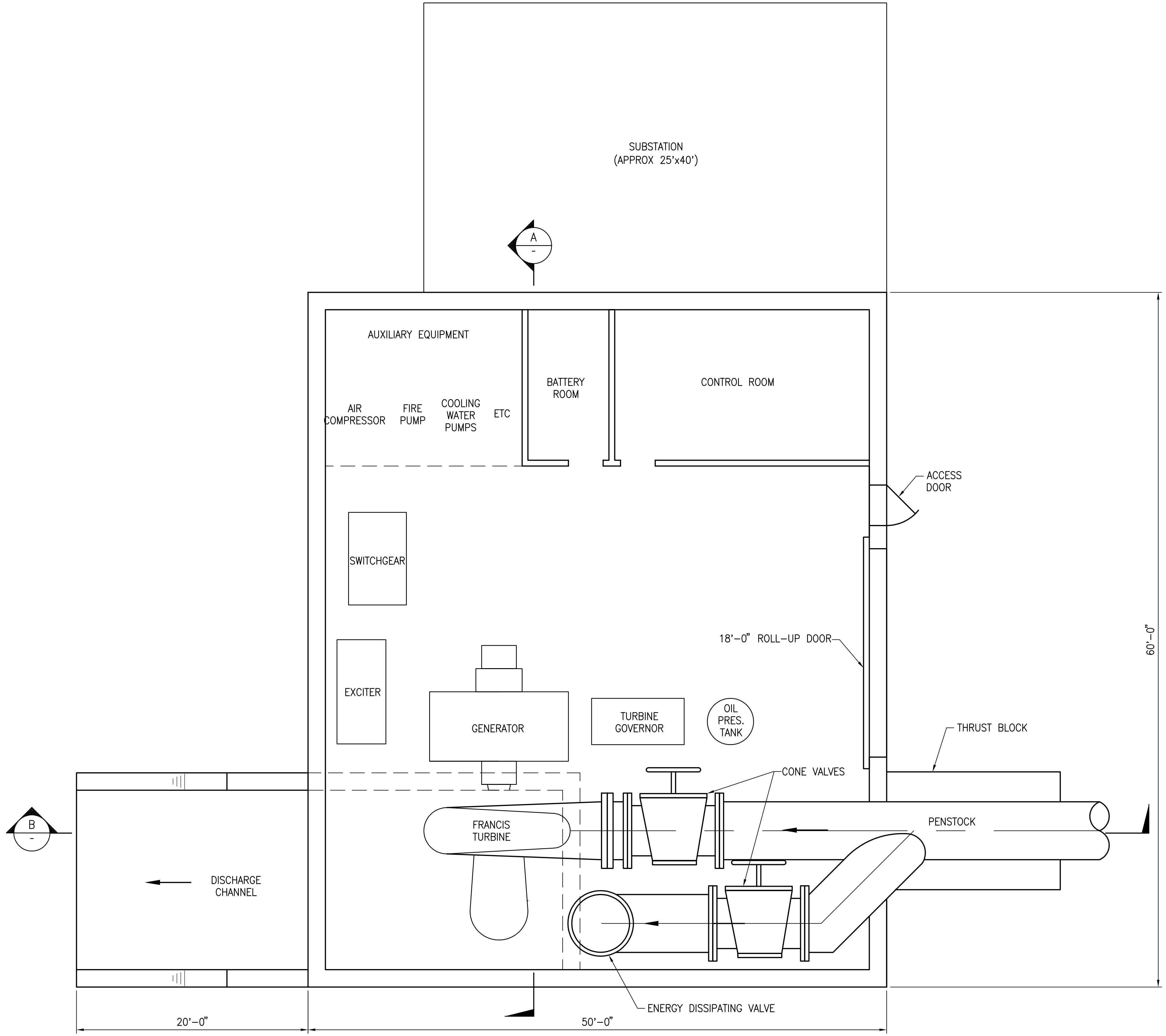
COLORADO RIVER RETURN RECONNAISSANCE STUDY

1400-FT 720 CFS PUMP STATION SECTION

FIGURE 6-9

DWG: Z:_DENVER PROJECTS\C72\501\CAD\PLAN SET\PUMPSTATION.dwg USER: mrau
DATE: Nov 14, 2003 2:14pm XREFS: IMAGES:



POWERHOUSE PLAN

SCALE: 1" = 10'

