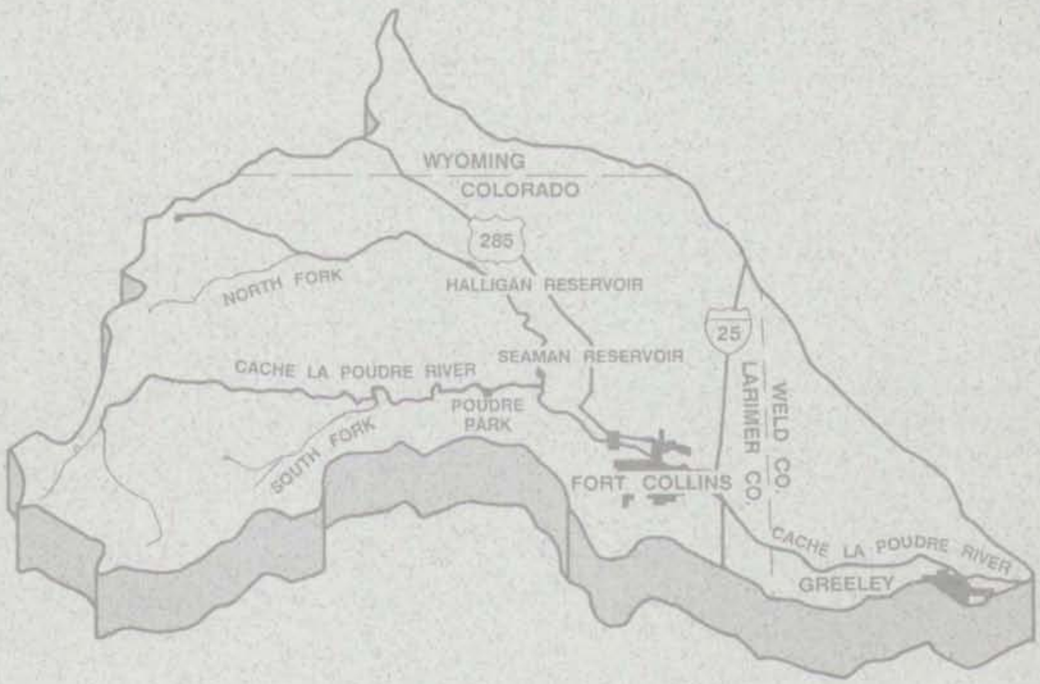
Cache la Poudre Basin Study Extension

Final Report Volume II



COLORADO WATER RESOURCES & POWER DEVELOPMENT AUTHORITY

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VOLUME II

CACHE LA POUDRE BASIN
STUDY EXTENSION

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Colorado Water Resources & Power Development Authority

Project Sponsor:

Northern Colorado Water Conservancy District

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CHAPTER 7.0

ALTERNATIVE STAGE I SITES AND PRELIMINARY SITE SELECTION

7.0 ALTERNATIVE STAGE 1 SITES AND PRELIMINARY SITE SELECTION

7.1 INTRODUCTION

This chapter of the Final Report describes the initial engineering studies undertaken as part of the Basin Study Extension to identify and compare alternative sites for a Stage 1 water storage project in the Cache la Poudre Basin. These initial studies were based on storage and yield information developed during the Authority's Cache la Poudre Basin Study (Basin Study; Harza, 1987) and updated costs from that study. The comparison of potential alternatives for Stage 1 water storage resulted in a preliminary selection of the Grey Mountain site on the mainstem Cache la Poudre River. Further engineering studies (Chapter 9.0) concentrated on refining the Stage 1 Grey Mountain alternative. However, environmental studies, conducted as part of the Cache la Poudre Basin Study Extension (Basin Study Extension), concentrated on the Grey Mountain alternative and the second most cost effective alternative, a storage project at the Poudre site on the mainstem Cache la Poudre River, about two miles upstream from the Grey Mountain site.

7.2 PROJECT EVALUATION - BASIN STUDY

Seven alternative plans for development of water supply and hydroelectric power in the Cache la Poudre River Basin were identified during the Basin Study. These plans involved various water storage project locations, storage volumes, and configurations of pumped-storage hydroelectric power facilities. Alternative plans were evaluated in terms of technical and economic performance, as well as probable environmental effects and mitigation/enhancement opportunities. Based on these evaluations, two plans (Plan B and Plan C) were recommended for further study.

Plan B involved a water storage reservoir formed by constructing a dam at the Grey Mountain site on the mainstem Cache la Poudre River, an 1800 MW pumped-storage project operating on the head differential between a forebay reservoir (Cache la Poudre Forebay) below Greyrock Mountain and the Grey Mountain Reservoir, and an off-channel water storage reservoir at the Glade site which would be filled by gravity diversions from Grey Mountain Reservoir. Plan C involved the same components as Plan B except that water storage on the mainstem Poudre River would be provided by constructing a dam at the Poudre site which is located about two miles upstream from the Grey Mountain site (about 0.3 miles downstream from the mainstem-North Fork confluence). The Basin Study recognized the potential for staging individual components of the two recommended plans, particularly the potential for constructing the mainstem water storage facility prior to constructing the pumped-storage and off-channel storage facilities.

Based on the Basin Study results, Task 16 of the Basin Study Extension focused on investigations related to Stage 1 of the Cache la Poudre Project. As currently planned, the Cache la Poudre Project could be implemented in three stages:

Stage 1: Mainstem water storage reservoir, conventional hydroelectric powerplant, and associated transmission facilities.

Stage 2: Glade Feeder Tunnel and off-channel water storage at the Glade Reservoir site. (Glade would be supplied by gravity diversions through the Glade Feeder Tunnel from the mainstem storage reservoir constructed during Stage 1).

Stage 3: Pumped-storage hydroelectric project and associated local transmission facilities. (The mainstem water storage facility completed during Stage 1 would form the afterbay reservoir for the pumped-storage project.)

Each stage of the total project would be studied independently, evaluated, and implemented as needed.

7.3 METHODOLOGY

During Task 16, various water storage options that conceivably could serve as Stage 1 of the project were evaluated. Sites located on the mainstem Cache la Poudre River, on tributaries, and off-channel were considered. Potential water storage options were previously identified during the Basin Study and were re-examined as part of Task 16. Based on this re-examination, certain of the engineering studies were focused on a mainstem reservoir provided by constructing a dam at the Grey Mountain site. However, the initial studies performed for Grey Mountain Reservoir do not preclude selection of another alternative as more information concerning all potentially viable alternatives is assimilated. The decision to focus initial engineering studies on the Grey Mountain site was made based on the reasons presented in Section 7.6 of this chapter. It should be noted that certain of the engineering studies in Task 16, particularly highway relocations, flood control benefits, and topographic mapping, also relate directly to other alternatives for water storage being considered for the Stage 1 Project.

Adoption of the staged approach to potential project development required that further evaluations of project layouts and cost estimates be performed to identify the most feasible alternatives for a Stage 1 Project. Based on these evaluations, alternatives were screened so that additional engineering, environmental, and economic analyses performed during the Basin Study Extension could be focused on a limited number of alternatives.

7.3.1 Site Screening

Ten potential water storage facilities were identified during the Basin Study: Portal, Grey Mountain, Poudre, Trailhead, and Footbridge, located on the mainstem of the Cache la Poudre River; Rockwell on the South Fork; New Seaman, New Halligan, and Calloway Hill on the North Fork; and Glade, located off-channel. Proposed locations for these facilities are shown on Figure 7.1.

Of these ten potential sites, two were eliminated from consideration in the plan formulation for Stage 1 for the following reasons. Footbridge Dam was a secondary diversion structure and did not provide any significant water storage. Calloway Hill was eliminated because it was found to have costs about double those of New Halligan for equivalent storage capacity and yield.

Cost estimates for the Rockwell site on the South Fork were originally developed for a dam at an axis identified in earlier studies for the City of Fort Collins prepared by Woodward-Clyde in 1960. This site could provide 17,000 acre-feet (af) of storage without encroaching on an upstream segment of the river designated under the Wild and Scenic legislation (Figure 7.2). However, the limited storage at this location was found to be more expensive than other options (Harza, 1987). A downstream dam axis (Site C) was investigated during the evaluations described herein. The location of this axis corresponds to the downstream terminus of the lower segment designated under the Wild and Scenic legislation (Figure 7.2). Up to 55,000 af of storage could be provided at Rockwell (Site C) without encroaching on the designated Wild and Scenic segments of the South Fork. This option was included in the site screening process.

The seven potential storage projects that warranted consideration as Stage 1 facilities were: Portal, Grey Mountain, Poudre, New Halligan, New Seaman, Rockwell (Site C), and Glade with Trailhead. Portal was included because it affords the maximum storage potential on the mainstem. Rockwell (Site C) and New Seaman were included because a combination of storage at these two sites might eliminate the need for a dam on the mainstem of the Poudre River below Poudre Park. Similarly, Glade with Trailhead was considered because of substantially smaller impacts on the mainstem of the Poudre River. New Halligan was included because of apparent low cost. However, a New Halligan Dam and Reservoir without another storage facility was not considered. The Halligan site is poorly located within the Basin from the standpoint of regional water management, because only regulation of native storable flows on the North Fork can be achieved. Additionally, the estimated incremental yield of 7000 af/yr is small in relation to the estimated yields provided by other alternatives.

7.3.2 Cost Updates

Comparative costs for dams and appurtenant structures were taken from the Basin Study. These costs were based on January 1986 prices (Harza, 1987) which then were updated to June 1987 price levels, using the composite Bureau of Reclamation Water and Power cost index (Engineering News Record, 1987). Materials, equipment, and labor prices for the construction of dams and appurtenant structures increased an average of about two percent between January 1986 and June 1987. The costs for conventional hydroelectric installations were not included in the initial screening process, because the differences in hydroelectric benefits and costs among the plans would be relatively small.

For the purpose of estimating costs, all dams were assumed to be concrete gravity structures using roller compacted concrete (RCC) with the exception of Glade which was assumed to be an embankment dam. RCC was chosen for estimating costs because it is less expensive than conventionally placed concrete. The highest RCC dam constructed to date is the 338-foot high Tamagaw Dam in Japan (Hansen, 1987). For comparison, the heights of Portal, Grey Mountain, and Poudre Dams would be 446, 416, and 326 feet, respectively. Conservatism would suggest that conventional concrete placement methods be assumed for estimating the costs of Portal and Grey Mountain dams at this level of study. However, as will be shown later, Portal is not a cost-effective storage facility, in comparison to other options, even if RCC construction is assumed. The Grey Mountain site appears to be well suited for a concrete arch dam. Because they require less concrete volume, arch dams are usually less expensive than gravity dams. The assumption of a RCC gravity dam, rather than a conventional concrete gravity dam at Grey Mountain, provides a cost estimate which is expected to more closely approximate the cost of a concrete arch dam.

The updated costs associated with land purchase and highway relocations were based on estimated costs from the Basin Study. These estimates for highway relocation costs are considered to be adequate for initial evaluations, because the lengths of highway relocations do not vary significantly among the alternatives involving mainstem reservoirs. Highway relocation costs subsequently were refined, as described in Chapter 8.0.

Costs associated with environmental mitigation were not considered in the initial comparison of alternative plans. Mitigation costs may be substantial and could vary among the alternative plans. Consequently, the sensitivity of economic feasibility to potential mitigation costs was assessed during the economic evaluation of the Stage 1 Project described in a later chapter of this report. Similarly, potential flood control benefits were not considered for this initial comparison of alternative plans.

7.4 ALTERNATIVE PLANS

Eight alternative plans for a Stage 1 project to develop additional water storage in the Basin were identified, as shown in Table 7.1. A ninth plan, dredging existing plains reservoirs, to recover storage capacity lost to sedimentation, was also considered. During the Basin Study, the cost of recovering lost storage capacity by dredging was found to exceed the cost of new reservoir storage by a factor of five or more, without even considering costs to provide sufficient diversion capacity to enlarged plains reservoirs (Harza, 1986). Due to high cost, dredging is not a viable option. Therefore, potential storage gains and yields from dredging existing reservoirs are not shown in Table 7.1.

Each plan presented in Table 7.1, with the exception of Plan 9, includes a pumping station at Horsetooth Reservoir and a pipeline from Horsetooth to the proposed storage facility. In Plan 6, the pipeline extends from Horsetooth to New Seaman Reservoir and in Plans 7 and 8, from Horsetooth to Glade Reservoir. The pumping station and pipeline is proposed to convey and store water from the Colorado-Big Thompson (C-BT) Project and the Windy Gap Project.

Plan 1 - Portal Reservoir

Portal Reservoir (Figure 7.3) would provide the largest active storage volume on the mainstem of the Poudre River. Portal Dam would be located at the mouth of Poudre Canyon and would provide approximately 265,000 af of active reservoir storage. The maximum reservoir water surface elevation would be limited by the Wild and Scenic River designation above Poudre Park. The yield from storage provided at Portal Reservoir was estimated, on a preliminary basis, to be 47,000 af/yr from regulation of native storable flows and storage of C-BT and Windy Gap imports to the Basin.

TABLE 7.1

Alternative Plans for Stage 1 Development

Plan No.	Dams and Reservoir	Active Storage[2] (acre-feet)	Estimated Yield[1] (af/yr)
1	Portal	265,000	47,000
2	Grey Mountain	187,000	32,000
3	Poudre	130,000	23,000
4A	Grey Mtn./New Halligan	187,000	32,000
4B	Grey Mtn./New Halligan	240,000	39,000
5	Poudre/New Halligan	183,000	31,000
6	Rockwell (Site C) and New Seaman	198,000	34,000
7	Glade with Trailhead	184,000	32,000
8	Glade with Trailhead/ New Halligan	237,000	39,000
9	Dredge Existing Reservoirs	ND[3]	ND[3]

(1) Based on storage of native storable flows and C-BT and Windy Gap imports to the Basin using Basin Study results. Yield estimates were refined during the Task 17 hydrologic investigations conducted by the District.

(2) Full storage at sites developed for water supply. No storage allocated for possible future pumped-storage addition.

(3) Not determined because of excessively high cost.

Portal would be a 446-foot high concrete gravity dam costing an estimated $289 million to construct. The Horsetooth pumping station and pipeline would cost an additional $33 million to construct. Total construction cost for Plan 1 is estimated to be $322 million.

Plan 2 - Grey Mountain Reservoir

The Grey Mountain Damsite (Figure 7.4) is located about two miles upstream from the Portal site. Approximately 187,000 af of active storage could be provided. Yield from storage provided under Plan 2 was estimated, on a preliminary basis, to be 32,000 af/yr from regulation of native storable flows and storage of C-BT and Windy Gap imports to the Basin.

Grey Mountain would be a 416-foot high concrete gravity or concrete arch dam. The construction cost for Grey Mountain Dam is estimated to be $160 million. The Horsetooth pumping station and pipeline would cost an additional $43 million. The total construction cost for Plan 2 is estimated to be $203 million.

Plan 3 - Poudre Reservoir

The Poudre Damsite (Figure 7.5) is about 2 miles upstream from the Grey Mountain site. This damsite was identified as a potentially viable site during the Basin Study and would result in the smallest inundation of the Poudre Canyon while still regulating flows on both forks of the river. Approximately 130,000 af of active storage could be provided. The yield under this plan was estimated to be 23,000 af/yr, on a preliminary basis.

Poudre Dam would be a 326-foot high concrete gravity dam with an estimated construction cost of $125 million. The Horsetooth pumping station and pipeline would cost an additional $51 million. Total construction cost of Plan 3 is estimated to be about $176 million.

Plan 4A - Grey Mountain and New Halligan Reservoirs

This plan (Figures 7.4 and 7.6) was formulated to test whether storage provided by a smaller Grey Mountain Dam together with storage provided by a New Halligan Dam could result in a more economical development than Plan 2 (Grey Mountain alone). A total of 187,000 af of active storage would be provided with

Plan 4A, which equals the storage that could be provided by Plan 2. Under Plan 4A, the capacity of Grey Mountain Reservoir would be 134,000 af. This would provide storage capacity for native flows and C-BT and Windy Gap imports. At New Halligan, 53,000 af of active storage would be provided to regulate native storable flows on the North Fork. The yield from the combined operation of the two reservoirs was estimated to be 32,000 af/yr.

Under Plan 4A, Grey Mountain Dam would be a 395-foot high concrete gravity or arch dam structure. Halligan Dam would be a 196-foot high concrete gravity or arch dam structure. The combined construction cost for the two dams is estimated to be $148 million ($118 million for Grey Mountain and $30 million for New Halligan). The total construction cost for Plan 4A is estimated to be $191 million, including the Horsetooth pumping station and pipeline ($43 million). The construction cost indicated for New Halligan in Plan 4A, as well as Plans 4B and 5 below, does not include the cost associated with purchasing the existing Halligan Dam and reservoir or the associated water rights.

Plan 4B - Grey Mountain and New Halligan Reservoirs

This plan is similar to Plan 4A except that storage at Grey Mountain is increased to the maximum achievable under the Wild and Scenic designation (187,000 af). Grey Mountain Dam would be as described in Plan 2. The storage at Halligan (53,000 af) is the maximum considered during the Basin Study. The total active storage volume of 240,000 af was estimated to provide a yield of 39,000 af/yr through regulation of native storable flows and storage of C-BT and Windy Gap imports. The total construction cost of this plan is estimated to be $233 million, including Grey Mountain Dam ($160 million), New Halligan Dam ($30 million), and the Horsetooth pumping station and pipeline ($43 million). However, like Plan 4A, the cost to purchase the existing Halligan Dam and Reservoir or the associated water rights were not included.

Plan 5 - Poudre and New Halligan Reservoirs

Under Plan 5 (Figures 7.5 and 7.6), a total of 183,000 af of active storage would be provided at two sites. Storage at the Poudre site would be 130,000 af, providing capacity for native flows and C-BT and Windy Gap imports. At New Halligan, active storage would be 53,000 af providing regulation of native storable flows on the North Fork. The yield from combined operation of both reservoirs is estimated to be 31,000 af/yr. Poudre would be a 320-foot high concrete gravity dam. New Halligan would be a 196-foot high concrete gravity or arch dam. Total construction costs are estimated to be $155 million for both dams ($125 million for Poudre and $30 million for New Halligan). Total construction costs for Plan 5 are estimated to be $206 million, including $51 million for the Horsetooth pumping station and pipeline, again excluding costs to purchase the existing Halligan Dam and Reservoir or the associated water rights.

Plan 6 - Rockwell (Site C) and New Seaman Reservoirs

This plan (Figures 7.2 and 7.7) was formulated to provide an indication of the costs for providing storage without construction of a dam in the mainstem canyon below Poudre Park. Rockwell would control flows on the South Fork, which accounts for about 65 percent of the storable native flows on the mainstem above the North Fork confluence. New Seaman would control North Fork flows and store C-BT and Windy Gap imports. Combined operation of these two reservoirs is estimated to provide a yield of 34,000 af/yr.

Total storage capacity would be 198,000 af (50,000 af at the Rockwell Site C and 148,000 af at New Seaman). Both dams would be concrete gravity structures. Rockwell would be 318-feet high ($58 million) and New Seaman would be 356-feet high ($123 million). Total construction costs for both dams are estimated to be $181 million. Total construction costs for Plan 6 are estimated to be $235 million, including $54 million for the Horsetooth pumping station and pipeline.

Plan 7 - Glade Reservoir with Trailhead Diversion Dam

This plan (Figure 7.8) provides storage at the off-channel Glade Reservoir; however it does require a diversion dam on the mainstem Cache la Poudre River. Total active storage in Glade would be about 184,000 af. Yield is estimated to be about 32,000 af/yr from regulation of native storable flows and from storage of C-BT and Windy Gap imports. Native flows would be stored in Glade by diverting storable flows from the mainstem. This would be accomplished by constructing Trailhead Dam and by upgrading the existing North Poudre conveyance facilities to accommodate pressure flow, or by constructing entirely new conveyance facilities. Under Plan 7, storable flows on the North Fork would not be regulated by provision of new storage capacity. Glade would be a 290-foot high embankment dam with an estimated cost of $277 million. Trailhead would be a 220-foot high RCC dam with an estimated cost of $39 million. Total construction costs for this plan are estimated to be $369 million, including the costs of upgrading the existing North Poudre conveyance facilities ($20 million), or constructing new facilities, and the Horsetooth pumping station and pipeline ($33 million).

Plan 8 - Glade Reservoir with Trailhead Diversion Dam and New Halligan Reservoir

This plan is the same as Plan 8, except that an additional storage element is introduced to provide regulation of native storable flows on the North Fork. The combination of storage at Glade and New Halligan would provide an active volume of 237,000 af. Estimated yield from native storable flows and C-BT and Windy Gap imports is estimated to be 39,000 af/yr. Glade and Trailhead Dams would be as described in Plan 7 and New Halligan Dam would be as described in Plan 5. Total construction costs for Plan 8 would be $401 million, including the cost of upgrading the existing North Poudre conveyance facilities, or constructing new facilities, and the Horsetooth pumping station and pipeline.

Plan 9 - Dredge Existing Plains Reservoirs

During the Basin Study, considerable attention was devoted to the application of non-structural measures to enhance water management in the Poudre Basin. Non-structural plan elements were defined as follows (Harza, 1987):

> **Non-structural elements are those which do not involve major physical structures or facilities for water management. Generally, they can be implemented at low cost in comparison to structural elements such as dams and reservoirs. They include measures to enhance available water supplies and to reduce the demand for water. They also include institutional changes to improve the ways in which the water resource is managed.**

Dredging to recover storage capacity lost due to sediment deposition does not involve implementation of major physical structures. However, available data indicate that dredging costs will exceed the costs of providing storage through constructing a new dam by a factor of five or more, excluding costs to either improve existing diversion facilities or to construct new diversion facilities that would provide increased diversion capacity to enlarged plains reservoirs.

Estimates for removal of accumulated sediment in Cherry Creek Reservoir in the suburban Denver area were developed by the Corps of Engineers (COE, 1985). Cherry Creek Reservoir is a large flood control structure with significant fishery and recreational resources. The study considered two sediment removal options: (1) hydraulic dredging; and (2) drainage of the reservoir and removal by conventional excavation.

Cost estimates developed by the COE indicate sediment removal costs range from \$3.30 to \$14 per cubic yard (cy) of sediment removed for dredging, and \$5 to \$9 per cy for lake drainage and removal using earthmoving equipment. This corresponds to a cost range of \$5400 to \$22,600 per af of sediment removed and storage volume regained. These costs could be reduced somewhat if dredged material could be sold for use as fill or for landscaping. However, revenues from the sale of dredged material would not be sufficient to make dredging of existing reservoirs an economically viable alternative.

Because of the high costs, dredging is not considered a potentially viable alternative. Therefore, estimates were not developed concerning: (1) how much storage capacity might be recovered by dredging; and (2) the degree to which existing diversion structures and ditches used to fill the reservoirs would need to be improved and enlarged to deliver larger volumes of water.

7.5 PRELIMINARY COMPARISON OF PLANS

The nine alternative plans described above were compared in terms of active storage provided, yield from native storable flows and C- BT and Windy Gap imports, and estimated costs. A summary of the comparison of alternative plans is provided in Table 7.2.

The construction costs shown in Table 7.2 were converted to annual costs using criteria described in the Basin Study Final Report. Annual costs include construction costs, interest during construction, and financing costs (30-year bond term and interest rate of 8 percent).

The combination of two storage projects (Grey Mountain and New Halligan) in Plans 4A and 4B appears to be the most cost-effective in terms of the cost of yield provided. It should be noted, however, that the construction costs for plans involving New Halligan do not include the costs of purchasing existing Halligan facilities (dam, reservoir lands, and ancillary facilities) and associated water rights. There is also more inherent uncertainty in the costs of constructing two projects in comparison to the cost for constructing a single project. Plan 2 compares favorably with Plans 4A and 4B in terms of active storage and the unit cost of yield developed. Plan 2 involves construction of a single project, a mainstem reservoir formed by a dam at the Grey Mountain site.

TABLE 7.2

Comparison of Unit Yield Costs for Alternative Plans

Plan No.	Unit Yield Cost ($/af)	Cost Rank[1]	Cost Factor[2]
1 (Portal)	853	4	1.14
2 (Grey Mountain)	800	2	1.07
3 (Poudre)	870	5	1.16
4A (Grey Mtn./New Halligan)	756[3]	1	1.01
4B (Grey Mtn./New Halligan)	751[3]	1	1.00
5 (Poudre/New Halligan)	839[3]	3	1.12
6 (Rockwell/New Seaman)	871	6	1.16
7 (Glade w/Trailhead)	1560	8	2.08
8 (Glade w/Trailhead and New Halligan)	1380[3]	7	1.84
9 (Dredge Existing Reservoirs)	ND	9	---

Note: Based on annualized construction cost, excluding environmental mitigation and enhancement costs.

(1) Rank (low to high).

(2) Unit yield cost divided by lowest unit yield cost (Plan 4B).

(3) Excludes cost of purchasing existing Halligan Dam and associated water rights.

Table 7.2 presents a comparison of the unit yield costs for the alternative plans. The lowest costs are associated with Plans 2, 4A, and 4B, all of which include Grey Mountain Reservoir. The costs for other plans are significantly higher. The next most attractive alternative (Plan 3) involves storage at the mainstem Poudre site.

In addition to storage, yield, and cost, other evaluation criteria were applied during the Basin Study. These criteria included potential flood control benefits, water management flexibility, operational reliability, and risk of construction delay and cost increases (Harza, 1987).

For flood control benefits, all plans involving larger-sized mainstem reservoirs (Plans 1, 2, 3, 4A, 4B, 5) can be rated equal, because planned flood control storage could be provided in addition to the incidental benefits from reservoir surcharge storage. Plan 6 involves storage on the South Fork and North Fork, leaving the mainstem above the North Fork partially unregulated. Therefore, flood control opportunities under Plan 6 are less than for Plans 1 through 5. Plan 7 involves no major mainstem storage and has no significant flood control capability. Plan 8 includes storage on the North Fork, but flood control benefits would be significantly less than for Plans 1 through 5. Obviously, no flood control benefits can be obtained from Plan 9. Potential flood control benefits from a mainstem reservoir subsequently were examined in greater detail, as described in a later chapter of this report.

All plans can include storage for native storable flows and C-BT and Windy Gap imports. However, those plans involving larger storage volumes can be rated somewhat higher in terms of enhanced water management flexibility. Plans 1 through 8 involve delivery of C-BT and Windy Gap imports to storage by pumping from Horsetooth Reservoir and are rated equal in terms of operational reliability. However, Plan 9 is considered to be less reliable because whether additional storage in plains reservoirs could be filled depends on timely diversions of river flows to convey water through existing (or improved) canals.

The risk of construction delays and subsequent cost increases can be related to the number of structures required for implementation of each plan. Plans 1, 2, and 3 involve only one major structure. Plans 4A, 4B, 5, 6, 7, and 8 each involve building at least two major structures and would probably be subject to greater risk of construction delay and subsequent cost increases. Plan 9 (dredging) would not involve heavy construction and would be less susceptible to major delays, provided dredged material could be readily sold or disposed of easily and mitigation for environmental effects could be readily provided.

Plans 4A and 4B (Grey Mountain and New Halligan) appear to be the most cost-effective, when acquisition costs for the present Halligan facilities and water rights are not included. Plan 2 (Grey Mountain) is the second ranking plan based on cost of yield developed. All three plans rank high in terms of the other indicators discussed in preceding paragraphs, although construction of two dams (Plans 4A and 4B) would be subject to greater risks of construction delays and attendant cost increases.

7.6 PRELIMINARY SITE SELECTION

Based on preliminary technical evaluations and cost comparisons, studies conducted as part of the Basin Study Extension for Stage 1 of the Cache la Poudre Project focused on plans which include a mainstem reservoir. All of the lowest cost plans (plans having a cost factor less than 1.10 in Table 7.2) involved a reservoir at the Grey Mountain site. Consequently, further studies to define facility requirements and costs were concentrated on the Grey Mountain site. However, this decision does not preclude consideration of other potential sites during subsequent detailed feasibility studies. Also, certain of the engineering studies, particularly the Highway 14 relocation study, are directly applicable to any Stage 1 project involving storage on the mainstem Cache la Poudre River.

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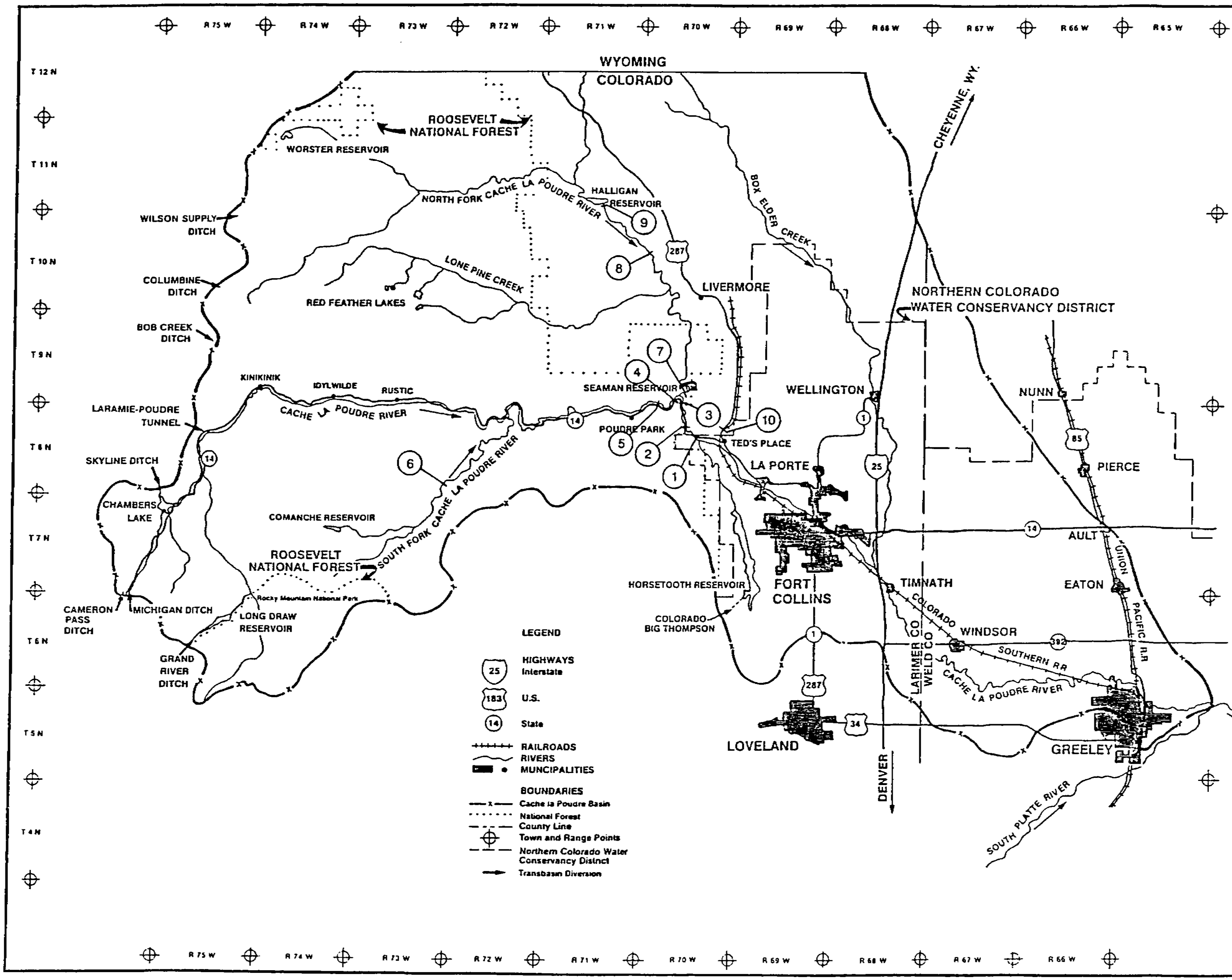


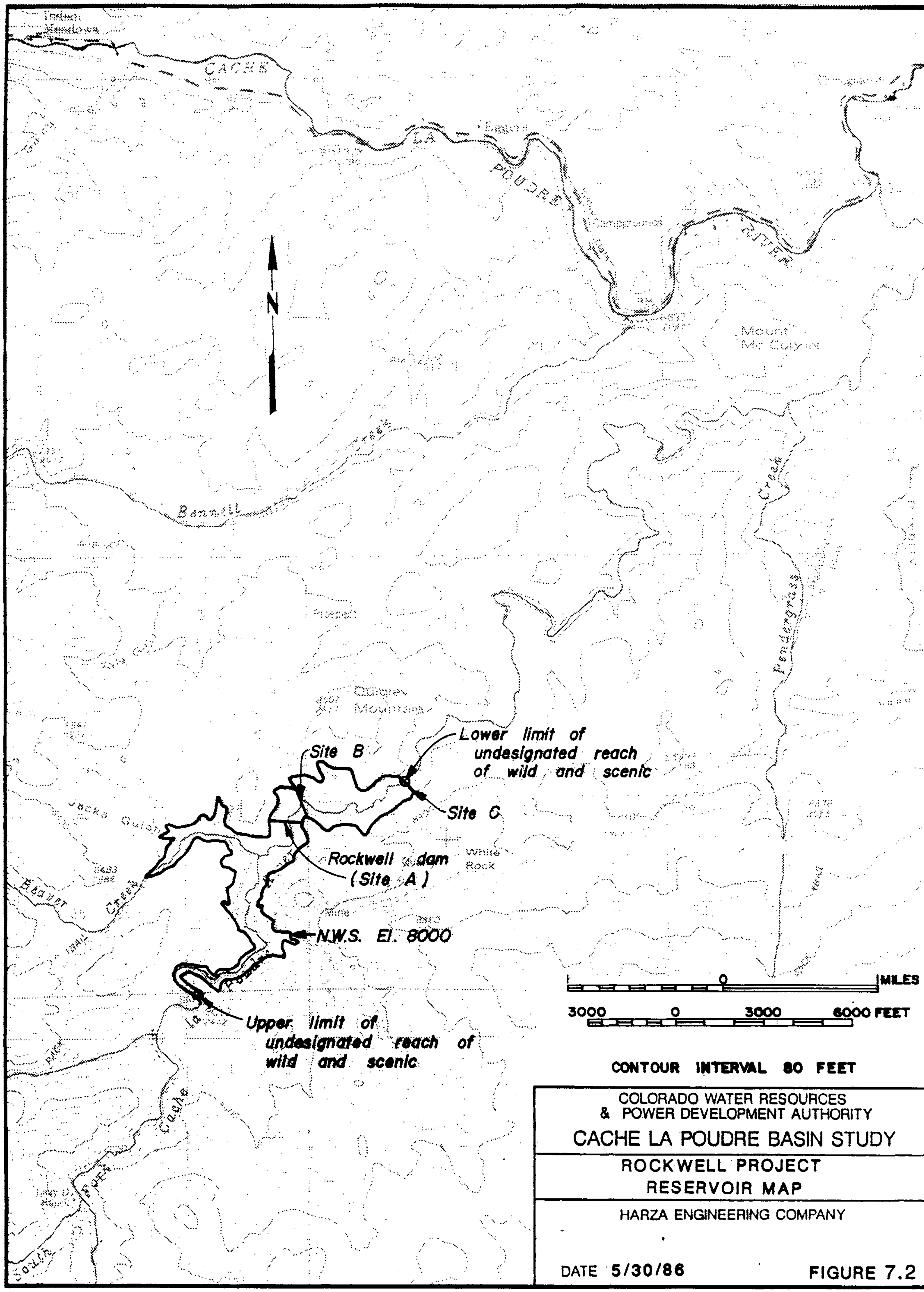
COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY

LOCATION OF POTENTIAL STORAGE PROJECTS

HARZA ENGINEERING COMPANY

DATE 10/11/86 FIGURE 7.1



COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY

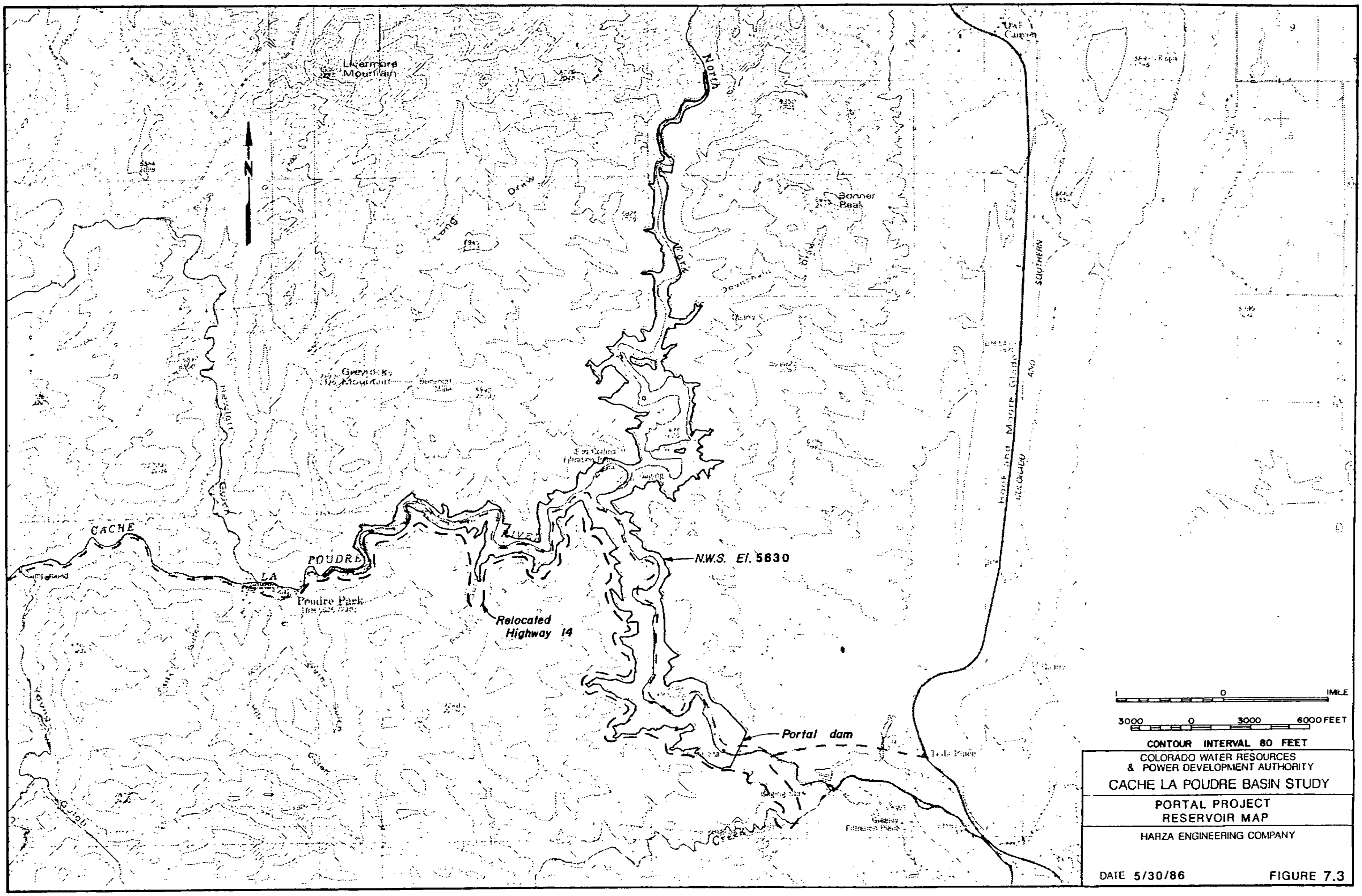
CACHE LA POUDRE BASIN STUDY

ROCKWELL PROJECT
RESERVOIR MAP

HARZA ENGINEERING COMPANY

DATE 5/30/86

FIGURE 7.2



COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY

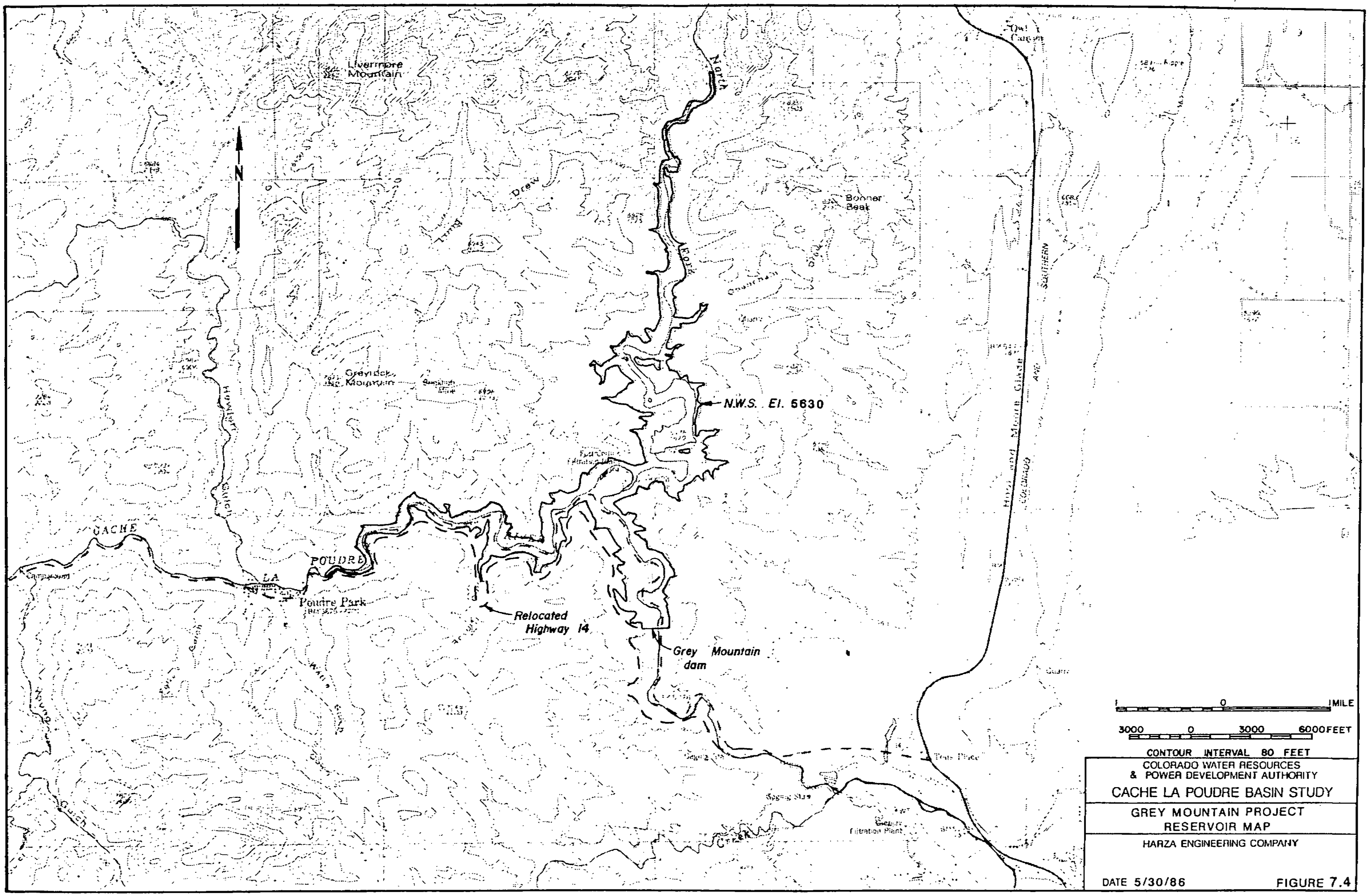
CACHE LA POUDRE BASIN STUDY

PORTAL PROJECT
RESERVOIR MAP

HARZA ENGINEERING COMPANY

DATE 5/30/86

FIGURE 7.3



COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY

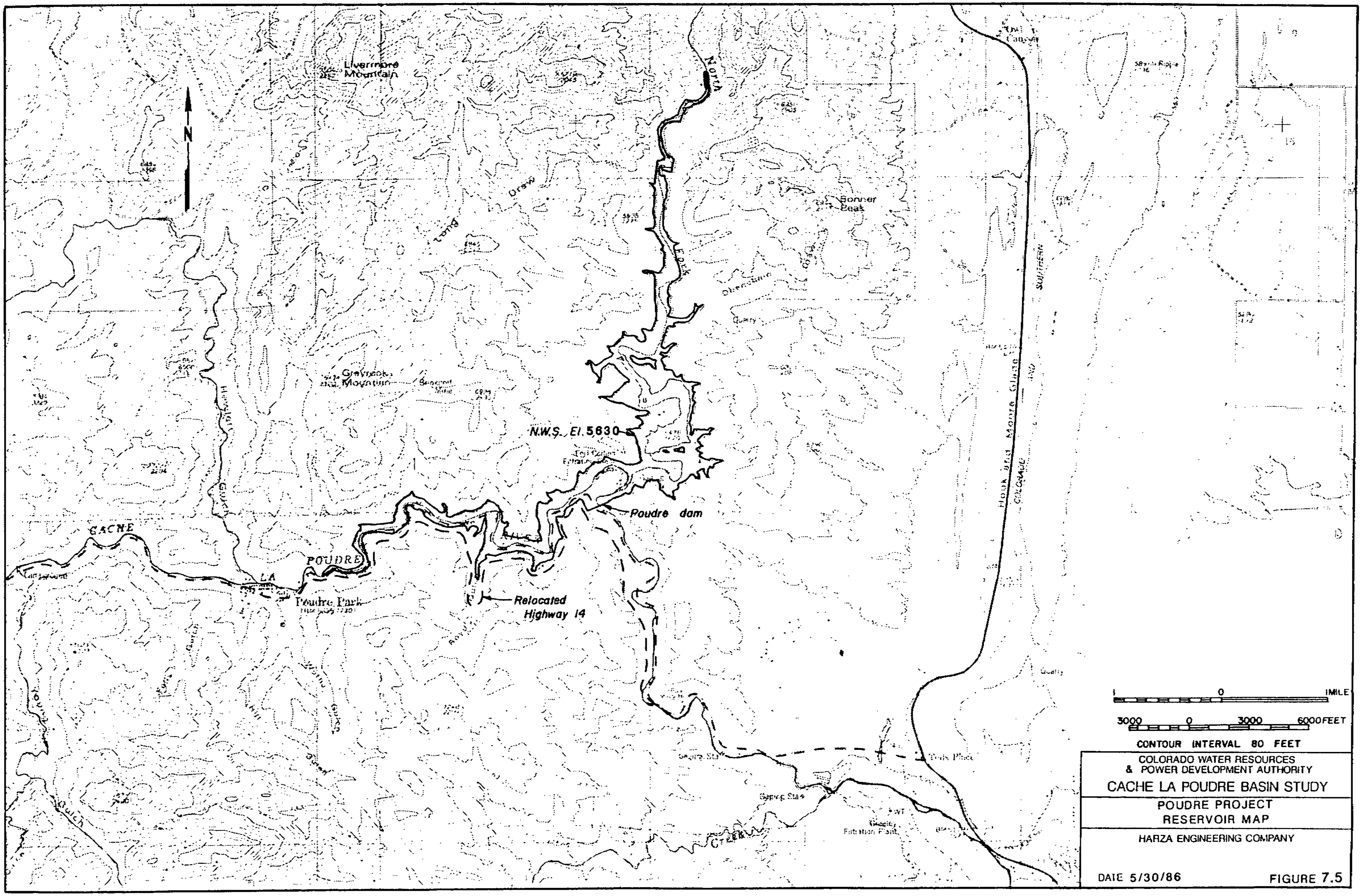
CACHE LA POUDRE BASIN STUDY

GREY MOUNTAIN PROJECT
RESERVOIR MAP

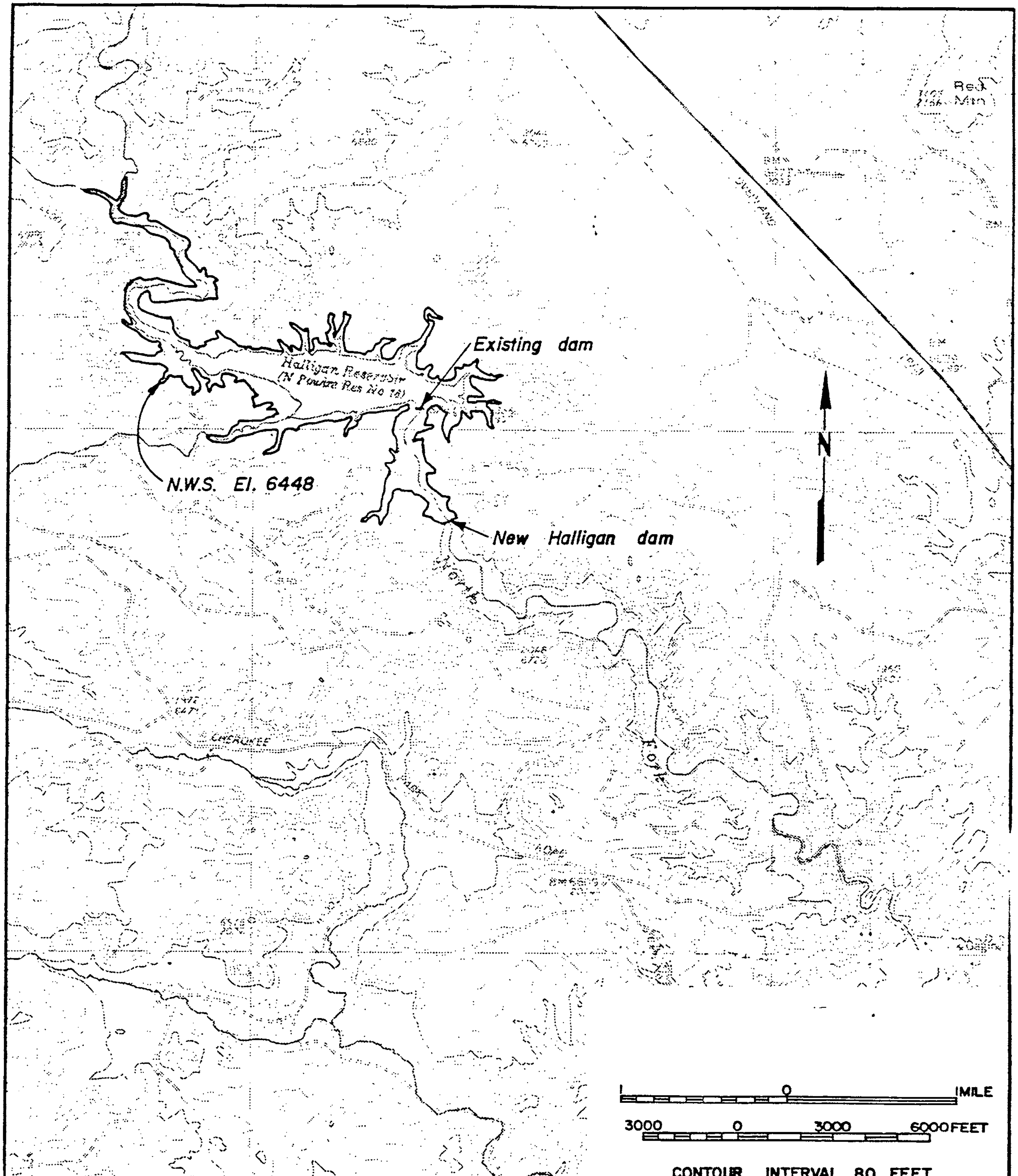
HARZA ENGINEERING COMPANY

DATE 5/30/86

FIGURE 7.4



N
Livermore Mountain
Bonner Peak
Long Draw
North Fork
Greyrock Mountain
N.W.S. El. 5630
Poudre dam
CACHE
LA
POUDRE
Poudre Park
Relocated
Highway 14
SOUTHERN
COLORADO
Hook and Moore Glade
Creek
1 0 1 MILE
3000 0 3000 6000 FEET
CONTOUR INTERVAL 80 FEET
COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY
CACHE LA POUDRE BASIN STUDY
POUDRE PROJECT
RESERVOIR MAP
HARZA ENGINEERING COMPANY
DATE 5/30/86
FIGURE 7.5



COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY

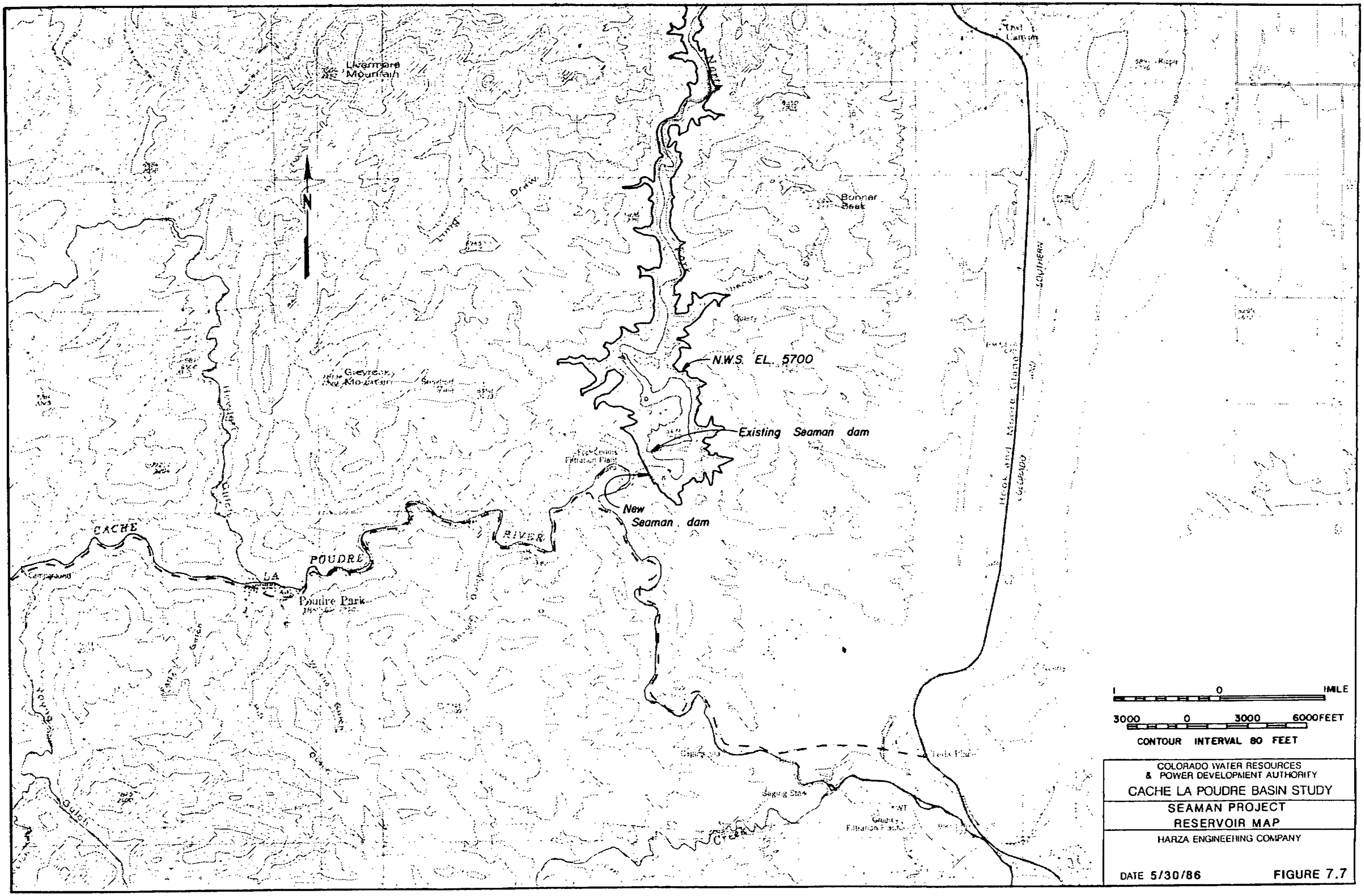
CACHE LA POUDRE BASIN STUDY

HALLIGAN RESERVOIR

HARZA ENGINEERING COMPANY

DATE 8/7/86

FIGURE 7.6



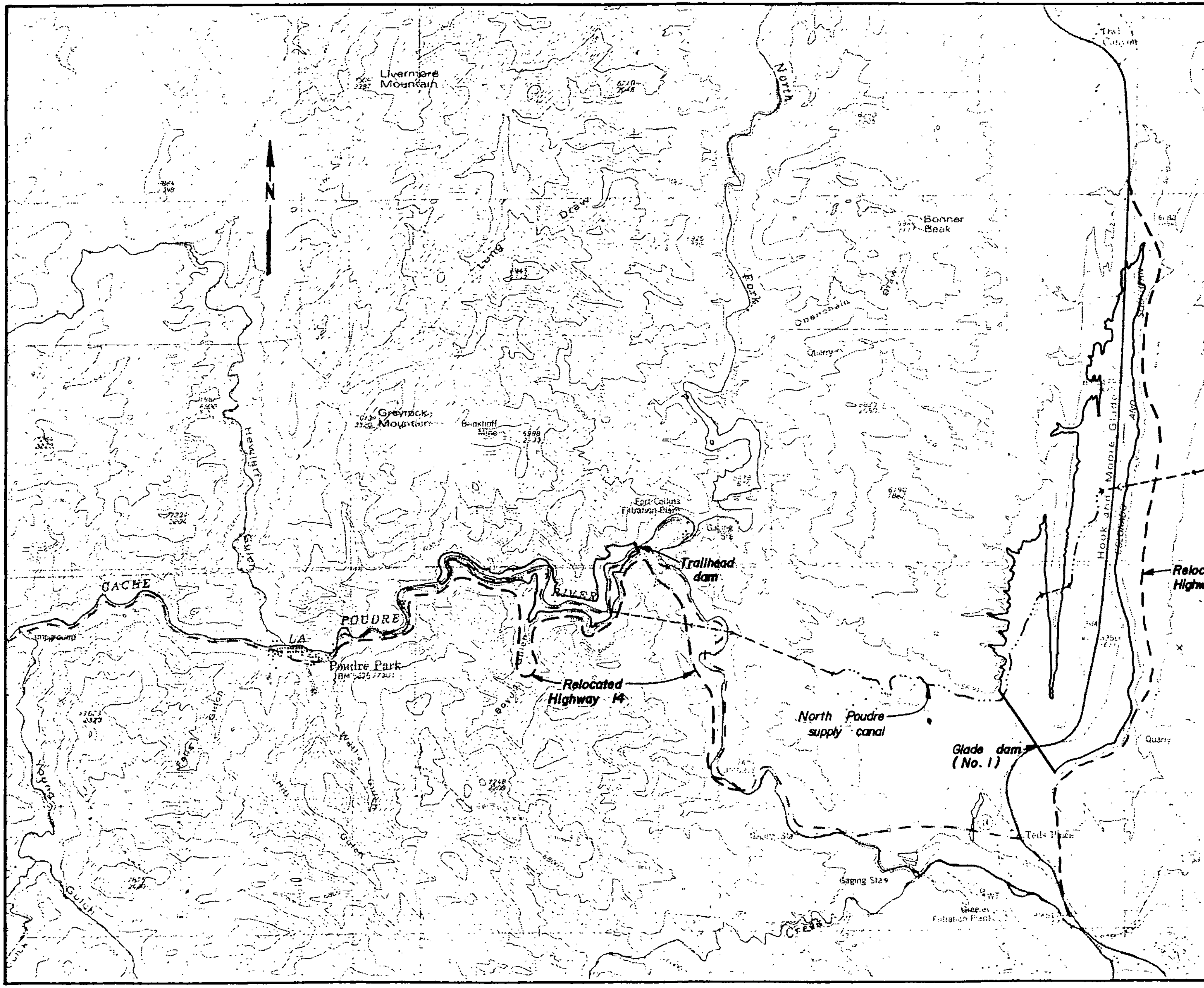
COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY
CACHE LA POUDRE BASIN STUDY

SEAMAN PROJECT
RESERVOIR MAP

HARZA ENGINEERING COMPANY

DATE 5/30/86

FIGURE 7.7



COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY
CACHE LA POUDRE BASIN STUDY

GLADE WITH TRAILHEAD

HARZA ENGINEERING COMPANY

DATE 8/7/86

FIGURE 7.8

CHAPTER 8.0

HIGHWAY RELOCATIONS STUDY

8.0 HIGHWAY RELOCATIONS STUDY

Construction of any water storage reservoir on the mainstem Cache la Poudre River between Poudre Park and the mouth of the Poudre Canyon will require partial relocation of Colorado State Highway 14. Criteria for highway relocation will need to follow the Colorado Design Manual (CDOH, 1987a). U.S. 40 provides access throughout the Poudre Canyon to small towns including Poudre Park, Rustic, and Idylwilde, as well as access for recreational opportunities (camping, picnicking, hiking, fishing, and river-based boating, etc.). Colorado Highway 14 is also the main alternate to U.S. Highway 34 for traveling between northern front range communities and northern western slope communities. During 1985, the average annual traffic load on Highway 14 near Ted's Place was estimated by the Colorado Division of Highways (CDOH) to be 1450 vehicles per day with nine percent trucks. Traffic load in 2007 is estimated by CDOH to reach about 2710 vehicles per day (CDOH, 1987b).

Construction of the Stage 2 component of the Cache la Poudre Project, an off-channel storage dam and reservoir at the Glade site, would require relocation of U.S. Highway 287. A preliminary study of relocating this highway was included in the Basin Study Extension to determine whether the planned U.S. 287 relocation associated with Glade Reservoir would be compatible with the Fort Collins Expressway (La Porte Bypass) and to estimate the cost for the highway relocation for the Stage 2 Glade Reservoir. The scope of the highway relocation study involved alignment selections, preliminary estimation of construction quantities, and preparation of cost estimates.

NCWCD obtained general criteria for the relocation of Colorado Highway 14 and U.S. Highway 287 from CDOH via a December 3, 1987 letter (CDOH, 1987b). These general criteria were followed in preparing preliminary layouts for the relocated highways. CDOH classified Highway 14 as a rural/recreational, mountainous terrain road serving as a major collector in the state's secondary road system. U.S. 287 was classified as a rural/rolling terrain principal arterial, part of the State's primary road system.

8.1 TOPOGRAPHIC MAPPING

Task 16 of the Basin Study Extension included topographic mapping to obtain information to support engineering studies of Stage 1 mainstem reservoir alternatives and the relocation of Colorado Highway 14, portions of which would be inundated if any of the mainstem storage alternatives described in Chapter 7.0 were constructed. Aerial photographs taken in October 1986 were used to prepare the following topographic maps:

Location	Approximate Coverage (acres)	Scale	Contour Interval (feet)
Highway 14 Relocation Corridor	700	1:2400	10
Poudre Damsite	130	1:1200	5
Grey Mountain Damsite	130	1:1200	5
Glade Damsite	260	1:2400	5
Total	1220		

Mapping was prepared by Delta Aerial Surveys, Inc. of Denver, using photographs and ground control provided by NCWCD.

8.2 COLORADO HIGHWAY 14

The main purposes of preparing refined layouts and cost estimates for relocating Highway 14 were to reduce the uncertainty in preliminary cost estimates and identify additional relocation alternatives which may be potentially less costly. The resulting cost estimates provided part of the input for the economic evaluation of Stage 1 water storage alternatives. At a prefeasibility level of detail, the layouts were based on conservative assumptions without any attempt to optimize the alignment of the relocated highway. Estimated costs for the relocation were believed to be conservative on the high side. Further studies at a feasibility level may identify ways in which relocation costs could be reduced.

8.2.1 General Design Parameters

Layouts for relocating Highway 14 around a potential mainstem reservoir were prepared using the following general design parameters suggested by CDOH (CDOH, 1987b):

Right-of-way	150 feet (minimum)[(1)]
Typical roadway section	Type B (8-foot shoulders, 12-foot traffic lanes)
Maximum grades	Up to 45 mph - 10 percent Up to 55 mph - 9 percent
Design speed	45 mph
Climbing lanes	Based on grade[(2)]
Drainage design	25-year storm for minor drainage[(3)]

(1) Existing right-of-way varies from 60 to 100 feet. Width in National Forest lands is by agreement with U.S. Forest Service and is dictated by actual need.

(2) Apply criteria in Section 202.5 of CDOH Roadway Design Manual.

(3) Minor drainage not evaluated in the preliminary layouts for Task 16.

The 1987 CDOH Roadway Design Manual was used in preparing preliminary layouts and construction quantity estimates.

It was initially assumed that the relocated highway would be on the south side of any mainstem reservoir. Relocation to the north side was not considered because a north side location would require a long bridge across the North Fork arm of the reservoir or a significantly longer alignment. Another alternative would be to divert traffic north along Highway 287 to Red Feather Lakes Road and then interconnect the Red Feather Lakes Road with the existing Highway 14 at a location upstream from Poudre Park. A north-south link could be constructed between Red Feather Lakes Road and Highway 14 in the vicinity of Mishawaka. This option was not considered; however, an alternative providing access to Poudre Park from the south was considered (Rist Canyon Alternative).

8.2.2 Relocation Layouts

Cost estimates were developed for three Highway 14 relocation alternatives. Two of these alignments involve relocation within Poudre Canyon adjacent to a mainstem reservoir. These alignments are shown on Figure 8.1. The third alignment, the Rist Canyon Alternative, is depicted on Figure 8.2 and involves a southerly access route from Fort Collins into Poudre Park.

8.2.2.1 Poudre Canyon Alignments A and B

Alignment A includes three tunnel segments, as shown on Figure 8.1. Alignment B would not involve tunnel construction. Each alignment would require six bridges providing crossings over drainages to the Cache la Poudre River. Alignment A would have a total length of 5.8 miles; Alignment B would be 6.8 miles long. Maximum grade under either alignment would be about 6.4 percent. From the existing Highway 14, the initial segment of Alignment A would be about 2.0 miles long with an average grade of 4.8 percent (a total climb of about 500 feet). The remaining 3.8 miles of highway would descend at an average grade of less than 1 percent into Poudre Park. Alignment B, being somewhat longer, would involve somewhat flatter average grades.

Cost estimates for Alignments A and B are based on meeting CDOH requirements as stated to NCWCD. If the 45 mph design speed requirement could be relaxed at several locations, it is expected that costs could be reduced.

Cost estimates for Alignments A and B in Poudre Canyon are provided in Table 8.1. These estimates are derived from preliminary construction quantity estimates developed using the 1:2400 scale topographic mapping identified in Section 8.1.

Table 8.1

Cost Estimates for Highway 14 Relocation - Poudre Canyon Alignments A and B

		Alignment A	Alignment B
Length		5.8 miles	6.8 miles
Excavation(1)		$12,560,000	$19,700,000
Roadway(2)		2,470,000	2,930,000
Tunnels		8,750,000	---
Bridges		7,440,000	7,440,000
	Subtotal (Direct Cost)	$31,220,000	$30,070,000
	Contingency (20%)	6,240,000	6,010,000
	Eng. & Admin.	5,640,000	5,420,000
	Construction Cost	$43,100,000	$41,500,000

(1) Includes disposal of excavated material.

(2) Includes sub-base and base courses, asphalt, road fill, guardrails, etc.

8.2.2.2 Rist Canyon Alternative

Under this alternative (Figure 8.2), the existing road from State Highway 28 into Rist Canyon would be upgraded and a new road would be constructed from Rist Canyon to Poudre Park. General characteristics of this alternative are provided below:

	Upgraded Rist Canyon Road	Road from Rist Canyon to Poudre Park
Length (miles)	6.0	3.6
Max. Grade (%)	10.0	10.0
Average Grade (%)	5.2	7.5

The road segment from Highway 28 through Rist Canyon to the new road segment would be 6.0 miles long, involving a steady climb with an average grade of about 5.2 percent. The new road from Rist Canyon to Poudre Park would involve a 0.5-mile climb at 5.6 percent grade followed by a 3.1-mile descent along Hill Gulch into Poudre Park.

The Rist Canyon relocation layout was prepared using USGS 7½ - minute mapping (1:24,000 scale and 40-foot contour interval), whereas the highway relocations nearer the proposed mainstem reservoir described previously were studied using 1:2400 scale topographic maps with 5-foot contours. Excavation quantity estimates were very sensitive to topographic conditions. Therefore, the excavation (and fill) quantities estimated for the Rist Canyon Alternative from less-detailed mapping were subject to greater uncertainties. Also, it was expected that the quantities of excavation and fill estimated using less-detailed mapping may be somewhat lower than those obtained using more-detailed mapping. Previously identified criteria, as provided by CDOH, were followed for investigating the Rist Canyon relocation alternative. However, the less-detailed topography did not allow for accurate consideration of grade changes, radius of curvature, and other factors.

Cost estimates for the Rist Canyon alignment are provided in Table 8.2. A higher contingency allowance (30 percent) was used because of greater uncertainties about construction quantities.

TABLE 8.2

Cost Estimate for Highway 14 Relocation - Rist Canyon Alignment

Upgraded Rist Canyon Road		Cost
Length		6.0 miles
Excavation(1)		$ 3,180,000
Roadway(2)		4,050,000
	Subtotal	$ 7,230,000
New Road (Rist Canyon - Poudre Park)		
Length		3.6 miles
Excavation(1)		1,970,000
Roadway(2)		2,150,000
Bridge		2,980,000
	Subtotal	$ 7,100,000
	Subtotal (Direct Cost)	$14,330,000
	Contingency (30%)	4,300,000
	Eng. & Admin.	2,770,000
	Construction Cost	$21,400,000

(1) Includes disposal of excavated material.

(2) Includes sub-base and base courses, asphalt, roadfill, guardrails, etc.

8.2.3 Comparison of Alternative Alignments

The estimated excavation quantities for the road segment between Rist Canyon and Poudre Park are significantly less, on an average unit length basis, than the quantities estimated for Poudre Canyon Alignments A or B. Average excavation for Alignment A is about 80 cy/ft of length, excluding the tunnel and bridge sections, based on detailed topographic mapping. Estimated excavation quantities for the new road from Rist Canyon to Poudre Park indicate an average of only 17 cy/ft of length, excluding a bridge section, based on USGS 7-1/2-minute topographic mapping. If the new road section from Rist Canyon to Poudre

Park required an average excavation of 80 cy/ft over its entire length, total cost of the Rist Canyon alternative would be increased to nearly $30 million.

The Rist Canyon alignment should be studied at the full feasibility level because of possible cost advantages in comparison to either of the Alignments A or B in the Poudre Canyon. Further investigation of Alignments A and B may also be warranted depending on inputs from CDOH and local governmental entities. Topographic mapping at 1:2400 scale and 5-foot contour interval will be needed along the Rist Canyon alignment to provide mapping equivalent to that available for the alternative Poudre Canyon alignments. CDOH will also need to be consulted about the Rist Canyon alternative in relation to overall road system planning for Northern Colorado. Possible disadvantages of the Rist Canyon alternative include longer travel distance and time from Fort Collins to Poudre Park, longer and steeper grades, and increased traffic flow along the existing Rist Canyon road. However, the Rist Canyon alignment appears, at the present time, to be significantly less costly than either of the two canyon alignments that have been studied.

8.3 U.S. HIGHWAY 287

Requirements for relocating U.S. Highway 287 were considered during the Basin Study. However, consideration was not given to intertying the relocated highway with the Fort Collins Expressway, a new highway bypassing La Porte to the north. Location of the Fort Collins Expressway relative to Highway 287 and the potential Glade Reservoir area is shown on Figure 8.3. Because of changes since the Basin Study, it was decided to reconsider location of U.S. Highway 287 during the Basin Study Extension and to redefine potential costs for this relocation, which would be incurred during Stage 2 of the Cache la Poudre Project.

8.3.1 General Design Parameters

Layouts for relocating Highway 287 around the potential Glade Reservoir area were prepared using the following general design parameters suggested by CDOH (CDOH, 1987b):

Right-of-way:	150 feet (minimum)[1]
Typical roadway section:	Type A, four-lane with median (10-foot outside shoulders, 12-foot traffic lanes, 4-foot inside shoulders)
Maximum grades:	Up to 45 mph - 6 percent Up to 55 mph - 5 percent Up to 70 mph - 4 percent
Design speed:	70 mph
Climbing lanes:	Based on grade[2]
Drainage design:	50-year storm for cross drainage[3]

(1) Existing right-of-way varies from 80 to 200 feet.

(2) Apply criteria in Section 202.5 of CDOH Roadway Design Manual.

(3) Drainage not specifically considered in design; cross-drainage requirements would be relatively minor for the relocation alignment considered.

CDOH standards were followed in preparing preliminary layouts and construction quantity estimates. Layouts were prepared using USGS 7½ - minute quad sheets (1:24,000 scale with 20-foot contour interval) and, therefore, quantity estimates were subject to the same uncertainties as described for the Rist Canyon alternative for relocating Colorado Highway 14.

8.3.2 Relocation Layout

U.S. Highway 287 would be relocated along the east side of the potential Glade Reservoir area, as shown on Figure 8.3. The alignment would extend from an interchange at the Fort Collins Expressway north to existing Highway 287 near Owl Canyon, a length of about 7.5 miles. Maximum grade would be 4 percent. Construction cost is estimated to be about $43 million, as indicated in Table 8.3.

TABLE 8.3

Cost Estimate for U. S. Highway 287 Relocation

	Cost
Length	7.5 miles
Excavation(1)	$16,340,000
Roadway(2)	12,320,000
Subtotal (Direct Cost)	$28,660,000
Contingency (30%)	8,600,000
Engineer and Administration	5,540,000
Construction Cost	$42,800,000

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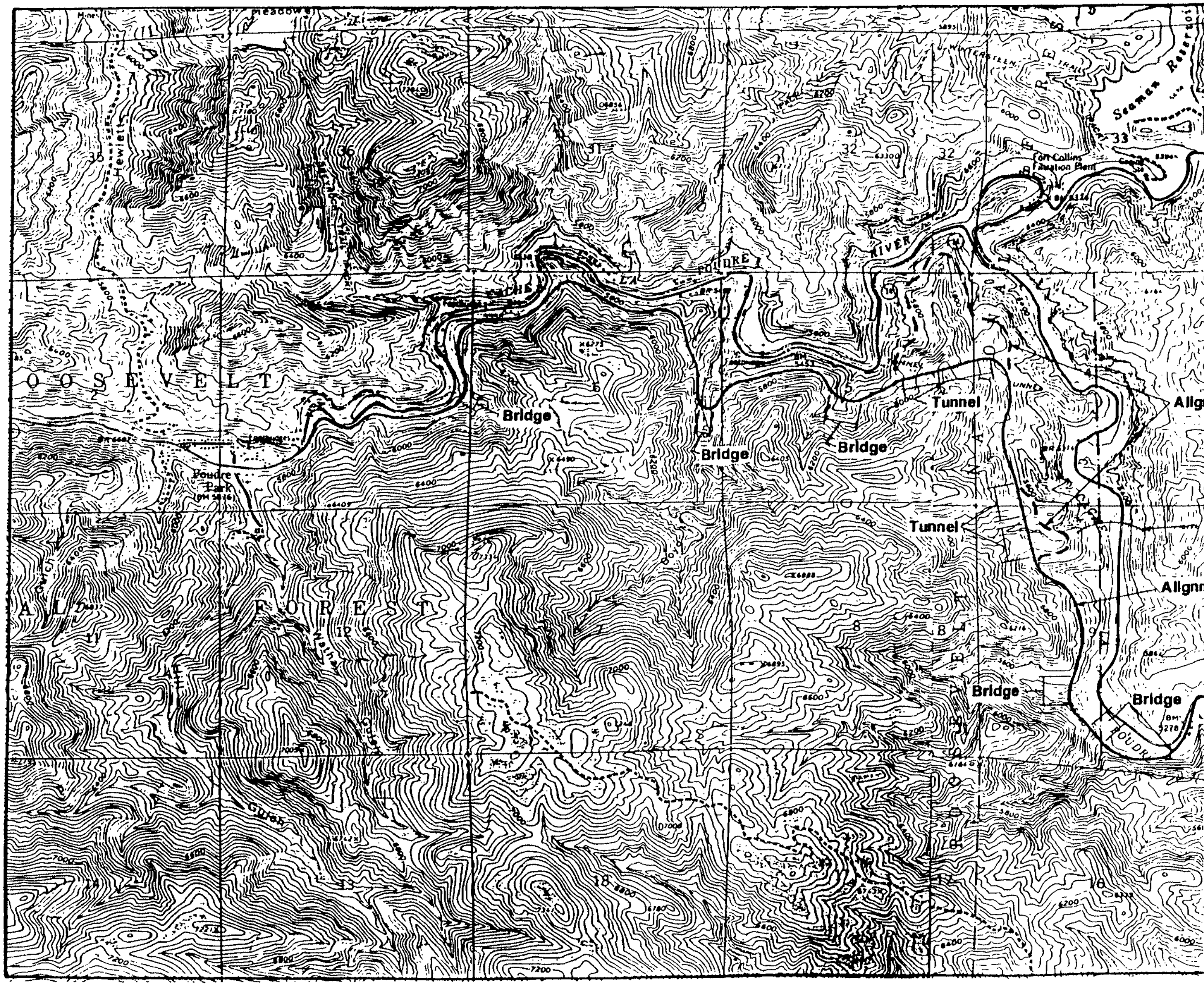
(1) Includes disposals of excavated material and use of excavation for road fill.

(2) Includes sub-base and base courses, asphalt, guardrails, etc.

8.4 REFERENCES

Colorado Department of Highways (CDOH), Division of Highways, January 1987a. Roadway Design Manual. (1987 CDOH Design Manual)

Colorado Department of Highways (CDOH), 1987b. Letter from the CDOH to the Northern Colorado Water Conservancy District dated December 3, 1987.

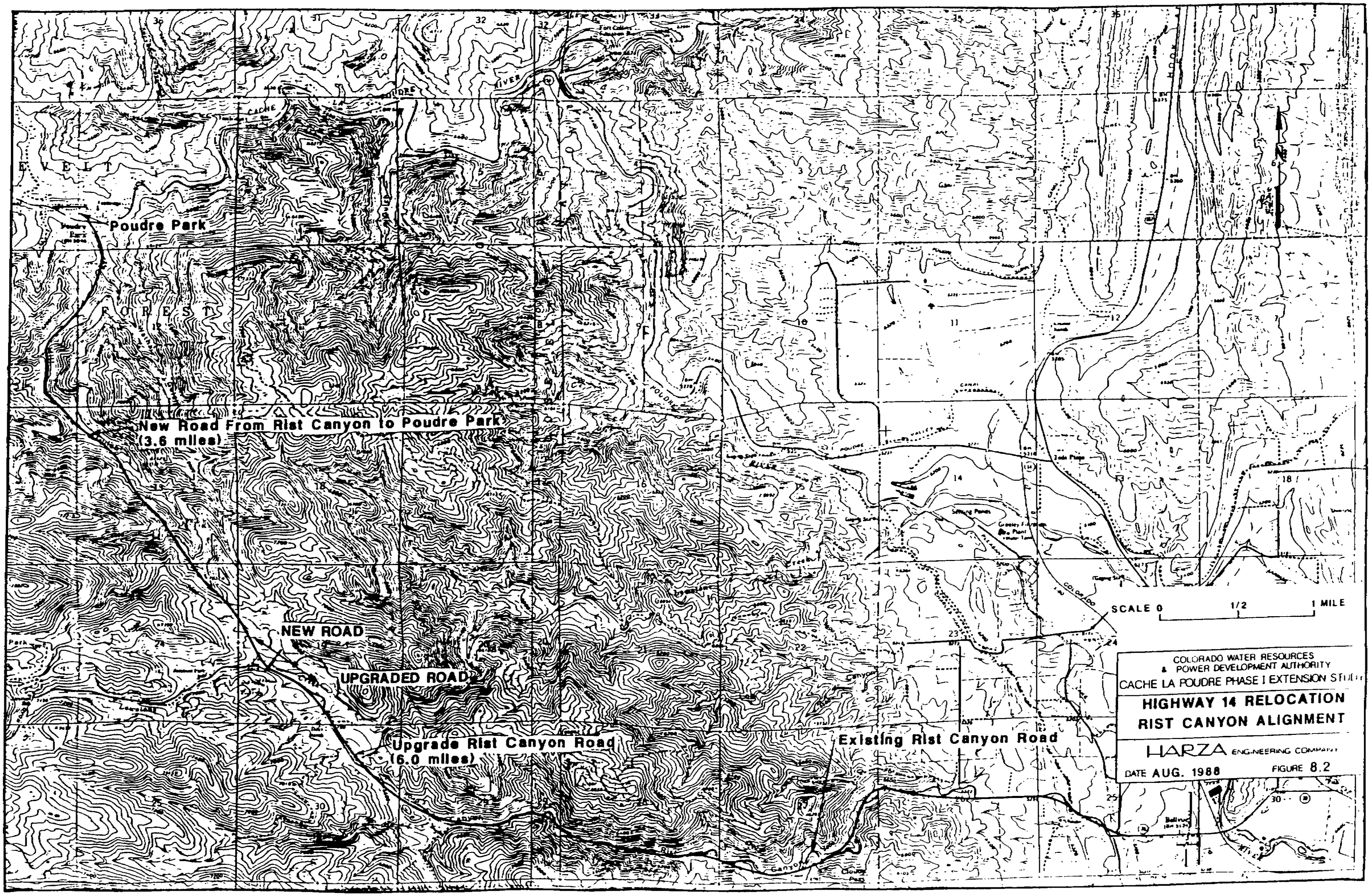


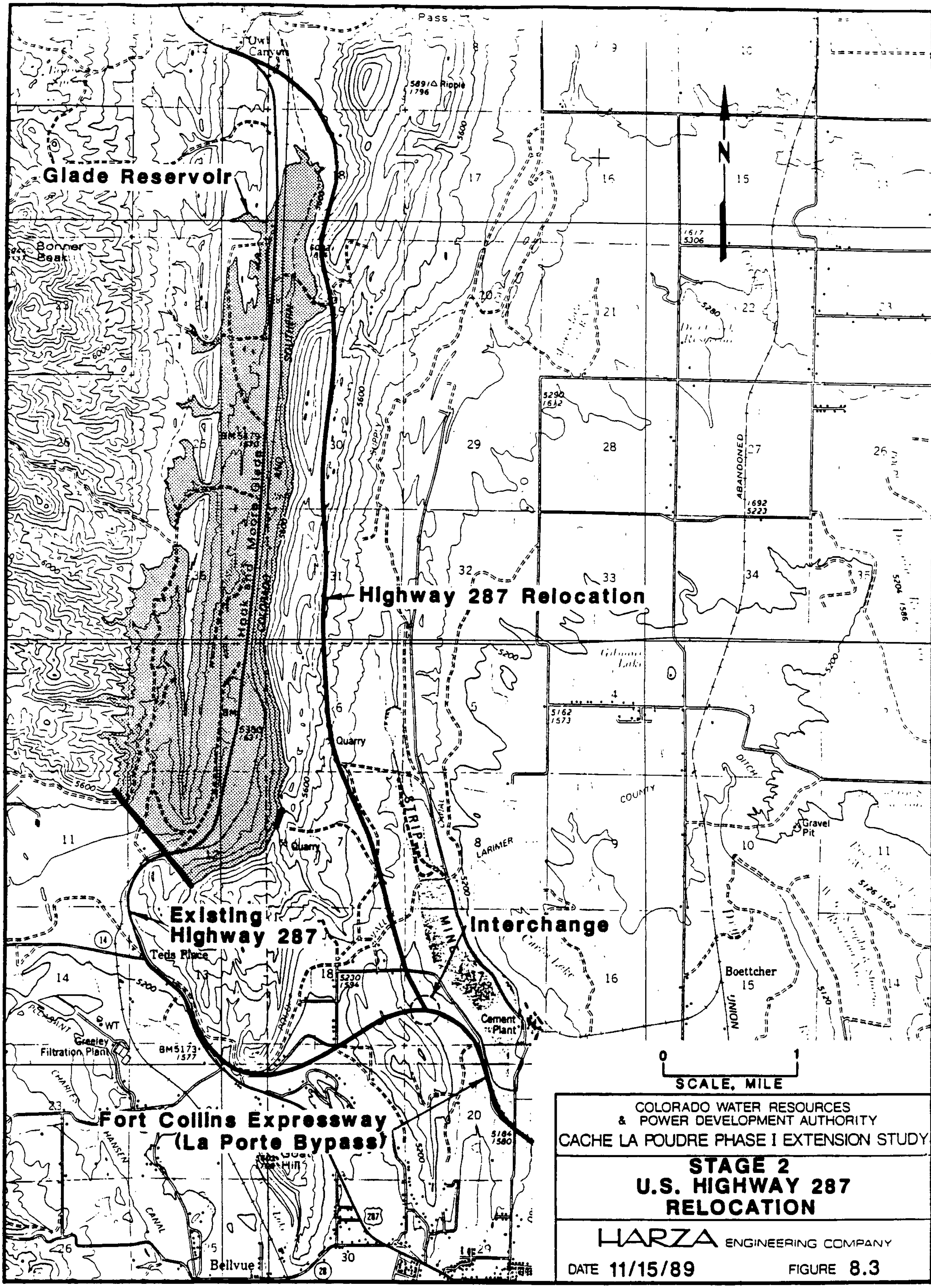
COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY
CACHE LA POUDRE PHASE I EXTENSION STUDY

HIGHWAY 14 RELOCATION
POUDRE CANYON
ALIGNMENTS A AND B

HARZA ENGINEERING COMPANY

DATE 4/18/88 FIGURE 8.1


Poudre Park
New Road From Rist Canyon to Poudre Park
(3.6 miles)
NEW ROAD
UPGRADED ROAD
Upgrade Rist Canyon Road
(6.0 miles)
Existing Rist Canyon Road
SCALE 0 1/2 1 MILE
COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY
CACHE LA POUDRE PHASE I EXTENSION STUDY
HIGHWAY 14 RELOCATION
RIST CANYON ALIGNMENT
HARZA ENGINEERING COMPANY
DATE AUG. 1988
FIGURE 8.2



COLORADO WATER RESOURCES & POWER DEVELOPMENT AUTHORITY
CACHE LA POUDRE PHASE I EXTENSION STUDY

STAGE 2
U.S. HIGHWAY 287
RELOCATION

HARZA ENGINEERING COMPANY

DATE 11/15/89 FIGURE 8.3

CHAPTER 9.0

REFINEMENT OF STAGE I
GREY MOUNTAIN
STORAGE ALTERNATIVE

9.0 REFINEMENT OF STAGE 1 GREY MOUNTAIN STORAGE ALTERNATIVE

9.1 LOCATION AND FUNCTION

The site for Grey Mountain Dam is located about two miles upstream from the mouth of the Poudre Canyon. This damsite originally was identified by the USBR and was studied in some detail during the early 1970's. Data compiled for the Basin Study (Harza, 1987) indicated that a gross storage volume of 195,000 af could be provided at the Grey Mountain site, assuming a maximum normal reservoir water surface elevation (NWS) of 5630 ft. With allowance for the estimated 100-year sediment accumulation, active storage in Grey Mountain Reservoir would be about 185,000 af.

Storage in a mainstem reservoir such as the Grey Mountain alternative would serve three basic functions:

(1) **Regulation of native flows** in the Cache la Poudre Basin which are storable under a conditional water right (decree pending) with an appropriation date of May 1980. Essentially, storable flows are high river flows, which usually occur in the Spring and exceed downstream senior water rights. Without storage, these flows would pass through the Poudre Basin unused. With a storage reservoir, water stored during high flow periods can be made available later in the year, or in another year, when low flows are not adequate to meet competing demands for water.

(2) **Storage of imported water** that can be brought into the Poudre Basin through existing water conveyance facilities. Operation studies performed by NCWCD indicate that incremental amounts of C-BT and Windy Gap water currently unused but available under existing water rights can be conveyed into the Poudre Basin provided a terminal storage reservoir is available.

(3) **Enhanced regional water management** can be provided within the NCWCD service area in Northern Colorado if additional water storage is

provided in the Poudre Basin. Enhanced water management includes increased capacity for exchanges of water among various users and improved capabilities to conserve water resources for long-term drought protection.

Hydrologic modeling studies performed by NCWCD (Chapter 10.0) indicate that 195,000 af of total reservoir storage at a mainstem reservoir on the Poudre River could provide a safe yield of as much as 46,000 af/yr from native storable flows and water imports from the C-BT and Windy Gap Projects into the Poudre Basin. The resulting ratio of storage volume to safe yield is about four to one. The safe yield estimate is a "zero shortage yield" for a 1954-1983 simulation period, assuming at least 150,000 af of water is stored in the reservoir at the beginning of the simulation period. It is also based on providing the minimum bypass flows stipulated in the Grey Mountain conditional water rights filing.

Along with providing additional water supply, a mainstem reservoir constructed as Stage 1 of the Poudre Project would provide the opportunity for conventional hydroelectric power generation. This would be accomplished by constructing a powerhouse at the base of the dam. Generating equipment would use the elevation difference between the reservoir and the river below the dam, and releases from the reservoir for downstream water demands and bypass flows to produce hydroelectric power. Depending on how the reservoir is operated, the installed conventional hydroelectric generating capacity may range from about 18 MW to 24 MW. Corresponding energy production would range from 39 gigawatt hours (GWh) per year to 52 GWh per year.

A mainstem reservoir would also provide significant regulation of peak flood discharges, thereby reducing damages caused by overbank flooding downstream from the mouth of the Poudre Canyon. Storage at a mainstem reservoir site would also provide various instream flow management opportunities, which are being evaluated as part of other tasks associated with the Basin Study Extension.

Major features of a Stage 1 mainstem reservoir project would be similar for any of the alternative damsites presently being considered. Further discussions in this chapter of the Final Report relate directly to the Grey Mountain alternative, although final selection of the Stage 1 development has not been made.

Major features of the potential Grey Mountain Project would include:

(1) Grey Mountain Dam (either a concrete arch or concrete gravity dam);

(2) Grey Mountain Reservoir, with a surface area of about 1600 acres at maximum NWS El 5630 ft;

(3) Multi-level outlet works to release water for downstream demands and control river water temperatures;

(4) Facilities to supply the existing North Poudre Irrigation system from the reservoir;

(5) Conventional hydroelectric powerplant and associated local transmission facilities;

(6) Facilities to convey water from Horsetooth Reservoir to Grey Mountain Reservoir;

(7) Access roads to the project area; and

(8) Relocated segment of State Highway 14 around the reservoir.

Descriptions of major project features provided later in this chapter are intended to provide an indication of the potential project configuration and to establish a basis for estimating construction costs. Significant data for selected features of the Grey Mountain alternative are provided in Table 9.1.

9.2 GEOTECHNICAL INVESTIGATIONS

Preliminary surficial investigations and review of previous geotechnical studies, conducted as part of the earlier Basin Study as well as the Basin Study Extension, indicate that the Grey Mountain Damsite is topographically and geologically suitable for construction of a concrete arch or gravity dam. Limited subsurface investigations for a gravity dam with an axis about 600 ft downstream of the arch dam site were conducted by the USBR in 1973 (Cast, 1973). The USBR analysis of data obtained at the downstream axis identified questions with respect to the suitability of this site for an arch dam. Review of the available data and further field examination indicate that the expected gouge zone at the toe of the left abutment does not correspond to an active fault. Material in this zone can be treated to prevent under seepage and is not expected to present any structural problems. Additional geotechnical information is provided in Appendix I of this Final Report. This appendix provides results from review of prior investigations and a program of field geologic mapping carried out by Harza.

9.3 TOPOGRAPHIC MAPPING

The topographic mapping program carried out during the Basin Study Extension is described in Chapter 8.0. Mapping of the Grey Mountain and Poudre Damsites was prepared at a 1:1200 scale with 5-foot contour interval. About 130 acres of mapping was completed at each of the two damsites. This mapping is suitable for detailed engineering feasibility studies that would be carried out in the next phase of project implementation.

9.4 CONCRETE ARCH ALTERNATIVE

The Grey Mountain site is suitable for construction of an embankment dam, a concrete gravity dam, or a concrete arch dam. During the Basin Study, a comparison was made between an embankment dam (rockfill with central impervious core) and a concrete gravity dam constructed of roller compacted concrete (RCC). The RCC dam was found to be significantly less costly than the rockfill dam. An arch dam was not studied at the Grey Mountain site during the Basin Study. However, it was recognized that the site most likely would be suitable for construction of a concrete arch dam. Generally, if a damsite is suitable for arch dam construction, this type of dam usually is the least costly for the site. For this reason, it was decided to examine the arch dam alternative for the Grey Mountain site as part of the Basin Study Extension.

TABLE 9.1

Significant Data for Stage 1 of the Cache la Poudre Project (Grey Mountain Arch Dam Alternative and Associated Facilities)

Grey Mountain Dam and Reservoir	
Maximum Dam Height	415 ft
Crest Length	1580 ft
Crest Elevation	5655
Diversion Works Capacity	9500 cfs
Spillway Capacity	122,000 cfs
Spillway Crest Elevation	5630
Max. Normal Water Surface	5630
Reservoir Area at Max. Normal Water Surface	1600 acres
Selective Withdrawal System Capacity	850 cfs
Low-Level Outlet Works Capacity	1150 cfs
Anticipated Firm Yield	40,000 to 46,000 af/year
Conventional Hydroelectric Powerplant	
Installed Capacity	17.7 to 23.9 MW
Average Annual Energy Production	39 to 52 GWh
Average Capacity Factor	25%
Horsetooth-Grey Mountain Facilities	
Pipeline Length	7.5 miles
Pipeline Capacity	170 cfs
Total Pumping Capacity	16,800 HP (Two Lift Stations)
Access Roads	4 miles
Highway 14 Relocation[(1)]	6 miles

(1) See Chapter 8.0 of the report. Length shown is that of the existing highway which would be affected by mainstem reservoir construction.

A general layout for an arch dam at the Grey Mountain damsite is shown on Figure 9.1. The proposed dam would have a maximum structural height of 415 feet and a crest length of about 1580 feet. The dam crest would be at El 5655 ft. Total concrete volume in the arch dam would be about 760,000 cubic yards (cy).

An ungated overflow spillway would be located over the center section of the dam. The spillway crest would be at El 5630 ft, the normal maximum reservoir water surface elevation. As currently envisioned, the spillway would consist of five 50-foot wide bays separated by piers to support a bridge over the spillway. This bridge would be at the crest elevation of the dam (El 5655 ft). The piers would also assist in aerating the spillway discharge and would help to control vibration. The spillway would be a bucket-shaped ogee to provide for an almost horizontal jet leaving the structure. Flows from the spillway would be directed by the bucket lip into a pre-excavated plunge pool, located about 100 feet downstream from the toe of the dam. The plunge pool would be excavated to sound rock and protected by a concrete apron.