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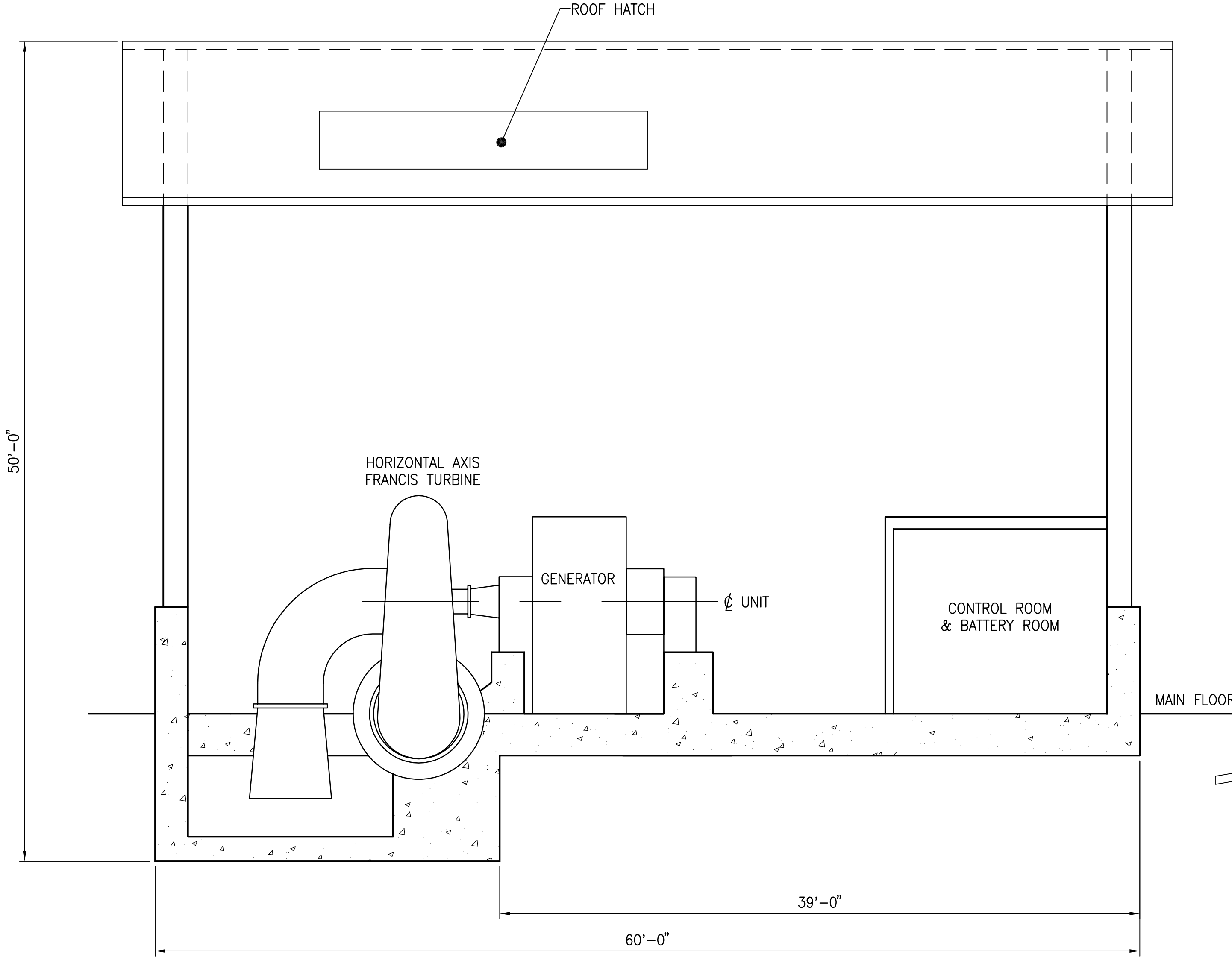