Spillway capacity would be 122,000 cfs. This capacity is about seven times the peak discharge (17,400 cfs) expected during a 100-year flood event. The probable maximum flood (PMF) for the Grey Mountain site is estimated to be 327,000 cfs, with a total inflow volume of 707,000 af. The spillway, as currently sized, would be able to pass about one-third of the peak PMF discharge. During the PMF, Grey Mountain Dam would be overtopped by about 11 feet (to El 5666 ft) if the spillway were designed to pass one-third of the PMF. During overtopping, some erosion of the foundation abutments could occur; however, this very infrequent potential erosion would not impair the structural stability of the dam. Specific requirements for sizing the spillway will need to be discussed with the State Engineer's staff and finalized during a full feasibility study of the project.

9.5 RESERVOIR

The reservoir created by Grey Mountain Dam would have a total storage volume of about 195,000 af and an active storage volume of 185,000 af at NWS El 5630 ft. The maximum NWS was selected during the Basin Study in accordance with the amendment to the Wild and Scenic Rivers Act (1986) which requires any mainstem reservoir to be below the West 1/2 Section 1, Township 8 North, Range 71 West (below the Town of Poudre Park). The reservoir would have a normal maximum depth of 350 ft near the upstream heel of the dam. At NWS El 5630 ft, the reservoir length would be 7.5 miles along the mainstem Cache la Poudre and about 7.5 miles along the North Fork. The reservoir surface area would be approximately 1600 acres at NWS El 5630 ft, and the reservoir shoreline would be about 25 miles in length.

9.6 OUTLET WORKS

Final design details for the outlet works configuration associated with any potential reservoir will be dependent on particular operational requirements, including downstream water quality considerations. For preliminary planning, it was assumed that a combination low-level outlet works and selective withdrawal system would be provided. However, specific requirements for a selective withdrawal system and its capacity can not be determined until the feasibility or design phase of project implementation. For planning purposes, it was assumed that the low-level outlet works and the selective withdrawal system, operating in tandem, would be capable of discharging 2000 cfs with the reservoir at its minimum level. About 40 percent of the discharge capability would be provided in the selective withdrawal system and 60 percent in the low-level outlet works.

The selective withdrawal system would consist of gated, multi-level intake ports on the upstream face of the dam. The number and elevation of intake ports would be selected during the design phase, based on results of reservoir water quality modeling studies (particularly temperature and dissolved oxygen studies). For preliminary cost estimates, it was assumed that three intake levels would be provided between NWS El 5630 ft and El 5400 ft (low-level outlet works elevation). The selective withdrawal system would make most of the releases from the reservoir. The selective withdrawal system would have a capacity of 850 cfs and would supply water to the conventional hydro plant under normal operating conditions. Bypass valves located in a valve house at the base of the dam would be used to discharge water from the selective withdrawal system when the powerhouse is not operating.

The low-level outlet works would consist of two gated intakes on the upstream face of the dam at about El 5400 ft. Releases from the low-level outlets would be made through a separate valve system located in the valve house at the base of the dam. The low-level outlet system would serve as a backup to the selective withdrawal system and would operate when additional discharge capacity is required. The low-level outlet system would have a capacity of 1150 cfs.

It should be possible to incorporate the outlet works with the river diversion conduits and thereby reduce outlet works cost. Final selection of the outlet works configuration and capacity, including low-level outlets and/or a selective withdrawal system, will be made in the full feasibility or design phase. It should be noted that costs associated with outlet works are a small percentage of total costs for the dam, and that the final size and configuration of these facilities will not affect project viability.

9.7 FACILITIES TO SUPPLY THE NORTH POUDRE IRRIGATION SYSTEM

Grey Mountain Reservoir will inundate a portion of the facilities operated by the North Poudre Irrigation Company. If the dam and reservoir are constructed, continued supply to North Poudre facilities from the mainstem Cache la Poudre River will need to be provided by: (1) outlet works in the dam and new conveyance facilities from the dam to the existing North Poudre Irrigation facilities; or (2) modifications to the existing conveyance facilities to incorporate a submerged reservoir intake. During the Basin Study, it was assumed that new conveyance facilities would be provided. Studies conducted as part of the Basin Study Extension indicate that it would be possible to utilize existing facilities at a cost less than that for new conveyance facilities.

The invert of existing Tunnel Number 2 of the North Poudre Irrigation facilities is at El 5413 ft on the east side of the proposed reservoir. A plan for utilizing the existing tunnel, which was designed for non-pressurized flow, would include: (1) construction of an intake structure at the existing tunnel portal; (2) excavation of a shaft from a point on the hillside above El 5655 ft (dam crest elevation) down to the tunnel; (3) excavation of a chamber to house a gate that would reduce operating pressure in the downstream 4200 ft of the existing tunnel; and (4) concrete lining and ring grouting of the upper 500 ft of existing tunnel. The intake structure would be gated and would be capable of delivering the required 250 cfs to the North Poudre Irrigation system.

9.8 POWERHOUSE AND POWER FACILITIES

The proposed conventional hydroelectric powerhouse would be located at the base of the dam adjacent to the valve house, as indicated on Figure 9.1.

A range of potential hydroelectric generating capacities were investigated based on two assumed release cases from Grey Mountain Reservoir. These release cases are:

- **Case A** - Water supply from the reservoir is provided by pipeline (i.e., flows not required to meet downstream senior rights or bypass flows are delivered from the reservoir by pipeline and are not available for power generation).

- **Case B** - Water supply from the reservoir is released to the river below the dam (i.e., virtually all flows are available for power generation).

Under Case B, the amount of water available for power generation is increased over Case A by safe yield, not average 41,000 af/yr for the 1954-83 hydrologic simulation period.

Monthly flows for the 1954-83 period were obtained for each case listed above, based on results of modeling activities performed by NCWCD during Task 17. NCWCD also provided corresponding reservoir elevations for each month which were used to estimate the gross head available for power generation on a monthly basis. Annual flow-duration curves for the Case A and Case B release conditions are provided on Figures 9.2 and 9.3, respectively.

Energy estimates described in this chapter are based on interim hydrologic analysis results from Task 17. When the final Task 17 results were compiled and compared to the interim results, it was found that average monthly reservoir levels used in the hydropower analysis were about 5% lower than the final reservoir elevations provided in Chapter 10.0 for the Grey Mountain Alternative. Similarly, reservoir and flows used for the hydropower analysis were about 2.5%

lower than the final reservoir outflows provided in Chapter 10.0 for the Grey Mountain Alternative. Because of the relatively small differences and the fact that energy estimates are conservatively based on lower flows and available head, it was decided not to revise energy estimates at this time.

Energy production estimates were developed under each case for a range of installed plant capacities, using a simplified spreadsheet procedure based on monthly flows and reservoir elevations. In making these estimates, the following assumptions were made:

(1) Tailwater was assumed to be constant at El 5290 ft. Maximum tailwater variation over the expected range of reservoir releases was estimated to be about 3 feet, or about one percent of the maximum head on the generating units. Headwater elevations were varied as indicated by results from the hydrologic studies performed by NCWCD.

(2) Turbine efficiency was assumed to be 90 percent over the full range of turbine discharge and operating head. Generator and transformer efficiencies were assumed to be 98 percent and 99 percent, respectively.

(3) No reductions in energy production estimates were included for scheduled outages for plant maintenance. These outages, expressed as a percentage of energy production, would be outside the range of accuracy of the preliminary energy production estimates presented in this report.

A preliminary selection of plant capacity was prepared for Case A. This selection was based on an economic analysis to determine the capacity at which the estimated cost of providing incremental generating capacity exceeded the estimated revenue associated with the incremental energy production provided. Revenue estimates were based on 1987 avoided cost rates published by Public Service of Colorado. These rates were $17.84 per kW-month (capacity component tied to plant capacity factor) and $.0153 per kWh (energy component). The combined rate, covering both capacity and energy, was \$.0458 per kWh of energy produced.

For Case A, the hydraulic capacity was selected to be 850 cfs (rated capacity), which corresponds to an installed generating capacity of 17,700 kW. This provided an average plant factor of about 25 percent. Energy production under Case A was estimated to be about 39 GWh per year. For Case B release conditions, it was assumed that the plant capacity factor was also about 25 percent, resulting in selection of a 23,900 kW installation and estimated production of about 52 GWh per year of electrical energy. The hydraulic capacity of this installation was 1200 cfs. Figures 9.2 and 9.3 depict the utilization of water available for power generation associated with the selected capacities for Case A and Case B, respectively.

Significant data relating to the selected hydropower projects are provided below:

Item	Case A	Case B
Unit Type	Francis	Francis
No. of Units	2	2
Plant Hydraulic Capacity (cfs)	850	1200
Generating Capacity (kW)		
Unit 1	4,600	6,200
Unit 2	13,100	17,700
Total	17,700	23,900
Average Energy Production (GWh/yr)	39	52
Average Plant Factor (%)	25	25

As indicated above, a two-unit powerhouse installation is assumed such that power generation over a wide range of flow rates can be provided. Cost estimates for each hydro installation, which are presented in Section 9.12, include water conductors, civil works, buildings, and electrical and mechanical equipment. Major mechanical equipment items include the Francis turbines, inlet valves, and speed-regulating governors. Electrical equipment items include the synchronous generators, accessory electrical equipment, and switchyard equipment.

Cost estimates were developed for generating capacities under Case A and under Case B release conditions. This approach provided a range of costs for potential generating capacities for a conventional hydroelectric facility at Grey Mountain Dam. Further studies, undertaken in a subsequent phase of project implementation, are needed to optimize the hydroelectric facility. This optimization would be based on the results of additional hydrologic and reservoir operation modeling studies and would involve a more-detailed power operations study.

9.9 HORSETOOTH-GREY MOUNTAIN CONVEYANCE

Water from the C-BT and Windy Gap Projects, imported through existing C-BT conveyance facilities, could be stored by the Cache la Poudre Project. The additional water would be diverted on the West Slope and conveyed to Horsetooth Reservoir. From Horsetooth Reservoir, this water could be conveyed to storage in a mainstem reservoir on the Cache la Poudre River. Results from hydrologic studies performed by NCWCD indicate that the delivery rate from Horsetooth Reservoir to Grey Mountain Reservoir should be sized for 10,000 af per month (170 cfs).

Preliminary cost estimates were developed for conveyance facilities between Horsetooth Reservoir and Grey Mountain Reservoir. The maximum NWS in Horsetooth Reservoir is El 5430 ft, 200 feet lower than the proposed maximum NWS in Grey Mountain Reservoir (El 5630 ft). Therefore, C-BT and Windy Gap water would need to be conveyed by pumping from Horsetooth Reservoir to the proposed Grey Mountain Reservoir. Total conveyance length would be about 7.5 miles.

A pipeline having a diameter of 51 inches (4.25 ft) would be required along with two 8,400 HP pumping stations. One station would be located at Horsetooth Dam, the other about half-way between Horsetooth Dam and Grey Mountain Dam. Total dynamic head at each pumping station would be about 370 feet.

For estimating purposes, it was assumed that the pipeline would be welded steel pipe buried in a trench. Cathodic protection probably would be needed to prevent corrosion of the pipe. The general location of the potential water conveyance facilities is shown on Figure 9.4.

9.10 ACCESS ROADS

Permanent access to the dam and ancillary facilities of a mainstem reservoir would be via the existing Colorado Highway 14 to the downstream side of the dam and from a service road leading from the existing or relocated Highway 14, depending on which highway relocation alternative is selected. The service road would be about 0.5 miles in length and would provide direct access to the right abutment of the dam. The road then would extend across the dam crest and spillway to the left abutment and would continue on the left side of the reservoir in a northerly direction for a distance of about 1.2 miles to the intake area for the North Poudre Irrigation facilities.

Access to areas upstream of the dam during construction would be via a road from the right abutment leading down to the base of the canyon. This road would be about 1.5 miles long. Construction access to the North Poudre Tunnel No. 2 facilities would be from the upstream side of the dam via a road from the valley floor. This road would be about 0.9 miles long.

If Highway 14 is relocated in the vicinity of the mainstem reservoir, the access road from Route 14 to the right abutment area could be converted into a visitor access route after construction is complete. Also, a visitor center/look-out area could be provided at the dam. Visitor access could also be provided to the downstream side of the dam via existing Route 14. If the Rist Canyon alternative is selected for relocating Highway 14, other provisions for public access to the reservoir would be needed.

9.11 CONSTRUCTION CONSIDERATIONS

This section describes the proposed plan for diversion and care of water during dam construction, the availability of construction materials, and the probable sequencing of facility construction.

9.11.1 Construction Materials

The major requirement for construction material would be sand and gravel for concrete aggregate to construct the dam and appurtenant structures. Other requirements would be for fill and impervious core material for the cofferdams and a small amount of riprap or cobble gravel. Gravel would also be needed for access roads, building pads, parking areas, and fill.

A suitable and nearby gravel source for aggregate and other needs is the alluvium of the Cache la Poudre River. Assuming an average gravel depth of 30 ft, about one million cubic yards should be available from the river bed and terrace deposits in the reservoir area between the damsite and the inactive Fort Collins filtration plant, about 1.5 miles upstream from the proposed site for Grey Mountain Dam. This quantity of gravel should be sufficient for dam construction and other requirements.

The river and terrace deposits consist of bouldery-cobble gravel composed mostly of granitic rocks, gneiss, quartz, and minor amounts of schist, feldspar, and amphibolite. Two aggregate sources in the river alluvium were tested by the Bureau of Reclamation and were considered to be acceptable for use in constructing the facilities associated with the North Poudre Supply Canal (Cast, 1973).

Impervious core material is available from an area one to two miles east of the damsite and north of Colorado Highway 14. This large, gently sloping area is composed of alluvium and colluvium derived in part from the Fountain, Ingleside, and Satanka Formations. Data obtained by the Bureau of Reclamation (Cast, 1973) indicates that most of the area consists of micaceous sand, silt, and clay up to an average depth of 25 ft.

Information obtained while conducting subsurface investigations at the proposed Glade Damsite during the Basin Study indicates that ample quantities of impervious core material are also available within a haul distance of less than 4 miles. The Glade Damsite is located 2.5 miles east of the Grey Mountain Damsite.

Future feasibility studies should include a comprehensive sampling and testing program for both concrete aggregate and impervious core material so that quantities can be confirmed and the engineering properties of the material can be obtained for use in preparing designs.

9.11.2 River Diversion

The preliminary plan for river diversion during construction involves a twin-barrel, closed concrete conduit and a concrete bench flume. The closed conduit would consist of two 12-ft square 420-ft long, box conduits. The concrete bench flume would be about 370 ft long with a bottom width of 35 ft and depth of 15 ft. The diversion works would be sized for a peak discharge of 9500 cfs, the estimated 25-year flood.

An upstream cofferdam would protect the construction area and provide adequate elevation to pass the 25-year flood through the diversion conduits. The upstream cofferdam would be an embankment structure. An initial stage cofferdam would be constructed to permit dewatering of the downstream area of the cofferdam site using the diversion conduit. The final cofferdam, incorporating an impervious core and seepage control measures, would be constructed in the dry against the downstream side of the initial cofferdam. The upstream cofferdam would have a maximum height of about 40 feet above the existing river bed.

The diversion conduits and bench flume would discharge below a downstream cofferdam constructed to an elevation which assures that backwater during a 25-year flood event would not affect the construction area.

An alternative plan for river diversion would involve construction of a diversion tunnel. This option should be considered during full feasibility studies.

9.11.3 Construction Sequence and Timing

Construction of the Grey Mountain Dam and ancillary facilities will require about five years of construction time. The first year would involve relocation of Highway 14. The highway relocation needs to be undertaken first so that traffic flow on Highway 14 will not be disrupted by construction operations.

The next year of construction would involve mobilization for construction of the dam and ancillary facilities and construction of the diversion works. Actual construction of the dam could begin in the second year. Construction of the valve house, powerhouse, North Poudre intake, and other facilities, as well as plunge pool excavation and reservoir clearing, would proceed concurrently with construction of the dam. A three-year construction period would be required to complete construction of the dam and associated facilities.

During the final year of construction, prior to complete demobilization, areas disturbed by construction activities would be restored by appropriate revegetation and slope stabilization measures. Excavated materials, which cannot be used in construction, would be disposed in the reservoir area.

9.12 OPERATIONAL CHARACTERISTICS

Hydrologic modeling and reservoir operation studies were conducted by NCWCD. Operation of the Grey Mountain Reservoir or other mainstem storage alternative for water supply will involve: (1) storing native flows from the Poudre Basin during the high runoff season (May through July) for use later in the year (seasonal regulation) or in a subsequent dry year (carryover storage); and (2) storing and regulating imports of C-BT and Windy Gap water that can be brought into the Basin through existing C-BT facilities. Storage of native flows for later use will cause a decrease in high flows below the dam but will increase streamflows during low-flow periods when releases are made from storage to supplement naturally occurring flows. Importation of C-BT and Windy Gap water into the Basin will produce a net gain in the Basin's water supply. Generally, the C-BT and Windy Gap water will enhance water supply during low-flow periods and have little effect on high flows. Fluctuations in reservoir levels will occur depending on inflows and demands for water in storage.

Opportunities may exist to operate the Grey Mountain Reservoir to benefit the stream fishery and enhance recreation both upstream and downstream from the dam. Some of these opportunities were investigated in other tasks of the Basin Study Extension and will continue to be investigated as part of future studies.

The proposed conventional hydroelectric power plant will be operated using releases made to downstream demands. Releases from storage to enhance hydropower operations are not planned.

9.13 REVISED COST ESTIMATES

Construction, operation, and maintenance costs for the Grey Mountain Project and the Highway 14 relocation were estimated at January 1988 price levels. Construction cost estimates were based on preliminary construction quantity takeoffs for major construction items and the prior experience of Harza Engineering Company. Annual O&M costs were estimated based on prior Harza experience for similar projects.

9.13.1 Construction Costs

Construction costs at the January 1988 price level were determined for each major component of the proposed Stage 1 development. Estimated direct costs of civil components include construction materials, equipment, transportation, and labor, and are based on quantity estimates obtained from the project layouts. Electrical and mechanical equipment costs are estimated on the basis of manufacturer's price information supplied for other projects. The prices are adjusted to compensate for transportation to the site, installation of the equipment, and contractor's profit. The civil costs and electrical and mechanical equipment costs are added to obtain the subtotal of direct costs. Allowances for contingencies, engineering, and owner's overhead are added to the foregoing costs. The contingency allowance applied is 25 percent for all items. The cost of engineering and owner's overhead is estimated to be 15 percent of direct costs plus contingencies.

9.13.1.1 Grey Mountain Dam and Reservoir

Construction of Grey Mountain Dam is estimated to cost $164 million, as shown in Table 9.2. This cost excludes facilities for conventional hydroelectric power generation, Horsetooth conveyance facilities, access roads, and the Route 14 relocation which were estimated separately.

TABLE 9.2

Cost Estimate for Grey Mountain Dam and Reservoir[(1)]

Major Item	Cost
Diversion and Care of Water	$ 3,570,000
Dam and Spillway	
Excavation	4,300,000
Foundation Treatment	880,000
Grout Curtain	4,000,000
Drainage Curtain	470,000
Arch Dam Concrete	87,400,000
Spillway, Pier and Beam Concrete	1,740,000
Plunge Pool Concrete Slab	1,000,000
Outlet Works	
North Poudre Supply Facilities	1,480,000
Low-Level Outlet	520,000
Selective Withdrawal System	1,700,000
Valves and Valvehouse	3,550,000
Reservoir Clearing	1,600,000
Land Acquisition	1,600,000
Powerline and Telephone Line Relocations	210,000
Subtotal (Direct Cost)	$114,020,000
Contingency (25%)	28,500,000
Subtotal	$142,520,000
Eng. and Admin.	21,280,000
Construction Cost (January 1988)	$163,900,000

(1) Excludes costs for environmental mitigation and enhancement, road relocations and access road construction, dwelling and business relocations, conventional hydroelectric power plant, and facilities to convey water from Horsetooth Reservoir to Grey Mountain Reservoir.

9.13.1.2 Conventional Hydroelectric Powerplant

Cost estimates for a conventional hydroelectric power plant at Grey Mountain Dam were prepared for two selected capacities, based on criteria presented in Section 9.7. These costs are shown in Table 9.3.

TABLE 9.3

Cost Estimates for Conventional Hydroelectric Plant at Grey Mountain Dam

Item	Cost	
	Case A	Case B
Water Conductors and Powerhouse	$ 1,040,000	$ 1,370,000
Mechanical and Electrical Equipment	6,080,000	7,910,000
Transmission Line(1)	390,000	390,000
Subtotal	$ 7,510,000	$ 9,670,000
Contingency (25%)	1,880,000	2,420,000
Subtotal	$ 9,390,000	$12,090,000
Eng. and Admin. (15%)	1,410,000	1,810,000
Construction Cost (January 1988)	$10,800,000	$13,900,000
Installed Generating Capacity	17,700 kW	23,900 kW
Unit Cost	$610 per kW	$582 per KW

(1) Based on transmission line length of six miles.

9.13.1.3 Access Roads

Construction cost for access roads during construction and for operation and maintenance after construction is estimated to be $1.9 million.

9.13.1.4 Horsetooth-Grey Mountain Conveyance

This component of the Stage 1 development has an estimated construction cost of $29 million, as shown in Table 9.4. A general description of required facilities is provided in Section 9.9.

TABLE 9.4

Cost Estimate for Horsetooth-Grey Mountain Conveyance (10,000 af/month)

Item		Cost
Pipeline		$13,900,000
Pumping Stations		6,000,000
Right-of-Way		300,000
	Subtotal (Direct Cost)	$20,200,000
	Contingency (25%)	5,050,000
	Subtotal	$25,250,000
	Eng. and Admin. (15%)	3,750,000
	Construction Cost (January 1988)	$29,000,000

9.13.1.5 Route 14 Relocation

Construction cost of the Route 14 relocation is estimated to be $21.4 million, as described in Chapter 8.0. This estimate is based on the "Rist Canyon" alternative.

9.13.1.6 Total Construction Cost

Implementation of all components of the Stage 1 development at Grey Mountain is estimated to have a construction cost of $230 million in January 1988 dollars, as shown in Table 9.5.

TABLE 9.5

Total Construction Cost for Stage 1 Development(1)
(Grey Mountain Alternative)

Component	January 1988 Construction Cost ($ Million)
Grey Mountain Dam and Reservoir	163.9
Conventional Hydroelectric Plant(2)	13.9
Horsetooth-Grey Mountain Conveyance	29.0
Access Roads	1.9
Route 14 Relocation(3)	21.4
Total	230.1

(1)Excludes costs for environmental mitigation and enhancements.
(2)Based on 23,900 kW installation (see Section 7.3.6).
(3)Based on the "Rist Canyon" alternative (see Chapter 5.0).

The total cost in Table 9.5 does not include costs that may be incurred for mitigating environmental effects or providing environmental enhancements. Preliminary estimates for potential components of these costs were developed in other study tasks. The overall sensitivity of project economics to potential mitigation costs is considered in the economic evaluation described in Chapter 13.0.

9.13.2 Operation and Maintenance (O&M) Costs

O&M costs were estimated based on prior experience. Total O&M cost for the Stage 1 development is estimated to be about $360,000 per year, as shown in Table 9.6. The O&M estimate for the dam and conventional hydroelectric powerplant was based on a line-item breakdown and checked against data published by the USBR. O&M in Table 9.6 excludes energy costs for the Horsetooth-Grey Mountain Conveyance. It was assumed that a portion of the energy produced at the conventional hydroelectric plant at Grey Mountain Dam would be used to offset energy consumption by pumping.

TABLE 9.6

Estimated O&M Cost for Stage 1 Development[1] (Grey Mountain Alternative)

Component	Annual O&M ($ per Year)
Grey Mountain Dam[2]	260,000
Horsetooth-Grey Mountain Conveyance[3]	100,000
Total (January 1988)	360,000

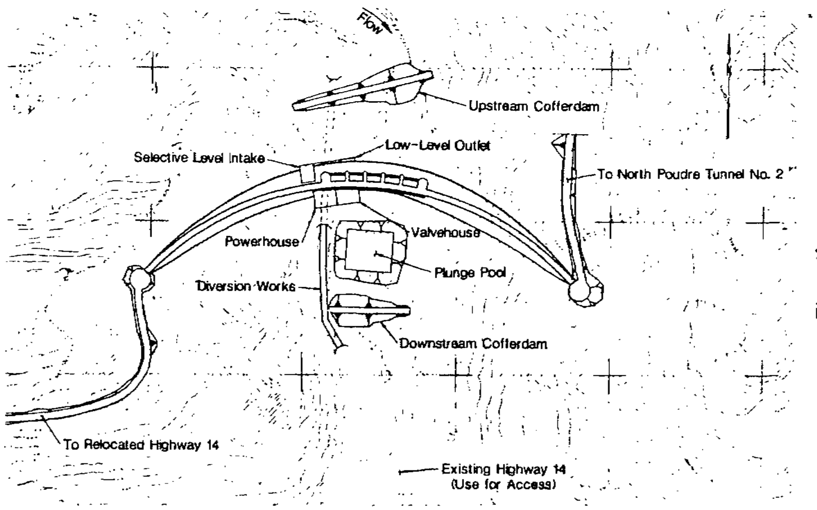
(1) Excludes costs for environmental mitigation and enhancements.
(2) Includes conventional hydroelectric powerplant.
(3) Excludes pumping energy which is assumed to be offset by generation at the conventional hydroelectric powerplant.

9.14 REFERENCES

Harza Engineering Company, January 1987. Cache la Poudre Basin Study - Final Report, Volumes I and II.

"A Bill to Amend the Wild and Scenic Rivers Act to Designate Certain Segments of the Cache Poudre River and the South Fork of the Cache la Poudre River in Colorado as a Component of the National Wild and Scenic River System," HR4350, 1st Section of the 99th Congress, October 30, 1986.

Cast, L.D., 1973. Feasibility Engineering Geology Report - Grey Mountain Damsite. Front Range Unit, Picle-Sloan Missouri Basin Program, U.S. Bureau of Reclamation.



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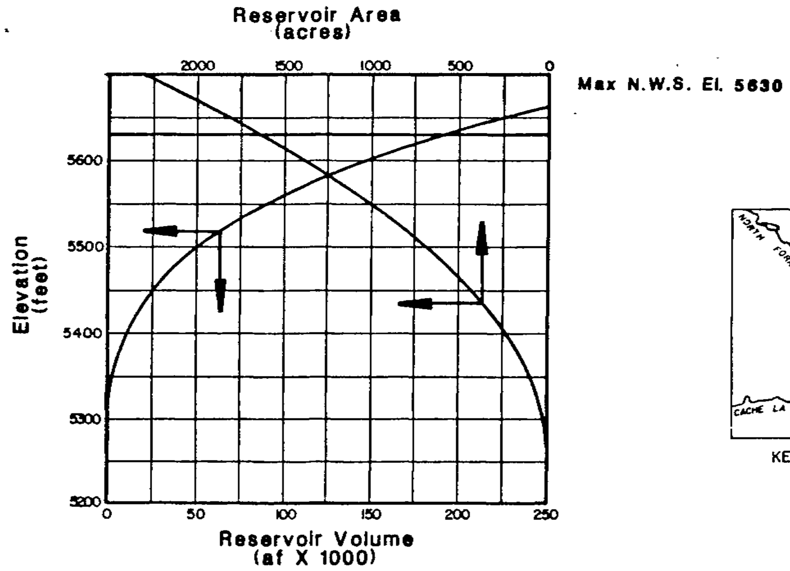
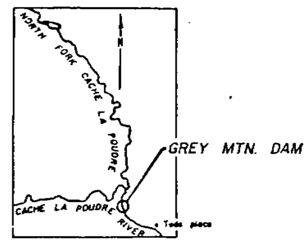
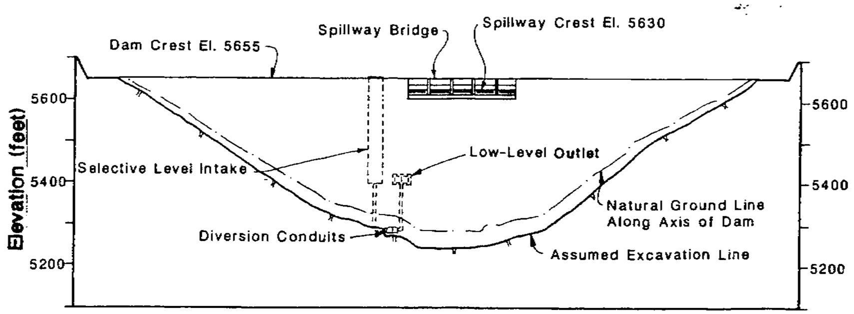


AREA-VOLUME CURVE



KEY MAP



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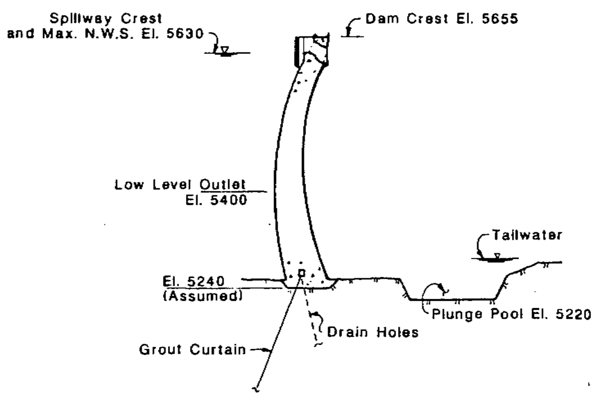

SECTION THROUGH CROWN
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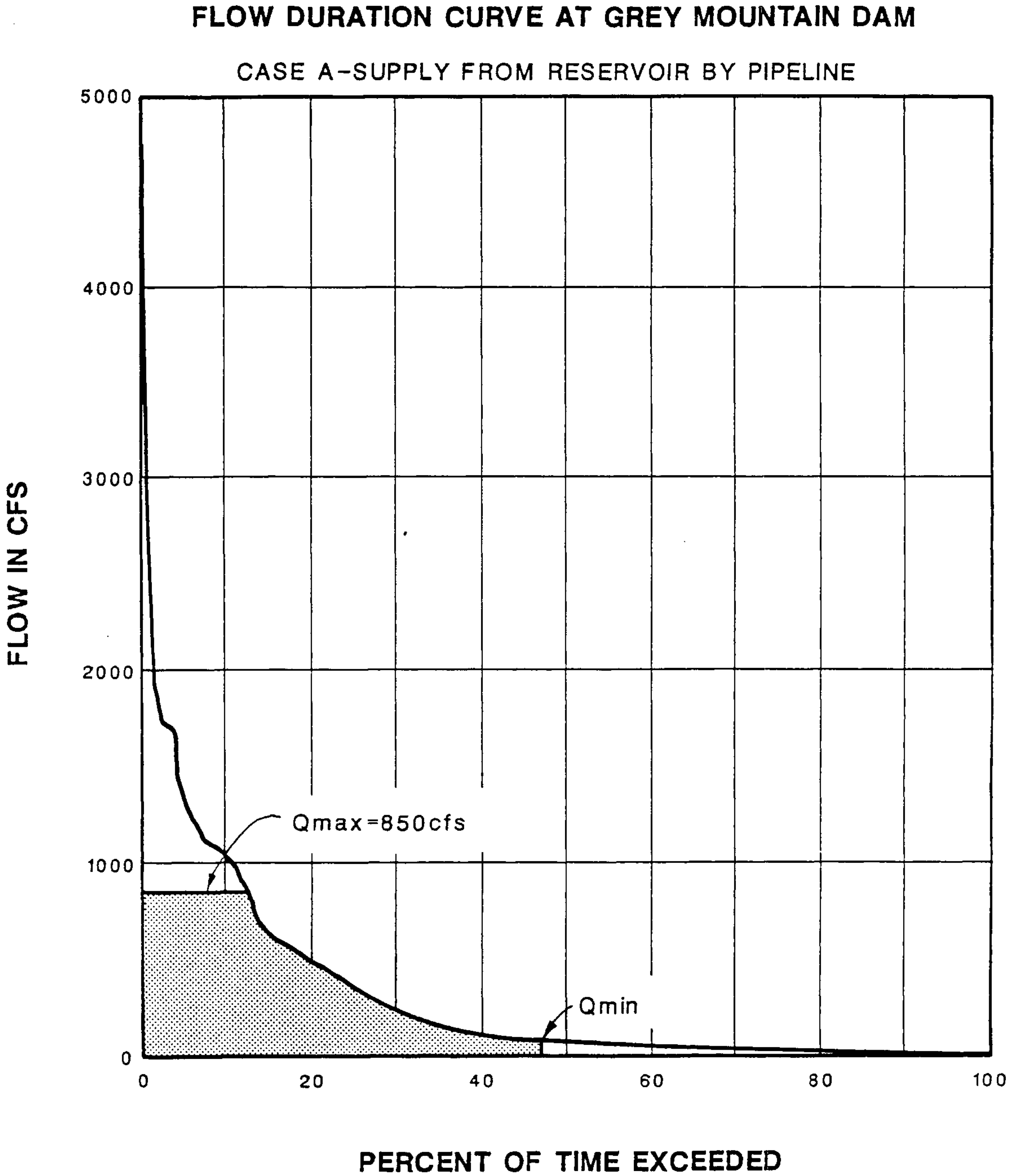
COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY
CACHE LA POUDRE PHASE I EXTENSION STUDY

GREY MOUNTAIN DAM
PLAN PROFILE AND SECTION

HARZA ENGINEERING COMPANY

DATE 3/4/88 FIGURE 9.1



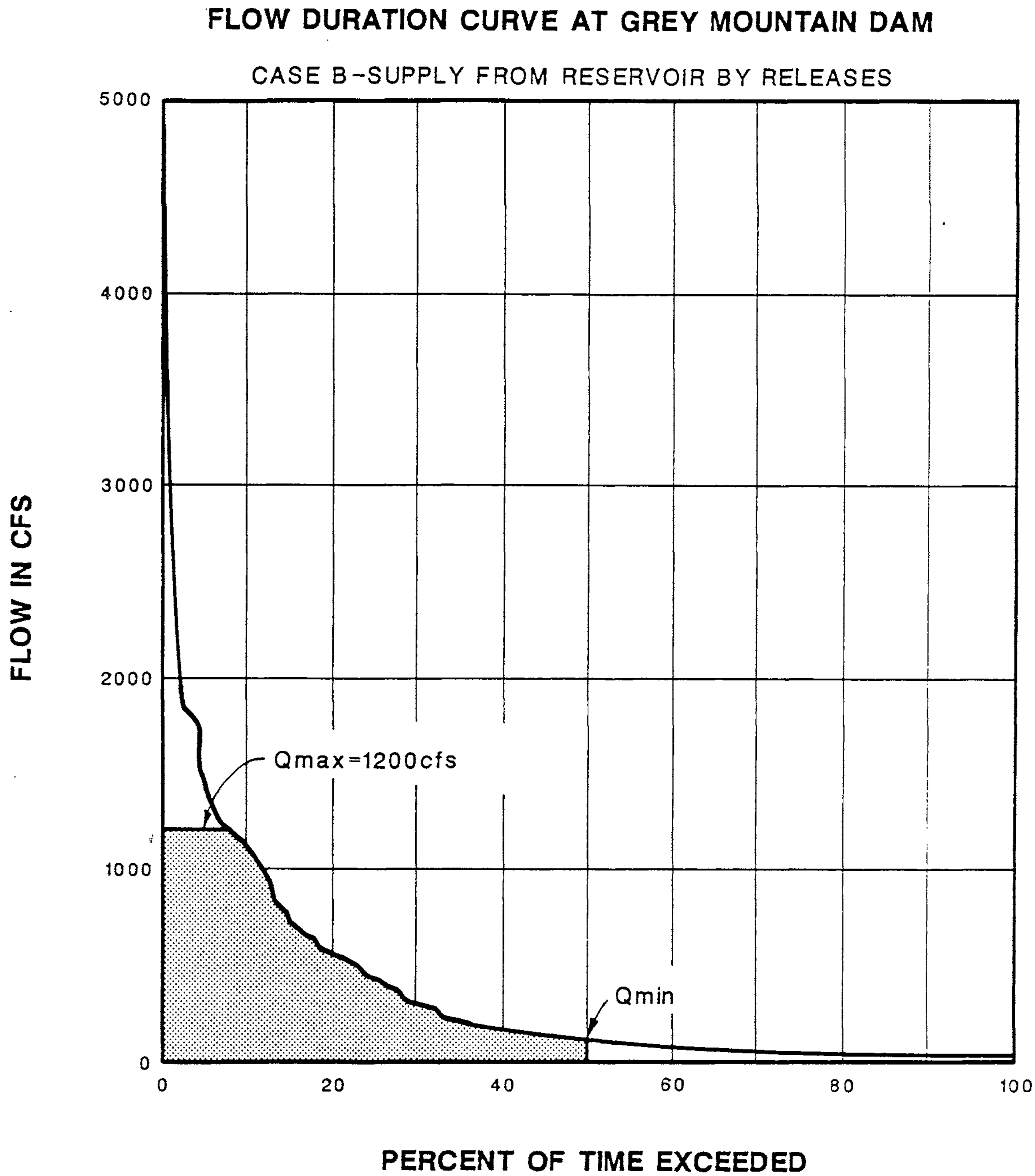
BASED ON MONTHLY FLOWS 1954-83

COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY
CACHE LA POUDRE PHASE I EXTENSION STUDY

FLOWS AVAILABLE FOR POWER AT GREY MOUNTAIN - CASE A

HARZA ENGINEERING COMPANY

DATE 10/27/88 FIGURE 9.2



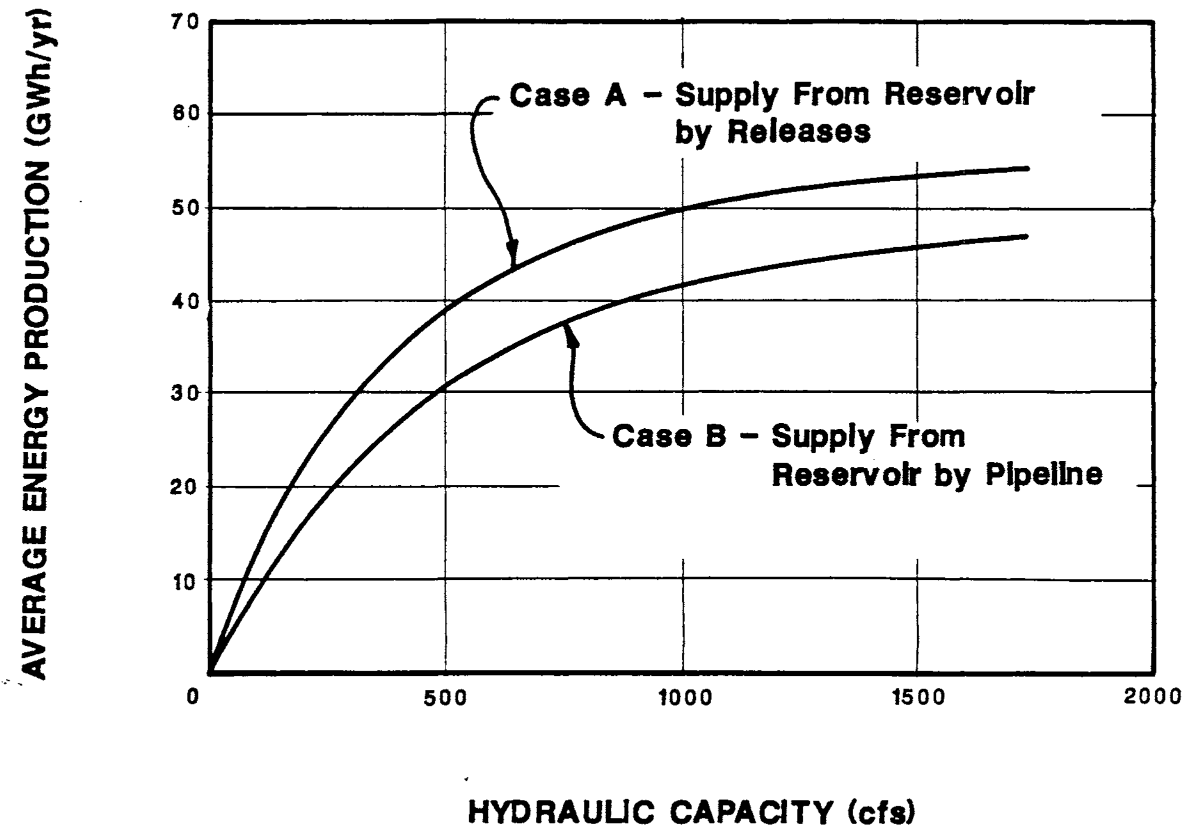
BASED ON MONTHLY FLOWS 1954-83

COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY
CACHE LA POUDRE PHASE I EXTENSION STUDY

FLOWS AVAILABLE FOR POWER AT GREY MOUNTAIN - CASE B

HARZA ENGINEERING COMPANY

DATE 10/27/88 FIGURE 9.3



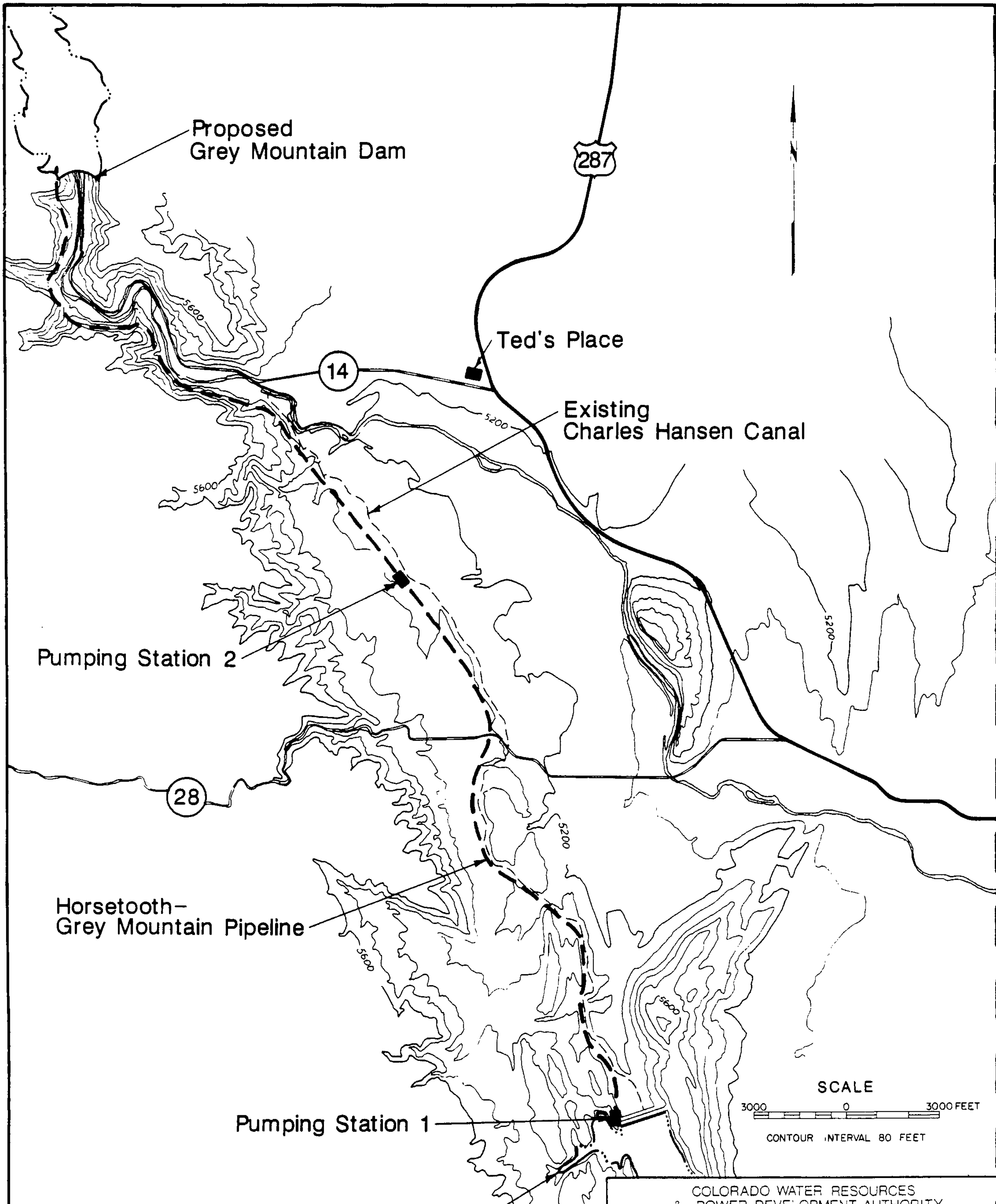
COLORADO WATER RESOURCES & POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE PHASE I EXTENSION STUDY

RANGE OF ENERGY PRODUCTION AT GREY MOUNTAIN CONVENTIONAL HYDROPOWER PLANT

HARZA ENGINEERING COMPANY

DATE 10/24/88 FIGURE 9.4



COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY
CACHE LA POUDRE PHASE I EXTENSION STUDY

HORSETOOTH-GREY MOUNTAIN PIPELINE

HARZA ENGINEERING COMPANY

DATE **11/3/88** FIGURE **9.5**

CHAPTER 10.0

HYDROLOGIC MODELING

10.0 HYDROLOGIC MODELING

10.1 INTRODUCTION

Based on a review of the Cache la Poudre Basin Study (Basin Study; Harza, 1987), and in consultation with the Colorado Water Resources & Power Development Authority (Authority), the Northern Colorado Water Conservancy District (NCWCD) conducted additional hydrologic modeling studies during 1987 and 1988 for the Cache la Poudre River Basin (Basin Study Extension). The general goal of the additional modeling was to integrate simulations of different river basins and supply systems (Colorado River, Colorado-Big Thompson [C-BT] Project, Windy Gap Project, and Poudre River) to determine the individual and integrated effects on the yield of proposed storage alternatives for Stage 1 of the Cache la Poudre Water and Power Project.

The engineering firm Hydro-Triad Ltd. from Lakewood, Colorado was retained by NCWCD to assist with developing and utilizing the network optimization model MODSIM (Hydro-Triad, 1988). Mr. Michael L. Brown and Mr. John E. Law performed the work for Hydro-Triad. Prof. John Labadie and Dr. Kim Hiew of Colorado State University (CSU) were also retained to provide technical review of the work.

10.1.1 Summary of Initial Modeling During Basin Study

The Poudre Basin Study utilized a hydrologic computer model for analyzing the existing water supply systems in the Poudre River Basin. The River Basin Simulation Model (RIBSIM) employed by the hydrologic modeling consultant, Leonard Rice Consulting Water Engineers Inc., accounted for water demands by using a flow network that included water rights priorities. RIBSIM was used to assess water shortages for alternative future demand conditions in the study area and to estimate storable flows -- those river flows now leaving the Poudre Basin that could be available for storage in a new reservoir.

The RIBSIM network for the Poudre Basin Study included 29 diversion structures and ditch systems along with 20 composite reservoirs grouped to represent 54 selected reservoirs in the Basin. Each ditch system was described as a demand sector driven by crop irrigation requirements and by numerous supply and return flow links or sources (i.e. surface, reservoir, and groundwater). The distribution of supply and return flows along these links was accomplished through estimated conveyance and farm headgate efficiencies as well as estimated proportioning between surface and subsurface return flows. The assumption was also made that all "non-effective" precipitation during March through October could be treated as additional precipitation contributing to the overall Poudre Basin water supply.

The USGS gaging stations on the Poudre River at the mouth of the Poudre Canyon and at the City of Greeley, located at the downstream end of the Poudre Basin, were used for calibration. At the gaging station located at the mouth of the Poudre Canyon, modeled flows were within 5 percent of historical flows during each year of the 30 year study period (1951 - 1980), which provides an indication of the adequacy of the model's input data. At the Greeley gage, flows modeled using RIBSIM were within plus or minus 20 percent of the measured flows in 20 years of the 30 year historic study period. This level of agreement at the Greeley gage was considered to be sufficiently adequate for the preliminary level of the Basin Study.

10.1.2 Hydrologic Modeling Verification

The process of model verification insures that a model accurately simulates the physical processes of the actual systems. Verification, accomplished prior to model calibration and validation, is a procedure that checks how well a particular computer model describes the physical system. For a water resources system, verification consists of checking the model's configuration to insure that reservoirs are properly connected hydraulically; that physical features have accurate capacity limitations; that inflows, outflows, and losses are calculated by a reasonable engineering analysis; and that these flow quantities are introduced in the system at the correct locations.

Verification of all assumptions and data used in the RIBSIM model for the Poudre Basin from river and reservoir to farm deliveries and crop demands would be unproductive given the revisions to the model configuration needed for the purposes of the Basin Study Extension. Instead, NCWCD chose to cross-check the RIBSIM model by comparing the storable flows computed by RIBSIM with those computed from a spreadsheet water-balance accounting model of historic Poudre River flows and diversions. The spreadsheet model developed by NCWCD, which is further described in Section 10.4.3.2, computed storable flows from a point-flow water balance requiring only historic inflow, outflow, and diversion data for specific river reaches. Together with the gaged Poudre River flows at the mouth of the Poudre Canyon and the City of Greeley, the USGS gaging station at the City of Fort Collins was utilized to improve the analysis of unmeasured return flows. The spreadsheet point-flow analysis for storable flows required no other assumptions about the distribution of water within ditch systems following diversion from the river.

Utilizing the spreadsheet point-flow analysis to compare with results from the RIBSIM model was especially expedient since the input data used in the RIBSIM model was difficult to verify directly. Much of the data was based on the voluminous Water Commissioner's records for Water District 3 in which each source of water was listed for each different ditch system along with whether the use was for irrigation or storage. The diversion data used in the RIBSIM model was provided in the tables titled "All Sources for All Uses" in Appendix B of the final report for the Basin Study. Given the complexities of the exchanges and trades between ditch systems, it was difficult to directly check the input to RIBSIM or to determine how offstream reservoir sources within a ditch system or trades of offstream reservoir sources between ditch systems were included.

10.1.3 Additional Hydrologic Modeling Requirements for Basin Study Extension

The RIBSIM modeling performed during the Basin Study included the delivery of water from the C-BT Project to different ditch systems based on the number of shares owned or leased under each ditch system multiplied by the estimated or declared quota for each year of the modeling period (1951 - 1980). Water from the Windy Gap Project was not included when modeling the historical conditions in the Basin. However, during evaluations of present and future water supply and demand conditions, water from the Windy Gap Project was considered outside of the RIBSIM model. These evaluations of future storage requirements for water delivered from the Windy Gap Project and additional water delivered from the C-BT Project were based on preliminary estimates supplied by NCWCD.

The preliminary NCWCD estimates of potential deliveries from the Windy Gap Project were based on 1980 studies using a Bureau of Reclamation (USBR) computer program simulating project operations in the Western Division - Pick-Sloan Missouri Basin, which used a mass balance accounting process (Bureau of Reclamation, 1981). Estimated pumping flows from the Windy Gap Project were added into the C-BT Project for subsequent delivery and storage. Since the Windy Gap Project was designed to minimally impact the C-BT Project, neither up-front borrowing of C-BT water nor carry-over storage of Windy Gap water in East Slope reservoirs was assumed to be allowed. This assumption resulted in the determination that 65,000 acre-feet of storage could be needed in the Poudre Basin or elsewhere to meet the needs of the Windy Gap Project participants (Bureau of Reclamation, 1981).

For the Basin Study, the effects of additional storage in the Poudre Basin on yields from the C-BT Project were analyzed separately by NCWCD using mass balance accounting to minimize spills on the West Slope. The temporal distribution of spills from Lake Granby and Willow Creek Reservoir were compared to pumping, conveyance, and storage capacity. One of the limiting constraints within the C-BT Project was East Slope storage. Based on historic records and preliminary mass balance accounting, an estimated 59,000 acre-feet of storage could be utilized within the Poudre Basin to fully develop C-BT water rights.

Since the hydrologic modeling performed for the Basin Study did not simulate conveyance limits of C-BT project facilities, it could not be determined whether sufficient capacity existed to convey all the additional water available to the C-BT and Windy Gap Projects. Consequently, for the Basin Study, it was assumed that a total of 124,000 acre-feet of additional storage (65,000 acre-feet for Windy Gap plus 59,000 acre-feet for C-BT) in the Poudre Basin would produce an additional 24,000 acre-feet per year of safe (zero-shortage) yield from both the C-BT and Windy Gap Projects, based on historic hydrologic conditions.

A concern regarding the approximations introduced by these assumptions for C-BT and Windy Gap storable flows was one of the primary reasons for conducting additional hydrologic modeling during the Basin Study Extension. The focus of the modeling effort during the Basin Study using RIBSIM was the Poudre Basin and not the integrated operation of the C-BT and Windy Gap delivery and storage facilities with a Poudre Basin reservoir. It was therefore decided that during the Basin Study Extension, NCWCD would undertake additional hydrologic modeling efforts that would address these concerns. The introduction of additional water resources systems not considered during the Poudre Basin Study was a major reason for selecting and developing a model that could be easily expanded through its data base rather than through coding changes in software.

10.2 OBJECTIVES

The major difference between the hydrologic modeling effort for the Basin Study Extension and earlier studies was the addition of storable flows from the C-BT and Windy Gap Projects and their integration into potential alternatives for reservoir storage in the Poudre Basin. The following, then, were the objectives for the additional hydrologic modeling during the Cache la Poudre Basin Study Extension:

1. Estimate the yield of Stage 1 reservoir alternatives on the mainstem of the Cache la Poudre River;

2. Estimate the potential contribution to the yield of selected reservoir alternatives from additional diversions under current water rights for the C-BT and Windy Gap Projects when operated to maximize deliveries under different West Slope development scenarios;

3. Estimate the reduction in yield of selected reservoir alternatives associated with allocating a portion of storage volume specifically for flood control;

4. Estimate potential releases that could pass through a conventional hydroelectric power plant at the river outlet of selected reservoir alternatives;

5. Estimate monthly reservoir water surface elevations for mainstem reservoir alternatives and at key C-BT storage reservoirs; and

6. Estimate postproject flows at selected locations along the Cache la Poudre River as well as the Colorado River on the West Slope.

10.3 MODELING APPROACH

The requirements for the hydrologic modeling conducted during the Basin Study Extension encompassed some of the requirements for hydrologic modeling during the original Basin Study. These requirements established the criteria for choosing a hydrologic modeling technique.

10.3.1 General Model Requirements

General requirements considered by NCWCD in the selection process included:

1. Use of long term historic hydrologic data as input;
2. Simulation of reservoir operations;
3. Capability for handling streamflow diversions;
4. Operation according to the Colorado water rights priority system;
5. Use of a monthly time step; and
6. Use of a model that was nonproprietary.

A major requirement imposed by NCWCD in the selection of a model for the additional hydrologic analyses was that the model be nonproprietary. This was deemed important by NCWCD so that the source code for the model could be obtained and modified for future uses. A generalized model was sought which could easily be customized by NCWCD to the river basins being investigated. The model needed to be user-friendly so that input data and model configuration could be easily changed for different planning and operating scenarios without recoding the model. The model also needed to provide flexibility in choosing and summarizing desired output.

After a review of existing reservoir operations models, a generalized network model utilizing optimization techniques for prioritizing demands and indicating shortages to those demands was determined to be the most appropriate for the Basin Study Extension. Advantages of network models include:

1. A network model formulation provides a physical idealization showing the configuration of the system;

2. Network optimization techniques, such as the out-of-kilter algorithm, are efficient solution techniques;

3. Large problems (in terms of network components) can be solved; and

4. Changes in system components can be easily incorporated by manipulation of the previously constructed network.

10.3.2 Model Selection

The network simulation model MODSIM (MODSIMX, Version 2.51) (Labadie, 1987), developed at Colorado State University, was selected for the additional hydrologic modeling performed by NCWCD for the Basin Study Extension. NCWCD had been using MODSIM in conjunction with Prof. John Labadie and Dr. Kim Hiew of Colorado State University to study the C-BT system and the effect of alternative management and operational strategies on both water availability and electrical power generation (Labadie and Hiew, 1987). This experience demonstrated that MODSIM met the general modeling requirements and would be applicable for satisfying the additional modeling objectives for the Basin Study Extension.

Hydro-Triad was selected by NCWCD as the consultant to assist in developing MODSIM for the Poudre Basin Study Extension (Hydro-Triad, 1988). Hydro-Triad had used MODSIM extensively on other projects, including development of a Colorado River Basin model for a study of projects on the West Slope (Hydro-Triad, 1986), and had modified the input and output subroutines in MODSIM to make them flexible and user-friendly for large networks and extensive data bases. Considerable time was also saved by starting with existing network configurations and data bases for the C-BT Project (Labadie and Hiew, 1987) and for the Colorado River Basin (Hydro-Triad, 1986).

MODSIM operates on a monthly time step, but has the potential for analyzing weekly or daily time steps. This may be valuable to NCWCD for future operational studies. Historical hydrologic data can be utilized as inflows or inputs to MODSIM, and historical streamflow diversions can be modeled as demands with assigned priorities. MODSIM models the complete reservoir water balance and allows considerable flexibility in changing reservoir operating rule curves or target levels. The overriding control of flow and distribution of water in MODSIM is determined by setting priorities on demands and filling reservoir storage. It is this ability to emulate the Colorado water rights structure that makes MODSIM an appropriate model for simulation of Colorado water systems.

MODSIM is a non-dynamic optimization model that allocates water according to a priority list for meeting demands and filling storage for a system of reservoirs and river reaches by use of an efficient linear programming technique known as the out-of-kilter algorithm (Fulkerson, 1961). MODSIM is nondynamic in that the optimization takes place within the time period being considered, but global optimization for the entire study period is not necessarily achieved. This accurately simulates actual conditions, since it is physically not possible to reallocate water for past periods of time to achieve optimal efficiency. Typical mass balance at reservoirs is maintained, and the model relies on rule curves to link and sustain the desired reservoir storage levels for all time periods during a model run. Constraints are formulated such that minimum flows through the system links (e.g. river reaches, canals, or conduits) are achieved while meeting all other requirements.

The core model for MODSIM was developed by the Texas Water Development Board and was named SIMYLD (Texas Water Development Board, 1972). It employed the basic network system configuration and linear programming solution based on the out-of-kilter algorithm. When SIMYLD was modified to create MODSIM, input and output functions were interactive (Shafer, 1979).

Hydro-Triad subsequently made revisions so that input and output files could be used for batch computer processing. The program, as utilized by NCWCD, employed input and output files that readily accommodated large systems (greater than 3-4 reservoirs) and multiple year analyses (study periods more than about 5 years). This version was also more convenient for making multiple runs when performing sensitivity studies.

Network models of water resources systems are based on an assignment of priorities that represent the water rights priority system, including an ability in the model to assign priorities to storing water. In the general network formulation, lower numbers assigned to senior water rights holders (represented by demand node requirements) are met first. This is accomplished in a linear programming algorithm by minimizing the cumulative sum of the product of the flow times its priority number in each link.

The input requirements to the network model are a set of unique files for each scenario investigated by the model including demands, unregulated inflows, and physical characteristics of the river basin systems. For the Basin Study Extension, these are graphically shown on Figure 10.1, the network configuration diagram.

The output from the network optimization for each scenario is a set of monthly values including flows in each link, end-of-month storage for all reservoirs, and shortages experienced at any nodes.

10.4 MODEL DEVELOPMENT

Hydro-Triad began the modeling effort for the Basin Study Extension in 1987. Their initial task was to integrate the previously developed network for the West Divide Project (Hydro-Triad, 1986) with the C-BT network developed by researchers at Colorado State University (Labadie and Hiew, 1987). Additionally, further detail was needed in the Upper Colorado River Basin to identify C-BT and Windy Gap project facilities. The other additions to the network needed were to model the Poudre Basin. These were successfully integrated by Hydro-Triad, and the initial system configuration was similar to the network shown in Figure 10.1.

10.4.1 Modeling Configuration

The data bases developed by Hydro-Triad were incorporated into the NCWCD data bases for the C-BT and Windy Gap Projects along with the data bases for the Poudre Basin. An extensive network was then designed to reflect the physical features of the systems and to produce the detailed output necessary to fulfill the study's objectives.

10.4.1.1 Study Period

A thirty year study period, from October 1954 through September 1983, was used for the hydrologic modeling performed for the Basin Study Extension. The year 1954 was selected as the first year of the study because this was the first year the majority of the facilities of the C-BT Project were in full operation. The year 1983 was selected as the final year because existing data bases used previously in Hydro-Triad's extensive Colorado River Basin MODSIM model terminated in 1983. The selected study period contained drought periods (1954 - 1956, 1977) as well as wet years (1957, 1978 - 1980, 1983).

The initial RIBSIM modeling performed during the Basin Study used 1951 through 1980 as the study period (Harza, 1987). The inclusion of the high runoff in 1983 for the Basin Study Extension increased the average available flow in the Poudre Basin. However, using 1983 as the last year of the simulation period did not increase estimates of historical safe (zero-shortage) yield. In determining safe yields for various alternatives, it was not average values that were important, but rather the amounts of shortages to demands and the specific times at which the shortages occurred. Hence, it was the low water years, compensated by carry-over storage, rather than the high water year at the end of the study period, that dictated projected zero-shortage yields.

10.4.1.2 Network Features

MODSIM modeling for the Basin Study Extension began with the development of a network that simulated the various diversion structures, reservoirs, and conveyances. Nodes were defined as connecting points in the network with links being the connectors. All inflows and demands occurred at nodes, and mass balance was maintained at all nodes. The final network developed for the Basin Study Extension, shown in Figure 10.1, included a total of 81 nodes, 92 links, and 20 reservoirs. Figure 10.1 shows the general physical arrangement of all elements which were considered significant. To a lesser extent, the existence of data bases and previous networks (Hydro-Triad, 1986; and Labadie and Hiew, 1987) also influenced the selection of elements which were included in the network.

A substantial amount of information concerning the network could not be shown on the network diagram because of space limitations. For example, the maximum allowable capacities in individual links, reservoir operating rule curves, and similar detailed information, which in some cases varied from one simulation to the next, could not be shown. Each model simulation also had two associated data files which described the detailed network configuration. These were named "structin.file" (Appendix M) and "structgn.file" (Appendix N). The structin.file described the complete network in terms of which links connected which nodes, priorities, reservoir volumes and rule curves, and link capacities. The structgn.file defined which inflow data files, demand data files, and evaporation loss files were used for a given model simulation.

Inflows and Demands

Each computer simulation using the network model had a unique set of input data files for inflows and demands. Inflows were usually unregulated natural inflows, but also included other water sources, such as return flows, as discussed in Sections 10.4.2 and 10.4.3.

Demands were either consumptive demands such as municipal, industrial, or irrigation; or nonconsumptive flow-through demands such as minimum fish flows or demands from hydroelectric power plants such as the Shoshone hydroelectric power plant on the Colorado River. All demands and all reservoirs were assigned relative priorities based on the seniority of their diversion or storage water rights. The assigned priorities are shown by the numbers in rectangles on the network diagram in Figure 10.1. The priority was expressed as a number ranging from 1 to 99, with a lower number representing a higher priority. The absolute values of the priority numbers were not significant. Rather, it was the relative sequencing of the priority numbers which determined the behavior of the model.

Other demands which were included in the model network but not activated were generally given a priority value of 98. Each of the river basins had a terminal node which had a dummy demand. These dummy demands were very large, but the relative priorities were the most junior at 99. This encouraged excess or surplus water to flow out of the system and allowed monitoring of that water by examination of the link immediately upstream.

On the network diagram in Figure 10.1, inflows are represented as ellipses and demands as hexagons or diamonds. The diamonds represent existing net consumptive use in the Colorado River Basin by irrigators, municipalities, and industrial users. Demands shown as diamonds indicate they are modeled as net consumptive use, rather than total diversions (hexagons) with associated return flows (ellipses). The major portion of the demands modeled as net consumptive use consists of senior water rights used for irrigation which remain equal to historical values in each simulation. Note, however, that there is no difference in the manner with which MODSIM treats the demands shown as diamonds, which do not change, and the demands shown as hexagons, which can vary for different simulations.

The names of the demands and unregulated inflows on the network diagram are similar to the names of the files used in the model runs. The suffix attached to each demand file name provides an indication of the demand level where:

".his" = historic demand level

".exi" = recent or existing demand level (average used for previous years)

".futl", ".fut2" = recent or existing demand level increased by assumed perfection of conditional rights.

The unregulated inflow and demand files which are used for a particular simulation are listed in the structgn.file (Appendix N). The actual monthly inflow data files are provided in Appendix O, and the demand data files are in Appendix P. Although the listings for these data files all start with year 1949 and end with year 1983, only the period 1954 through 1983 was used for the Basin Study Extension.

Nodes and Links

The network diagram in Figure 10.1 contains non-reservoir nodes, denoted as circles, which are confluences or points of flow intersection on links. The node names are selected so as to provide some geographical significance. Links in the network diagram represent conveyances such as river reaches, canals, and pipelines, with or without pumps or turbines. Pumps are represented by the letter "P" in a square on the network diagram, and turbines are represented by the letter "T". Each link can be defined with a maximum and minimum capacity as well as a maximum capacity that can vary by month to allow consideration of specific operational criteria such as maintenance downtime. MODSIM also has a feature for assigning "pseudo-costs" to links in order to indicate the relative preference of flow paths (without "pseudo-costs") where alternative paths exist.

Reservoirs

MODSIM is capable of flexible simulation of reservoir operation. Reservoir nodes are shown as triangles on the network diagram. The location of the reservoir within the model network will influence reservoir behavior. Reservoirs placed directly onstream, i.e. no diversion from a river to offstream storage, will be subject to downstream calls and will release water from storage to meet downstream demands that have lower priority numbers. If the reservoir is placed offstream, it cannot release water from storage back to the river or stream, but can only release water to those demands attached directly to the reservoir. Like onstream reservoirs, offstream reservoirs can divert water from the system, but only when it is not needed by demands having lower priority numbers.

In addition to being governed by the priority system and location within the model network, water in storage and releases from reservoirs may be controlled by operating rules where monthly target reservoir levels are assigned priorities like demands. The demand for filling a reservoir then competes in the system for available water along with other demands. MODSIM can account for reservoir evaporation through a relationship involving reservoir water surface area. However, unregulated inflows to reservoirs can consist of computed inflows from a water balance using historic storage and measured inflow/outflow data. Inflows defined in this manner are net inflows and are already reduced to account for evaporation and reservoir seepage losses.

Hydroelectric Plants

Turbine efficiency estimates were required by MODSIM in order to compute monthly energy generation from power plants. For the C-BT project, turbine efficiencies were expressed in terms of energy generated per unit of turbine release (kWh/AF). To compute energy generation, a reservoir must have been located upstream of the turbine in order to input head data on the turbine. For a run-of-the-river plant, this required a "dummy reservoir" with zero capacity when there was no actual reservoir. As a result, dummy reservoirs were placed as shown in Figure 10.1 at the Mary's Power Plant, located at the outlet of the Adams Tunnel (reservoir/node number 18), and at the Big Thompson Power Plant, located at the mouth of the Big Thompson Canyon (reservoir/node number 12), which was supplied with water from a C-BT canal. In the hydrologic simulations for the Basin Study Extension, monthly hydroelectric energy generation totals were not required, although they were automatically calculated by MODSIM.

10.4.2 West Slope Modeling

The Colorado River has a drainage area of about 7000 square miles upstream of Rifle, Colorado. The average annual flow is approximately 2.5 million acre-feet at the USGS gaging station located near Cameo, Colorado, 40 miles downstream of Rifle. Peak stream flows occur during the spring snowmelt period. By late summer, and continuing through the fall and winter, the flow in the river is relatively low. There is regulation of the flow by eight major reservoirs and a depletion of the natural flow by numerous transbasin diversions.

In addition to the natural influences of precipitation and runoff, the flow in the river is affected by the administration of Colorado's water rights system. The large upstream senior water rights which have the greatest influence are the Colorado-Big Thompson Project, transbasin diversions by the City of Denver, the Fryingpan-Arkansas Project, and the Homestake Project. The major downstream water rights having the greatest influence are the Shoshone Hydroelectric Power Plant, near the Town of Glenwood Springs, and the group of water rights above Grand Junction known as the Cameo Call.

10.4.2.1 Lower Colorado River Basin Network

For the purposes of the Basin Study Extension, the Lower Colorado River Basin was defined as that portion of the Colorado River Basin downstream of and including node number 32, denoted KREMM in Figure 10.1. This node geographically represented the Colorado River reach beginning at Hot Sulfur Springs. The network configuration for this part of the West Slope was mainly based on a previous MODSIM model of the Colorado River Basin which simulated the operation of major lower basin reservoirs (including the proposed Rock Creek Reservoir, for which the Muddy Creek Reservoir has subsequently been proposed as a preferable alternative), incorporated transbasin diversions (present and planned), and accounted for consumptive use within the lower basin (Hydro-Triad, 1986).

Lower Colorado River Basin Data Bases

The development of the network for the Lower Colorado River Basin was based on data obtained from the USBR Colorado River Simulation System (CRSS) model (Bureau of Reclamation, 1987). As part of data development for the CRSS model, natural flows (flows that would have occurred without human intervention) were estimated by USBR hydrologists. This was accomplished by tabulating the historic transbasin diversions for the many tunnels and ditches and computing reservoir storage changes, including evaporation. Local consumptive use was then estimated, and the natural flows at Glenwood Springs (link 43) and at Cameo (link 50) were computed by adjusting the historical measured flow according to tabulated diversions, storage changes, consumption, and other miscellaneous and/or incidental adjustments.

Inflows

The network and data files developed by Hydro-Triad for the Lower Colorado River Basin are based on combining the CRSS "natural flow" data files with USGS gaged flows to estimate the natural monthly flows from the major subbasins and areas above reservoirs. There are 17 inflow sources to the Lower Colorado River included in the model, as shown on the network diagram in Figure 10.1 by ellipses. The corresponding inflow data files are listed in Appendix O in alphabetical order according to the name in the ellipse. Additional details concerning these 17 inflow sources are provided in the following paragraphs.

Referring to Figure 10.1, the natural inflow or unregulated inflow denoted LEAL, which flows through node 77 into the Williams Fork Reservoir (reservoir/node number 2), was computed from the historically measured flows at the USGS gaging station below the Williams Fork Reservoir, adjusted for the changes in storage listed in the CRSS data file for the Williams Fork Reservoir. An increase or positive change of storage in Williams Fork Reservoir from the CRSS data file was added to the historic measured monthly flow below Williams Fork Reservoir to determine the inflow LEAL, while a decrease or negative change in storage was subtracted from the measured flow. The changes in storage included adjustments for evaporation, whereby estimated evaporation was added to the actual measured change in storage. For those reservoirs where CRSS changes in storage were utilized, evaporation was deducted during MODSIM execution.

The unregulated inflow denoted SNAKE, which flows into Dillon Reservoir (reservoir/node number 14), was assumed to be 55 percent of the natural flow of the Blue River; and the unregulated inflow denoted GORE, which flows into node 33, was assumed to be 45 percent of the natural flow of the Blue River. These percentages were based on the proportionate share of drainage area in the Blue River Basin as estimated by Hydro-Triad. Consequently, the inflow SNAKE represented the flow generated from the area above Dillon Reservoir, and the inflow GORE represented the flow generated from the area between Dillon Reservoir and Green Mountain Reservoir. The natural flow of the Blue River was computed from historically measured monthly flows at the USGS gaging station below Green Mountain Reservoir with adjustments made for CRSS changes in storage at Green Mountain and Dillon Reservoirs, transbasin diversions through the Roberts and Hoosier Tunnels (tunnel diversions were added to measured historic flows), and consumptive use estimates in the Blue River Basin from CRSS data.

The unregulated inflow denoted HOLY, which flows into node 36, was assumed to be 18 percent of the Eagle River's natural flow, the unregulated inflow denoted VAIL at node 37 was assumed to be 64 percent of the Eagle River's natural flow, and the inflow AVON at node 38 was assumed to be 18 percent of the Eagle River's natural flow. As for the Blue River flows, these percentages were based on estimates of proportionate subbasin areas. The natural flow in the Eagle River was computed from the historically measured flows at the USGS gaging station below the Town of Gypsum at the confluence with the Colorado River. Adjustments were made for changes in storage at Homestake Reservoir; transbasin diversions through the Homestake Tunnel; diversions to the Columbine, Ewing, and Wurtz Ditches; and consumptive use estimates in the Eagle River Basin from CRSS data.

For the Roaring Fork River, the unregulated inflow denoted ROAR at node 74 was assumed to be 5 percent of the natural flow, the inflow denoted ASPEN at node 43 was assumed to be 50 percent, the inflow denoted PAN at node 44 was assumed to be 25 percent, and the inflow denoted CRYSTAL at node 45 was assumed to be 20 percent. As before, the percentages were based on estimates of proportionate subbasin areas. The natural flow of the Roaring Fork River was computed from the historically measured flows at the USGS gaging station located near the Town of Glenwood Springs. Adjustments were made for changes in storage at Ruedi Reservoir; transbasin diversions through the Twin Lakes, Busk-Ivanhoe, and Boustead Tunnels; and consumptive use estimates for the Roaring Fork River Basin.

The unregulated inflow denoted RIFLE at node 46 was assumed to equal the natural inflows to the Colorado River from the drainage area and side tributaries between Glenwood Springs and Cameo, excluding the Roaring Fork River Basin. The inflow RIFLE was calculated from the natural flow at Cameo (as computed by the CRSS model), minus the natural flow at Glenwood Springs (as computed by the CRSS model), and minus the natural flow of the Roaring

Fork River determined as described in the previous paragraph. The inflow PLATEAU at node 48 was the historically measured flow at the USGS gaging station on Plateau Creek near Cameo. Gaged flows were used because no modeling of reservoirs, diversions, or consumptive use was performed for the Plateau Creek Basin.

After accounting for the 12 inflow sources to the Lower Colorado River described in the previous paragraphs, the remaining inflow was apportioned between 5 other unregulated inflows. The unregulated inflow denoted RABBIT at the proposed Rock Creek Reservoir (node number 16) was assumed to be 3 percent of the remaining inflow. The inflow denoted MUDDY at node 32 was assumed to be 30 percent of the remaining inflow. The inflow denoted STATE at node 35 was assumed to be 54 percent of the remaining inflow. The inflow denoted CANYON at node 41 was assumed to be 10 percent of the remaining inflow. Lastly, the inflow denoted LOWBLUE at node 63 was assumed to be 3 percent of the remaining inflow. As previously, these percentages were based on estimates of subbasin areas for drainage areas tributary to the Colorado River. The remaining natural flow was calculated from the CRSS natural flow at Cameo, less the unregulated natural inflows from the major tributaries to the Lower Colorado River (Rifle, Roaring Fork, Eagle, Blue, and Williams Fork) and less the river flow at Hot Sulphur Springs. The river flow at Hot Sulphur Springs was computed from the historically measured flows at the USGS gaging station at Hot Sulphur Springs adjusted for CRSS changes in storage (at Granby Reservoir, Willow Creek Reservoir, and Shadow Mountain Reservoir/Grand Lake), transbasin diversions (Grand River Ditch, Eureka Ditch, Adams Tunnel, Berthoud Pass Ditch, and Moffat Tunnel), and the consumptive use estimated for CRSS above Hot Sulphur Springs. The Hot Sulphur Springs flow consisted of the inflows denoted PARKB (node 75), MONARCH (node 27), FRASER (node 28), and RADIAL (node 29). These four inflows are described as part of the modeling for the Upper Colorado River Basin in Section 10.4.2.2.

<u>Demands</u>

Demands are shown on the network diagram in Figure 10.1 as diamonds or hexagons. The most senior demands in the Lower Colorado River Basin are the demands denoted CONSUM which consist of the consumptive use portions of agricultural water rights. Although these demands are the most senior, and represent the base agricultural and small municipal demand which must be met in all cases, they are not very large.

The data files for the CONSUM demands used as input to MODSIM are provided in Appendix P. The demands tabulated in these files consist only of the amount of the diversion that was actually consumed. Return flows for these diversions are already accounted for in the inflow data files because the inflows consist of USGS measured flows which include return flows. Since a monthly time step is used for modeling, and because the CONSUM demands in the Lower Colorado River Basin are for large river reaches and entire subbasins, the lag time between diversion and return flow does not cause significant errors.

Senior agricultural consumptive use demands in the Lower Colorado River Basin were obtained from the CRSS data base (USBR, 1987). The demand CONSUM.ROAR at node 45 represented the estimated historic consumptive use in the Roaring Fork River Basin and was assumed to be 40 percent of the CRSS consumptive use estimate between Glenwood Springs and Cameo. The demand CONSUM.LOCAL at node 46 represented the estimated historic consumptive use between Glenwood Springs and Cameo, excluding the Roaring Fork River Basin, and was assumed to be 60 percent of the CRSS consumptive use estimate between Glenwood Springs and Cameo. These percentages were based on irrigated acreage distributions estimated by the USBR.

The demand denoted CONSUM.LBLU at node 63 was assumed to be 2.5 percent of the CRSS consumptive use estimate for the Lower Colorado River Basin above Glenwood Springs and represented the estimated consumptive use in the Lower Blue River Basin below Green Mountain Reservoir. The demand denoted CONSUM.UBLU at node 33 was assumed to be 7.5 percent of the CRSS consumptive use estimate above Glenwood Springs and represented the consumptive use in the Upper Blue River Basin above Green Mountain Reservoir. The demand denoted CONSUM.DOT at node 35 was assumed to be 20 percent of the CRSS consumptive use estimate above Glenwood Springs and represented the estimated historic irrigation consumptive use near Dotsero. The demand denoted CONSUM.EAGLE at node 39 was assumed to be 30 percent of the CRSS consumptive use estimate above Glenwood Springs and represented the estimated consumptive use in the Eagle River Basin.

The demand denoted CONSUM.KREMM at node 32 was assumed to be 40 percent of the CRSS consumptive use estimate above Glenwood Springs, less the consumptive use above the Windy Gap Project. CONSUM.KREMM represented the estimated historic consumptive use between Windy Gap and Glenwood Springs, less the estimated consumptive use represented by CONSUM.LBLU, CONSUM.UBLU, CONSUM.DOT, and CONSUM.EAGLE. Again, these percentages were based on USBR estimates of irrigated acreage distributions from the CRSS model. The irrigation consumptive use above the Windy Gap Project is discussed in Section 10.4.2.2 as part of the Upper Colorado River Basin network and data.

The demand INCID at node 78 represented demands considered as miscellaneous and incidental adjustments in the CRSS model for the years 1975 through 1983. The other demands in the Lower Colorado River Basin, represented by hexagons in Figure 10.1, were demands that varied with different model scenarios depending on the level of assumed future West Slope development, as discussed in Section 10.4.2.5.

<u>Shoshone and Cameo Demands</u>

The Colorado River Basin model developed by Hydro-Triad was designed to estimate the frequency with which the demand at the Shoshone Hydroelectric Power Plant and the demands at Cameo would place a call on the river, thereby preventing junior upstream water rights from continuing to divert or store water. The demand denoted HYDRO at node 40 in Figure 10.1 was the demand which represented the Shoshone Hydroelectric Power Plant in the Glenwood Canyon. This demand was treated as a flow-through (non-consumptive) demand, whereby water needed to meet the HYDRO demand was removed from the river at node 40 (SHOW) and returned to the river at node 41 (SHONE). The Shoshone Power Plant demand has a 1905 Administration Date for 1250 cfs. The Shoshone demand data file which was used for the MODSIM simulations, provided in Appendix P, shows a continuous monthly demand of 1250 cfs or the natural flows at Glenwood Springs from the CRSS data base, whichever is less. During model calibration and validation, some of the monthly values in the Shoshone demand data file were further reduced to historic values at the USGS Dotsero gaging station (link 41 flows) if the 1250 cfs Shoshone water right was greater than the actual historic flow available at the Dotsero gage upstream of the Shoshone Power Plant.

The consumptive use demand denoted GRAND at node 48 (CAMEO) represented the four major water rights collectively known as the Cameo call. These rights consisted of:

1. Grand Valley Canal with decreed water rights of 520 cfs (Admin. Date 1912) and 120 cfs (Admin. Date 1934);

2. Government Highline Canal operated by the Grand Valley Water Users Association with decreed water rights totaling 874 cfs (Admin. Dates 1912 and 1934);

3. Orchard Mesa Power Plant operated by the Public Service Company of Colorado with decreed water rights of a 1020 cfs for electrical power generation, jointly owned by Grand Valley Water Users Association and United States (Admin. Date 1934); and

4. Orchard Mesa Irrigation District with decreed water rights totaling 460 cfs (Admin. Date 1912).

For the winter months (November through March and part of April), the Cameo call was assumed to have a constant demand of 800 cfs. This has been the average historic winter-time monthly demand from the Orchard Mesa Power Plant using its decreed water right. For the summer months (approximately midway in April through all of May and on through October), a constant demand of 2000 cfs was assumed for the Cameo call. This was judged to be an acceptable approximation of historic use in terms of modeling the upstream effects of the Cameo call. The actual average historic summer-time monthly demands have varied from about 1800 cfs to 2200 cfs, depending on the amount of water "checked-back" upstream by the Orchard Mesa Check Dam through a bypass canal to satisfy the Grand Valley Canal's water rights. During model calibration and validation, some of the monthly values in the demand data file for the GRAND demand were reduced to equal the sum of historic flows at the USGS gaging station at Cameo and at Plateau Creek so that the GRAND demand would not exceed the actual water flows available historically.

If full "check-back" could be achieved, the Cameo call would be reduced to 1678 cfs. However, in the last few years, the operation of the Orchard Mesa Check Dam has been changed and less water has been "checked-back". As a result, tailwater on the turbines and pump at the Orchard Mesa Power Plant has been less, more power has been generated, and pumped deliveries to the Orchard Mesa Irrigation District have increased. If no "check-back" were to occur, the Cameo call could be as high as 2260 cfs. If Green Mountain Reservoir releases were used to generate power at the Orchard Mesa Power Plant, the Division Engineer administering the river would require that the Green Mountain water used by the power plant be "checked-back" so that Green Mountain water could be rediverted by the Grand Valley Canal as required for a preferred use of water from Green Mountain Reservoir. In the future, the summer-time Cameo call could vary from 1678 cfs to 2260 cfs depending on the operation of the Orchard Mesa Check Dam and the amount of water "checked-back" to the Grand Valley Canal.

10.4.2.2 Upper Colorado River Basin Network

For the purposes of the Basin Study Extension, the Upper Colorado River Basin was defined as that part of the Colorado River Basin above node 32, denoted KREMM in Figure 10.1. Geographically, this definition represented the Fraser River Basin and the Colorado River Basin above Hot Sulphur Springs. The model developed by Hydro-Triad for the Lower Colorado River Basin, and adopted by NCWCD as described in previous paragraphs, incorporated a simplified treatment of the Upper Colorado River Basin. Since the goals of the hydrologic modeling performed for the Basin Study Extension included refining the estimates of the amount of additional water available for diversion from the Upper Colorado River Basin, as well as developing the basis for an analytical tool that could be used in the future to evaluate the integrated operation of the C-BT and Windy Gap Projects, a more detailed MODSIM network and data base was needed to represent the Upper Colorado River Basin.

Upper Colorado River Basin Network Features

The reservoirs in the Upper Colorado River Basin which were modeled in a more detailed manner consisted of Granby (the major storage facility), Willow Creek, and Shadow Mountain/Grand Lake; the latter being relatively small. Jasper Reservoir was also included in the network for future use, but its capacity was set at zero for all scenarios considered during this study.

Because MODSIM allowed a demand to extract water from storage in an onstream reservoir, the relationship between demands and reservoirs had to be carefully considered. The unregulated inflows denoted PARKB and MONARCH were stored in Granby Reservoir, subject to senior rights which were in priority in the Lower Colorado River Basin. However, once the water was stored in Granby, the water was controlled by the C-BT Project and was released only for specified demands. For Granby Reservoir, the major demand was the Adams Tunnel and the associated East Slope demands. However, there were additional small West Slope demands that were also met by releases from Granby Reservoir. These included the following:

1. SEEPG at Granby Reservoir (node 4), which accounted for uncontrolled seepage from the reservoir;

2. DIVN1.DEM at node 69, which accounted for local irrigation demands between Granby Reservoir and the USGS gaging station at the YMCA; and

3. GFISH.DEM at node 70, which provided for minimum flow requirements below Granby Reservoir.

The water which was lost to seepage (SEEPG) was used by the other two demands. However, minimum flows (GFISH.DEM) did not contribute to meeting irrigation demands (DIVN1.DEM), nor was the reverse true. The arrangement shown on the network diagram in Figure 10.1 provided for this relationship. The return flows from the demand denoted DIVN1.DEM were included by using an unregulated inflow denoted DIVN1.RET at node 64.

Flows into and out of Willow Creek Reservoir (node 3) and Shadow Mountain Reservoir (node 5) were similarly treated. Willow Creek Reservoir supplied a local irrigation demand (DIVT.WILL) from storage, with associated return flows included as unregulated inflow (RETURN.WILL at node 66). The minimum downstream flow (WFISH.DEM), which was 7 cfs or the inflow to Willow Creek Reservoir, whichever was less, was not permitted to withdraw water from storage. Shadow Mountain Reservoir had a calculated seepage (SEEPS) which was used to partially meet the minimum downstream flow (SFISH.DEM). However, if the seepage from Shadow Mountain Reservoir was insufficient to meet the minimum downstream flow, water was released from storage.

The Windy Gap demand denoted CITIES at node 30 was set at either the maximum pumping capacity of the project (equal to the conditional water right for 600 cfs) or zero, depending on which model scenario was being run. CITIES was a nonconsumptive demand that served to introduce water from the Windy Gap Project into the system. It was not an expression of the municipal East Slope demand for water from the Windy Gap Project. Rather, the demand CITIES was simply a "switch" that turned the Windy Gap pump network on or off. During the months of April, May, June, and July, the "switch" was turned on for a demand of 600 cfs, depending on model scenario, and the required minimum downstream flow of 90 cfs was included by the demand denoted FISH at node 31. During the months August through May, the "switch" was turned off. When "switched on", the demand CITIES and the flow-through demand FISH were the same for each year as listed in Appendix L.

The Windy Gap Project was joined to the C-BT Project through link 79, rather than link 77 which was set at zero, forcing water from the Windy Gap Project through the zero-capacity Jasper Reservoir. If there was available storage capacity in Granby Reservoir, the water from Windy Gap was transferred into storage via link 78. Otherwise, the excess water was "spilled" back to the river via link 81. Flows through link 79 represented the maximum diversions allowable from the Windy Gap Project within its priority. Flows through link 78 represented the maximum diversions that could be taken into the C-BT Project, limited by storage and/or conveyance capacity. Consequently, flows through link 81, which had no physical significance, equaled the difference between flows through link 79 and flows through link 78, or that amount of water which could have been diverted but was not because of insufficient capacity in the C-BT Project.

One of the major physical constraints on the delivery of water from the C-BT and Windy Gap Projects was the maximum flow through the Adams Tunnel. When historic Adams Tunnel flows were needed to calibrate and validate the model, the Adams Tunnel demand (ADAMS) was set equal to the historic flows in the tunnel, and the flow capacity of link 80 was set at zero. Following calibration and validation, the maximum allowable flow capacity of the tunnel was modeled by setting the demand ADAMS at zero and setting the flow capacity of link 80 at the monthly allowable maximum capacity.

The maximum flow capacity of the Adams Tunnel is 550 cfs. Assuming continuous operation at maximum capacity, the tunnel could deliver approximately 33,000 acre-feet of water each month. However, continuous operation at maximum capacity for an entire month could severely reduce the flexibility of hydroelectric power generation for load following and peaking.

To approximate the flexibility in the flow capacity of the Adams Tunnel needed for power operations, a 5 percent reduction in the maximum flow capacity was assumed for the 7 peak hours of each day, and a 10 percent reduction was assumed for the remaining 17 hours of each day. These assumptions resulted in a monthly maximum allowable flow for the modeled Adams Tunnel of 30,350 acre-feet, except for the month of June. During June, the tunnel was assumed to be unavailable for 2 weeks to approximate outages for annual maintenance resulting in a flow capacity of 17,424 acre-feet.

Upper Colorado River Basin Data Bases

Inflows

The data files for the unregulated inflows (Appendix O) and the demands (Appendix P) in the Upper Colorado River Basin were computed on a monthly basis from the USBR Basic Data Report for the C-BT Project (Bureau of Reclamation, 1988). The unregulated inflow denoted PARKB at node 75 was computed by first determining the net inflow to Shadow Mountain Reservoir and Grand Lake. The net inflow equaled the sum of the historic Adams Tunnel diversions, plus the Shadow Mountain Reservoir bypass flows down the Colorado

River to Granby Reservoir, plus the change in storage in Shadow Mountain Reservoir (storage at end of month minus storage at beginning of month), and minus the inflow to Shadow Mountain Reservoir pumped from Granby Reservoir. PARKB was then computed as the historic net inflow, plus the historic transbasin diversions to the Grand River and Eureka Ditches (demand denoted ROCKY at node 75), plus the historic consumptive irrigation use above Granby Reservoir (demand denoted CONSUM.RED at node 26).

The inflow denoted MONARCH at node 27 was determined from the historic net inflow to Granby Reservoir taken from the USBR Basic Data Report minus the net inflow to Shadow Mountain Reservoir and Grand Lake, computed as described in the previous paragraph. The inflow denoted RADIAL at node 29 was taken as the historic net inflow to Willow Creek Reservoir tabulated in the USBR Basic Data Report. The net inflows to Willow Creek Reservoir, Granby Reservoir, and Shadow Mountain Reservoir/Grand Lake, tabulated in the Basic Data Report, were calculated by the USBR from water balance computations. Since precipitation and evaporation were not explicitly identified in the water balance, they were accounted for in the determination of net inflows. Consequently, evaporation was not deducted during MODSIM simulations for these reservoirs, unlike the lower basin reservoirs where CRSS changes in storage were used.

In the Fraser River Basin, the historic unregulated net inflow denoted FRASER at node 28 was computed as the sum of the flows measured at the USGS gaging station at Hot Sulphur Springs (link 29), minus the computed net flows from the Upper Colorado River (link 54), plus the Moffat Tunnel flows (demand denoted MOFFAT at node 28), plus consumptive irrigation use in the Fraser Basin (demand denoted CONSUM.FRAS at node 76). A portion of the unregulated FRASER inflows included flows originating in the Upper Williams Fork Basin and diverted through the Gumlick and Vasquez Tunnels into the Fraser Basin. However, this additional supply of water to the Fraser Basin was counterbalanced by a corresponding increase in the demand denoted MOFFAT at node 28. The net flow from the Upper Colorado River (link 54) equaled the sum of the net flow in Willow Creek (sum of historic Willow Creek Reservoir releases, plus irrigation return flows from the lower section of the Redtop Ditch, minus consumptive irrigation use from Willow Creek), plus the net flow in the Colorado River below Granby Reservoir (Granby Reservoir releases minus consumptive irrigation use from the Upper Colorado River). The computation of consumptive use and return flows is described in a subsequent subsection captioned Return Flows.

Demands

The demand denoted MOFFAT at node 28 in Figure 10.1 equaled the total historical flow through the Moffat Tunnel plus tabulated historical transbasin diversions to the Berthoud Pass Ditch. Other demands in the Upper Colorado River Basin which were modeled consisted of ADAMS at node 5, CITIES at node 30, ROCKY at node 75, SEEPG at node 4, SEEPS at node 65, FISH at node 31, WFISH.DEM at node 29, GFISH.DEM at node 70, SFISH.DEM at node 71, and irrigation demands DIVT.WILL at node 3, DIVN1.DEM at node 69, CONSUM.RED at node 26, CONSUM.SELL at node 66, and CONSUM.FRAS at node 76. The demand ADAMS represented the flow capacity of the Adams Tunnel and was described previously in the description of Upper Colorado River Basin network features. The "switching" demand CITIES for the portion of the network representing the Windy Gap Project was also described in this earlier section as was the demand ROCKY, which equaled the historical transbasin diversion to the Grand River and Eureka Ditches. The remaining demands are described in the following paragraphs, except for the irrigation demands which are described in the subsection concerning return flows.

The flow-through demands denoted SEEPG and SEEPS represented uncontrolled seepage from Granby and Shadow Mountain Reservoirs, respectively, and varied by month as well as by year. Neither SEEPG nor SEEPS was included in the tabulations contained in the USBR Basic Data Report, and each was determined from monthly water balance computations. For each month, SEEPG was computed as the net inflow to Granby Reservoir, minus the net inflow to Shadow Mountain Reservoir and Grand Lake, plus the Shadow Mountain Reservoir bypass flow to Granby Reservoir, plus the pumped flow to Granby Reservoir from Willow Creek Reservoir, minus the Granby Reservoir change in storage, minus releases from Granby Reservoir down the Colorado River, minus the inflow to Shadow Mountain Reservoir pumped from Granby Reservoir. SEEPS was similarly determined from monthly water balance computations for Shadow Mountain Reservoir and Grand Lake. For SEEPS, the assumption was made that a negative computed net inflow to Shadow Mountain Reservoir and Grand Lake represented a net loss from Shadow Mountain Reservoir. The assumption was also made that SEEPS flows were taken into Granby Reservoir, as shown on the network diagram in Figure 10.1. Seepage below Willow Creek Reservoir was not included in the MODSIM model because it was typically less than 100 acre-feet per month and was insignificant relative to the accuracy of the data and model.

The flow-through demands denoted FISH at node 31, WFISH.DEM at node 29, GFISH.DEM at node 70, and SFISH.DEM at node 71 represented the minimum flow requirements below Windy Gap Reservoir, Willow Creek Reservoir, Granby Reservoir, and Shadow Mountain Reservoir, respectively. FISH, WFISH.DEM and SFISH.DEM were constant for a given month during each year modeled. For example, WFISH.DEM was 400 acre-feet per month (or 7 cfs) for October through April and was zero during the remainder of each year. These and all other constant demands are listed in Appendix L. However, GFISH.DEM varied by month and by year depending on inflow. The required minimum release below Granby Reservoir was reduced by up to 30 percent, according to established USBR criteria and as shown in Appendix P, when the sum of the net inflow to Shadow Mountain Reservoir/Grand Lake and Granby Reservoir (MONARCH) was less than specified levels.

Return Flows

All of the consumptive irrigation demands and return flows in the Upper Colorado River Basin below Granby Reservoir and below Willow Creek Reservoir were computed based on average historical diversions and measured acreage for mountain meadow hay, as determined from map and field observations. Mountain meadow hay was the only crop that had been grown on significant irrigated acreages in the Upper Colorado River Basin for the period of study. The irrigation season for mountain meadow hay has typically started in May and ended in August, and the irrigation water requirement or net consumptive use has averaged 1.43 acre-feet per acre (Kruse and Haise, 1974).