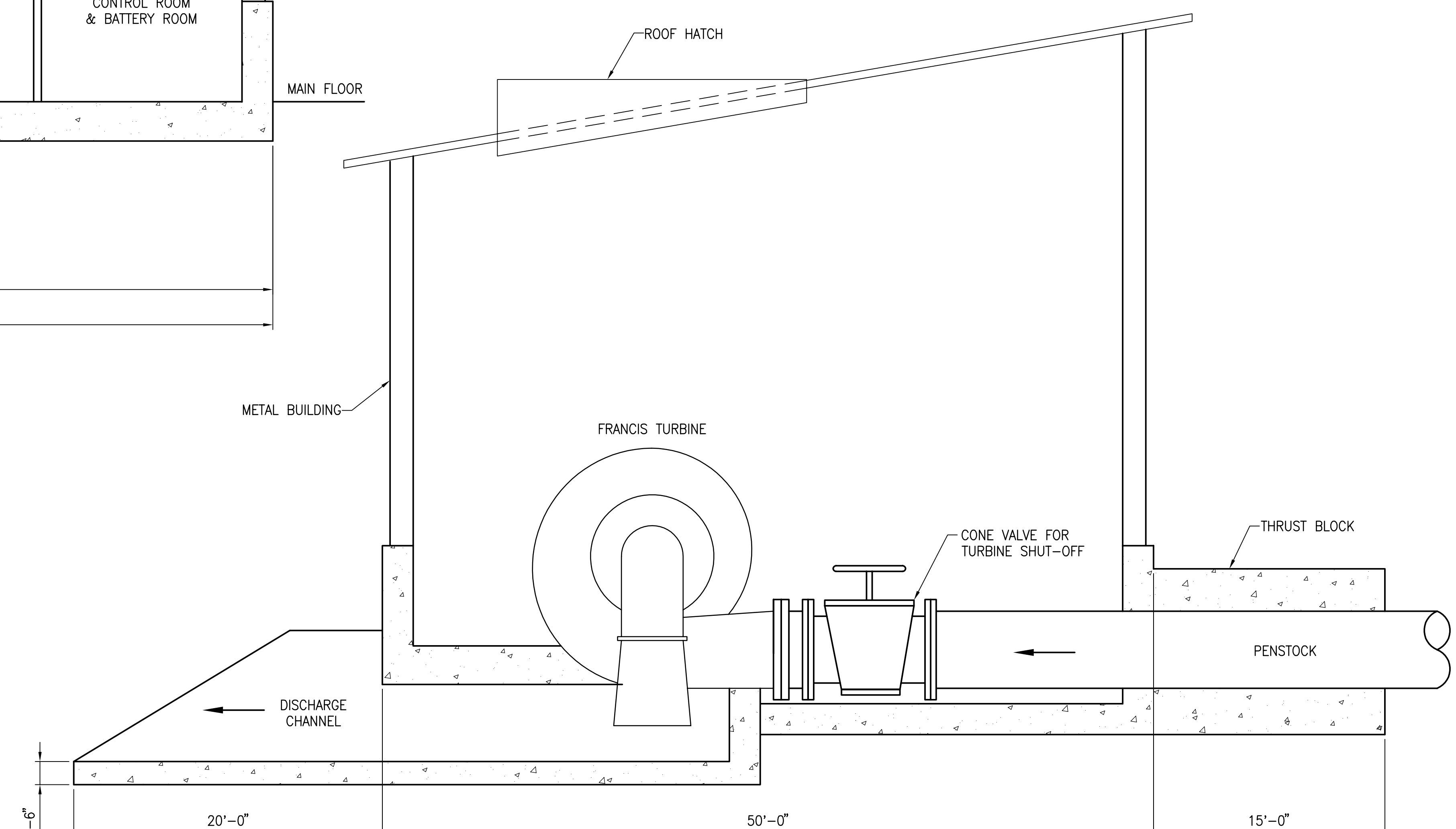
COLORADO RIVER RETURN RECONNAISSANCE STUDY