The demand denoted DIVT.WILL at node 3, Willow Creek Reservoir, was constant from year to year but varied monthly (nonzero from May through August, and zero for the remaining months) as shown in Appendix L. DIVT.WILL equaled the average historical monthly diversions of the Bunte HiLine Ditch and the Coffee-McQuerry Ditch, which divert from Willow Creek below Willow Creek Reservoir. The average irrigated acreage in mountain meadow hay for these two ditches was 750 acres. Comparing the diversion rates for these ditches to the crop water requirement provided an estimated average irrigation application efficiency of 14 percent. As a result, the average return flow from these ditches was estimated to be 86 percent of the diversion rate. The return flow was denoted RETURN.WILL and was represented as an inflow at node 66. The return flows were assumed to vary by month, but the monthly flow quantities were assumed to be the same for all years modeled, as shown in Appendix O. Although DIVT.WILL minus RETURN.WILL equaled the consumptive use of the Willow Creek Ditch diversions, the diversion and return flows physically occurred at different locations within the river basin. DIVT.WILL was from Willow Creek Reservoir while RETURN.WILL accrued mainly to the Colorado River.

The irrigation demand denoted DIVN1.DEM at node 69 below Granby Reservoir and the resulting return flows denoted DIVN1.RET at node 64 were modeled similarly to the diversions and return flows for irrigation below Willow Creek Reservoir. DIVN1.DEM represented the historical diversions for irrigation from the Colorado River between Granby Reservoir and the YMCA gaging station (node 64). The return flows from this irrigation diversion, DIVN1.RET, entered the Colorado River below the YMCA gaging station. There were approximately 270 irrigated acres served by DIVN1.DEM, and the irrigation application efficiency was estimated to be 14 percent, as for DIVT.WILL. The remaining 86 percent of the diversion amount provided the return flow DIVN1.RET which was assumed to vary by month, being nonzero during the months of May through August, but was the same for each year modeled as shown in Appendix O.

The demand denoted CONSUM.RED at node 26 was based on USBR estimates for irrigated acreage and constituted approximately 3.3 percent of the consumptive use estimated for the CRSS model above the Town of Glenwood Springs. The inflow denoted REDTOP at node 67 was the irrigation return flow into Willow Creek below Willow Creek Reservoir, which resulted from irrigated hay acreage near the end of the Redtop Ditch. Since the Redtop Ditch historically diverted from the Colorado River above Granby Reservoir, most of the irrigation return flows entered Granby Reservoir and were accounted for as portions of the net inflows computed for PARKB and MONARCH. Only the end of the Redtop Ditch historically irrigated land whose return flows did not enter Granby Reservoir. This irrigated land at the end of the Redtop Ditch consisted of about 1180 acres, based on shareholder delivery records. The irrigation efficiency for this acreage was estimated to average 34 percent. Therefore, the return flows REDTOP were computed to be 66 percent of the diversions to the acreage near the end of the ditch and were treated as constant inflow values for the months of May through August, as shown in Appendix O.

The irrigation demand denoted CONSUM.SELL at node 66 equaled the average annual historical consumptive use of mountain meadow hay from diversions and irrigation below the USGS gaging station at the YMCA (node 64). The average consumptive use was based on an estimated 530 acres being irrigated for hay production. The average was assumed constant during each year of the study but varied monthly from May through August (zero during the other months) as shown in Appendix L. CONSUM.SELL represented the consumptive use of the estimated irrigated acreage only, as the net diversions less return flows were specified at node 66. This simplified net demand representation was used because the actual diversions and return flows physically occurred in the portion of the river basin represented by a single node. A similar lumping of diversions and return flows could not adequately represent the irrigation diversions DIVT.WILL, DIVN1.DEM, CONSUM.RED, and associated return flows discussed previously.

The demand denoted CONSUM.FRAS at node 76 was based on USBR estimates for irrigated acreage and constituted approximately 9.1 percent of the consumptive use estimated for the CRSS model above the Town of Glenwood Springs. As for CONSUM.SELL, only the actual consumptive use for the estimated acreage was represented, since the historical diversions and return flows were lumped together at the same node.

10.4.2.3 West Slope Priorities

Two types of priorities were used in the MODSIM model; a direct flow demand priority, and a storage or reservoir priority. Whenever the water surface in a reservoir was below its rule curve elevation, or desired storage level, the reservoir will demand the water necessary to fill to its target level, according to the priority which was assigned to the reservoir. This reservoir demand then competed in the modeled system for available water along with all the other demands.

A list of the priorities developed for all the direct flow demands and reservoirs, included in the MODSIM model for both the West and East Slopes is presented in Table 10.1. The priority numbers are also shown in the small rectangles on the network diagram in Figure 10.1. The priorities were developed based on the existing models and on trial simulations to obtain water allocations consistent with water rights appropriations, the administration of the various river basins, and operations of the various existing reservoirs. Demands having low priority numbers were "senior" to demands having higher priority numbers. However, the absolute values of the numbers were not significant; it was the relative sequencing of the priority numbers which determined the behavior of the model.

TABLE 10.1

Priorities Sorted By Node Number

NODE NUMBER	MODSIM PRIORITY NUMBER	DEMAND NAME AND DESCRIPTION
1	47	GRN. MTN - Green Mountain Reservoir Storage
1	99	SPILL - Green Mountain Spill Route
2	50	WILLIAMS FK - Williams Reservoir Storage Demand
3	13	DIVT.WILL - Willow Creek Irrigation Requirement
3	46	WILLOW CR - Willow Creek Reservoir Storage
4	13	SEEPG - Granby Seepage
4	46	GRANBY - Granby Reservoir Storage Demand
5	42	ADAMS - Alva B. Adams Tunnel Diversions
5	43	SHDW MTN - Shadow Mountain Reservoir Storage
6	42	MARY - Marys Lake Storage/Power Generation
7	42	ESTES - Lake Estes Storage/Power Generation
8	42	PINE - Pinewood Storage/Power Generation
9	42	FLAT - Flatiron Storage/Power Generation
10	45	C-BT POOL - Storage Demand for C-BT Water
11	37	CARTER.DEM - Carter Demand
11	42	CARTER - Carter Lake Storage/Power Generation
12	42	BIGTPP - Big Thompson Power Generation
13	38	FCDIX.DEM - Demand on Horsetooth
13	42	HORSE - Horsetooth Storage
14	48	ROBERTS - Roberts and Hoosier Pass Tunnels
14	49	DILLON - Dillon Reservoir Storage Demand
15	70	ARK - Homestake Tunnel Diversions
15	71	HOMESTAKE - Homestake Reservoir Storage
16	75	ROCK CREEK - Rock Creek Reservoir Storage
17	63	IDEUR - Ruedi Water Sales
17	64	RUEDI - Ruedi Reservoir Storage
18	42	ADAMS T - Adams Tunnel Power Generation
19	44	MUNI.DEM - Demand on Main Storage/Supply
19	45	MAIN - Mainstem Poudre River Storage
20	98	JASPER - Jasper Reservoir Storage Demand
21	55	PVLC.DEM - Irrigation Demand on Lower Poudre
26	13	CONSUM.RED - Irrigation Requirement in Upper Colorado River Basin
28	33	MOFFAT - Denver and Colo. Spgs. 1. P. Diversions
29	41	WFISH.DEM - Willow Creek Reservoir Minimum Flow
30	88	CITIES - Windy Gap Demands

TABLE 10.1 - continued

Priorities Sorted By Node Number

NODE NUMBER	MODSIM PRIORITY NUMBER	DEMAND NAME AND DESCRIPTION
31	86	FISH - Minimum Flow Requirements for Windy Gap
32	13	CONSUM.KREMM - Kremmling Irrigation Requirement
33	14	CONSUM.UBLU - Irrigation above Green Mountain
35	11	CONSUM.DOT - Dotsero Irrigation Requirement
37	36	COLUMB - Columbine, Ewing and Wurtz Tunnels
38	78	EPINEY - Eagle-Piney Diversions (Denver)
39	12	CONSUM.EAGLE - Eagle Irrigation Requirement
40	26	HYDRO - Shoshone Run of River Power
42	65	BLUESTONE - Bluestone Project
43	40	TWIN - Twin Lakes Tunnel
44	62	TUNNELS - Ivanhoe and Boustead Tunnels
45	10	CONSUM.ROAR - Roaring Fork Irrigation Requirement
46	9	CONSUM.LOCAL - Rifle Area Irrigation Requirement
47	68	OILSHALE - Oil Shale Development
48	31	GRAND - Cameo Irrigation Demand
49	99	DUMMY - Large, Lowest Priority Demand
50	55	NO2.DEM - Irrigation Demand on Lower Poudre
51	99	SPCALLS - South Platte Demand
53	41	EFISH.DEM - Estes Minimum Flow
55	55	LAKE.DEM - Irrigation Demand on Lower Poudre
56	99	DUMMY - Large, Lowest Priority Demand
57	37	FEEDER.DEM - D. Hansen Feeder Demand
58	37	PHORSE - Lower Poudre Demands fed by Charles Hansen
59	43	PFISHS - Main Min. Flow Requirement (Storable Flow)
60	36	BIGTHP.DEM - Big Thompson Direct Flow Demands
61	55	SUM61F - LRM-WLD Irrigation Demand
62	49	PVCT.DEM - Poudre Valley Canal & Turnouts Demand
63	14	CONSUM.LBLU - Green Mountain Irrigation Requirement
65	13	SEEPS - Shadow Mountain Seepage
66	13	CONSUM.SELL - Granby Area Irrigation Requirement
69	13	DIVN1.DEM - Granby Irrigation Requirement
70	13	GFISH.DEM - Granby Minimum Flow
71	13	SFISH.DEM - Shadow Mountain Minimum Flow
72	99	DUMMY - Large, Lowest Priority Demand
73	55	COMP.DEM - Difference in NCWCD and WD3 Comm. Records
75	12	ROCKY - Eureka and Grand River Ditch Diversions
76	13	CONSUM.FRAS - Fraser Basin Irrigation Requirement
77	49	GUMLICK - Williams Fork Diversion Project
78	8	INCID - Incidental Losses from CRSS
79	55	FOSS.DEM - Fossil Creek Irrigation Requirement
80	55	GRDEM - Greeley Filter Plant Demand
81	37	BTCBT.DEM - Big Thompson C-BT Demand

The most senior demands on the West Slope were the consumptive uses (demands denoted CONSUM) associated with the diversions for senior agricultural water rights. These demands, represented by diamonds on the network diagram in Figure 10.1, were always met first in the MODSIM simulations and were assigned the highest priority corresponding to priority numbers which ranged from 9 through 14.

The next most senior demands on the West Slope were those elements which historically tended to control the administration of the Colorado River Basin; the Shoshone call (HYDRO at node 40) with priority 26 and the Cameo call (GRAND at node 48) with priority 31. Assignment of the remaining West Slope priority numbers was governed by the water rights associated with the respective demands.

Demands from a reservoir were always set one number less (more senior) than the priority number given storage in the reservoir, which allowed the storage to be used to meet the demands from the reservoir when necessary. Exchange reservoirs, such as Williams Fork and Green Mountain Reservoirs, were junior to the storage and diversion features which they were intended to protect. For example, the Williams Fork Reservoir was assigned a priority 50, while Moffat Tunnel was 33 and Dillon Reservoir was 49. This forced water to be released from the Williams Fork Reservoir to meet calls from Shoshone or Cameo before Dillon Reservoir was prevented from storing or Moffat was prevented from diverting. The same relationship was maintained between Green Mountain Reservoir and the C-BT Project. Green Mountain Reservoir was assigned priority 47, while storage in Granby Reservoir was assigned priority 46 and the Adams Tunnel demand was assigned priority 42. As a result, water from Green Mountain Reservoir was released to meet downstream calls before Granby Reservoir was prevented from storing or Adams Tunnel was prevented from diverting.

10.4.2.4 West Slope Reservoirs

<u>Evaporation</u>

As previously described, the net inflows used for Granby Reservoir, Shadow Mountain Reservoir/Grand Lake, and Willow Creek Reservoir were computed from historic end-of-month storage, measured inflow, and measured outflow data. Consequently, the computed net inflows to these reservoirs appropriately accounted for evaporation losses, and no further reductions in storage because of evaporation were made during the MODSIM simulations. For the other West Slope reservoirs (Green Mountain, Williams Fork, Dillon, Homestake, Ruedi, and the proposed Rock Creek), evaporation was not included as part of net unregulated inflows. For these reservoirs, evaporation losses were calculated separately during model simulations based on reservoir water surface areas and recorded weather data from a high-altitude weather station located at Estes Park, Colorado. (For East Slope reservoirs located on the plains, recorded weather data from a lower-altitude weather station at Fort Collins, Colorado were used to calculate evaporation losses.)

When included separately, MODSIM accounts for reservoir evaporation as a function of the surface area of the reservoir. Appendix L provides the calculated values in acre-feet per surface acre per month of net reservoir evaporation (evaporation less precipitation) used as input for the MODSIM simulations. The calculated net evaporation values are treated as monthly constants and do not vary by year.

Operating Criteria

Besides the pattern of demands on a reservoir, MODSIM can control water surface elevation or end-of-month storage for a reservoir through assigned rule curves. Rule curves, or target storage levels, can be set at historic levels, such as was done for calibration and validation, or can be set according to desired operating criteria.

To allow demands to withdraw water from reservoir storage, the demands were assigned priorities senior to the priorities assigned to reservoir storage. For the three replacement reservoirs on the West Slope (Green Mountain, Williams Fork, and Ruedi), there were no major demands connected directly to the reservoirs. Without direct demands, the MODSIM model would tend to simulate storage levels in these reservoirs at higher levels than operated at historically. To more accurately reflect the historic use of releases from these three reservoirs for hydroelectric power generation, rule curves similar to historic operations were established thereby tending to force water out of storage for all scenarios modeled.

Initial Reservoir Storage Volumes

The initial West Slope reservoir storage volumes assumed for the MODSIM simulations are listed in Table 10.2. Also listed for reference are the maximum reservoir volumes and the minimum or dead storage volumes. The initial storage volumes assumed for Williams Fork, Dillon, Homestake, and Ruedi Reservoirs equaled the average historical storage volumes at the end of September for all years of the historical record. The initial storage volumes for Green Mountain, Willow Creek, Granby, and Shadow Mountain Reservoirs equaled the actual storage volumes at the end of September 1953 when the study period for the MODSIM simulations began.

TABLE 10.2

Initial, Maximum, and Minimum Storage Volumes for West Slope Reservoirs

Reservoir	Node	Initial Storage	Maximum Storage	Minimum Storage
Green Mountain	1	121,600 af	153,639 af	6,860 af
Williams Fork	2	58,200	97,000	0
Willow Creek	3	10,300	10,553	1,486
Granby	4	481,000	539,758	74,190
Shadow Mountain	5	18,100	18,369	16,530
Dillon	14	217,500	262,200	3,270
Homestake	15	30,500	50,000	0
Ruedi	17	92,200	103,900	61
Rock Creek (proposed)	16	20,000	50,000	0

10.4.2.5 Existing and Future West Slope Demand Scenarios

The MODSIM modeling described in this report was performed in part to refine estimates for the amount of additional water that could be diverted under existing water rights from the Upper Colorado River Basin by the C-BT and Windy Gap Projects for storage and use out of the proposed Stage 1 Cache la Poudre Project. Since the additional water available depends on the future development of other West Slope water rights, which will compete for a portion of the available water, it was important to incorporate a realistic range of future West Slope water development as part of the modeling effort.

To establish a realistic range of West Slope water development which may occur in the future, potential water projects which were considered the most likely to actually be developed were identified. Since the purpose for including future West Slope water development was to test the sensitivity of the yield from additional diversions by the C-BT and Windy Gap Projects to such development, it was only necessary to identify projects representative of what might be developed, rather than precisely predict exactly which projects would be developed and when they would be developed.

The potential water projects considered to be representative of likely development, along with the projected effects of these projects, are listed in Table 10.3. To represent the range of potential future demands for West Slope water, three levels or scenarios for future development were defined; existing development (no additional development), medium level of additional development, and full development. The potential projects included in each of the future development scenarios are also shown in Table 10.3.

A comparison of the assumptions used in this study for future West Slope water development and the assumptions used in another recent study involving Green Mountain Reservoir (Boyle Engineering, 1987) is provided in Table 10.4. In most cases, the estimates for future development and demand are similar. The primary differences occur because of the inclusion of several relatively speculative potential projects in the Green Mountain Reservoir Study which were not included in the study for the Stage 1 Poudre Project.

TABLE 10.3

Summary of Colorado Water Projects
Included in Future Demand Scenarios

Project	Future Demand Scenario: Medium Development	Future Demand Scenario: Full Development	Network Effect
Two Forks	X	X	Increase Roberts Tunnel Demand by 66,000 af annually.
Eagle-Piney		X	Annual demand of 64,000 af applied to Eagle River Basin, diverted to Dillon. Roberts Tunnel Demand increased an additional 64,000 af.
Williams Fork Expansion		X	Demand "Gumlick" with average annual volume of 22,500 af.
Fraser River Expansion	X	X	Demand "Moffat" is increased 15,000 af annually above present trends.
Homestake II	X	X	Homestake tunnel (Demand "ARK") demand increased of 20,900 af annually above present levels.
Rock Creek Reservoir		X	50,000 af of junior storage made available to meet calls.
Oilshale Development		X	Average annual consumptive use of 9,300 af applied using demand "Oilshale".
Ruedi Water Sales		X	100 percent consumptive demand on Ruedi Reservoir "IDEUR" increased by 31,000 af annually.

TABLE 10.4

West Slope Demand Scenarios
Comparison of Average Annual Flows

(Acre-Feet X 1000)

GREEN MTN STUDY	POUDRE STUDY	RECORDED DIVERSIONS 1951-83	1973-83	1949-83	STUDY SCENARIOS EXISTING	PROJECTED MEDIUM	PROJECTED FULL
Adams Tunnel		219.7	230.6		288.2	288.2	288.2
	adams.his			208.4		variable	
	adams.max			382.2		variable	
Boustead Tunnel		16.2	45.7		52.5		
Busk-Ivanhoe Tunnel		5.9	6.9		6.0		
Total		22.1	52.6		58.5	58.5	58.5
	tunnels.exi				60.4	60.4	60.4
	tunnels.his			21.2			
Columbine Ditch		1.5	1.7		1.6		
Ewing Ditch		1.0	1.0		1.1		
Wurtz Ditch		2.5	2.9		2.5		
Total		5.0	5.6		5.2	5.2	5.2
	columbine.his			5.0	5.0	5.0	5.0
Gumlick Tunnel		5.0	4.6		27.1		
Moffat Tunnel (no Gumlick)		45.4	52.4		72.4		
Total		50.5	57.0		99.5	99.5	99.5
These include	{moffat.his			49.8			
about 5000 af in	{moffat.exi				56.4		
Gumlick Tunel	{moffat.fut					71.4	71.4
	gumlick.fut						22.5
	Total						93.9
Homestake Tunnel		12.3	24.2		29.4	50.4	50.4
	ark.his			11.6			
	ark.exi				29.4		
	ark.fut					50.3	50.3
Roberts Tunnel		29.6	62.0		153.4	153.4	153.4
Hoosier Tunnel		7.7	7.9		8.2	8.2	8.2
Total		37.3	69.9		161.6	161.6	161.6
	roberts.his			42.4			
	roberts.exi				87.0		
	roberts.fut1					153.0	
	roberts.fut2 (includes Eagle-Piney)						217.0
Twin Lakes Tunnel		42.8	43.7		42.8	42.8	42.8
	twin.his			42.5	42.5	42.5	42.5
Oilshale					3.0	6.0	136.0
	oilshale.fut						9.3
	ideur.fut						31.0
	Total						40.3
Pueblo-Eagle							3.0
Eagle-Arkansas							6.0
Continental-Hoosier							6.0
West Divide							25.0
Red Cliff							25.0
Local Irrigation					320.0	320.0	336.0
Bluestone Project					0.0	0.0	4.0

The projected levels of future West Slope water development were used together with various assumptions concerning the demand for water from the Windy Gap Project, the pumping capacity at Windy Gap, and the available flow capacity through the Adams Tunnel to define 10 sensitivity studies, as shown in Table 10.5 (Hydro-Triad, 1988). Those sensitivity studies were developed to test the performance of the MODSIM model and determine the effects of various assumptions, including future West Slope water development. The demand files used for the sensitivity studies are illustrated in Table 10.6, and the results from the studies are described in Section 10.5.3.

TABLE 10.5

Definition of Sensitivity Runs

RUN NO.	WEST SLOPE ASSUMPTIONS			EAST SLOPE ASSUMPTIONS
	WINDY GAP PUMPING CAPACITY	ADAMS TUNNEL CAPACITY	LEVEL OF WEST SLOPE DEVELOPMENT	WINDY GAP DEMAND LEVEL
1	none	historic	existing	none
2	none	maximum	existing	none
3	maximum	maximum	existing	none
4	none	historic	full	none
5	none	maximum	full	none
6	maximum	maximum	full	none
7	maximum	maximum	existing	maximum
8	maximum	maximum	full	maximum
9	maximum	maximum	medium	maximum
10	maximum	maximum	medium	none

TABLE 10.6

Demand Files for Sensitivity Runs

******* EAST SLOPE ASSUMPTIONS *******

Windy Gap Demand Levels = None or Maximum

Node No.	Current Demand Node Name	Demand File Name: None	Demand File Name: Maximum
11	CARTER	carter.his	carter.max
13	HORSE	fcdix.exi	fcdix.max
81	BTM	btcbt.his	btcbt.his
57	FLOW	feeder.exi	feeder.max
58	HANSEN	phorse.his	phorse.his
60	LOVE	bigthp.his	bigthp.his
62	BIFURC	pvct.his	pvct.max

******* WEST SLOPE ASSUMPTIONS *******

1. Windy Gap Pumping Capacity
   none ---> cities = 0
   fish = 0
   max ---> cities = cities.max
   fish = 90 cfs

2. Adams Tunnel Demand
   hist ---> adams = adams.his
   max ---> adams = adams.max

3. Levels of West Slope Development

Node No.	Current Demand Node Name	Demand File Name: Existing	Demand File Name: Projected Medium	Demand File Name: Projected Full
77	KEY	0	0	gumlick.fut
14	DILLON	roberts.exi	roberts.fut1	roberts.fut2
15	HOMESTK	ark.exi	ark.fut	ark.fut
16	ROCK CREEK	0	0	50,000 af
17	RUEDI	0	0	ideur.fut
28	WINTER	moffat.exi	moffat.fut	moffat.fut
37	DEET	columbin.his	columbin.his	columbin.his
38	EG	0	0	epiney.fut
42	GLENN	0	0	blueston.fut
43	BELLS	twin.his	twin.his	twin.his
44	FRY	tunnels.exi	tunnels.exi	tunnels.exi
47	MUNIC	0	0	oilshale.fut

10.4.3 East Slope Modeling

10.4.3.1 East Slope Network

The East Slope portion of the MODSIM model was also based largely on a previously developed model (Labadie and Hiew, 1987). The major water storage reservoirs included in the East Slope portion of the model were Carter Lake, Horsetooth Reservoir, and the proposed mainstem reservoir for Stage 1 of the Cache la Poudre Project. Smaller reservoirs included Mary's Lake, Lake Estes, Flatiron Reservoir, and Pinewood Reservoir. Dummy reservoirs with zero capacity were also used to simulate operations of run-of-river hydroelectric power plants (MODSIM can only model hydroelectric power plants at reservoirs). Dummy reservoirs were added to model power plants at the Adams Tunnel (denoted ADAMST at node 18 in Figure 10.1) and the Big Thompson Power Plant (denoted BIGTPP at node 12).

The pump and pipeline system which supplies water to Carter Lake from Flatiron Reservoir was represented by link 72 in Figure 10.1. The capacity of link 72 was made variable to adequately simulate monthly operation and maintenance of the system. The return to Flatiron Reservoir from Carter Lake through the turbine shown in link 9 was assigned a small "pseudo-cost" to discourage demands in the Big Thompson River Basin from drawing water out of storage in Carter Lake through Flatiron Reservoir, which is consistent with normal operations when those demands can be met otherwise. Link 73 from Flatiron Reservoir to Pinewood Reservoir does not currently exist, but was included to accommodate future evaluation of the potential for pumped storage power generation between Pinewood Reservoir and Carter Lake. Link 73 was assigned zero capacity for all of the studies described in this report. The capacities of the links representing the Charles Hansen Feeder Canal (links 10, 14, and 15) were reduced during the months of October and November to simulate reductions in availability associated with normal maintenance schedules, as shown in the structin.files provided in Appendix M.

Two reservoirs (denoted MAIN at node 19 and C-BT POOL at node 10) were used in the model to simulate the proposed mainstem reservoir for Stage 1 of the Cache la Poudre Project. The total storage capacity of the mainstem reservoir varied depending on whether the Grey Mountain Damsite or the Poudre Damsite was assumed for the mainstem reservoir. The portion of the mainstem reservoir storage denoted MAIN was allowed to store water termed "Poudre River storable flows" as well as water from the C-BT and Windy Gap Projects. The other portion of mainstem reservoir storage, denoted C-BT POOL, had a fixed storage capacity of 25,000 acre-feet and was allowed to store only C-BT and Windy Gap Water. The reason for modeling the proposed mainstem reservoir as two reservoirs was to prevent spilling Poudre River storable flows, which could have been otherwise stored during a particular month except for water from the C-BT and Windy Gap Projects having been already stored during that month. In other words, it was not desirable to allow water from the C-BT or Windy Gap Projects, which had to be pumped into storage, to displace water from the Poudre River which could have been stored without pumping. The fixed storage capacity of C-BT POOL was set to accomodate the expected maximum additional diversions from the C-BT and Windy Gap Projects. Link 83 to the C-BT POOL was provided for future operational studies in which criteria for allocating storage in the mainstem reservoir for C-BT and Windy Gap water could be evaluated. For all of the analyses described in this report, the capacity of link 83 was set at zero.

The terminology "Poudre River storable flows" was used to refer to that quantity of water in the Poudre River that could be stored in a reservoir according to the conditional water rights for storage held by NCWCD. As shown in Figure 10.1, Poudre River storable flows (POUDRES) entered the model at node 54 and then flowed into the mainstem reservoir (MAIN at node 19) via link 17. Poudre River storable flows were stored first in MAIN, up to the available capacity in MAIN, before water from the C-BT POOL was transferred to MAIN. This configuration, along with a small "pseudo-cost" assigned to link 82, kept Poudre River storable flows from being spilled in a month because of the introduction of water from the C-BT and Windy Gap Projects into MAIN during that month. Poudre River storable flows were derived from a spreadsheet accounting model of historic Poudre River flows and diversions as described in Section 10.4.3.2.

Poudre River unstorable flows (POUDREU) entered the model at node 22 and equaled the historic Poudre River flows required to satisfy all historic demands downstream of the USGS gaging station located at the mouth of the Poudre Canyon. POUDREU was computed as the difference between the measured flows at the Poudre Canyon gage and the storable flows (POUDRES). Both POUDRES and POUDREU actually flowed through the site of the proposed mainstem reservoir. Therefore, outside the MODSIM model, the flows POUDREU were added to the flows in link 56 below MAIN, along with the historic diversions to the Poudre Valley Canal above the Canyon gage, to determine the flows that could be released to the Poudre River from a mainstem reservoir through a conventional hydroelectric power plant below the reservoir.

The network model for the Lower Cache la Poudre Basin (below node 22 in Figure 10.1) included various demands and unregulated inflows quantified from the spreadsheet accounting model of historic Poudre River flows and diversions described in Section 10.4.3.2. Data files for the demands, provided in Appendix P, were computed as the sums of historic ditch diversions, minus measured point inflows (such as creeks and waste treatment effluents), plus the seepage losses from the river. The demand denoted GR.DEM at node 80 represented the diversion to the water treatment plant at Bellvue owned by the City of Greeley. The demand denoted PVLC.DEM at node 21 represented the sum of the diversions for the Pleasant Valley & Lake Canal together with the Larimer County Canal. The demand denoted SUM61F at node 61 included the seven diversions for the Jackson, New Mercer, Larimer County No. 2, Little Cache, Taylor and Gill, Arthur, and Larimer & Weld Canals. The demand denoted LAKE.DEM at node 55 consisted of the three diversions for the Ames, Lake, and Coy Ditches. FOSS.DEM at node 79 consisted of the four diversions for the Timnath Reservoir Inlet, the Chaffe Ditch, the Boxelder Ditch, and the Fossil Creek Reservoir Inlet. The demand NO2.DEM at node 50 included the seven diversions for the New Cache No. 2, Whitney, B.H. Eaton, Jones, Canal No. 3, Boyd & Freeman, and Ogilvey Ditches. The SPCALLS demand at node 51 was assumed to equal the storable flows computed from the spreadsheet accounting model when flows which would otherwise be storable would probably be passed to satisfy calls by senior appropriators downstream.

The unregulated inflows at nodes 80, 61, and 79 (SUMGLCRE, RETLRM, and RETBOX, respectively), as listed in Appendix O, consisted of historic return flows computed from the spreadsheet analysis. The unregulated inflow at node 73 denoted PHORSE represented the inflow to the Poudre River from releases out of Horsetooth Reservoir through the Charles Hansen Supply Canal to satisfy the demand denoted PHORSE at node 58. The inflow PHORSE essentially equaled the demand PHORSE. However, there were some relatively minor inconsistencies between water delivery records maintained by NCWCD/USBR (used to specify the demand PHORSE) and the inflow records maintained by the Poudre River Water Commissioner (used to specify the inflow PHORSE). To account for these relatively minor differences, and maintain compatibility with both the USBR records and Water Commissioner records, adjustments were made through the demand denoted COMP.DEM at node 73 and the unregulated inflow denoted COMP.UNR at node 21. When recorded deliveries (demand PHORSE) exceeded historical inflows (inflow PHORSE), an amount of water equal to the difference was subtracted from Poudre River flows through COMP.DEM. When recorded deliveries were less than historical inflows, an amount of water equal to the difference was added to Poudre River flows through COMP.UNR.

The network configuration for the Lower Poudre Basin provided for output of computed river flows from the MODSIM model at the USGS Poudre Canyon gaging station (link 20), below the Larimer County Canal Diversion (link 21), below the Larimer and Weld Canal Diversion (link 22), at the USGS Ft. Collins gaging station (link 23), and at the USGS Greeley gaging station (link 57). These locations were the most important control points with regard to flows in the Lower Poudre River.

10.4.3.2 Poudre River Basin Hydrology

NCWCD developed a spreadsheet accounting model of historic flows and diversions along the Lower Poudre River to compute storable flows available for the proposed mainstem reservoir. The spreadsheet model was based on point flow water balances using historic USGS stream gaging records and Water Commissioner diversion records. The model represented historic operations and water year conditions and did not consider any possible changes in demands or operations which might result from construction of a mainstem reservoir.

The 55 miles of the Lower Poudre River between the USGS gaging station near the mouth of the Poudre Canyon and the confluence with the South Platte River, near the City of Greeley, contains 24 diversions for irrigation or storage. Consequently, development of the spreadsheet model began with an extensive effort to compile and verify historic diversions from the river and stream gage records by month for the years 1950 through 1985. The data from this time period were the most reliable and representative data available, though only a portion of the data was used for the hydrologic simulations performed for the Basin Study Extension (1954-1983). A complex system of water accounting has been developed by Poudre River Water Commissioners to track the various sources of water contributing to the flows in the Poudre River. These sources consist of native water originating within the Poudre Basin; imported water from either the Colorado, North Platte, or Laramie River Basins; and releases from a number of mountain and plains reservoirs.

Historical records for diversions along the Lower Poudre River were obtained for each diversion from the Water Commissioner and from the State of Colorado Water Data Bank maintained on a computer system at Colorado State University. The diversion records were carefully tabulated on a monthly basis and checked to ensure that the diversion data used in the spreadsheet model were river headgate diversions and excluded deliveries from offstream reservoirs to ditch systems. The river headgate diversions for the various canals were then tabulated in a spreadsheet by year, along with inflows and gaged flows, starting at the USGS gaging station at the mouth of the Poudre Canyon and progressing downstream to the USGS gaging station at the City of Greeley, as shown in Table 10.7.

Water administration in the Poudre Basin relies heavily on the use of return flows to satisfy senior water rights. The surface and subsurface return flows to the Lower Poudre River from irrigated agriculture can be as high as 8 cfs per mile. The reuse of these returns, coupled with an elaborate system of exchanges using numerous plains reservoirs, results in the very efficient use of the divertable water supply within the Poudre Basin. Return flows along the Lower Poudre River vary markedly depending on time of year and location along the river, with return flows in lower portions being significantly larger than return flows in upper portions. The reasons for the variations in return flow quantities with location include differing amounts of irrigation as well as varying characteristics along the riverbed and associated aquifers.

TABLE 10.7

Inflows, Diversions, Gaged Flows, and Computed Return Flows
Water Year 1983
(cfs-days)

INPUT/DIVERSION	MILES	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	TOTAL
Canyon Gage	70.83	1369	1723	1400	1959	2965	18445	54790	143030	68976	21985	6292	4812	327746
C-BT	71.80									6069	12169	6506	778	25522
Greeley Filters	71.30	468	469	461	465	498	513	627	597	618	588	641	610	6555
Pleasant Valley&Lake	72.08							152	1244	2236	1985	857	389	6863
Larimer County	73.17								3400	11189	9044	3635	300	27568
Jackson	75.34								48	909	918	445		2320
New Mercer	76.49								261	1366	1244	807	263	3941
Larimer County #2	76.49							475	73	1903	169	275	691	3586
Little Cache	76.49							1075	17	1662	1896	390	424	5464
Taylor & Gill	76.49							200	324	390	389	375	81	1759
Ideal Cement Pump														0
Arthur	78.78								102	517	278	9		906
Larimer & Weld	79.12							295	3794	15034	12347	2903	453	34826
Larimer & Weld Rp*	79.14								144018	43852	7436	2074	2354	199734
Ames	79.74													0
Lake	81.11								521	3179	1608	662		5970
Coy	81.41									88	119	81	36	324
Ft. Collins Gage	82.03	1317	1856	1347	1318	2646	19546	54590	143120	44936	9003	3157	2414	285250
Ft. Collins #1 Trt (I)	82.78	231	207	208	292	186	199	233	266	306	306	280	268	2881
Tinmath Inlet	83.76		81	663	269	123	154						2081	3371
Chaffe	83.76													0
Dry Creek (I)	84.34													0
Boxelder Ditch	85.67									907	989	92		1988
Fossil Res Inlet	86.08	2311	20	204	1487	1889	948	192	553	2079		47		9730
Boxelder Gage	87.22	537	1412	703	1088	2272	15030	49684	132890	39931	7678	3631	1297	256153
Boxelder Creek (I)	87.62													0
Fossil Res Outlet (I)	92.63		782	545		1063	1411	401		4944				9146
New Cache	93.50							1730	2755	10505	3498	581		19069
New Cache Rp	94.03	3337	3985	1916	2295	5541	22920	58550		37477	8010	6327		150358
Whitney	97.96								730	1925	1765	781	161	5362
B.H.	98.09								450	1120	1078	881	342	3871
Jones	107.14								105	324	421	205		1055
Canal #3	112.54	75						392	915	2608	2624	1598	864	9076
Boyd & Freeman	113.76								98	248	222	48		616
Seeley Release (I)		130			142		71					67		410
Greeley City Trt (I)	121.28	344	352	342	293	310	321	369	349	347	362	346	364	4099
Ogilvey	122.28								1434	621	1658	1410	488	5611
Greeley Gage	124.28	3296	7011	4506	3441	6277	25079	59480	143580	45726	10205	5515	4306	318422
Sum of Inputs		2074	3064	2495	2585	4524	20447	55793	143645	80642	34822	13491	6222	369804
Sum of Diversions		2854	570	1328	2221	2510	1615	5138	17421	59428	42840	16723	7183	159831
RETURN FLOW COMPUTATION														
Canyon to F.C. Gage		416	602	408	-176	179	1614	2624	10471	8982	5434	1439	71	32064
Canyon to Greeley Gage		4076	4517	3339	3077	4263	6247	8825	17356	24512	18223	8747	5267	108449

*Rp = Riverpoint used for accounting purposes by Water Commissioner

To account for these differences in the spreadsheet water balance model, the Lower Poudre River was divided into an upper segment and a lower segment; the boundary between segments being the USGS gaging station east of U.S. Highway 287 in the City of Fort Collins. Using the spreadsheet tabulations of inflows, diversions, and gaged flows, monthly river water balance calculations were made to compute net return flows for the upper segment during the years 1975 through 1985. Since the gaging station at Fort Collins was not established until 1975, return flows could not be directly computed for earlier years. Instead, a regression analysis was performed to compute return flows in the upper segment prior to 1975. The regression relationship was developed using monthly return flows during 1975 through 1985 as dependent variables and a combination of inflows (river flows at the Canyon Gage plus releases from Horsetooth Reservoir), headgate diversions, and precipitation, as independent variables. Regressions were conducted for each of the following four monthly time periods: November through April; May; June; and July through October.

Return flows in the lower segment of the river extending from the Fort Collins gaging station downstream to the gaging station at Greeley were computed as the difference between the total return flows between the Canyon and Greeley gaging stations, minus the return flows in the upper segment. Mean monthly returns, expressed as flow per mile, were then computed for both the upper and lower segments and were subsequently used in computing storable flows.

Using the spreadsheet water balance calculations, storable flows (river flows available for storage in the proposed mainstem reservoir) were then computed as those flows passing the gaging station at the mouth of the Poudre Canyon that were not needed to meet historic downstream headgate diversions (those diversions having been satisfied by return flows, releases from Horsetooth Reservoir, and some portion of the flow passing the mouth of the Poudre Canyon). The resulting storable flow volumes are listed in Table 10.8. For comparison purposes, Table 10.9 lists the storable flow volumes computed using the model RIBSIM during the initial Basin Study (Harza, 1987). For a comparable period of 1954 through 1980, an average annual storable flow volume of 42,376 acre-feet was computed using the RIBSIM model, while the spreadsheet water balance model resulted in an estimated average annual storable flow volume of 46,456 acre-feet. Some of the individual yearly volumes differ significantly. For example, in 1965 the RIBSIM model estimated a storable flow volume of 11,389 acre-feet, all of which occurred during the month of June. The spreadsheet water balance estimated a storable flow volume of 72,266 acre-feet in 1965, of which 1,863 acre-feet occurred during May and 70,403 acre-feet occurred during June. For the MODSIM hydrologic simulations performed for the Basin Study Extension, the storable flows computed from the spreadsheet water balance model were considered to be the most reliable estimates available because of the extensive verification of the data used and the relatively few assumptions that were made.

10.4.3.3 Additional East Slope Data

Inflows

The inflows denoted ESTES.UN at node 53 and PANORAMA at node 25 were computed from USGS stream gaging records and the USBR Basic Data Report for the C-BT Project (Bureau of Reclamation, 1988). ESTES.UN was computed as the net historic inflow to Lake Estes and Mary's Lake based on a water balance for these two reservoirs. ESTES.UN equaled the sum of the measured flows through the Olympus Tunnel (link 55), plus historic streamflows recorded at the USGS gaging station on the Big Thompson River near Estes Park immediately downstream of Lake Estes (link 24), minus the recorded flows through the Adams Tunnel (link 6). Storage changes in Mary's Lake and Lake Estes were not considered because of the small storage volumes involved and the small month-to-month variations in storage. Since ESTES.UN was computed as the net inflow from a water balance, evaporation and seepage losses were included, and no separate accounting for evaporation or seepage was required.

The inflow denoted PANORAMA at node 25 was computed as the sum of the historic flows recorded at the USGS gaging station on the Big Thompson River at the mouth of the canyon near Drake (link 19), plus the tabulated flows through the Dille Tunnel (link 18), minus the flows recorded at the USGS gaging station on the Big Thompson River near Estes Park (link 24). PANORAMA represented the unregulated inflow to the Big Thompson River between Lake Estes and the mouth of the Big Thompson Canyon.

TABLE 10.8

Poudre Storable Flows
NCWCD Spreadsheet Analysis

(acre-feet)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Total
Avg.	449.	349.	133.	140.	223.	479.	3283.	16826.	28237.	4297.	476.	0.	54892.
1950	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1951	0.	0.	0.	0.	0.	0.	0.	2505.	0.	0.	0.	0.	2505.
1952	0.	0.	0.	0.	0.	0.	5013.	5643.	6966.	0.	0.	0.	17622.
1953	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1954	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1955	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1956	0.	0.	0.	0.	0.	0.	0.	4673.	3473.	0.	0.	0.	8146.
1957	0.	0.	0.	0.	0.	0.	0.	6207.	38859.	0.	0.	0.	45066.
1958	0.	0.	0.	0.	0.	0.	10245.	67112.	15452.	0.	0.	0.	92809.
1959	0.	0.	0.	0.	0.	0.	8001.	11197.	4667.	0.	0.	0.	23865.
1960	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1961	0.	0.	0.	0.	0.	0.	4067.	34236.	66615.	0.	0.	0.	104918.
1962	11072.	6055.	2538.	3037.	5247.	4922.	7914.	3950.	22138.	0.	0.	0.	66873.
1963	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1964	0.	0.	0.	0.	0.	0.	0.	1913.	0.	0.	0.	0.	1913.
1965	0.	0.	0.	0.	0.	0.	0.	1863.	70403.	0.	0.	0.	72266.
1966	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1967	0.	0.	0.	0.	0.	0.	0.	1467.	26985.	10664.	0.	0.	39116.
1968	0.	0.	0.	0.	0.	0.	0.	1689.	10128.	0.	0.	0.	11817.
1969	0.	0.	0.	0.	0.	0.	0.	725.	18757.	0.	0.	0.	19482.
1970	0.	0.	0.	0.	0.	0.	0.	3625.	39410.	0.	0.	0.	43035.
1971	0.	0.	0.	0.	0.	0.	6391.	56327.	35557.	9047.	0.	0.	107322.
1972	0.	0.	0.	0.	0.	0.	0.	1196.	15430.	0.	0.	0.	16626.
1973	0.	0.	0.	0.	0.	0.	0.	58164.	28920.	7170.	0.	0.	94254.
1974	4180.	5805.	1978.	1729.	2321.	3077.	2445.	5584.	31177.	0.	0.	0.	58296.
1975	0.	0.	0.	0.	0.	0.	0.	0.	27560.	6518.	0.	0.	34078.
1976	0.	0.	0.	0.	0.	0.	0.	0.	2558.	0.	0.	0.	2558.
1977	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1978	0.	0.	0.	0.	0.	0.	0.	2332.	40463.	0.	0.	0.	42795.
1979	0.	0.	0.	0.	0.	0.	0.	36533.	77638.	4013.	0.	0.	118184.
1980	0.	0.	0.	0.	0.	8302.	31892.	158438.	52262.	0.	0.	0.	250894.
1981	0.	0.	0.	0.	0.	0.	0.	0.	15359.	0.	0.	0.	15359.
1982	0.	0.	0.	0.	0.	0.	0.	0.	32131.	27676.	0.	0.	59807.
1983	0.	0.	0.	0.	0.	0.	35640.	106740.	277154.	81006.	16179.	0.	516719.
Min	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Max	11072.	6055.	2538.	3037.	5247.	8302.	35640.	158438.	277154.	81006.	16179.	0.	516719.
Sdev	1979.	1396.	536.	583.	958.	1670.	8119.	34615.	48476.	14354.	2734.	0.	95264.

TABLE 10.9

Storable Flows at Canyon Gage from RIBSIM Model
(Harza, 1987)

(acre-feet)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Avg.	48	19	79	931	14,725	23,301	161	0	0	170	229	102	39,764
1951	0	0	0	0	0	13,865	0	0	0	0	0	542	14,407
1952	0	0	0	0	11,289	23,094	0	0	0	0	0	0	34,383
1953	0	0	0	0	0	0	0	0	0	0	0	0	0
1954	0	0	0	0	0	0	0	0	0	0	0	0	0
1955	0	0	0	0	0	0	0	0	0	0	0	0	0
1956	0	0	0	0	7,373	5,850	0	0	0	0	0	0	13,223
1957	0	0	0	0	2,734	31,013	0	0	0	0	0	0	33,747
1958	0	0	0	0	80,369	9,986	0	0	0	0	0	0	90,355
1959	0	0	0	0	14,373	12,404	0	0	0	0	0	0	26,777
1960	0	0	0	0	0	4,952	0	0	0	0	0	0	4,952
1961	0	0	0	0	27,099	71,709	0	0	0	5,091	6,856	2,517	113,272
1962	1,454	569	2,377	8,009	2,287	36,672	0	0	0	0	0	0	51,368
1963	0	0	0	0	0	0	0	0	0	0	0	0	0
1964	0	0	0	0	0	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	11,389	0	0	0	0	0	0	11,389
1966	0	0	0	0	0	0	0	0	0	0	0	0	0
1967	0	0	0	0	0	46,679	4,831	0	0	0	0	0	51,510
1968	0	0	0	0	0	23,014	0	0	0	0	0	0	23,014
1969	0	0	0	0	1,422	23,282	0	0	0	0	0	0	24,704
1970	0	0	0	0	0	38,621	0	0	0	0	0	0	38,621
1971	0	0	0	1,430	51,899	50,720	0	0	0	0	0	0	104,049
1972	0	0	0	0	0	1,426	0	0	0	0	0	0	1,426
1973	0	0	0	0	43,351	49,702	0	0	0	0	0	0	93,053
1974	0	0	0	0	0	28,346	0	0	0	0	0	0	28,346
1975	0	0	0	0	0	42,176	0	2	0	0	0	0	42,178
1976	0	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	25,359	0	0	0	0	0	0	25,359
1979	0	0	0	0	36,060	86,759	0	0	0	0	0	0	122,819
1980	0	0	0	18,479	163,487	62,013	0	0	0	0	0	0	243,979

Three other inflows on the East Slope were also computed from water balances; inflows denoted PINE.UN, HORSE.UN, and CTRLAK.UN. The inflow PINE.UN into Pinewood Reservoir at node 8 represented unmeasured and unregulated net inflows into the Charles Hansen Feeder Canal, which carries water north out of Flatiron Reservoir to the Big Thompson River and into storage in Horsetooth Reservoir. PINE.UN was computed as the recorded flows in the canal at the trifurcation structure located at the mouth of the Big Thompson Canyon, minus releases into the canal from Flatiron Reservoir. The inflows HORSE.UN into Horsetooth Reservoir at node 13 and CTRLAK.UN into Carter Lake at node 11 represented the unmeasured net inflows to Horsetooth Reservoir and Carter Lake, respectively, from the surrounding watersheds. Both inflows were computed from water balance calculations for the reservoirs using measured inflows, outflows, seepage, storage changes, and estimated evaporation.

Demands

C-BT, Windy Gap, and Ditch Company Demands

Aside from the demands in the Lower Poudre River Basin described previously, and the projected demand associated with the proposed mainstem reservoir, the remaining East Slope demands were consolidated into seven demands; BIGTHP.DEM at node 60, BTCBT.DEM at node 81, CARTER.DEM at node 11, PHORSE at node 58, PVCT.DEM at node 62, FCDIX.DEM at node 13, and FEEDER.DEM at node 57. The data files that were used as input to MODSIM for these demands are provided in Appendix P. For each demand file in Appendix P, the title indicates the level of demand associated with each data set; historical, existing, or projected maximum. That is, if the historical level of demand was assumed for say CARTER.DEM, the corresponding data file in Appendix P would be labeled "carter.his". If the existing level of demand was assumed for FCDIX.DEM, the corresponding data file would be labeled "fcdix.exi". If the projected maximum level of demand was assumed for FCDIX.DEM, the corresponding data file would be labeled "fcdix.max".

Whether the historical, existing, or projected maximum level of demand was used depended on whether or not demand for water from the Windy Gap Project was included. When it was assumed that there was no demand for Windy Gap water, either historical or existing levels of demand were used. When demand for Windy Gap water was included, the maximum level of demand was used where appropriate.

Three of the seven demands were assumed to be the same whether or not there was demand for water from the Windy Gap Project. The three demands which were independent of Windy Gap demand were BIGTHP.DEM, BTCBT.DEM, and PHORSE. These demands were expressed by data files bigthp.his, btcbt.his, and phorse.his, respectively. The demand BIGTHP.DEM at node 60 represented the senior water rights on the Big Thompson River. The data file bigthp.his was developed from monthly records obtained from the Water Commissioner documenting historic direct flow diversions and diversions to storage for the Handy, Home Supply, Louden, George-Rist, Barnes, and Greeley-Loveland Ditches. The demand BTCBT.DEM at node 81 represented the delivery of water from the C-BT Project to the Big Thompson River. The demand PHORSE represented the delivery of water from the C-BT Project to the Poudre River via the Charles Hansen Supply Canal. The corressponding data files btcbt.his and phorse.his, respectively, were taken directly from monthly USBR Water Order Sheets for the study period.

The remaining four demands (CARTER.DEM, PVCT.DEM, FCDIX.DEM, and FEEDER.DEM) were dependent on the assumed demand for water from the Windy Gap Project. The demand CARTER.DEM at node 11 represented the demand for water out of Carter Lake. The demand PVCT.DEM at node 62 represented the demand for water via turnouts along the Charles Hansen Supply Canal and via the Poudre River Siphon from the Charles Hansen Supply Canal Extension to the Poudre Valley Canal. The demand FCDIX.DEM at node 13 represented the demand for water from Horsetooth Reservoir by the City of Fort Collins and other entities served by the City of Fort Collins. The demand FEEDER.DEM represented the demand for water from the Charles Hansen Feeder Canal by the City of Loveland.

For the MODSIM analyses, when no demand for Windy Gap water was included, CARTER.DEM and PVCT.DEM were assumed to be at historic levels. The corresponding data files carter.his and pvct.his were taken directly from monthly USBR Water Order Sheets for the study period. However, since the demands for C-BT water by the Cities of Fort Collins and Loveland, represented by FCDIX.DEM and FEEDER.DEM, have increased in recent years, existing levels of demand were used instead of historical levels. The corresponding data files were denoted fcdix.exi and feeder.exi, respectively. For the period 1980 through 1983, the data file fcdix.exi was developed directly from monthly USBR Water Order Sheets, while for the period 1954 through 1979, the average monthly demand for the 1980-1983 period was used. The data file feeder.exi was similarly developed. For the period 1979 through 1983, the historic record from USBR Water Order Sheets was used, while for the period 1954 through 1978, the average monthly demand for the 1979-1983 period was used.

When demands for water from the Windy Gap Project were considered, the historic and existing demands, which included entities owning shares in the Windy Gap Project, were increased proportionately based on a total assumed demand for Windy Gap water of 48,000 acre-feet annually. The demand files which included Windy Gap demands were denoted carter.max, feeder.max, fcdix.max, and pvct.max, as listed in Appendix P. The assumed demand for water from the Windy Gap Project was distributed monthly based on historical patterns of municipal water use, as documented in the supplemental report to the Environmental Impact Statement for the Windy Gap Project (Water and Power Resources Service, 1981), and varied yearly according to C-BT quota allocation. The monthly averages for this distribution are listed in Table 10.10.

The demand file carter.max included 41.7 percent of the demand assumed for water from the Windy Gap Project (48,000 acre-feet) in addition to the historic Carter Lake demands (carter.his). This equaled 200 of the 480 Windy Gap units available (80 units for Boulder, 80 units for Longmont, and 40 units for the Superior Metro District). The demand file feeder.max included 8.3 percent of the Windy Gap demand in addition to the existing demand on the Charles Hansen Feeder Canal (feeder.exi) to account for the 40 Windy Gap units owned by the City of Loveland. The demand file fcdix.max included 33.3 percent of the Windy Gap demand in addition to the existing demand (fcdix.exi) to account for the 160 Windy Gap units owned by the Platte River Power Authority. The demand file pvct.max includes 16.7 percent of the Windy Gap demand in addition to the historical demand on the Charles Hansen Supply

Canal Extension (pvct.his) to account for the 80 Windy Gap units owned at the time of this study by the City of Greeley.

Demand on Proposed Mainstem Reservoir

The future demand on the proposed mainstem reservoir for Stage 1 of the Cache la Poudre Project was assumed to be entirely municipal. The demand denoted MUNI.DEM at reservoir node 19 in Figure 10.1 was assumed to be met by deliveries through a pipeline from the reservoir, as illustrated, or by deliveries to the Poudre River. These alternate delivery assumptions provided a means for estimating minimum and maximum bounds, respectively, for post-project flows in the Poudre River downstream of the proposed mainstem reservoir. Initially, MODSIM simulations were performed with MUNI.DEM set at 50,000 acre-feet annually to determine whether shortages would occur for this level of demand. The actual safe or zero-shortage demand (yield) which could be met by the mainstem reservoir was determined during subsequent simulations, as described in Section 10.8.

To select an appropriate monthly distribution for the demand MUNI.DEM, three different water use patterns representative of municipal demand were considered:

1. The pattern of historical releases to the City of Fort Collins and others via the Dixon Canal and Soldier Canyon Dam outlet works at Horsetooth Reservoir (FCDIX.DEM in Figure 10.1);

2. The pattern of demands assumed for the Cities of Fort Collins and Greeley in an earlier study of water supply alternatives in the Cache la Poudre Basin (Tudor, 1982); and

3. Projected demands for municipal water use from the Windy Gap Project considered in the Windy Gap EIS for an average year (Water and Power Resources Service, 1981).

A comparison of these demand distributions is shown in Table 10.10 which follows.

TABLE 10.10

Monthly Flow as a Percent of Annual Flow

Month	Historical FCDIX.DEM	Ft Collins/Greeley Demand Assumed in Tudor Report	Windy Gap EIS Demand	Percentage Used In Basin Study Extension
Oct.	8	8	0	7
Nov.	3	6	4	3
Dec.	2	6	4	2
Jan.	2	6	2	2
Feb.	2	5	2	3
Mar.	3	6	4	3
Apr.	7	8	7	6
May	8	9	22	9
June	14	11	32	15
July	21	13	23	20
Aug.	18	12	0	18
Sept.	12	10	0	12

The distribution used in this study was selected to represent a combination of the relatively uniform deliveries assumed previously to be appropriate for the Cities of Fort Collins and Greeley and the intermittent pattern of demand expected for the Windy Gap Project.

East Slope Minimum Flows

Two minimum flow requirements were included in the East Slope portion of the MODSIM model as flow-through (nonconsumptive) demands: the demand denoted EFISH.DEM at node 53, and the demand denoted PFISHS at node 59. The demand EFISH.DEM represented the minimum flow required in the Big Thompson River below Lake Estes and was treated as a constant monthly demand during all years (Appendix L). However, during model calibration and validation, EFISH.DEM equaled the lesser of the constant demand or the actual historic releases made to the Big Thompson River.

The demand PFISHS represented a minimum flow that would otherwise be storable but was passed through the proposed mainstem reservoir to maintain an assumed minimum flow in downstream reaches of the Poudre River. PFISHS was assumed to be similar to the stipulation in the water rights decree for Case No. 80CW355 in District Court, Water Division 1. This stipulation required that the water rights for the proposed Cache la Poudre Project be subordinated in priority to a water right for the Bellview-Watson Trout Rearing Station such that the lesser of 50 cfs or storable inflow to the proposed reservoir must be passed during the period between April 15 and October 14, inclusive, and the lesser of 25 cfs or storable inflow to the proposed reservoir must be passed between October 15 and April 14. Actual minimum instream flow requirements will be determined during future consultations with natural resource agencies.

10.4.3.4 East Slope Priorities

All of the priorities assigned to demands and reservoirs for both the East Slope and West Slope portions of the MODSIM model are listed in Table 10.1. The priorities for the East Slope portion of the model were set to insure delivery of water to satisfy the most senior water rights. For example, the demand denoted BIGTHP.DEM at node 60 represented the senior direct flow rights on the Big Thompson River which predated the C-BT Project. Consequently, the demand BIGTHP.DEM was assigned priority 36, the most senior East Slope priority number.

In establishing East Slope priorities, the following relationships were considered to be key factors:

1. All of the C-BT reservoirs on the East Slope were assigned the same priority (42). The East Slope reservoirs were made senior to Granby Reservoir (priority 46) so that Granby was forced to release water to meet East Slope storage demands. Similarly, the C-BT and Windy Gap demands on the East Slope were all made senior to Carter Lake and Horsetooth Reservoir so that water was forced from storage to meet demands.

2. The municipal demand denoted MUNI.DEM on the proposed mainstem reservoir (MAIN) was made senior (priority 44) to storage in MAIN (priority 45) while both the municipal demand and storage were senior to storage in Granby Reservoir (priority 46). This sequence of priorities caused the municipal demand to be met before water was stored in the mainstem reservoir. In addition, water was forced to be pumped from Granby to meet the municipal demand before filling storage in the mainstem reservoir when water and conveyance capacity was available.

3. The minimum flow required to be passed through the proposed mainstem reservoir (PFISHS at node 59) was assigned a priority (43) which was senior to MUNI.DEM so that bypass flow requirements were met before the municipal demand.

The priorities assigned to the demands associated with the senior rights along the Lower Poudre River were all equal and had no effect on the modeling of the proposed mainstem reservoir. There was no effect because all of the senior rights were satisfied by the inflow POUDREU (unstorable inflow) which exactly equaled the net demand remaining after utilization of return flows and other inflows.

10.4.3.5 East Slope Reservoirs

Evaporation and Seepage Losses

For the smaller East Slope reservoirs (Mary's Lake, Lake Estes, Pinewood Reservoir, and Flatiron Reservoir), inflows were included as net inflows. Consequently, losses through evaporation and seepage were accounted for during the water balance calculations made to determine net inflows. For the larger East Slope Reservoirs (Carter Lake, Horsetooth Reservoir, and the proposed mainstem reservoir on the Poudre River), historical weather data recorded at a weather station in Fort Collins were used to compute average monthly evaporation losses (acre-feet lost per water surface acre), as listed in Appendix L. Seepage losses were also included for Carter Lake and Horsetooth Reservoir, as shown in Appendix L. Seepage losses were determined from recorded seepage amounts correlated with reservoir storage, and therefore, also correlated with reservoir surface area. This correlation was made so that seepage losses could be expressed in units equivalent to evaporation losses (acre-feet per surface acre) to allow summation of the losses for the MODSIM model.

Initial Resevoir Storage Volumes

The initial storage volumes assumed for the East Slope reservoirs are listed in Table 10.11 below. The storage volumes associated with the smaller East Slope reservoirs (Mary's Lake, Lake Estes, Pinewood Reservoir, and Flatiron Reservoir) do not vary significantly from month to month, and the initial storage volumes assumed for these reservoirs equaled the average yearly storage volumes at the beginning of the month of October. Since Carter Lake was not fully operational until March of 1954, the initial volume assumed was the average storage volume at the beginning of October for the years of record. For Horsetooth Reservoir, the initial storage volume was the actual storage recorded at the beginning of October of 1953.

TABLE 10.11

Initial, Maximum, and Minimum Storage Volumes for East Slope Reservoirs

Reservoir	Node	Initial Storage	Maximum Storage	Minimum Storage
Mary's Lake	6	800 af	927 af	380 af
Lake Estes	7	2,700	3,069	2,148
Pinewood	8	1,900	2,181	613
Flatiron	9	600	760	324
Carter Lake	11	45,500	112,230	3,306
Horsetooth	13	47,300	156,735	7,003
C-BTPOOL	10	0	25,000	0
MAIN (Grey Mtn.)	19	150,000	170,000	10,368
MAIN (Poudre)	19	83,530	83,590	5,000

The proposed mainstem reservoir was represented in the MODSIM model as the combination of C-BT POOL and MAIN. The total storage capacity for this combination was 195,000 acre-feet at the assumed spillway crest elevation (El. 5,630 ft) when the reservoir was formed by a dam constructed at the Grey Mountain Damsite. The initial storage volume assumed for this combination with the Grey Mountain alternative was 150,000 acre-feet, or 77 percent of maximum capacity, which was comparable to the historical average storage in Granby Reservoir at the beginning of October. When the alternative Poudre

Damsite was considered for the mainstem reservoir, the maximum total storage volume was 108,590 acre-feet at the assumed spillway crest elevation (El. 5,600 ft). The initial storage volume for the Poudre alternative was assumed to be 83,530 acre-feet, which also was 77 percent of maximum capacity based on the historical average storage in Granby Reservoir at the beginning of October.

Area-Capacity Curves for Mainstem Reservoir

The area-capacity curves for the proposed mainstem reservoir for both the Grey Mountain Damsite alternative and the Poudre Damsite alternative, as provided in Appendix K, were developed using 7.5 minute USGS topographic maps with 40 foot contour intervals. Linear interpolation was used between contour intervals when necessary.

10.5 CALIBRATION, VALIDATION, AND SENSITIVITY SIMULATIONS

There are three steps involved in checking the accuracy and reproducability of a mathematical model:

1. verification - assuring the model accurately represents the physical system;

2. calibration - defining parameters and constants for the model based on recorded data so that the model reproduces actual conditions;

3. validation - determining how accurately the model can predict actual conditions not reflected in the calibration period.

During development of the MODSIM model used for the Basin Study Extension, Hydro-Triad and NCWCD worked jointly to verify the configuration of the final network model, making certain the model was linked together properly, and to insure that the model would closely simulate the physical river basin systems. The final configuration of the model, as shown in Figure 10.1, reflects the changes that were made to the configuration during development.

For both calibration and validation, the initial conditions used for the model corresponded to the historic conditions existing as of the starting dates of the simulations. The starting dates used for final calibration and validation were October 1, 1975 and October 1, 1979, respectively. Therefore, the initial storage levels for all reservoirs equaled the historical storage volumes that existed on October 1, 1975 for calibration and on October 1, 1979 for validation.

10.5.1 Calibration

Hydro-Triad initially calibrated a trial configuration of the model for the period 1980 through 1983. A major aspect of the calibration for the network model was to validate the assignment of priority numbers to demands and reservoir storage according to Colorado's priority system of water rights. NCWCD did not change any of the priority assignments initially made by Hydro-Triad, but did assign priorities to demands added to the model during subsequent revisions in accordance with the priorities of the water rights associated with the added demands. In addition to insuring that the priorities of demands and reservoir storage were properly related, the actual historical storage levels were assigned to each reservoir as storage rule curves to effectively limit storage at historical levels while maintaining the priority of filling according to the assigned priority values. This procedure was adopted by both Hydro-Triad and NCWCD for all calibrations performed.

NCWCD performed the final calibrations for the water years 1976 through 1979, prior to the construction and operation of the Windy Gap Project and prior to the high water years experienced throughout Colorado watersheds during the mid-1980s. This period was chosen by NCWCD for final calibration because it represented a recent time when accurate streamflow and water delivery records could be thoroughly verified and included a different hydrologic regime than the calibration period used by Hydro-Triad. Final calibration was necessary to confirm the accuracy of the data files used by Hydro-Triad for the West Slope portion of the model, which predominantly consisted of those previously developed by the USBR for the CRSS (Bureau of Reclamation, 1987), and to check the function of revisions to the model made by NCWCD. The final West Slope network configuration and data files used by

NCWCD, as described in Sections 10.4.2.1 and 10.4.2.2, included minor revisions to those initially used by Hydro-Triad. The primary revisions were the inclusion of the demand denoted INCID at node 78, and the associated data file as defined by the USBR, and changes in consumptive use percentages calculated by mass balance accounting between the Glenwood Springs and Cameo gaging stations.

The following five locations within the MODSIM network configuration were used for calibration:

1. Colorado River flow at Kremmling (link 33);
2. Colorado River flow at Dotsero (link 41);
3. Colorado River flow at Glenwood Springs (link 48);
4. Big Thompson River flow at the mouth of the canyon (link 60);
5. Poudre River flow at Greeley (link 57).

The results of the calibration at these locations are shown in Figures 10.2 to 10.6, respectively.

Flows were also monitored at the following seven additional locations to insure that calibration at the five primary locations listed above was not achieved by introducing errors to the flows in other parts of the network:

1. Colorado River flow at Hot Sulphur Springs (link 29);
2. Colorado River flow at Cameo (link 50);
3. Blue River flow below Green Mountain Reservoir (links 52 + 67);
4. Williams Fork River flow below Williams Fork Reservoir (link 2);
5. Eagle River flow at Gypsum (link 40);
6. Roaring Fork River flow at Glenwood Springs (link 85);
7. Charles Hansen Feeder Canal flow into Horsetooth Reservoir (link 15).

For the calibration period, the modeled flows versus historic flows at these locations are shown in Figures 10.7 to 10.13, respectively.

End-of-month storage levels in reservoirs were also monitored to insure that water was not being drawn out of storage to meet historic flows at river points during the calibration. Storage levels in the following six reservoirs were monitored:

1. Dillon Reservoir (node 14);
2. Green Mountain Reservoir (node 1);
3. Williams Fork Reservoir (node 2);
4. Granby Reservoir (node 4);
5. Carter Lake Reservoir (node 11);
6. Horsetooth Reservoir (node 13).

Figures 10.14 to 10.19 show the results from the calibration simulation at these reservoirs. During calibration, flows in all the other links (streams, canals, and conduits) and end-of-month storage levels in all the other reservoirs (nodes) were spot checked for differences from historic levels.

Comparisons of the flows and storage levels in Figures 10.2 to 10.19 show that there was remarkably good agreement between historic operations and simulated operations during the calibration period. Flows in the Colorado River at the Kremmling gaging station, flows in the Blue River below Green Mountain Reservoir, and end-of-month storage in Dillon Reservoir were the only locations of concern. Simulated values at these locations were within 13, 67, and 5 percent of historical values, respectively, during the month producing the largest discrepancies, June of 1978.

The difference between the simulated and historical flows in the Blue River initially seemed rather large. But when the amount of water produced in the Blue River Basin was compared with the total flows at the Lower Colorado River gaging stations, the difference was considered to be insignificant. This difference partially resulted from the consumptive use in the Colorado River Basin above Glenwood Springs being lumped into one value in the CRSS accounting. NCWCD divided the consumptive use in the Blue River Basin into lower and upper basin uses, after accounting for a similar split among all other consumptive uses in the Colorado River Basin above Glenwood Springs. The consumptive use apportionments were the same for every month of the study period, regardless of monthly and yearly weather changes. Prior to the division of consumptive use in the Blue River Basin, even larger differences were noticed between simulated and historical flows in the Blue River below Green Mountain Reservoir and end-of-month storage levels in Green Mountain Reservoir. The model configuration after dividing consumptive use was different than Hydro-Triad's initial configuration where only the demand denoted CONSUM.GRNMTN was considered for the Blue River Basin.

Similarly, unregulated inflows were divided among the basins tributary to the Colorado River Basin above Glenwood Springs, based on individual basin area as a percentage of total area. Since the basin unregulated flow percentages were held constant throughout the simulation period, small variations in climate patterns between watersheds in the same basin could produce varying resultant flows in different parts of that basin. The variations were not simulated by the MODSIM model, even though the total simulated flows at calibration points along the Colorado River were in excellent agreement with historical flows. This variation between watersheds is exactly what occurred in the Blue River Basin during the months where simulated flows during the calibration period diverged significantly from historical flows. An analysis of climate data for the Colorado River Basin revealed that in May of 1978, maximum temperatures averaged almost 20 degrees higher than normal. This higher than normal temperature would have caused earlier than normal runoff, especially in the lower altitude watersheds. Along with early runoff, high temperatures early in the irrigation season would have caused a higher consumptive use demand on the available streamflow than would have been indicated by long term averages. Similar circumstances occurred in May of 1979, as reflected in the flows recorded at the Kremmling gaging station. The only way to account for these anomalies would be to assign different percentages for consumptive use and unregulated inflow for each month during the simulation period based on relationships with climate data for each watershed and sub-watershed. This effort was not deemed necessary after reviewing the overall calibration results.

10.5.2 Validation

For validation, the MODSIM model was used to simulate conditions during water years 1980 through 1983, which tested the model's capability to accurately simulate both high and low hydrologic runoff conditions. The 1983 water year included one of the largest runoff events on record, especially during the months of June and July. In contrast, the runoffs during water years 1981 and 1982 were quite low. Hydro-Triad used the period 1980 through 1983 for calibration, largely because of the availability of quality data. However, this period was more valuable for validation to test how well the model predicted operations based on the parameter identification and estimation performed during final calibration.

The fundamental test of the model during validation was whether it could accurately simulate historical conditions for a different time period than used to establish model parameters during calibration. For the validation simulation, the target storage levels at all of the major existing reservoirs (Green Mountain, Williams Fork, Willow Creek, Granby, Shadow Mountain, Carter, Horsetooth, Dillon, Homestake, and Ruedi) were set at historic levels, as was done during calibration. The target storage volumes were set at historic levels rather than attempting to assess the model's performance with rule curves because it was essential to determine whether the priorities assigned demands and reservoir storage during calibration would result in accurate simulations for the validation period. In addition, rule curves used for assessing alternative scenarios for operation may be quite different than those used historically and may be inappropriate for validation comparisons.

The same flow points used for calibration were used to assess the adequacy of the model during the validation period. These flow points were:

1. Colorado River at Kremmling (link 33);
2. Colorado River at Dotsero (link 41);
3. Colorado River at Glenwood Springs (link 48);
4. Big Thompson River at the mouth of the canyon (link 60);
5. Poudre River at Greeley (link 57);
6. Colorado River at Hot Sulphur Springs (link 29);
7. Colorado River at Cameo (link 50);
8. Blue River below Green Mountain Reservoir (link 52 + 67);
9. Williams Fork River below Williams Fork Reservoir (link 2);

10. Eagle River at Gypsum (link 40);
11. Roaring Fork River at Glenwood Springs (link 85);
12. Charles Hansen Feeder Canal into Horsetooth Reservoir (link 15).

The simulated flows at these locations are shown along with corresponding historical flows in Figures 10.20 to 10.31. The simulated flows for the validation period accurately portrayed historic conditions, including the high spring runoff flows in 1983 and the low flows in 1981 and 1982.

As a further validation check, end-of-month reservoir storage volumes were also compared. The comparisons are shown in Figures 10.32 to 10.37 for the following reservoirs:

1. Dillon Reservoir (node 14);
2. Green Mountain Reservoir (node 1);
3. Williams Fork Reservoir (node 2);
4. Granby Reservoir (node 4);
5. Carter Lake Reservoir (node 11);
6. Horsetooth Reservoir (node 13).

A comparison between the validation simulations for end-of-month storage volumes and historical storage volumes shows the model accurately simulated reservoir operations while distributing available water based on priorities for demand and storage. Simply setting the reservoir target storage levels equal to historic levels would not have guaranteed that simulated end-of-month storage volumes would have been consistent with historic levels, unless the priorities for demand and storage volumes were accurate. Additionally, other parameters such as reservoir area-capacity tables, reservoir evaporation and other losses, as well as estimates of ungaged demands must have been properly determined during calibration for the validation results to have been accurate.

10.5.3 Sensitivity Simulations

Once the model had been initially developed and calibrated, 10 scenarios were defined for model simulation to further check the performance of the model, provide a basis for making appropriate revisions to the model prior to final calibration and validation, and test the sensitivity of simulated water availability for storage in the proposed mainstem reservoir to a variety of differing conditions. These initial 10 simulations were termed "sensitivity runs" in contrast to subsequent simulations which were termed "management runs". Sensitivity runs were performed to assess the effects of varying the characteristics of a single model feature, such as the capacity of a particular link or the level of a particular demand. Management runs were performed to identify the effects of incorporating a broad range of varying conditions, such as including a set of undeveloped West Slope water projects which if developed, would have water rights senior to the Windy Gap Project, versus assuming West Slope development would remain at current levels.

One of the objectives for the hydrologic simulations performed for the Basin Study Extension was to refine the estimated contribution to the yield of a mainstem reservoir from additional diversions from the C-BT and Windy Gap Projects under current water rights. During the course of developing the MODSIM model, the following four factors were identified as being critical for realistically estimating the yield available from additional C-BT and Windy Gap diversions:

1. Pumping capacity at the Windy Gap Project;

2. East Slope demand for water from the Windy Gap Project;

3. Available capacity for bringing additional diversions through the Adams Tunnel; and

4. Level of additional West Slope water project development.

The fourth factor was considered particularly important for reliably estimating the additional amount of water that could be available from the Windy Gap Project beyond an average of 48,000 acre-feet annually, since some undeveloped projects on the West Slope would have water rights priorities senior to the Windy Gap rights, if such projects were developed. There were no known undeveloped water projects on the East Slope which if developed, would significantly affect the potential yield of the proposed mainstem reservoir.

The conditions adopted for the 10 sensitivity runs performed using the model initially developed by Hydro-Triad are listed in Table 10.5. The definitions of existing, medium, and full development scenarios for water projects in West Slope river basins tributary to the Colorado River are provided in Tables 10.3 and 10.4. The varying levels of West and East slope demands were input to the MODSIM model through the demand files listed in Table 10.6. Results from the sensitivity runs, assuming the proposed mainstem reservoir was formed by constructing a dam at the Grey Mountain Damsite, are summarized in Table 10.12.

After thoroughly reviewing the results from the sensitivity runs, several changes to the configuration of the network model and input data were made to improve the model's performance. These changes consisted of the following:

1. Reconfiguration of the pumping network for the Windy Gap Project;

2. Division of the proposed mainstem reservoir into two components denoted C-BT POOL and MAIN;

3. Reduction in the capacity of the Adams Tunnel to account for scheduled maintenance;

4. Modification of assigned priorities;

5. Modification of initial storage levels assumed in reservoirs; and

6. Modification of variable link capacities.

All of these changes are fully detailed in Hydro-Triad's final report (Hydro-Triad, 1988), and all of the changes were incorporated prior to the final calibration and validation described in Section 10.5.

TABLE 10.12

Summary of Model Results from Sensitivity Runs 1-10
(Hydro-Triad, 1988)

average annual values in acre-feet

RUN#	WEST SLOPE ASSUMPTIONS			EAST SLOPE	RESULTS							
	Windy Gap Pumping Capacity	Adams Tunnel Demand	Level of Basin Devlopmnt	Windy Gap Demand Level	Annual Muni.Dem Demand	Main Shortage Node 10+ Node 59	Number of Months of Shortage Muni	Number of Months of Shortage Fish	Number of Years of Shortage Muni	Number of Years of Shortage Fish	Main Delivery Link 76	Main Spills Link 59
1a	none	hist	existing	none	40,000	7,147	67	40	11	10	3,360	20,590
1b					15,000	482	7	6	1	1	1,809	36,393
2a	none	max	existing	none	40,000	4,317	36	21	6	5	7,503	21,703
2b					15,000	482	7	6	1	1	2,281	36,865
3a	max	max	existing	none	40,000	2,881	22	12	3	3	11,334	23,830
3b					15,000	291	4	4	1	1	5,631	39,946
4a	none	hist	full	none	40,000	7,148	67	40	11	10	3,360	20,590
4b					15,000	482	7	6	1	1	1,809	36,395
5a	none	max	full	none	40,000	4,317	36	21	6	5	7,503	21,703
5b					15,000	482	7	6	1	1	2,281	36,395
6	MAX	MAX	FULL	NONE	40,000	3,541	28	16	5	4	10,370	23,564
7a	max	max	existing	max	40,000	5,692	49	31	9	7	5,380	21,023
7c*					40,000	2,246	20	13	3	2	24,471	35,956
8	max	max	full	max	40,000	5,793	51	32	9	7	4,780	20,557
9	max	max	medium	max	40,000	5,693	49	31	9	7	4,880	20,557
10	max	max	medium	none	40,000	3,441	28	16	5	4	10,692	23,778

RUN#	RESULTS (cont.)								
	Big Thp. Loss Link 71	Windy Gap Delivery Link 77	Adams Delivery Link 5	West Slope Spills Links 27, 64 & 81	Shortage to Cartr.Dem Node 11	Shortage to Horsetooth Nodes 13, 58 & 62	Shortage to Big Thompson Nodes 57 & 81	No. of Shoshone Calls Link 42	No. of Cameo Calls Link 51
1a	9,019	0	230,090	20,350	0	4,945	553	105	44
1b	10,572	0	230,090	21,063	0	4,945	553	105	44
2a	7,702	0	240,750	11,095	0	54	53	105	44
2b	10,682	0	238,507	13,338	0	54	53	105	44
3a	13,719	76,028	250,801	77,073	0	0	36	111	44
3b	17,704	76,144	249,083	78,906	0	0	36	111	44
4a	9,019	0	230,090	21,063	0	5,117	479	157	55
4b	10,570	0	230,090	21,063	0	5,017	479	157	55
5a	7,702	0	240,750	11,095	0	54	53	157	55
5b	10,682	0	230,507	13,388	0	54	53	157	55
6	12,270	66,494	248,364	69,976	0	0	36	159	55
7a	6,316	72,535	281,938	42,442	0	1,867	76	111	44
7c*	7,649	71,501	301,103	22,350	0	2,948	76	111	44
8	6,095	62,970	280,763	33,873	0	2,099	76	159	55
9	6,095	64,578	281,020	35,404	0	1,983	76	129	44
10	12,549	68,400	248,973	71,272	0	0	36	129	44

*Run 7c was the same as 7a execpt in Run 7c, MAINSTEM priority was 45 and MUNI.DEM priority was 44.

10.6 MANAGEMENT SIMULATIONS

After making the revisions to the MODSIM network configuration and input data following the sensitivity simulations described in the previous section, Hydro-Triad performed three management simulations to assess the combined effects from a broad range of conditions on the potential yield of the proposed mainstem reservoir. The model configuration was further revised by NCWCD prior to the final calibration and validation conducted by NCWCD. A concluding set of management simulations was then performed to estimate the yield of the proposed mainstem reservoir for both the Grey Mountain and Poudre Damsite alternatives, simulate preproject flows in the potentially affected river basins, and estimate maximum and minimum bounds for postproject flows.

The scenarios adopted by Hydro-Triad for the initial set of management simulations corresponded to the conditions assumed for sensitivity runs 1, 2, and 8 as illustrated in Table 10.5. These conditions are resummarized in Table 10.13 below, and selected results from the simulations, assuming the proposed mainstem reservoir was formed by constructing a dam at the Grey Mountain Damsite, are provided in Table 10.14.

TABLE 10.13
Management Runs Performed by Hydro-Triad

RUN NO.	WEST SLOPE ASSUMPTIONS			EAST SLOPE ASSUMPTIONS
	WINDY GAP PUMPING CAPACITY	ADAMS TUNNEL DEMAND	LEVEL OF WEST SLOPE DEVELOPMENT	WINDY GAP DEMAND LEVEL
1	none	historic	existing	none
2	none	maximum	existing	none
8	maximum	maximum	full	maximum

TABLE 10.14

Summary of Model Results from Management Runs Performed by Hydro-Triad (Hydro-Triad, 1988)

average annual values in acre-feet

RUN#	WEST SLOPE ASSUMPTIONS			EAST SLOPE	RESULTS							
	Windy Gap Pumping Capacity	Adams Tunnel Demand	Level of Basin Devlopmnt	Windy Gap Demand Level	Annual Muni.Dem Demand	Main Shortage Node 19+ Node 59	Number of Months of Shortage Muni	Number of Months of Shortage Fish	Number of Years of Shortage Muni	Number of Years of Shortage Fish	Main Delivery Link 76	Main Spills Link 59
1.1	none	hist	existing	none	50,000	12,388	126	0	17	0	2,024	17,423
2.1	none	max	existing	none	50,000	931	8	0	2	0	26,533	29,646
8.1	max	max	full	max	50,000	1,223	18	0	5	0	26,972	30,401

RUN#	RESULTS (cont.)								
	Big Thp. Loss Link 71	Windy Gap Delivery Link 78	Adams Delivery Link 5	West Slope Spills Links 27, 64 & 81	Shortage to Cartr.Dem Node 11	Shortage to Horsetooth Nodes 13, 58 & 62	Shortage to Big Thompson Nodes 57 & 81	No. of Shoshone Calls Link 42	No. of Cameo Calls Link 51
1.1	7,572	0	231,932	24,367	0	763	120	107	44
2.1	10,319	0	259,483	2,168	272	1,311	802	107	44
8.1	6,737	55,335	305,672	10,821	79	0	0	162	55

Since there were changes made to the model network configuration between Hydro-Triad's sensitivity simulations and management simulations, as described in Section 10.5.3, there were corresponding differences between the results obtained from the sensitivity runs (Table 10.12) and from the management runs for corresponding scenarios (Table 10.14).

Following further revisions to the model network configuration, NCWCD performed final calibration and validation simulations, as described in Sections 10.5.1 and 10.5.2. NCWCD then performed management simulations corresponding to the conditions assumed for sensitivity runs 2, 7, and 8 as summarized in Table 10.15 below.

TABLE 10.15

Management Runs Performed by NCWCD

RUN NO.	WEST SLOPE ASSUMPTIONS			EAST SLOPE ASSUMPTIONS
	WINDY GAP PUMPING CAPACITY	ADAMS TUNNEL DEMAND	LEVEL OF WEST SLOPE DEVELOPMENT	WINDY GAP DEMAND LEVEL
2	none	maximum	existing	none
7	maximum	maximum	existing	maximum
8	maximum	maximum	full	maximum

These conditions were the most significant in terms of estimating the yield of the proposed mainstem reservoir and simulating pre- and postproject flows. Runs 2 and 7 were performed to assess the effects of the Windy Gap Project on the yield of the mainstem reservoir proposed for Stage 1 of the Cache la Poudre Project. Although the Windy Gap Project is currently operational, there have not been sufficient operating experience and resulting data to quantify the effects of Windy Gap diversions on the availability of additional water for diversion from the Colorado River. Therefore, it was important to perform simulations with and without the Windy

Gap Project to adequately determine water availability and separate the effects of Windy Gap diversons on flows in the Colorado River from the effects on flows resulting from additional diversions from the Colorado River for storage in the proposed mainstem reservoir. The data files required for these simulations are included in Appendixes M and N. The files STRUCTIN.xx define the system configuration, storage rule curves, demand identification, and physical constraints used to model the river systems. The files STRUCTGN.xx identify the unregulated inflow and demand files listed in Appendixes O and P, respectively, which were used. In this description, the "xx" refers to the numerical identification for the simulations performed. For example, STRUCTIN.2-F refers to the structural organization file for the model used during final run 2.

The results of the three management runs performed by NCWCD, assuming the proposed mainstem reservoir was formed by constructing a dam at the Grey Mountain Damsite, are summarized in Table 10.16. The results from run 2 portray the effects of the proposed mainstem reservoir on the existing water resources system, without the Windy Gap Project in full operation. The results from run 7 portray the effects with the Windy Gap Project in full operation. The results from run 8 form the basis for estimating the yield of the proposed mainstem reservoir and the resultant post-project flows including the effects of "full" development of water rights on the West Slope.

It is interesting to note that during run 7, an additional 4,150 acre-feet of water was delivered to the proposed mainstem reservoir (Main Delivery - Link 76), on an average annual basis, beyond the amount indicated from run 2. However, the average annual spills from the mainstem reservoir (Main Spills - Link 59) increased by 3,099 acre-feet during run 7 as compared with run 2. Also, shortages to the annual municipal demand from the mainstem reservoir were cut in half with the introduction of Windy Gap flows (Main Shortage - Nodes 19 and 59) during run 7, but the shortages were only 2 percent of the annual demand. Although the average annual amount of water transferred to the East Slope from the West Slope increased by 50,784 acre-feet from run 2 to run 7 (Adams Delivery - Link 5), the number of calls at Shoshone and Cameo remained the same. This reflected proper modeling of

TABLE 10.16

Summary of Model Results from Management Runs Performed by NCWCD

average annual values in acre-feet

RUN#	WEST SLOPE ASSUMPTIONS			EAST SLOPE	RESULTS							
	Windy Gap Pumping Capacity	Adams Tunnel Demand	Level of Basin Devlopmnt	Windy Gap Demand Level	Annual Muni.Dem Demand	Main Shortage Node 19 & Node 59	Number of Months of Shortage Muni	Number of Months of Shortage Fish	Number of Years of Shortage Muni	Number of Years of Shortage Fish	Main Delivery Link 76	Main Spills Link 59
2	none	max	existing	none	50,000	2,005	27	0	4	0	22,947	27,193
7	max	max	existing	max	50,000	1,004	13	0	3	0	27,097	30,292
8	max	max	full	max	50,000	1,882	22	0	5	0	24,845	28,987

RUN#	RESULTS (cont.)								
	Big Thp. Loss Link 71	Windy Gap Delivery Link 78	Adams Delivery Link 5	West Slope Spills Links 27, 64 & 81 W.C. & Jasper	Shortage to Cart.Dem Node 11	Shortage to Horsetooth Nodes 13, 58 & 62	Shortage to Big Thompson Nodes 57 & 81	Number of Shosone Calls Link 42	Number of Cameo Link 51
2	9,521	0	259,981	2,114	481	746	802	145	39
7	6,941	62,559	310,765	15,709	102	0	0	149	39
8	6,875	56,014	307,597	8,698	840	0	0	205	47

the water rights system, since both the Windy Gap Project and the Poudre Project were junior to the Shoshone and Cameo rights.

Assuming full development of senior West Slope water rights (run 8) naturally decreased the amount of water available for the proposed mainstem reservoir from the availability without further West Slope development (run 7). This was reflected by the decreased average annual flows in the Adams Tunnel of 3,168 acre-feet and the decreased deliveries of water to the proposed mainstem reservoir of 2,252 acre-feet. Although the number of calls at Shoshone and Cameo increased to 205 and 47, respectively, during run 8, the increases were not attributable to deliveries to the mainstem reservoir. Rather, the larger number of calls were the result of decreased flows in the Lower Colorado River caused by the "full" development of senior water rights on the West Slope.

Selected output from management runs 2, 7, and 8 are included in Appendix Q.3. In all of these runs, the annual demand on the mainstem reservoir was set at 50,000 acre-feet, which resulted in shortages to the demand in all runs. This indicated that the safe yield of the proposed mainstem reservoir was less than 50,000 acre-feet annually. The estimation of safe yield is discussed further in Section 10.8.

10.7 PREPROJECT HYDROLOGY

To determine the effects on river flows of constructing and operating the proposed mainstem reservoir, it was necessary to first establish river flows that would exist at various locations without the construction of the mainstem reservoir. To establish these preproject flows, management simulations comparable to the conditions outlined for runs 2 and 7 in Table 10.15 were performed with the mainstem reservoir and associated demands deleted from the MODSIM model.

The use of preproject simulations for conditions associated with both runs 2 and 7 was necessary because operation of the proposed mainstem reservoir would be integrated with the operation of the C-BT and Windy Gap Projects. Although the Windy Gap Project has been fully operational since 1986, the project has not been fully utilized because demands for the water have not fully developed. Since postproject simulations were required for future conditions when the Windy Gap Project would be fully utilized, it was important to avoid incorrectly combining the effects of full utilization of the Windy Gap Project with the effects of constructing and operating a mainstem reservoir on the Poudre River. Consequently, preproject simulations were performed for conditions associated with run 2 (without the Windy Gap Project) as well as run 7 (full utilization of the Windy Gap Project) so that the effects attributable to the proposed mainstem reservoir could be correctly quantified.

Selected output from the preproject simulations both with and without simulated operation of the Windy Gap Project is provided in Appendix Q.2. The results of the preproject simulations for flows in the Colorado River at the Hot Sulphur Springs gaging station through the study period, assuming no diversions at Windy Gap, are shown in Table 10.17. Simulated preproject flows at the Hot Sulphur Springs gaging station assuming the Windy Gap Project is fully utilized, with average annual deliveries of 48,000 acre-feet, are shown in Table 10.18. Similarly, simulated flows in the Poudre River at the USGS gaging station at the mouth of the Poudre Canyon are shown in Table 10.19. Only one table is needed to show preproject flows in the Poudre River at the Canyon gage, since preproject deliveries of water from the Windy Gap Project are introduced to the Poudre River from the Charles Hansen Supply Canal which is downstream of the gaging station.

TABLE 10.17

Simulated Preproject Flows in the Colorado River at the Hot Sulphur Springs Gaging Station

(Sum of links 29 and 81 - Management Run 2 without Windy Gap)

(mean monthly cfs)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Avg.	79.	76.	63.	60.	66.	78.	214.	540.	735.	424.	143.	69.
1954	35.	56.	39.	43.	54.	49.	153.	146.	113.	108.	48.	14.
1955	43.	56.	44.	44.	46.	57.	213.	298.	219.	122.	126.	23.
1956	49.	71.	66.	60.	66.	78.	269.	906.	505.	130.	92.	20.
1957	37.	59.	58.	57.	59.	58.	178.	813.	1984.	983.	268.	114.
1958	100.	97.	88.	83.	85.	78.	171.	1024.	518.	130.	68.	20.
1959	56.	90.	89.	79.	77.	81.	185.	438.	495.	202.	130.	38.
1960	115.	95.	70.	59.	69.	141.	414.	569.	727.	225.	120.	46.
1961	64.	88.	44.	41.	53.	75.	151.	367.	324.	198.	125.	183.
1962	297.	156.	85.	56.	65.	69.	622.	1011.	1270.	881.	123.	58.
1963	65.	52.	51.	37.	61.	74.	170.	186.	218.	143.	134.	72.
1964	57.	55.	45.	50.	52.	49.	147.	441.	286.	169.	103.	45.
1965	41.	53.	57.	62.	62.	62.	258.	677.	882.	420.	282.	88.
1966	107.	101.	92.	73.	70.	114.	165.	248.	184.	160.	91.	36.
1967	62.	64.	59.	54.	56.	93.	222.	373.	519.	459.	131.	66.
1968	77.	85.	62.	59.	65.	72.	146.	334.	461.	218.	151.	71.
1969	74.	56.	56.	57.	64.	57.	225.	639.	990.	407.	125.	69.
1970	93.	80.	61.	67.	71.	67.	208.	1267.	1010.	359.	118.	85.
1971	110.	92.	82.	82.	78.	139.	444.	718.	1250.	788.	175.	100.
1972	82.	68.	57.	52.	69.	123.	202.	390.	493.	236.	139.	95.
1973	90.	80.	66.	62.	69.	74.	149.	695.	1255.	1061.	189.	78.
1974	79.	81.	59.	67.	76.	97.	251.	883.	2174.	334.	166.	80.
1975	80.	83.	64.	62.	73.	77.	161.	414.	456.	454.	162.	73.
1976	66.	65.	58.	58.	66.	68.	157.	253.	252.	209.	135.	70.
1977	73.	70.	43.	45.	55.	56.	138.	176.	216.	183.	104.	60.
1978	67.	71.	74.	67.	67.	82.	258.	480.	711.	339.	134.	68.
1979	72.	69.	67.	72.	75.	72.	198.	564.	901.	362.	144.	61.
1980	66.	66.	66.	69.	69.	67.	181.	718.	914.	351.	131.	68.
1981	60.	63.	56.	45.	50.	61.	99.	168.	265.	186.	102.	48.
1982	59.	64.	59.	61.	65.	85.	142.	411.	492.	469.	185.	98.
1983	87.	80.	75.	74.	82.	72.	134.	591.	1977.	2439.	276.	117.
Min	35.	52.	39.	37.	46.	49.	99.	146.	113.	108.	48.	14.
Max	297.	156.	92.	83.	85.	141.	622.	1267.	2174.	2439.	282.	183.
Sdev	45.	20.	14.	12.	9.	23.	106.	282.	548.	451.	54.	34.

TABLE 10.18

Simulated Preproject Flows in the Colorado River at the Hot Sulphur Springs Gaging Station

(Sum of links 29 and 81 - Management Run 7 with Windy Gap)

(mean monthly cfs)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Avg.	79.	76.	63.	60.	66.	78.	103.	166.	641.	311.	143.	69.
1954	35.	56.	39.	43.	54.	49.	153.	91.	91.	108.	48.	14.
1955	43.	56.	44.	44.	46.	57.	91.	91.	91.	122.	126.	23.
1956	49.	71.	66.	60.	66.	78.	91.	301.	91.	130.	92.	20.
1957	37.	59.	58.	57.	59.	58.	133.	208.	1379.	378.	268.	114.
1958	100.	97.	88.	83.	85.	78.	91.	419.	1195.	130.	68.	20.
1959	56.	90.	89.	79.	77.	81.	105.	91.	91.	91.	130.	38.
1960	115.	95.	70.	59.	69.	141.	91.	91.	122.	91.	120.	46.
1961	64.	88.	44.	41.	53.	75.	151.	91.	91.	198.	125.	183.
1962	297.	156.	85.	56.	65.	69.	91.	786.	2505.	881.	123.	58.
1963	65.	52.	51.	37.	61.	74.	91.	91.	91.	143.	134.	72.
1964	57.	55.	45.	50.	52.	49.	147.	91.	91.	91.	103.	45.
1965	41.	53.	57.	62.	62.	62.	91.	91.	277.	91.	282.	88.
1966	107.	101.	92.	73.	70.	114.	91.	91.	91.	160.	91.	36.
1967	62.	64.	59.	54.	56.	93.	91.	91.	91.	91.	131.	66.
1968	77.	85.	62.	59.	65.	72.	146.	91.	91.	91.	151.	71.
1969	74.	56.	56.	57.	64.	57.	91.	91.	385.	91.	125.	69.
1970	93.	80.	61.	67.	71.	67.	91.	662.	728.	388.	118.	85.
1971	110.	92.	82.	82.	78.	139.	91.	204.	3294.	788.	175.	100.
1972	82.	68.	57.	52.	69.	123.	91.	91.	91.	91.	139.	95.
1973	90.	80.	66.	62.	69.	74.	91.	91.	1243.	1061.	189.	78.
1974	79.	81.	59.	67.	76.	97.	91.	278.	2268.	325.	166.	80.
1975	80.	83.	64.	62.	73.	77.	91.	91.	91.	91.	162.	73.
1976	66.	65.	58.	58.	66.	68.	91.	91.	91.	91.	135.	70.
1977	73.	70.	43.	45.	55.	56.	105.	115.	91.	183.	104.	60.
1978	67.	71.	74.	67.	67.	82.	91.	91.	106.	91.	134.	68.
1979	72.	69.	67.	72.	75.	72.	91.	91.	296.	91.	144.	61.
1980	66.	66.	66.	69.	69.	67.	91.	113.	2106.	292.	131.	68.
1981	60.	63.	56.	45.	50.	61.	99.	91.	91.	91.	102.	48.
1982	59.	64.	59.	61.	65.	85.	142.	91.	91.	91.	185.	98.
1983	87.	80.	75.	74.	82.	72.	91.	91.	1871.	2758.	276.	117.
Min	35.	52.	39.	37.	46.	49.	91.	91.	91.	91.	48.	14.
Max	297.	156.	92.	83.	85.	141.	153.	786.	3294.	2758.	282.	183.
Sdev	45.	20.	14.	12.	9.	23.	22.	169.	890.	517.	54.	34.