MEDIUM HEAD
8 MW 300-FT HEAD 350 CFS FLOW HYDROELECTRIC POWERHOUSE

FIGURE 6-11



SECTION A
SCALE: 1" – 10'



SECTION B
SCALE: 1" = 10'

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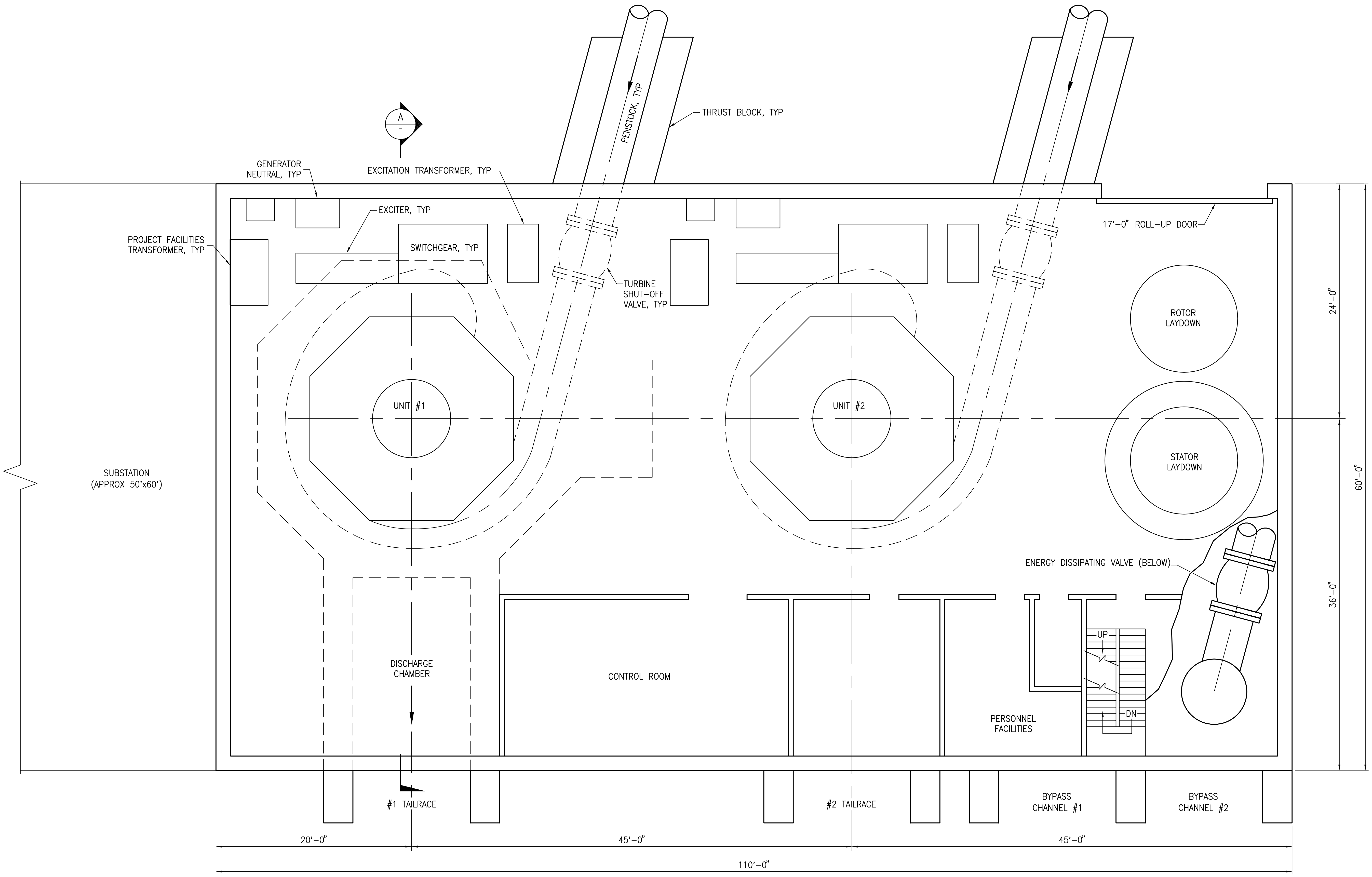
COLORADO RIVER RETURN RECONNAISSANCE STUDY

MEDIUM HEAD
8 MW 300-FT HEAD 350 CFS FLOW HYDROELECTRIC POWERHOUSE

FIGURE
6-12

DWG: Z:_DENVER PROJECTS\C72\501\CAD\PLAN SET\HYDROPOWER-MED.dwg
DATE: Nov 14, 2003 2:15pm USER: mrou
KREFS: IMAGES:



POWERHOUSE PLAN

SCALE: 1" = 10'

DWG: Z:_DENVER PROJECTS\C72\501\CAD\PLAN SET\HYDROPOWER-HIGH.dwg USER: mrau
DATE: Nov 14, 2003 2:16pm XREFS: IMAGES: hydropower.tif hydropower-sec.tif

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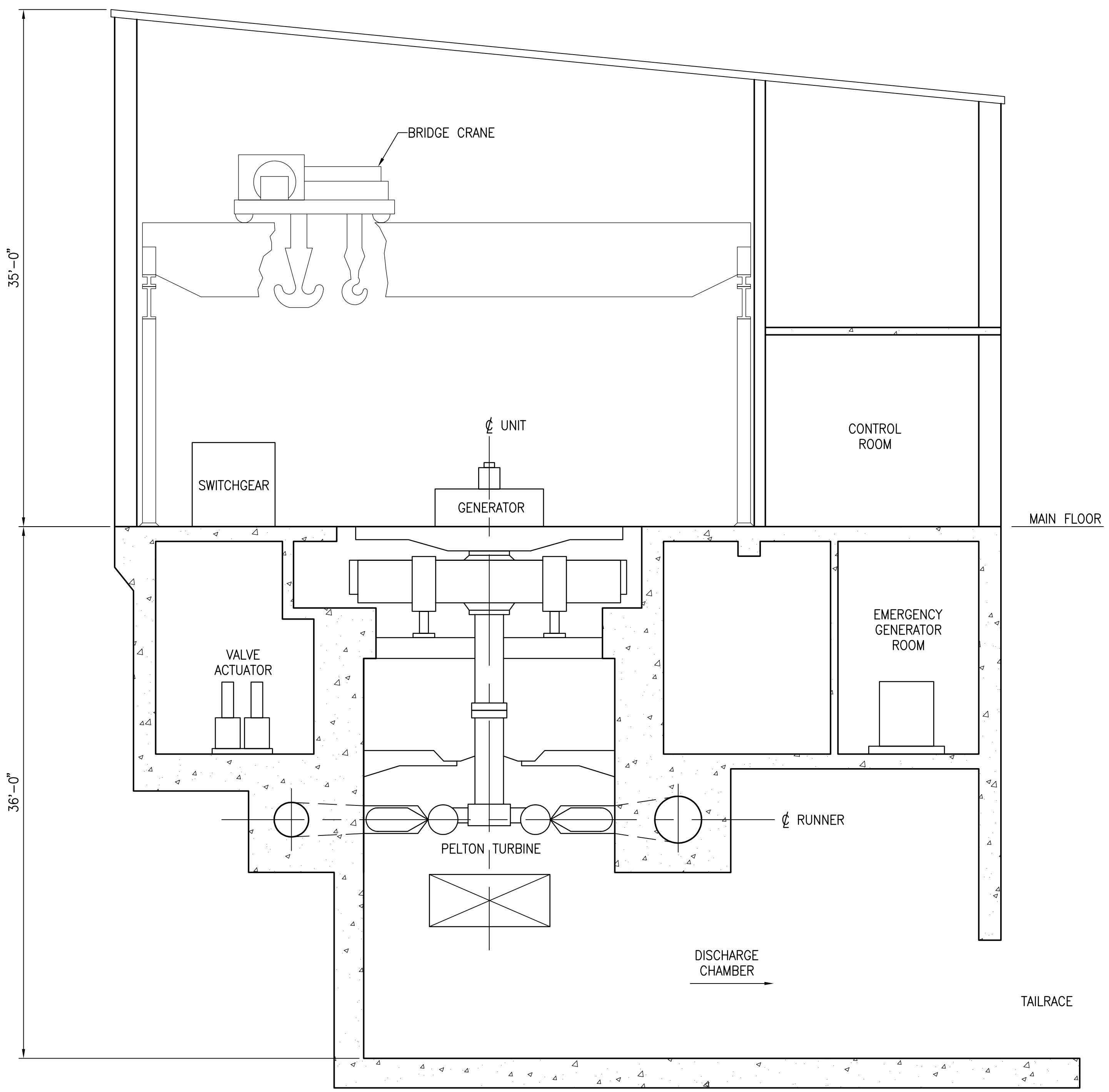
COLORADO RIVER RETURN RECONNAISSANCE STUDY

HIGH HEAD

200 MW 2500-FT HEAD 1100 CFS FLOW HYDROELECTRIC POWERHOUSE

FIGURE 6-13



SECTION (A)
SCALE: 1" – 10'

COLORADO RIVER RETURN RECONNAISSANCE STUDY

HIGH HEAD

200 MW 2500-FT HEAD 1100 CFS FLOW HYDROELECTRIC POWERHOUSE

BEC PROJECT NO. DN-C72-501-01

FIGURE 6-14

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