TABLE 10.19

Simulated Preproject Flows in the Poudre River at the Canyon Mouth Gaging Station

(Sum of link 20 and Poudre Valley Canal - Management Run 2)

(mean monthly cfs)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Avg.	65.	44.	30.	27.	31.	38.	123.	817.	1643.	726.	257.	104.
1954	56.	33.	33.	32.	28.	25.	50.	416.	578.	247.	61.	96.
1955	81.	28.	17.	20.	17.	20.	33.	358.	1023.	458.	254.	73.
1956	50.	39.	40.	28.	25.	31.	59.	1182.	1469.	398.	189.	54.
1957	33.	20.	26.	21.	24.	23.	118.	577.	2287.	1698.	330.	163.
1958	82.	46.	43.	34.	37.	44.	183.	1506.	1613.	264.	66.	55.
1959	52.	32.	33.	27.	36.	50.	203.	717.	1742.	403.	176.	68.
1960	74.	63.	19.	17.	14.	49.	93.	815.	1626.	453.	106.	71.
1961	49.	29.	25.	37.	30.	46.	133.	1153.	1980.	523.	307.	198.
1962	265.	114.	53.	59.	104.	89.	324.	1128.	1437.	753.	185.	38.
1963	62.	36.	29.	18.	19.	12.	68.	447.	641.	200.	192.	125.
1964	61.	36.	16.	14.	16.	25.	39.	586.	1114.	515.	177.	75.
1965	30.	17.	13.	14.	16.	14.	43.	529.	2195.	1264.	417.	128.
1966	66.	18.	21.	19.	22.	27.	48.	488.	565.	159.	102.	99.
1967	47.	24.	13.	12.	10.	18.	31.	432.	1289.	712.	117.	71.
1968	29.	55.	46.	36.	46.	32.	51.	472.	1744.	670.	332.	114.
1969	42.	36.	27.	19.	19.	27.	106.	831.	1259.	583.	113.	127.
1970	69.	32.	15.	14.	11.	24.	95.	969.	1843.	915.	282.	106.
1971	78.	71.	31.	30.	25.	32.	197.	1020.	2399.	925.	218.	162.
1972	41.	76.	36.	27.	33.	36.	67.	589.	1459.	415.	85.	106.
1973	64.	44.	26.	24.	26.	34.	59.	1464.	2089.	1073.	375.	64.
1974	85.	110.	51.	39.	53.	93.	123.	1291.	1829.	605.	108.	79.
1975	78.	46.	23.	13.	13.	19.	36.	308.	1470.	1292.	282.	101.
1976	53.	29.	27.	25.	26.	25.	39.	454.	1101.	447.	311.	60.
1977	76.	27.	16.	15.	15.	22.	50.	205.	663.	172.	232.	63.
1978	40.	38.	27.	23.	23.	27.	66.	595.	2165.	1082.	322.	99.
1979	47.	30.	21.	19.	17.	24.	87.	843.	2085.	973.	566.	149.
1980	54.	31.	43.	91.	79.	150.	554.	2597.	2409.	678.	276.	105.
1981	84.	73.	51.	29.	20.	21.	76.	369.	940.	341.	202.	98.
1982	35.	26.	25.	20.	54.	20.	33.	377.	1482.	1316.	620.	164.
1983	72.	46.	56.	45.	71.	96.	619.	1778.	4801.	2239.	714.	211.
Min	29.	17.	13.	12.	10.	12.	31.	205.	565.	159.	61.	38.
Max	265.	114.	56.	91.	104.	150.	619.	2597.	4801.	2239.	714.	211.
Sdev	41.	24.	12.	16.	21.	30.	140.	515.	793.	474.	157.	43.

To calculate preproject flows in any segment of the Poudre River below the proposed damsites, historic flow data, historic diversion data, and calculated return flow data are provided in Appendix Q.1. The historic data provided in Appendix Q.1 includes:

Diversion	Location from Poudre Canyon Gage
Poudre Valley Canal	0.46 miles upstream
Greeley Intake	0.47 miles downstream
Pleasant Valley and Lake Canal	1.25 miles downstream
Larimer County Canal	2.34 miles downstream
Jackson Ditch	4.51 miles downstream
New Mercer Ditch	5.66 miles downstream
Larimer County Canal No.2	5.66 miles downstream
Little Cache la Poudre Ditch	5.66 miles downstream
Taylor & Gill Ditch	5.66 miles downstream
Arthur Ditch	7.95 miles downstream
Larimer & Weld Canal	8.29 miles downstream

Historic deliveries to the Cache la Poudre River from the Hansen Supply Canal (0.97 miles downstream of the Poudre Canyon gage) are also provided in Appendix Q.1 along with calculated return flows (mean monthly cfs) (+ gains, - losses) in cfs per mile. Calculated return flows are for the upper segment of the river between the mouth of the Poudre Canyon and the USGS gaging station in Fort Collins (11.2 miles downstream of the gaging station).

10.8 POSTPROJECT HYDROLOGY

For the purposes of estimating the safe yield from the proposed mainstem reservoir and establishing maximum and minimum bounds for postproject flows, the most conservative of the future conditions identified during the sensitivity studies, as related to water availability, were adopted. Consequently, all of the postproject simulations were performed for conditions associated with run 8. As summarized in Tables 10.3, 10.4, and 10.5, the conditions associated with run 8 include the assumption that all but the most speculative conditional water rights in the Colorado River

Basin, senior to the Windy Gap Project, will be developed in the future. This assumption combined with the assumed full utilization of the Windy Gap Project served to limit the amount of additional water which could be available for diversion from the Colorado River Basin for use through the proposed mainstem reservoir. As a result, the safe yield and minimum/maximum bounds for postproject flows may have been somewhat underestimated.

During the Basin Study Extension, no attempts were made to develop a prescribed operating criteria for the proposed mainstem reservoir. Such efforts would have been premature since negotiations have not been completed with the natural resource agencies responsible for management of streamflow-related resources. However, to provide a basis for bounding the potential effects from constructing and operating the mainstem reservoir, as well as to provide for a preliminary design of a conventional hydroelectric power plant utilizing releases from the mainstem reservoir, postproject simulations were performed for a maximum bounding release scenario and a minimum bounding release scenario. As described in Section 10.4.3.3, the maximum bounding release scenario was based on the assumption that releases from the mainstem reservoir to meet the assumed municipal demand were made to the Poudre River for subsequent diversion at an undetermined downstream location. The minimum bounding scenario was based on the assumption that releases from the mainstem reservoir to the assumed municipal demand were made to a pipeline which transported the water to be used to an undetermined location out of the Poudre River Basin.

To facilitate evaluations of safe yield for changes in assumed conditions for the mainstem reservoir, involving the initial volume of water in storage and the storage capacity allocated for flood control, Hydro-Triad developed a simple yield model which used mass balance accounting to determine safe yield. Inputs to the reservoir mass balance yield model were the pumped flows resulting from additional diversions from the C-BT and Windy Gap Projects (link 76), the unregulated storable flows available from the Poudre River (POUDRES at node 54), and the storage parameters assumed for the reservoir. The model was used to provide preliminary estimates of safe yield resulting from management simulations. However, the final estimates of safe yield were verified by performing additional MODSIM simulations in which the municipal demand in the network model (MUNI.DEM at node 19) was set equal to a particular safe yield estimate, and the results were checked to confirm that no shortages occurred for that demand.

10.8.1 Grey Mountain Alternative

The Grey Mountain Damsite is located approximately 2 miles downstream of the confluence of the Poudre River with its North Fork. The mainstem reservoir formed by constructing the Grey Mountain Dam would have a total storage capacity of 195,000 acre-feet. The data files used to perform postproject simulations for the mainstem reservoir formed by the Grey Mountain Dam are included in Appendixes M and N. The file STRUCTIN.8GM-F contains the model configuration, storage rule curves, demand identification, and physical constraints. The file STRUCTGN.8-F lists all the unregulated inflow and demand files used, as provided in Appendixes O and P, respectively, and the evaporation data files that were used, as provided in Appendix L.

Postproject simulations for the Grey Mountain alternative were performed assuming that the initial storage in the mainstem reservoir was 150,000 acre-feet (77 percent full as described in Section 10.4.3.4) and that none of the storage was allocated for flood control purposes. The safe yield for these conditions was 41,000 acre-feet, as shown in the following Table.

TABLE 10.20

Safe Yield versus Initial Storage and Flood Control Storage
Grey Mountain Alternative

(all values in 1000's of acre-feet)

INITIAL STORAGE	CONSERVATION STORAGE 195	180	160	150	140	120
195	46	--	--	--	--	--
180	46	44	--	--	--	--
160	44	44	41	--	--	--
150	41	41	41	40	--	--
140	39	39	39	39	39	--
120	33	33	33	33	33	33
FLOOD CONTROL STORAGE	0	15	35	45	55	75

This table also lists the safe yield estimate obtained from the yield model for other assumptions regarding the initial volume of water in storage at the beginning of the simulation and the amount of storage allocated for flood control. The results clearly show that the safe (or zero-shortage) yield is very sensitive to the volume of water initially assumed in storage. The sensitivity to initial storage occurred because the first few years of the simulation period were relatively dry, as shown in Table 10.8. This made the municipal demand which could be met from the mainstem reservoir highly dependent on initial storage, as shown by the end-of-month storage elevations for Grey Mountain Reservoir provided in Table 10.21. As shown by the results in Table 10.20, the firm yield is fairly insensitive to the amount of flood control storage allocated. However, future hydrology simulations for the proposed mainstem reservoir should include a more extensive hydrologic data base, and the tradeoffs between safe yield and storage allocated for flood control should be re-examined.

A separate postproject simulation for the Grey Mountain alternative using the MODSIM model was performed to determine the incremental contribution to safe yield due to additional diversions from the C-BT and Windy Gap Projects. This was accomplished by setting the capacity of the pump link between the C-BT Project facilities and the mainstem reservoir (link 76) to zero. This simulation resulted in a safe yield of 31,000 acre-feet from the Poudre River Basin only. Therefore, approximately 10,000 acre-feet of safe yield is contributed from additional diversions from the C-BT and Windy Gap Projects. The hydrologic simulations performed as part of the original Basin Study (Harza, 1987) included an estimated 24,000 acre-feet contributed to safe yield from additional diversions from the C-BT and Windy Gap Projects. The lower value of incremental safe yield indicated from MODSIM simulations resulted from correlations between the occurrences of low and high flow periods in the Colorado and Poudre River Basins. Consequently, there were relatively small contributions to storage in the mainstem reservoir from West Slope diversions when the diversions were the most needed to increase safe yield because of dry conditions in the Poudre Basin.

To ensure that the estimated safe yield for the study period was not overestimated because of withdrawals from reservoir storage at the end of the study period, leaving reservoir storage depleted as compared with storage at the beginning of the study period, simulated end-of-month reservoir water surface elevations were checked and compared. Simulated end-of-month reservoir water surface elevations for the Grey Mountain alternative, assuming that the initial reservoir storage was 150,000 acre-feet (77 percent full) and no flood control space was allocated, are listed in Table 10.21. As shown, the ending reservoir water surface elevation in the Grey Mountain Reservoir was simulated to be El 5626. This corresponds to an ending storage volume of approximately 189,000 acre-feet, or 97 percent full. However, the ending year of the study period, water year 1983, was abnormally wet, and storage was expected to end high. The simulated ending storage levels at all the other reservoirs included in the MODSIM model were similarly high at the end of water year 1983.

To provide a basis for defining operating criteria for the proposed mainstem reservoir in the future, postproject simulations were used to

TABLE 10.21

Simulated End-of-Month Reservoir Water Surface Elevations
Grey Mountain Alternative

(elevations in feet)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Avg.	5575.	5574.	5574.	5575.	5578.	5582.	5586.	5588.	5596.	5590.	5584.	5579.
1954	5596.	5595.	5595.	5594.	5593.	5592.	5590.	5588.	5582.	5575.	5568.	5563.
1955	5561.	5559.	5559.	5558.	5557.	5555.	5553.	5549.	5542.	5533.	5524.	5517.
1956	5513.	5511.	5510.	5509.	5507.	5505.	5502.	5499.	5489.	5474.	5458.	5446.
1957	5438.	5434.	5432.	5429.	5425.	5421.	5413.	5411.	5485.	5469.	5452.	5438.
1958	5430.	5426.	5423.	5425.	5483.	5522.	5555.	5619.	5623.	5617.	5612.	5608.
1959	5606.	5605.	5604.	5604.	5603.	5602.	5604.	5609.	5606.	5600.	5594.	5590.
1960	5587.	5586.	5586.	5585.	5584.	5583.	5600.	5605.	5600.	5593.	5587.	5583.
1961	5581.	5579.	5579.	5578.	5577.	5589.	5607.	5629.	5629.	5624.	5618.	5615.
1962	5618.	5621.	5627.	5629.	5629.	5629.	5629.	5627.	5629.	5624.	5618.	5615.
1963	5613.	5612.	5611.	5611.	5610.	5609.	5607.	5605.	5600.	5593.	5587.	5583.
1964	5580.	5579.	5579.	5578.	5577.	5576.	5574.	5571.	5565.	5557.	5549.	5544.
1965	5540.	5539.	5538.	5537.	5536.	5534.	5532.	5527.	5586.	5579.	5572.	5568.
1966	5565.	5564.	5563.	5562.	5570.	5590.	5607.	5604.	5600.	5593.	5587.	5583.
1967	5580.	5579.	5579.	5578.	5577.	5576.	5574.	5571.	5585.	5584.	5578.	5573.
1968	5571.	5570.	5569.	5568.	5567.	5566.	5564.	5560.	5561.	5553.	5545.	5539.
1969	5536.	5534.	5533.	5533.	5531.	5530.	5527.	5522.	5533.	5523.	5513.	5506.
1970	5502.	5500.	5499.	5498.	5496.	5524.	5550.	5560.	5590.	5583.	5576.	5572.
1971	5569.	5568.	5567.	5583.	5602.	5619.	5629.	5629.	5629.	5627.	5622.	5619.
1972	5617.	5616.	5615.	5615.	5614.	5614.	5628.	5626.	5629.	5624.	5618.	5615.
1973	5613.	5612.	5611.	5611.	5610.	5625.	5629.	5629.	5629.	5626.	5621.	5617.
1974	5617.	5619.	5618.	5629.	5629.	5629.	5629.	5628.	5629.	5624.	5618.	5615.
1975	5613.	5612.	5611.	5611.	5610.	5609.	5613.	5613.	5625.	5621.	5616.	5612.
1976	5610.	5609.	5609.	5608.	5613.	5629.	5629.	5628.	5624.	5618.	5612.	5609.
1977	5606.	5606.	5605.	5604.	5603.	5603.	5601.	5598.	5593.	5586.	5580.	5576.
1978	5573.	5572.	5571.	5571.	5569.	5568.	5566.	5563.	5589.	5582.	5575.	5571.
1979	5568.	5567.	5566.	5566.	5565.	5563.	5561.	5587.	5629.	5624.	5619.	5615.
1980	5613.	5613.	5623.	5629.	5629.	5629.	5629.	5629.	5629.	5624.	5618.	5615.
1981	5613.	5612.	5611.	5612.	5628.	5629.	5629.	5629.	5629.	5624.	5618.	5615.
1982	5613.	5612.	5611.	5611.	5610.	5609.	5607.	5606.	5622.	5629.	5624.	5623.
1983	5621.	5620.	5628.	5629.	5629.	5629.	5629.	5629.	5629.	5629.	5629.	5626.
Min	5430.	5426.	5423.	5425.	5425.	5421.	5413.	5411.	5485.	5469.	5452.	5438.
Max	5621.	5621.	5628.	5629.	5629.	5629.	5629.	5629.	5629.	5629.	5629.	5626.
Sdev	49.	50.	51.	52.	49.	47.	48.	49.	40.	43.	46.	48.

estimate postproject flows in the Colorado River and to establish maximum and minimum bounds for postproject flows in the Lower Poudre River. Assuming maximum diversions from the C-BT and Windy Gap Projects, simulated postproject flows (mean monthly cfs) in the Colorado River at the USGS gaging station at Hot Sulphur Springs for the Grey Mountain alternative are shown in Table 10.22. A comparison of these flows with those for the preproject scenario in Table 10.18 showed that the mainstem reservoir (Grey Mountain alternative) decreased the flows at the Hot Sulphur Springs gaging station by an average of 365 cfs during the peak flow month of June and by an average of 4 cfs during the low flow month of January. The preproject flows were determined based on the existing level of water resource development on the West Slope. However, postproject flows were determined assuming that full development of West Slope water rights senior to Windy Gap diversions would occur, as described in Section 10.4.2.5. As a result, simulated postproject flows for the proposed mainstem reservoir include any cumulative depletions from other future projects utilizing West Slope water rights above the Hot Sulphur Springs gaging station.

Simulated postproject flows in the Lower Poudre River were computed for a maximum bounding scenario and a minimum bounding scenario, depending on whether releases from the reservoir to meet the assumed municipal demand (MUNI.DEM at node 19) were assumed to be made to the river (maximum) or through a pipeline (minimum). The simulated minimum and maximum bounds of postproject flows (mean monthly cfs) immediately below the proposed Grey Mountain Reservoir on the mainstem of the Poudre River are displayed in Tables 10.23 and 10.24, respectively. The simulated minimum and maximum bounds of postproject flows for the proposed Grey Mountain alternative at the USGS gaging station located at the mouth of the Poudre Canyon are displayed in Tables 10.25 and 10.26, respectively. The differences in the flows between those immediately below the proposed reservoir and those at the USGS gaging station at the Canyon mouth are the diversions to the Poudre Valley Canal.

The simulated postproject minimum and maximum bounding flows in Tables 10.23 and 10.24 can be used directly for preliminary sizing of a conventional hydroelectric power plant below the mainstem reservoir. Adjustments to the

TABLE 10.22

Simulated Postproject Flows in the Colorado River at the Hot Sulphur Springs Gaging Station Grey Mountain Alternative

(sum of links 29 and 81 - Management Run 8)

(mean monthly cfs)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Avg.	69.	69.	59.	56.	63.	76.	120.	142.	276.	195.	119.	55.
1954	25.	49.	35.	39.	51.	46.	148.	91.	113.	108.	48.	14.
1955	34.	50.	39.	40.	43.	54.	91.	91.	91.	112.	102.	15.
1956	39.	65.	62.	57.	63.	75.	91.	265.	91.	130.	67.	20.
1957	27.	53.	54.	53.	56.	55.	173.	172.	1290.	328.	244.	99.
1958	90.	90.	83.	80.	82.	75.	166.	383.	91.	130.	60.	20.
1959	50.	88.	89.	79.	77.	81.	184.	91.	91.	91.	104.	24.
1960	100.	89.	67.	56.	66.	139.	91.	91.	91.	91.	100.	34.
1961	59.	86.	41.	38.	50.	73.	148.	91.	91.	158.	101.	160.
1962	294.	156.	85.	54.	62.	65.	91.	348.	91.	585.	93.	42.
1963	53.	44.	46.	33.	57.	71.	91.	91.	91.	129.	114.	51.
1964	46.	47.	40.	45.	48.	45.	143.	91.	91.	122.	83.	35.
1965	33.	46.	51.	57.	58.	59.	129.	91.	157.	91.	255.	67.
1966	105.	97.	89.	70.	70.	112.	91.	91.	91.	128.	76.	25.
1967	53.	57.	54.	49.	52.	89.	116.	91.	91.	91.	111.	55.
1968	69.	77.	57.	55.	62.	69.	141.	91.	91.	91.	126.	57.
1969	63.	46.	48.	51.	58.	52.	91.	91.	381.	91.	96.	54.
1970	79.	68.	52.	60.	65.	62.	203.	660.	357.	91.	89.	73.
1971	99.	81.	75.	77.	74.	136.	91.	106.	233.	91.	152.	86.
1972	72.	60.	52.	50.	67.	121.	91.	91.	91.	91.	126.	85.
1973	82.	73.	61.	59.	66.	72.	91.	91.	355.	237.	169.	69.
1974	71.	77.	56.	64.	74.	95.	91.	197.	1817.	268.	144.	69.
1975	72.	78.	60.	60.	71.	75.	91.	91.	91.	91.	137.	60.
1976	54.	56.	54.	55.	64.	65.	91.	91.	91.	91.	112.	54.
1977	56.	64.	39.	43.	53.	55.	132.	125.	91.	158.	90.	53.
1978	58.	65.	69.	64.	64.	79.	179.	91.	91.	91.	107.	56.
1979	64.	66.	65.	70.	73.	70.	91.	91.	229.	91.	114.	45.
1980	54.	62.	62.	66.	67.	65.	91.	99.	265.	215.	107.	54.
1981	56.	59.	53.	43.	48.	60.	91.	91.	91.	149.	90.	33.
1982	53.	59.	55.	58.	63.	83.	139.	91.	91.	91.	142.	69.
1983	68.	72.	69.	69.	78.	69.	131.	91.	1371.	1623.	221.	85.
Min	25.	44.	35.	33.	43.	45.	91.	91.	91.	91.	48.	14.
Max	294.	156.	89.	80.	82.	139.	203.	660.	1817.	1623.	255.	160.
Sdev	46.	22.	14.	12.	10.	23.	35.	122.	421.	283.	48.	29.

TABLE 10.23

Simulated Minimum Postproject Flows Immediately Below Proposed Grey Mountain Reservoir

(mean monthly cfs)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Avg.	72.	39.	29.	26.	30.	37.	112.	771.	1485.	707.	254.	110.
1954	58.	47.	33.	32.	28.	25.	49.	414.	574.	245.	61.	96.
1955	81.	32.	17.	20.	16.	20.	33.	356.	1029.	455.	252.	73.
1956	50.	42.	40.	28.	25.	31.	58.	1189.	1628.	402.	191.	54.
1957	36.	20.	26.	21.	24.	23.	118.	521.	1682.	1717.	331.	164.
1958	82.	45.	43.	34.	37.	43.	48.	452.	1403.	265.	68.	54.
1959	56.	31.	33.	27.	36.	50.	105.	632.	1735.	407.	177.	70.
1960	78.	63.	19.	17.	14.	49.	100.	849.	1744.	457.	106.	73.
1961	56.	29.	25.	37.	30.	46.	102.	884.	2048.	524.	305.	206.
1962	131.	37.	36.	34.	80.	69.	284.	1114.	1272.	766.	186.	40.
1963	66.	35.	29.	18.	19.	12.	68.	446.	717.	200.	192.	125.
1964	62.	36.	16.	14.	15.	25.	39.	588.	1123.	514.	177.	75.
1965	30.	17.	13.	14.	16.	14.	44.	532.	1052.	1264.	418.	129.
1966	65.	18.	21.	19.	22.	27.	47.	494.	575.	170.	103.	99.
1967	55.	24.	13.	12.	10.	18.	31.	504.	1196.	703.	117.	97.
1968	145.	55.	46.	36.	46.	32.	53.	477.	1886.	669.	331.	113.
1969	46.	36.	27.	19.	19.	27.	106.	1098.	1115.	583.	113.	129.
1970	69.	32.	14.	14.	11.	23.	126.	996.	1371.	921.	283.	107.
1971	78.	71.	30.	30.	24.	32.	126.	959.	2359.	825.	221.	167.
1972	77.	76.	35.	27.	33.	35.	67.	596.	1470.	416.	84.	105.
1973	63.	44.	26.	24.	26.	33.	75.	1435.	2012.	1018.	379.	91.
1974	55.	38.	43.	36.	38.	74.	119.	1265.	1728.	606.	109.	83.
1975	114.	46.	22.	13.	13.	19.	35.	339.	1117.	1236.	289.	100.
1976	53.	29.	27.	25.	25.	25.	39.	470.	1110.	449.	309.	59.
1977	112.	27.	16.	15.	15.	22.	50.	210.	667.	171.	230.	63.
1978	40.	37.	27.	23.	23.	32.	66.	787.	1705.	1084.	325.	98.
1979	46.	30.	21.	19.	17.	24.	187.	519.	1111.	963.	567.	152.
1980	57.	30.	43.	90.	79.	129.	513.	2537.	2302.	674.	282.	109.
1981	85.	73.	50.	29.	20.	21.	75.	378.	911.	344.	200.	97.
1982	38.	26.	25.	20.	54.	19.	33.	378.	1153.	1033.	618.	241.
1983	174.	47.	56.	45.	70.	96.	578.	1717.	4761.	2114.	596.	223.
Min	30.	17.	13.	12.	10.	12.	31.	210.	574.	170.	61.	40.
Max	174.	76.	56.	90.	80.	129.	578.	2537.	4761.	2114.	618.	241.
Sdev	33.	15.	11.	14.	19.	25.	127.	487.	770.	447.	147.	49.

TABLE 10.24

Simulated Maximum Postproject Flows Immediately Below Proposed Grey Mountain Reservoir

(mean monthly cfs)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Avg.	112.	73.	62.	59.	60.	64.	153.	824.	1581.	827.	354.	179.
1954	98.	81.	66.	65.	58.	52.	90.	467.	670.	365.	161.	165.
1955	121.	66.	50.	53.	46.	47.	74.	409.	1125.	575.	352.	142.
1956	90.	76.	73.	61.	55.	58.	99.	1242.	1724.	522.	291.	123.
1957	76.	54.	59.	54.	54.	50.	159.	574.	1778.	1837.	431.	233.
1958	122.	79.	76.	67.	67.	70.	89.	505.	1499.	385.	168.	123.
1959	96.	65.	66.	60.	66.	77.	146.	685.	1831.	527.	277.	139.
1960	118.	97.	52.	50.	44.	76.	141.	902.	1840.	577.	206.	142.
1961	96.	63.	58.	70.	60.	73.	143.	937.	2144.	644.	405.	275.
1962	171.	71.	69.	67.	110.	96.	325.	1167.	1368.	886.	286.	109.
1963	106.	69.	62.	51.	49.	39.	109.	499.	813.	320.	292.	194.
1964	102.	70.	49.	47.	45.	52.	80.	641.	1219.	634.	277.	144.
1965	70.	51.	46.	47.	46.	41.	85.	585.	1148.	1384.	518.	198.
1966	105.	52.	54.	52.	52.	54.	88.	547.	671.	290.	203.	168.
1967	95.	58.	46.	45.	40.	45.	72.	557.	1292.	823.	217.	166.
1968	185.	89.	79.	69.	76.	59.	94.	530.	1982.	789.	431.	182.
1969	86.	70.	60.	52.	49.	54.	147.	1151.	1211.	703.	213.	198.
1970	109.	66.	47.	47.	41.	50.	167.	1049.	1467.	1041.	383.	176.
1971	118.	105.	63.	63.	54.	59.	167.	1012.	2455.	945.	321.	236.
1972	117.	110.	68.	60.	63.	62.	108.	649.	1566.	536.	184.	174.
1973	103.	78.	59.	57.	56.	60.	116.	1488.	2108.	1138.	479.	160.
1974	95.	72.	76.	69.	68.	101.	160.	1318.	1824.	726.	209.	152.
1975	154.	80.	55.	46.	43.	46.	76.	392.	1213.	1356.	389.	169.
1976	93.	63.	60.	58.	55.	52.	80.	523.	1206.	569.	409.	128.
1977	152.	61.	49.	48.	45.	49.	91.	263.	763.	291.	330.	132.
1978	80.	71.	60.	56.	53.	59.	107.	840.	1801.	1204.	425.	167.
1979	86.	64.	54.	52.	47.	51.	228.	572.	1207.	1083.	667.	221.
1980	97.	64.	76.	123.	109.	156.	554.	2590.	2398.	794.	382.	178.
1981	125.	107.	83.	62.	50.	48.	116.	431.	1007.	464.	300.	166.
1982	78.	60.	58.	53.	84.	46.	74.	431.	1249.	1153.	718.	310.
1983	214.	81.	89.	78.	100.	123.	619.	1770.	4857.	2234.	696.	292.
Min	70.	51.	46.	45.	40.	39.	72.	263.	670.	290.	161.	109.
Max	214.	110.	89.	123.	110.	156.	619.	2590.	4857.	2234.	718.	310.
Sdev	33.	15.	11.	14.	19.	25.	127.	487.	770.	447.	147.	49.

TABLE 10.25

Simulated Minimum Postproject Flows at USGS Poudre Canyon Gauge
Grey Mountain Alternative

(mean monthly cfs)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Avg.	59.	38.	29.	26.	30.	36.	107.	725.	1393.	693.	251.	103.
1954	55.	33.	33.	32.	28.	25.	49.	414.	574.	245.	61.	96.
1955	81.	28.	17.	20.	16.	20.	33.	356.	1016.	455.	252.	73.
1956	50.	39.	40.	28.	25.	31.	58.	1147.	1448.	396.	188.	54.
1957	33.	20.	26.	21.	24.	23.	118.	521.	1668.	1687.	328.	162.
1958	81.	45.	43.	34.	37.	43.	48.	452.	1393.	262.	66.	54.
1959	51.	31.	33.	27.	36.	50.	105.	579.	1702.	400.	175.	68.
1960	73.	63.	19.	17.	14.	49.	93.	810.	1613.	450.	105.	71.
1961	49.	29.	25.	37.	30.	46.	102.	633.	1859.	520.	305.	196.
1962	120.	37.	36.	34.	80.	69.	282.	1106.	1270.	748.	184.	37.
1963	62.	35.	29.	18.	19.	12.	67.	444.	635.	199.	190.	124.
1964	60.	36.	16.	14.	15.	25.	39.	582.	1106.	512.	176.	75.
1965	30.	17.	13.	14.	16.	14.	43.	526.	1045.	1256.	415.	127.
1966	65.	18.	21.	19.	22.	27.	47.	485.	561.	158.	102.	99.
1967	46.	24.	13.	12.	10.	18.	31.	428.	872.	581.	116.	70.
1968	27.	55.	46.	36.	46.	32.	50.	470.	1609.	666.	330.	113.
1969	42.	36.	27.	19.	19.	27.	106.	822.	984.	580.	112.	126.
1970	68.	32.	14.	14.	11.	23.	94.	952.	1215.	910.	280.	105.
1971	78.	71.	30.	30.	24.	32.	126.	959.	2273.	820.	217.	161.
1972	40.	76.	35.	27.	33.	35.	67.	586.	1263.	413.	84.	105.
1973	63.	44.	26.	24.	26.	33.	58.	1400.	1965.	998.	372.	63.
1974	54.	38.	43.	36.	38.	74.	119.	1240.	1688.	601.	107.	79.
1975	77.	46.	22.	13.	13.	19.	35.	306.	1046.	1226.	281.	100.
1976	53.	29.	27.	25.	25.	25.	39.	451.	1093.	445.	309.	59.
1977	75.	27.	16.	15.	15.	22.	50.	204.	658.	171.	230.	63.
1978	40.	37.	27.	23.	23.	26.	66.	588.	1517.	1075.	320.	98.
1979	46.	30.	21.	19.	17.	24.	84.	287.	935.	950.	563.	147.
1980	54.	30.	43.	90.	79.	129.	513.	2537.	2285.	674.	274.	104.
1981	83.	73.	50.	29.	20.	21.	75.	367.	819.	339.	200.	97.
1982	35.	26.	25.	20.	54.	19.	33.	375.	979.	968.	616.	161.
1983	70.	46.	56.	45.	70.	96.	578.	1717.	4687.	2087.	577.	210.
Min	27.	17.	13.	12.	10.	12.	31.	204.	561.	158.	61.	37.
Max	120.	76.	56.	90.	80.	129.	578.	2537.	4687.	2087.	616.	210.
Sdev	20.	15.	11.	14.	19.	25.	127.	489.	766.	440.	145.	42.

TABLE 10.26

Simulated Maximum Postproject Flows at USGS Poudre Canyon Gauge
Grey Mountain Alternative

(mean monthly cfs)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Avg.	99.	72.	62.	59.	60.	63.	148.	778.	1489.	813.	351.	172.
1954	95.	67.	66.	65.	58.	52.	90.	467.	670.	365.	161.	165.
1955	121.	62.	50.	53.	46.	47.	74.	409.	1112.	575.	352.	142.
1956	90.	73.	73.	61.	55.	58.	99.	1200.	1544.	516.	288.	123.
1957	73.	54.	59.	54.	54.	50.	159.	574.	1764.	1807.	428.	231.
1958	121.	79.	76.	67.	67.	70.	89.	505.	1489.	382.	166.	123.
1959	91.	65.	66.	60.	66.	77.	146.	632.	1798.	520.	275.	137.
1960	113.	97.	52.	50.	44.	76.	134.	863.	1709.	570.	205.	140.
1961	89.	63.	58.	70.	60.	73.	143.	686.	1955.	640.	405.	265.
1962	160.	71.	69.	67.	110.	96.	323.	1159.	1366.	868.	284.	106.
1963	102.	69.	62.	51.	49.	39.	108.	497.	731.	319.	290.	193.
1964	100.	70.	49.	47.	45.	52.	80.	635.	1202.	632.	276.	144.
1965	70.	51.	46.	47.	46.	41.	84.	579.	1141.	1376.	515.	196.
1966	105.	52.	54.	52.	52.	54.	88.	538.	657.	278.	202.	168.
1967	86.	58.	46.	45.	40.	45.	72.	481.	968.	701.	216.	139.
1968	67.	89.	79.	69.	76.	59.	91.	523.	1705.	786.	430.	182.
1969	82.	70.	60.	52.	49.	54.	147.	875.	1080.	700.	212.	195.
1970	108.	66.	47.	47.	41.	50.	135.	1005.	1311.	1030.	380.	174.
1971	118.	105.	63.	63.	54.	59.	167.	1012.	2369.	940.	317.	230.
1972	80.	110.	68.	60.	63.	62.	108.	639.	1359.	533.	184.	174.
1973	103.	78.	59.	57.	56.	60.	99.	1453.	2061.	1118.	472.	132.
1974	94.	72.	76.	69.	68.	101.	160.	1293.	1784.	721.	207.	148.
1975	117.	80.	55.	46.	43.	46.	76.	359.	1142.	1346.	381.	169.
1976	93.	63.	60.	58.	55.	52.	80.	504.	1189.	565.	409.	128.
1977	115.	61.	49.	48.	45.	49.	91.	257.	754.	291.	330.	132.
1978	80.	71.	60.	56.	53.	53.	107.	641.	1613.	1195.	420.	167.
1979	86.	64.	54.	52.	47.	51.	125.	340.	1031.	1070.	663.	216.
1980	94.	64.	76.	123.	109.	156.	554.	2590.	2381.	794.	374.	173.
1981	123.	107.	83.	62.	50.	48.	116.	420.	915.	459.	300.	166.
1982	75.	60.	58.	53.	84.	46.	74.	428.	1075.	1088.	716.	230.
1983	110.	80.	89.	78.	100.	123.	619.	1770.	4783.	2207.	677.	279.
Min	67.	51.	46.	45.	40.	39.	72.	257.	657.	278.	161.	106.
Max	160.	110.	89.	123.	110.	156.	619.	2590.	4783.	2207.	716.	279.
Sdev	20.	15.	11.	14.	19.	25.	127.	489.	766.	440.	145.	42.

pattern of the assumed municipal demand from the mainstem reservoir might be possible to maximize power production, if releases for the municipal demand are made to the Poudre River instead of a pipeline. However, such optimization studies were not considered during the Basin Study Extension given the preliminary formulation of the proposed project.

Selected results at other points in the MODSIM model for postproject conditions associated with the Grey Mountain alternative are provided in Appendix R. Included in Appendix R are simulated flows at various locations in the Lower Poudre River, simulated flows in the Colorado River Basin, and resultant end-of-month storage levels in the major C-BT reservoirs.

10.8.2 Poudre Alternative

The Poudre Damsite is located just downstream of the confluence of the Poudre River with its North Fork. The mainstem reservoir formed by constructing the Poudre Dam would have a total storage capacity of 108,590 acre-feet. The data files used to perform postproject simulations for the mainstem reservoir formed by the Poudre Dam are included in Appendixes M and N. The file STRUCTIN.8P-F contains the model configuration, storage rule curves, demand identification, and physical constraints. The file STRUCTGN.8-F is the same as for the Grey Mountain alternative and lists all the unregulated inflow, demand, and evaporation data files used, which are provided in Appendixes O, P and L, respectively.

Postproject simulations for the Poudre alternative were performed assuming that the initial storage in the mainstem reservoir was 83,530 acre-feet (77 percent full as described in Section 10.4.3.4) and that none of the storage was allocated for flood control purposes. The safe yield for these conditions was 23,000 acre-feet, as shown in the following Table.

TABLE 10.27

Safe Yield versus Initial Storage and Flood Control Storage
Poudre Alternative

(all values in 1000's of acre-feet)

INITIAL STORAGE	CONSERVATION STORAGE 110	105	95	85	75	65
110	31	--	--	--	--	--
105	30	30	--	--	--	--
95	27	27	27	--	--	--
85	23	23	23	23	--	--
75	21	21	21	21	21	--
65	18	18	18	18	18	18
FLOOD CONTROL STORAGE	0	5	15	25	35	45

This table also lists the safe yield estimates obtained from the yield model for other assumptions regarding the initial volume of water in storage at the beginning of the simulation and the amount of storage allocated for flood control. As for the Grey Mountain alternative, the safe yield is very sensitive to the volume of water initially assumed in storage because of the relatively dry years at the beginning of the simulation period.

The mainstem reservoir formed by the Poudre Dam alternative did not receive any contribution to its safe yield due to additional diversions from the C-BT and Windy Gap Projects. A MODSIM simulation with only the native flows from the Poudre River Basin available showed that the safe yield of the mainstem reservoir for the Poudre alternative was 23,000 acre-feet, which equaled the safe yield when additional diversions from the C-BT and Windy Gap Projects were made available. The Poudre alternative was impeded in achieving a higher safe yield because of its smaller storage volume as compared with the Grey Mountain alternative. This was compounded by the relatively dry years at the beginning of the simulation period which caused initial storage to be used before significant storable native flows occurred or any contributions from C-BT or Windy Gap diversions were realized.

To check that the estimated safe yield for the study period was not overestimated because of large withdrawals from reservoir storage at the end of the study period, the ending reservoir storage volumes at existing reservoirs and the proposed mainstem reservoir were reviewed. Simulated end-of-month reservoir water surface elevations for the Poudre alternative, assuming that the initial reservoir storage was 83,530 acre-feet (77 percent full) and no flood control space was allocated, are listed in Table 10.28. As shown, the ending reservoir water surface elevation in the Poudre Reservoir was El 5597. This corresponds to an ending storage volume of approximately 106,000 acre-feet, or 97 percent full. However, the study period ended following an unusually wet year, and reservoir storage was expected to end high.

As for the Grey Mountain alternative, postproject simulations for the Poudre alternative were used to estimated postproject flows in the Colorado River and to establish maximum and minimum bounds for postproject flows in the Lower Poudre River. Assuming maximum diversions from the C-BT and Windy Gap Projects, simulated postproject flows (mean monthly cfs) in the Colorado River at the USGS gaging station at Hot Sulphur Springs for the Poudre alternative are shown in Table 10.29. A comparison of these flows with those for the preproject scenario in Table 10.18 showed that the mainstem reservoir (Poudre alternative) decreased the flows at the Hot Sulphur Springs gaging station by an average of 305 cfs during the peak flow month of June and by an average of 6 cfs during the low flow month of January. These changes are comparable to the changes in flow predicted for the Grey Mountain alternative.

Simulated postproject flows in the Lower Poudre River were computed for a maximum bounding scenario and a minimum bounding scenario, depending on whether releases from the reservoir to meet the assumed municipal demand were made to the Poudre River (maximum) or through a pipeline (minimum). The

TABLE 10.28

Simulated End-of-Month Reservoir Water Surface Elevations
Poudre Alternative

(elevations in feet above dead storage)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept
Avg.	5569.	5568.	5568.	5569.	5571.	5574.	5576.	5576.	5584.	5579.	5575.	5571.
1954	5574.	5573.	5573.	5572.	5571.	5571.	5569.	5567.	5562.	5556.	5551.	5547.
1955	5545.	5544.	5543.	5542.	5541.	5540.	5538.	5535.	5530.	5522.	5515.	5509.
1956	5506.	5505.	5504.	5503.	5501.	5500.	5497.	5496.	5489.	5477.	5464.	5455.
1957	5448.	5446.	5444.	5442.	5439.	5435.	5429.	5434.	5519.	5511.	5502.	5496.
1958	5493.	5491.	5490.	5492.	5537.	5570.	5600.	5600.	5600.	5595.	5591.	5588.
1959	5586.	5586.	5585.	5585.	5584.	5583.	5588.	5596.	5594.	5589.	5585.	5582.
1960	5580.	5579.	5579.	5579.	5578.	5577.	5599.	5600.	5597.	5592.	5587.	5585.
1961	5583.	5582.	5582.	5581.	5580.	5595.	5600.	5600.	5600.	5595.	5591.	5588.
1962	5595.	5598.	5600.	5600.	5600.	5600.	5600.	5599.	5600.	5595.	5591.	5588.
1963	5586.	5586.	5585.	5585.	5584.	5583.	5582.	5580.	5576.	5571.	5566.	5562.
1964	5560.	5560.	5559.	5558.	5558.	5557.	5555.	5552.	5548.	5541.	5535.	5531.
1965	5528.	5527.	5526.	5526.	5525.	5523.	5521.	5518.	5595.	5590.	5586.	5583.
1966	5581.	5581.	5580.	5580.	5588.	5600.	5600.	5598.	5595.	5590.	5585.	5582.
1967	5581.	5580.	5580.	5579.	5578.	5578.	5576.	5574.	5594.	5596.	5592.	5589.
1968	5588.	5587.	5587.	5586.	5585.	5585.	5583.	5581.	5585.	5580.	5575.	5572.
1969	5570.	5569.	5569.	5568.	5567.	5566.	5565.	5562.	5578.	5573.	5568.	5565.
1970	5563.	5562.	5561.	5561.	5582.	5600.	5600.	5600.	5600.	5595.	5591.	5588.
1971	5586.	5586.	5585.	5600.	5600.	5600.	5600.	5600.	5600.	5600.	5596.	5593.
1972	5591.	5591.	5590.	5590.	5589.	5590.	5600.	5599.	5600.	5595.	5591.	5588.
1973	5586.	5586.	5585.	5585.	5584.	5600.	5600.	5600.	5600.	5599.	5595.	5592.
1974	5592.	5596.	5596.	5600.	5600.	5600.	5600.	5600.	5600.	5595.	5591.	5588.
1975	5586.	5586.	5585.	5585.	5584.	5583.	5591.	5592.	5600.	5599.	5594.	5591.
1976	5590.	5589.	5589.	5588.	5595.	5600.	5600.	5599.	5596.	5591.	5587.	5584.
1977	5582.	5581.	5581.	5580.	5580.	5579.	5578.	5575.	5572.	5566.	5561.	5557.
1978	5555.	5554.	5554.	5553.	5552.	5551.	5550.	5547.	5585.	5580.	5576.	5572.
1979	5570.	5570.	5569.	5569.	5568.	5567.	5566.	5597.	5600.	5596.	5592.	5589.
1980	5587.	5588.	5600.	5600.	5600.	5600.	5600.	5600.	5600.	5595.	5591.	5588.
1981	5586.	5586.	5585.	5587.	5600.	5600.	5600.	5600.	5600.	5595.	5591.	5588.
1982	5586.	5586.	5585.	5585.	5584.	5583.	5582.	5583.	5600.	5600.	5596.	5597.
1983	5595.	5594.	5600.	5600.	5600.	5600.	5600.	5600.	5600.	5600.	5600.	5597.
Min	5448.	5446.	5444.	5442:	5439.	5435.	5429.	5434.	5489.	5477.	5464.	5455.
Max	5595.	5598.	5600.	5600.	5600.	5600.	5600.	5600.	5600.	5600.	5600.	5597.
Sdev	33.	34.	35.	35.	34.	35.	38.	38.	27.	29.	31.	33.

TABLE 10.29

Simulated Postproject Flows in the Colorado River
at the Hot Sulphur Springs Gaging Station
Poudre Alternative

(sum of links 29 and 81 - Management Run 8)

(mean monthly cfs)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept
Avg.	69.	69.	59.	56.	63.	76.	120.	142.	343.	265.	119.	55.
1954	25.	49.	35.	39.	51.	46.	148.	91.	113.	108.	48.	14.
1955	34.	50.	39.	40.	43.	54.	91.	91.	91.	112.	102.	15.
1956	39.	65.	62.	57.	63.	75.	91.	265.	91.	130.	67.	20.
1957	27.	53.	54.	53.	56.	55.	173.	172.	1290.	328.	244.	99.
1958	90.	90.	83.	80.	82.	75.	166.	383.	91.	130.	60.	20.
1959	50.	88.	89.	79.	77.	81.	184.	91.	91.	91.	104.	24.
1960	100.	89.	67.	56.	66.	139.	91.	91.	91.	91.	100.	34.
1961	59.	86.	41.	38.	50.	73.	148.	91.	91.	158.	101.	160.
1962	294.	156.	85.	54.	62.	65.	91.	348.	633.	820.	93.	42.
1963	53.	44.	46.	33.	57.	71.	91.	91.	91.	129.	114.	51.
1964	46.	47.	40.	45.	48.	45.	143.	91.	91.	122.	83.	35.
1965	33.	46.	51.	57.	58.	59.	129.	91.	157.	91.	255.	67.
1966	105.	97.	89.	70.	70.	112.	91.	91.	91.	128.	76.	25.
1967	53.	57.	54.	49.	52.	89.	116.	91.	91.	91.	111.	55.
1968	69.	77.	57.	55.	62.	69.	141.	91.	91.	91.	126.	57.
1969	63.	46.	48.	51.	58.	52.	91.	91.	381.	91.	96.	54.
1970	79.	68.	52.	60.	65.	62.	203.	660.	357.	91.	89.	73.
1971	99.	81.	75.	77.	74.	136.	91.	106.	1211.	739.	152.	86.
1972	72.	60.	52.	50.	67.	121.	91.	91.	91.	91.	126.	85.
1973	82.	73.	61.	59.	66.	72.	91.	91.	401.	1016.	169.	69.
1974	71.	77.	56.	64.	74.	95.	91.	197.	2051.	268.	144.	69.
1975	72.	78.	60.	60.	71.	75.	91.	91.	91.	91.	137.	60.
1976	54.	56.	54.	55.	64.	65.	91.	91.	91.	91.	112.	54.
1977	56.	64.	39.	43.	53.	55.	132.	125.	91.	158.	90.	53.
1978	58.	65.	69.	64.	64.	79.	179.	91.	91.	91.	107.	56.
1979	64.	66.	65.	70.	73.	70.	91.	91.	229.	91.	114.	45.
1980	54.	62.	62.	66.	67.	65.	91.	99.	457.	239.	107.	54.
1981	56.	59.	53.	43.	48.	60.	91.	91.	91.	149.	90.	33.
1982	53.	59.	55.	58.	63.	83.	139.	91.	91.	91.	142.	69.
1983	68.	72.	69.	69.	78.	69.	131.	91.	1371.	2042.	221.	85.
Min	25.	44.	35.	33.	43.	45.	91.	91.	91.	91.	48.	14.
Max	294.	156.	89.	80.	82.	139.	203.	660.	2051.	2042.	255.	160.
Sdev	46.	22.	14.	12.	10.	23.	35.	122.	482.	401.	48.	29.

simulated minimum and maximum bounds of postproject flows (mean monthly cfs) immediately below the proposed mainstem reservoir formed by the Poudre Dam alternative are displayed in Tables 10.30 and 10.31, respectively. The simulated minimum and maximum bounds of postproject flows for the proposed Poudre alternative at the USGS gaging station located at the mouth of the Poudre Canyon are displayed in Tables 10.32 and 10.33, respectively. The difference in flows between those immediately below the proposed reservoir and those at the USGS gaging station are the diversions to the Poudre Valley Canal. As for the Grey Mountain Alternative, the simulated postproject minimum and maximum bounding flows immediately below the mainstem reservoir can be used for the preliminary sizing of a conventional hydroelectric plant.

Selected results at other points in the MODSIM model for postproject conditions associated with the Poudre alternative are provided in Appendix S. Included in Appendix S are simulated flows at various locations in the Lower Poudre River, simulated flows in the Colorado River Basin, and resultant end-of-month storage levels in the major C-BT reservoirs.

10.9 ADDITIONAL HYDROLOGIC STUDIES RECOMMENDED

The Poudre River Basin has been extensively studied during this and previous work, especially during studies to determine potential reservoir sites and sizes. This is the first study, however, that directly incorporated modeling of out-of-basin water transfers into the Poudre River Basin, and is a good initial attempt at integrating the area's water resources for more efficient management.

Future studies should include additional detail, particularly in the Poudre River Basin, to analyze fuller integration of water resources systems. For instance, integrated operation of the mainstem reservoir with mountain and plains reservoirs, ditch and municipal delivery systems, and the potential for conjunctive use utilizing the mainstem reservoir as a source for recharge water should be further considered. As the operating criteria for the proposed mainstem reservoir are developed, additional studies will also be required to quantify daily variations in postproject flows.

TABLE 10.30

Simulated Minimum Postproject Flows Immediately Below Proposed Poudre Reservoir

(mean monthly cfs)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Avg.	72.	39.	29.	27.	30.	37.	116.	825.	1572.	718.	256.	110.
1954	58.	47.	33.	32.	28.	25.	49.	414.	574.	245.	61.	96.
1955	81.	32.	17.	20.	16.	20.	33.	356.	1029.	455.	252.	73.
1956	50.	42.	40.	28.	25.	31.	58.	1189.	1628.	402.	191.	54.
1957	36.	20.	26.	21.	24.	23.	118.	521.	1682.	1717.	331.	164.
1958	82.	45.	43.	34.	37.	43.	48.	1469.	1550.	265.	68.	54.
1959	56.	31.	33.	27.	36.	50.	105.	632.	1735.	407.	177.	70.
1960	78.	63.	19.	17.	14.	49.	100.	849.	1744.	457.	106.	73.
1961	56.	29.	25.	37.	30.	46.	102.	1362.	2096.	524.	305.	206.
1962	131.	37.	36.	51.	90.	78.	302.	1114.	1348.	766.	186.	40.
1963	66.	35.	29.	18.	19.	12.	68.	446.	717.	200.	192.	125.
1964	62.	36.	16.	14.	15.	25.	39.	588.	1123.	514.	177.	75.
1965	30.	17.	13.	14.	16.	14.	44.	532.	1052.	1264.	418.	129.
1966	65.	18.	21.	19.	22.	27.	47.	494.	575.	170.	103.	99.
1967	55.	24.	13.	12.	10.	18.	31.	504.	1196.	703.	117.	97.
1968	145.	55.	46.	36.	46.	32.	53.	477.	1886.	669.	331.	113.
1969	46.	36.	27.	19.	19.	27.	106.	1098.	1115.	583.	113.	129.
1970	69.	32.	14.	14.	11.	23.	126.	996.	1924.	921.	283.	107.
1971	78.	71.	30.	30.	24.	32.	173.	985.	2408.	842.	221.	167.
1972	77.	76.	35.	27.	33.	35.	67.	596.	1574.	416.	84.	105.
1973	63.	44.	26.	24.	26.	33.	75.	1461.	2061.	1018.	379.	91.
1974	55.	38.	43.	36.	40.	82.	119.	1273.	1796.	606.	109.	83.
1975	114.	46.	22.	13.	13.	19.	35.	339.	1321.	1236.	289.	100.
1976	53.	29.	27.	25.	25.	25.	39.	470.	1110.	449.	309.	59.
1977	112.	27.	16.	15.	15.	22.	50.	210.	667.	171.	230.	63.
1978	40.	37.	27.	23.	23.	32.	66.	787.	1705.	1084.	325.	98.
1979	46.	30.	21.	19.	17.	24.	187.	519.	2140.	963.	567.	152.
1980	57.	30.	43.	90.	79.	138.	531.	2563.	2351.	674.	282.	109.
1981	85.	73.	50.	29.	20.	21.	75.	378.	962.	344.	200.	97.
1982	38.	26.	25.	20.	54.	19.	33.	378.	1271.	1292.	618.	241.
1983	174.	47.	56.	45.	70.	96.	596.	1744.	4810.	2177.	654.	223.
Min	30.	17.	13.	12.	10.	12.	31.	210.	574.	170.	61.	40.
Max	174.	76.	56.	90.	90.	138.	596.	2563.	4810.	2177.	654.	241.
Sdev	33.	15.	11.	15.	20.	27.	133.	515.	784.	462.	152.	49.

TABLE 10.31

Simulated Maximum Postproject Flows Immediately Below Proposed Poudre Reservoir

(mean monthly cfs)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Avg.	95.	59.	48.	46.	46.	52.	139.	855.	1626.	786.	313.	148.
1954	81.	67.	52.	51.	44.	40.	72.	444.	628.	313.	118.	134.
1955	104.	52.	36.	39.	32.	35.	56.	386.	1083.	523.	309.	111.
1956	73.	62.	59.	47.	41.	46.	81.	1219.	1682.	470.	248.	92.
1957	59.	40.	45.	40.	40.	38.	141.	551.	1736.	1785.	388.	202.
1958	105.	65.	62.	53.	53.	58.	71.	1499.	1604.	333.	125.	92.
1959	79.	51.	52.	46.	52.	65.	128.	662.	1789.	475.	234.	108.
1960	101.	83.	38.	36.	30.	64.	123.	879.	1798.	525.	163.	111.
1961	79.	49.	44.	56.	46.	61.	125.	1392.	2150.	592.	362.	244.
1962	154.	57.	55.	70.	106.	93.	325.	1144.	1402.	834.	243.	78.
1963	89.	55.	48.	37.	35.	27.	91.	476.	771.	268.	249.	163.
1964	85.	56.	35.	33.	31.	40.	62.	618.	1177.	582.	234.	113.
1965	53.	37.	32.	33.	32.	29.	67.	562.	1106.	1332.	475.	167.
1966	88.	38.	40.	38.	38.	42.	70.	524.	629.	238.	160.	137.
1967	78.	44.	32.	31.	26.	33.	54.	534.	1250.	771.	174.	135.
1968	168.	75.	65.	55.	62.	47.	76.	507.	1940.	737.	388.	151.
1969	69.	56.	46.	38.	35.	42.	129.	1128.	1169.	651.	170.	167.
1970	92.	52.	33.	33.	27.	38.	149.	1026.	1978.	989.	340.	145.
1971	101.	91.	49.	49.	40.	47.	196.	1015.	2462.	910.	278.	205.
1972	100.	96.	54.	46.	49.	50.	90.	626.	1628.	484.	141.	143.
1973	86.	64.	45.	43.	42.	48.	98.	1491.	2115.	1086.	436.	129.
1974	78.	58.	62.	55.	56.	97.	142.	1303.	1850.	674.	166.	121.
1975	137.	66.	41.	32.	29.	34.	58.	369.	1375.	1304.	346.	138.
1976	76.	49.	46.	44.	41.	40.	62.	500.	1164.	517.	366.	97.
1977	135.	47.	35.	34.	31.	37.	73.	240.	721.	239.	287.	101.
1978	63.	57.	46.	42.	39.	47.	89.	817.	1759.	1152.	382.	136.
1979	69.	50.	40.	38.	33.	39.	210.	549.	2194.	1031.	624.	190.
1980	80.	50.	62.	109.	95.	153.	554.	2593.	2405.	742.	339.	147.
1981	108.	93.	69.	48.	36.	36.	98.	408.	1016.	412.	257.	135.
1982	61.	46.	44.	39.	70.	34.	56.	408.	1325.	1360.	675.	279.
1983	197.	67.	75.	64.	86.	111.	619.	1774.	4864.	2245.	711.	261.
Min	53.	37.	32.	31.	26.	27.	54.	240.	628.	238.	118.	78.
Max	197.	96.	75.	109.	106.	153.	619.	2593.	4864.	2245.	711.	279.
Sdev	33.	15.	11.	15.	20.	27.	133.	515.	784.	462.	152.	49.

TABLE 10.32

Simulated Minimum Postproject Flows at USGS Poudre Canyon Gauge
Poudre Alternative

(mean monthly cfs)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Avg.	59.	38.	29.	27.	30.	37.	110.	778.	1479.	704.	253.	103.
1954	55.	33.	33.	32.	28.	25.	49.	414.	574.	245.	61.	96.
1955	81.	28.	17.	20.	16.	20.	33.	356.	1016.	455.	252.	73.
1956	50.	39.	40.	28.	25.	31.	58.	1147.	1448.	396.	188.	54.
1957	33.	20.	26.	21.	24.	23.	118.	521.	1668.	1687.	328.	162.
1958	81.	45.	43.	34.	37.	43.	48.	1469.	1540.	262.	66.	54.
1959	51.	31.	33.	27.	36.	50.	105.	579.	1702.	400.	175.	68.
1960	73.	63.	19.	17.	14.	49.	93.	810.	1613.	450.	105.	71.
1961	49.	29.	25.	37.	30.	46.	102.	1111.	1907.	520.	305.	196.
1962	120.	37.	36.	51.	90.	78.	300.	1106.	1346.	748.	184.	37.
1963	62.	35.	29.	18.	19.	12.	67.	444.	635.	199.	190.	124.
1964	60.	36.	16.	14.	15.	25.	39.	582.	1106.	512.	176.	75.
1965	30.	17.	13.	14.	16.	14.	43.	526.	1045.	1256.	415.	127.
1966	65.	18.	21.	19.	22.	27.	47.	485.	561.	158.	102.	99.
1967	46.	24.	13.	12.	10.	18.	31.	428.	872.	581.	116.	70.
1968	27.	55.	46.	36.	46.	32.	50.	470.	1609.	666.	330.	113.
1969	42.	36.	27.	19.	19.	27.	106.	822.	984.	580.	112.	126.
1970	68.	32.	14.	14.	11.	23.	94.	952.	1768.	910.	280.	105.
1971	78.	71.	30.	30.	24.	32.	173.	985.	2322.	837.	217.	161.
1972	40.	76.	35.	27.	33.	35.	67.	586.	1367.	413.	84.	105.
1973	63.	44.	26.	24.	26.	33.	58.	1426.	2014.	998.	372.	63.
1974	54.	38.	43.	36.	40.	82.	119.	1248.	1756.	601.	107.	79.
1975	77.	46.	22.	13.	13.	19.	35.	306.	1250.	1226.	281.	100.
1976	53.	29.	27.	25.	25.	25.	39.	451.	1093.	445.	309.	59.
1977	75.	27.	16.	15.	15.	22.	50.	204.	658.	171.	230.	63.
1978	40.	37.	27.	23.	23.	26.	66.	588.	1517.	1075.	320.	98.
1979	46.	30.	21.	19.	17.	24.	84.	287.	1964.	950.	563.	147.
1980	54.	30.	43.	90.	79.	138.	531.	2563.	2334.	674.	274.	104.
1981	83.	73.	50.	29.	20.	21.	75.	367.	870.	339.	200.	97.
1982	35.	26.	25.	20.	54.	19.	33.	375.	1097.	1227.	616.	161.
1983	70.	46.	56.	45.	70.	96.	596.	1744.	4736.	2150.	635.	210.
Min	27.	17.	13.	12.	10.	12.	31.	204.	561.	158.	61.	37.
Max	120.	76.	56.	90.	90.	138.	596.	2563.	4736.	2150.	635.	210.
Sdev	20.	15.	11.	15.	20.	27.	132.	513.	774.	455.	150.	42.

TABLE 10.33

Simulated Maximum Postproject Flows at USGS Poudre Canyon Gauge Poudre Alternative

(mean monthly cfs)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Avg.	82.	58.	48.	46.	46.	52.	133.	808.	1533.	772.	310.	141.
1954	78.	53.	52.	51.	44.	40.	72.	444.	628.	313.	118.	134.
1955	104.	48.	36.	39.	32.	35.	56.	386.	1070.	523.	309.	111.
1956	73.	59.	59.	47.	41.	46.	81.	1177.	1502.	464.	245.	92.
1957	56.	40.	45.	40.	40.	38.	141.	551.	1722.	1755.	385.	200.
1958	104.	65.	62.	53.	53.	58.	71.	1499.	1594.	330.	123.	92.
1959	74.	51.	52.	46.	52.	65.	128.	609.	1756.	468.	232.	106.
1960	96.	83.	38.	36.	30.	64.	116.	840.	1667.	518.	162.	109.
1961	72.	49.	44.	56.	46.	61.	125.	1141.	1961.	588.	362.	234.
1962	143.	57.	55.	70.	106.	93.	323.	1136.	1400.	816.	241.	75.
1963	85.	55.	48.	37.	35.	27.	90.	474.	689.	267.	247.	162.
1964	83.	56.	35.	33.	31.	40.	62.	612.	1160.	580.	233.	113.
1965	53.	37.	32.	33.	32.	29.	66.	556.	1099.	1324.	472.	165.
1966	88.	38.	40.	38.	38.	42.	70.	515.	615.	226.	159.	137.
1967	69.	44.	32.	31.	26.	33.	54.	458.	926.	649.	173.	108.
1968	50.	75.	65.	55.	62.	47.	73.	500.	1663.	734.	387.	151.
1969	65.	56.	46.	38.	35.	42.	129.	852.	1038.	648.	169.	164.
1970	91.	52.	33.	33.	27.	38.	117.	982.	1822.	978.	337.	143.
1971	101.	91.	49.	49.	40.	47.	196.	1015.	2376.	905.	274.	199.
1972	63.	96.	54.	46.	49.	50.	90.	616.	1421.	481.	141.	143.
1973	86.	64.	45.	43.	42.	48.	81.	1456.	2068.	1066.	429.	101.
1974	77.	58.	62.	55.	56.	97.	142.	1278.	1810.	669.	164.	117.
1975	100.	66.	41.	32.	29.	34.	58.	336.	1304.	1294.	338.	138.
1976	76.	49.	46.	44.	41.	40.	62.	481.	1147.	513.	366.	97.
1977	98.	47.	35.	34.	31.	37.	73.	234.	712.	239.	287.	101.
1978	63.	57.	46.	42.	39.	41.	89.	618.	1571.	1143.	377.	136.
1979	69.	50.	40.	38.	33.	39.	107.	317.	2018.	1018.	620.	185.
1980	77.	50.	62.	109.	95.	153.	554.	2593.	2388.	742.	331.	142.
1981	106.	93.	69.	48.	36.	36.	98.	397.	924.	407.	257.	135.
1982	58.	46.	44.	39.	70.	34.	56.	405.	1151.	1295.	673.	199.
1983	93.	66.	75.	64.	86.	111.	619.	1774.	4790.	2218.	692.	248.
Min	50.	37.	32.	31.	26.	27.	54.	234.	615.	226.	118.	75.
Max	143.	96.	75.	109.	106.	153.	619.	2593.	4790.	2218.	692.	248.
Sdev	20.	15.	11.	15.	20.	27.	132.	513.	774.	455.	150.	42.

The results of this study are dependent on the expectation that the hydrology of future water years will be consistent with the characteristics of the historic record. How well the proposed mainstem reservoir would operate under a different hydrologic regime should also be analyzed. This can be accomplished by using some form of synthetic hydrology that statistically correlates with the historic hydrologic record.

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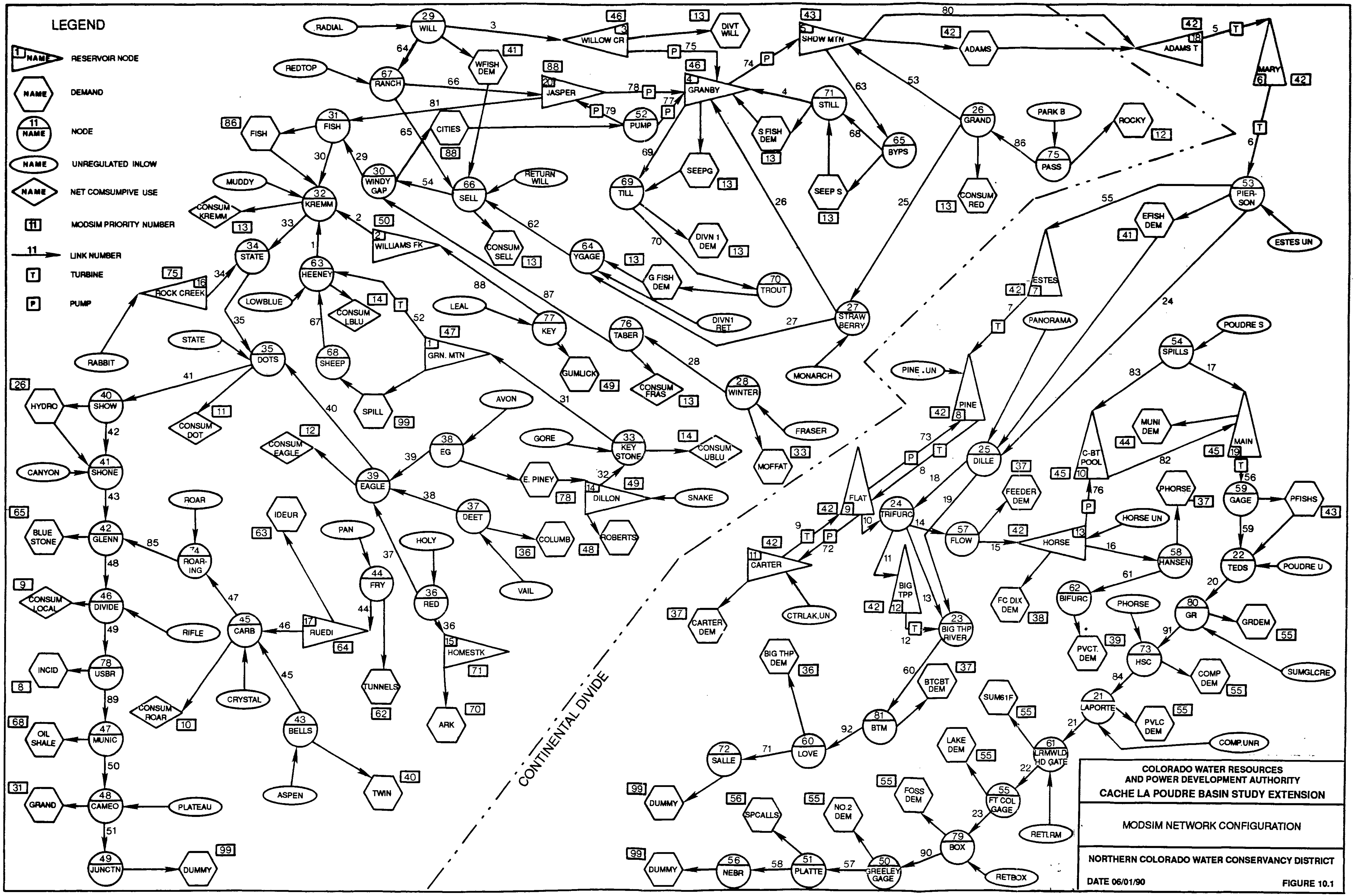


COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

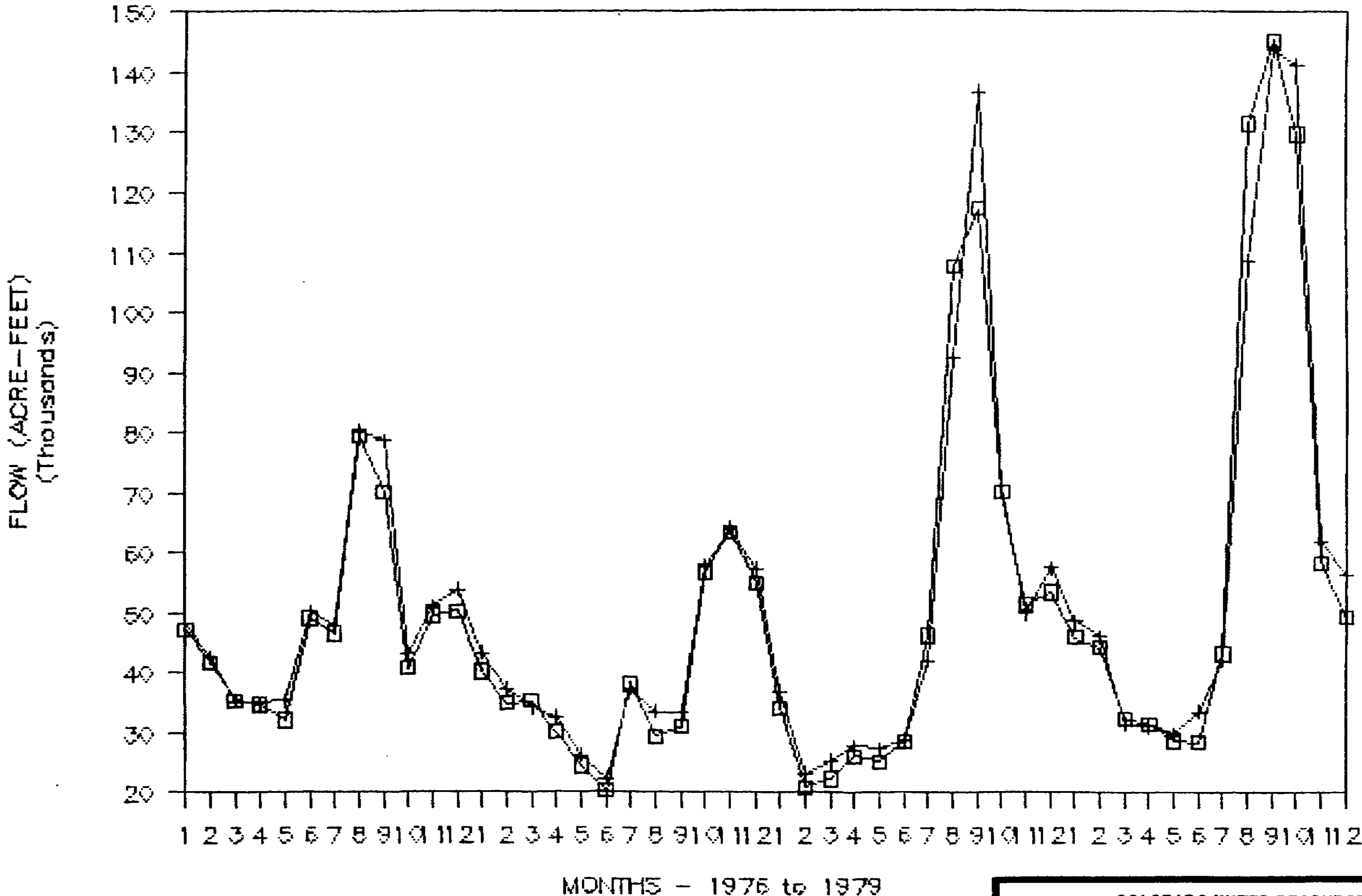
CACHE LA POUDRE BASIN STUDY EXTENSION

MODSIM NETWORK CONFIGURATION

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 06/01/90

FIGURE 10.1



□ HISTORIC FLOWS + MODEL RESULTS

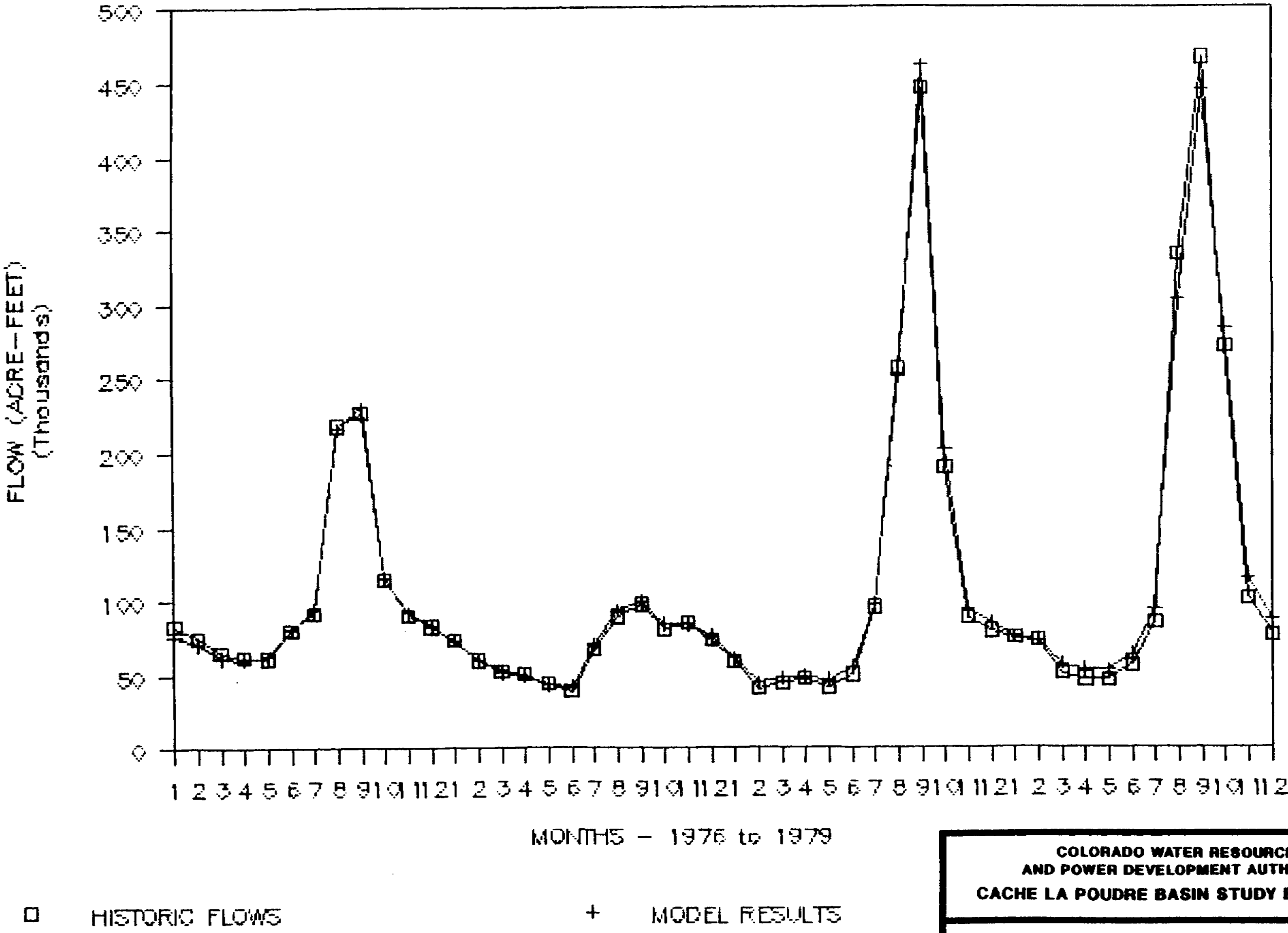
COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

CALIBRATION AT KREMMLING GAGE
MODEL LINK 33 ON COLORADO RIVER

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 FIGURE 10.2



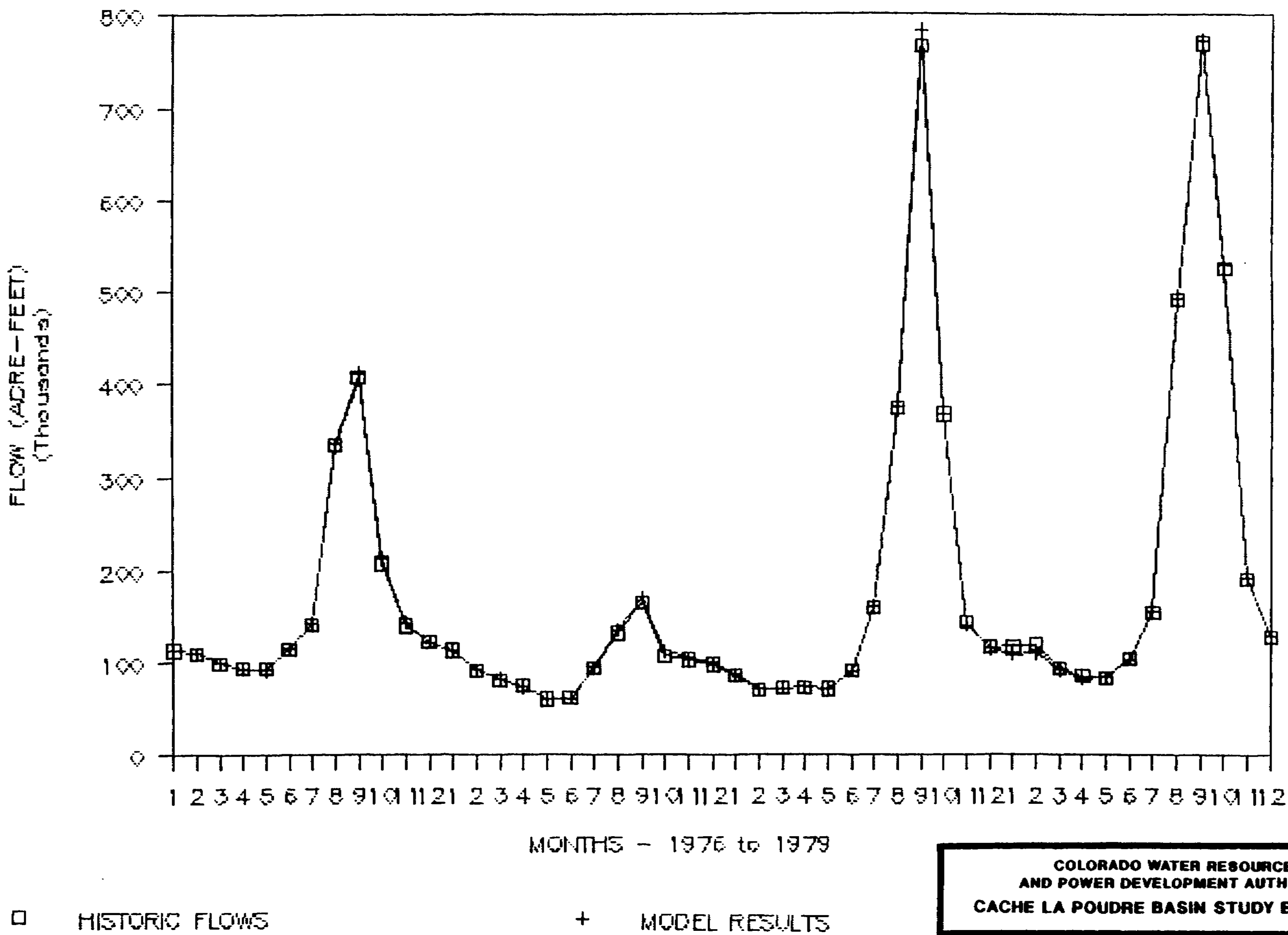
COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

CALIBRATION AT DOTSERO GAGE
MODEL LINK 41 ON COLORADO RIVER

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 **FIGURE 10.3**



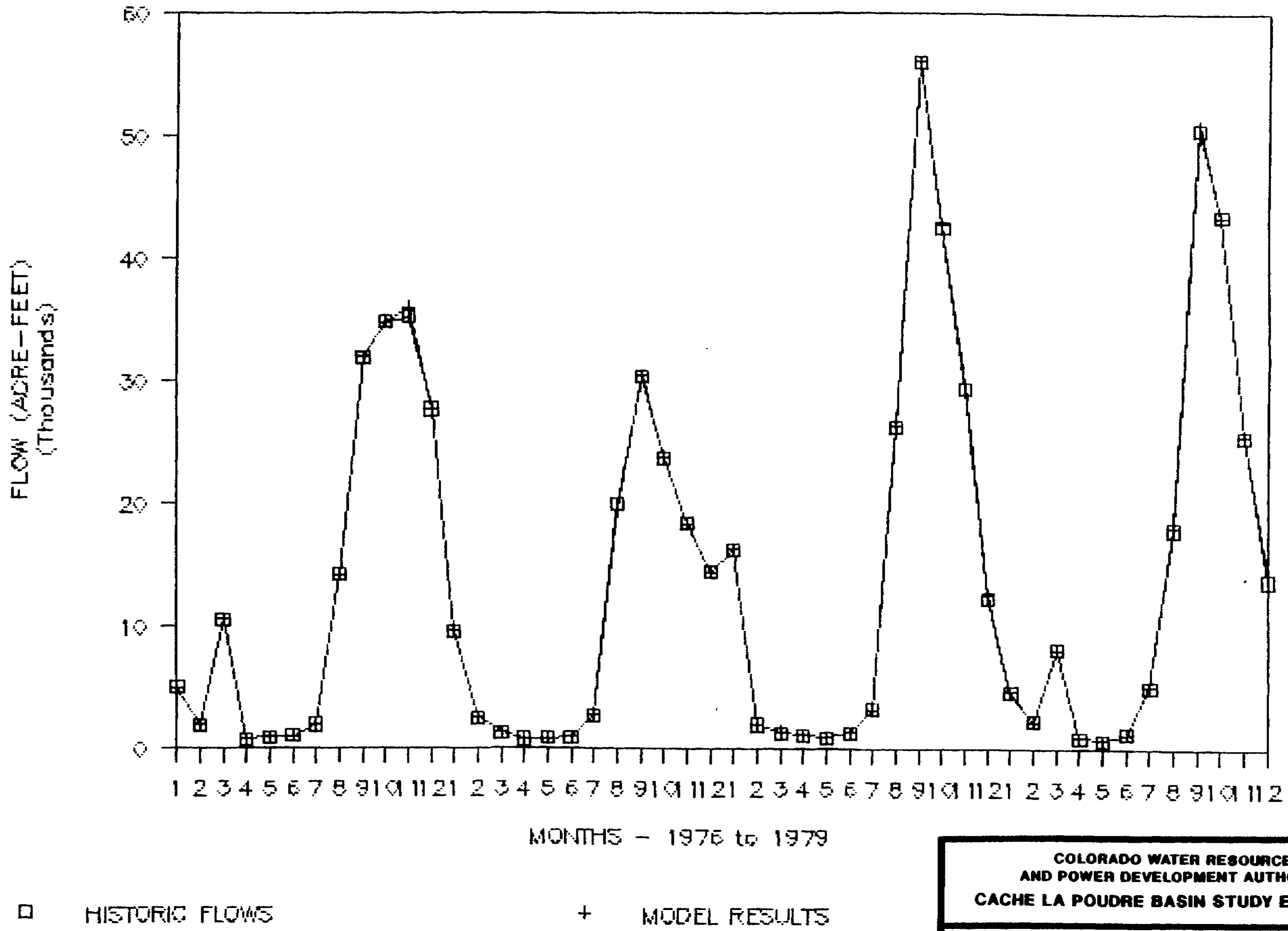
COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

CALIBRATION AT GLENWOOD SPRINGS GAGE
MODEL LINK 48 ON COLORADO RIVER

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 FIGURE 10.4



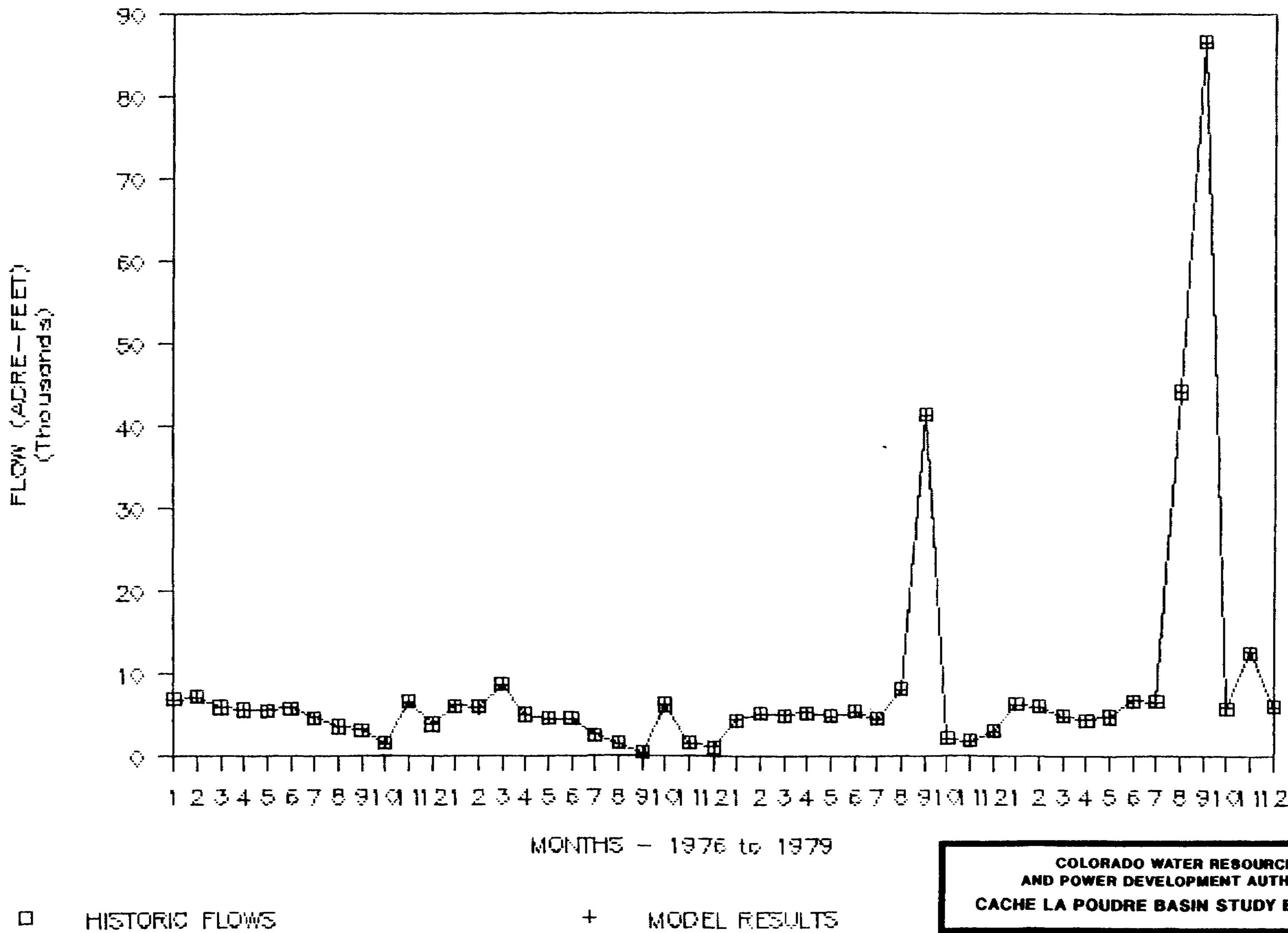
COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

CALIBRATION AT BIG THOMPSON RIVER
MODEL LINK 60 AT MOUTH OF CANYON

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 **FIGURE 10.5**



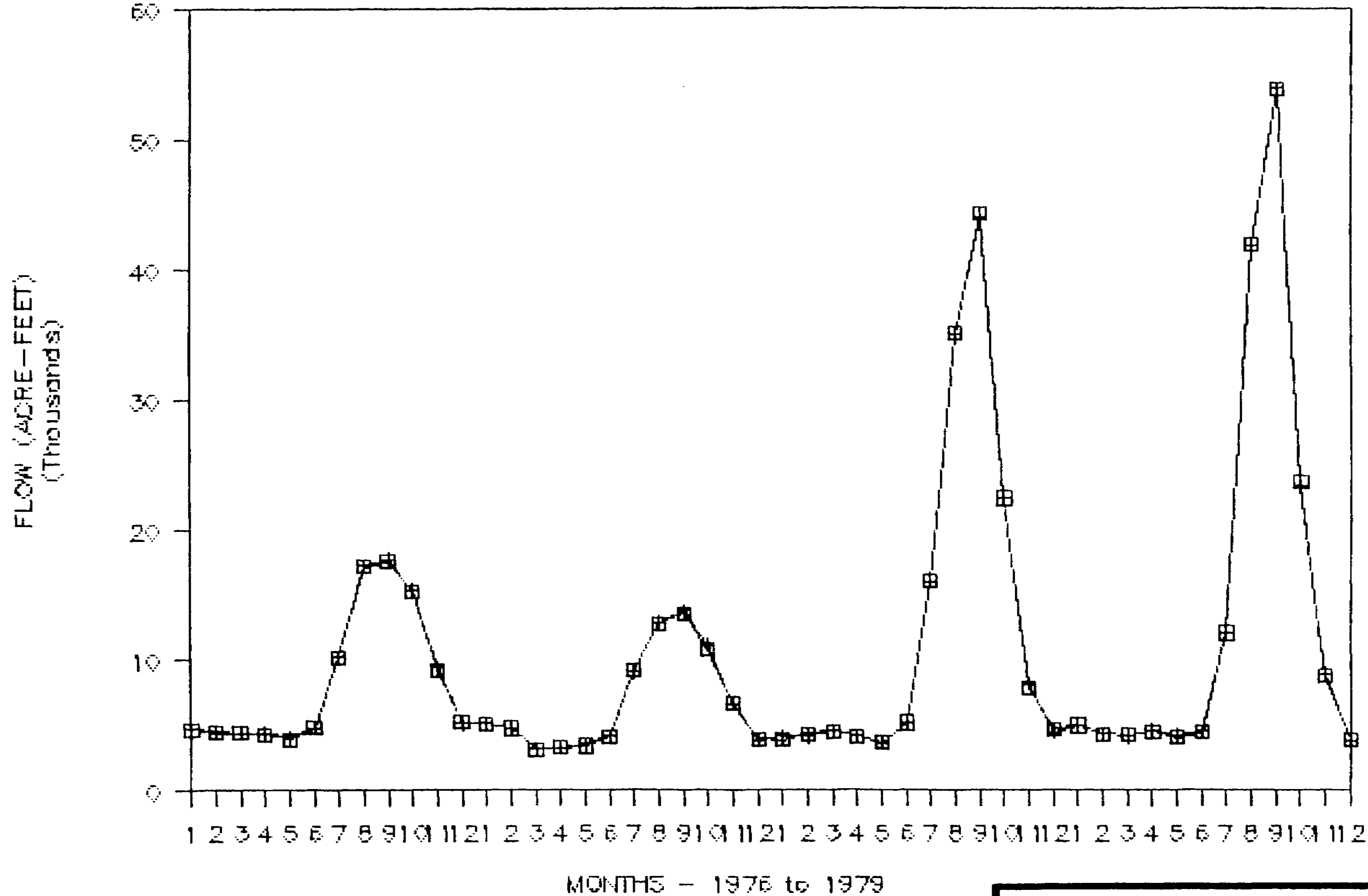
COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

CALIBRATION AT GREELEY GAGE
MODEL LINK 57 ON POUDRE RIVER

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 FIGURE 10.6



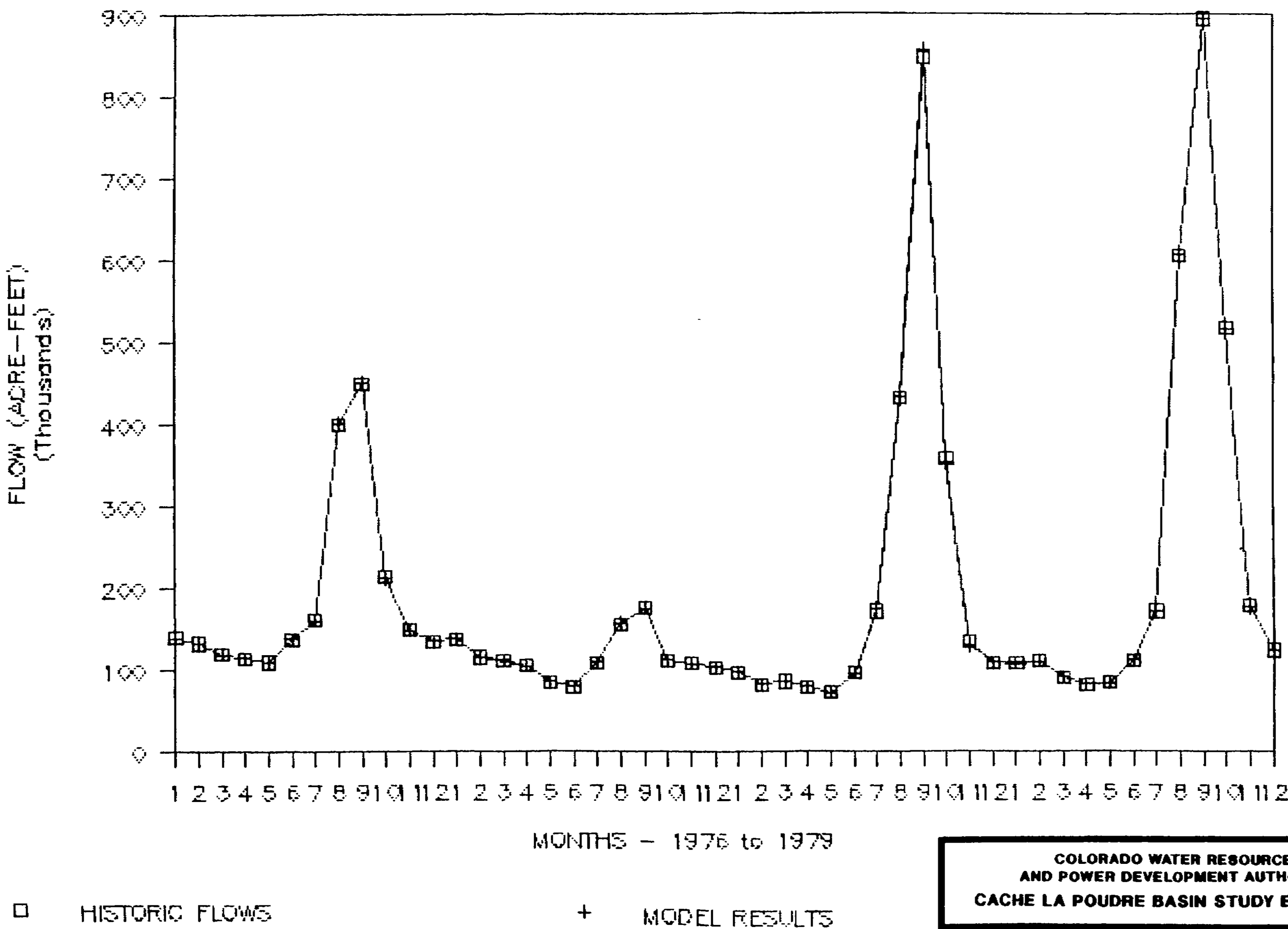
**COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY**

CACHE LA POUDRE BASIN STUDY EXTENSION

CALIBRATION AT HOT SULPHUR SPRGS GAGE
MODEL LINK 29 ON COLORADO RIVER

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 **FIGURE 10.7**



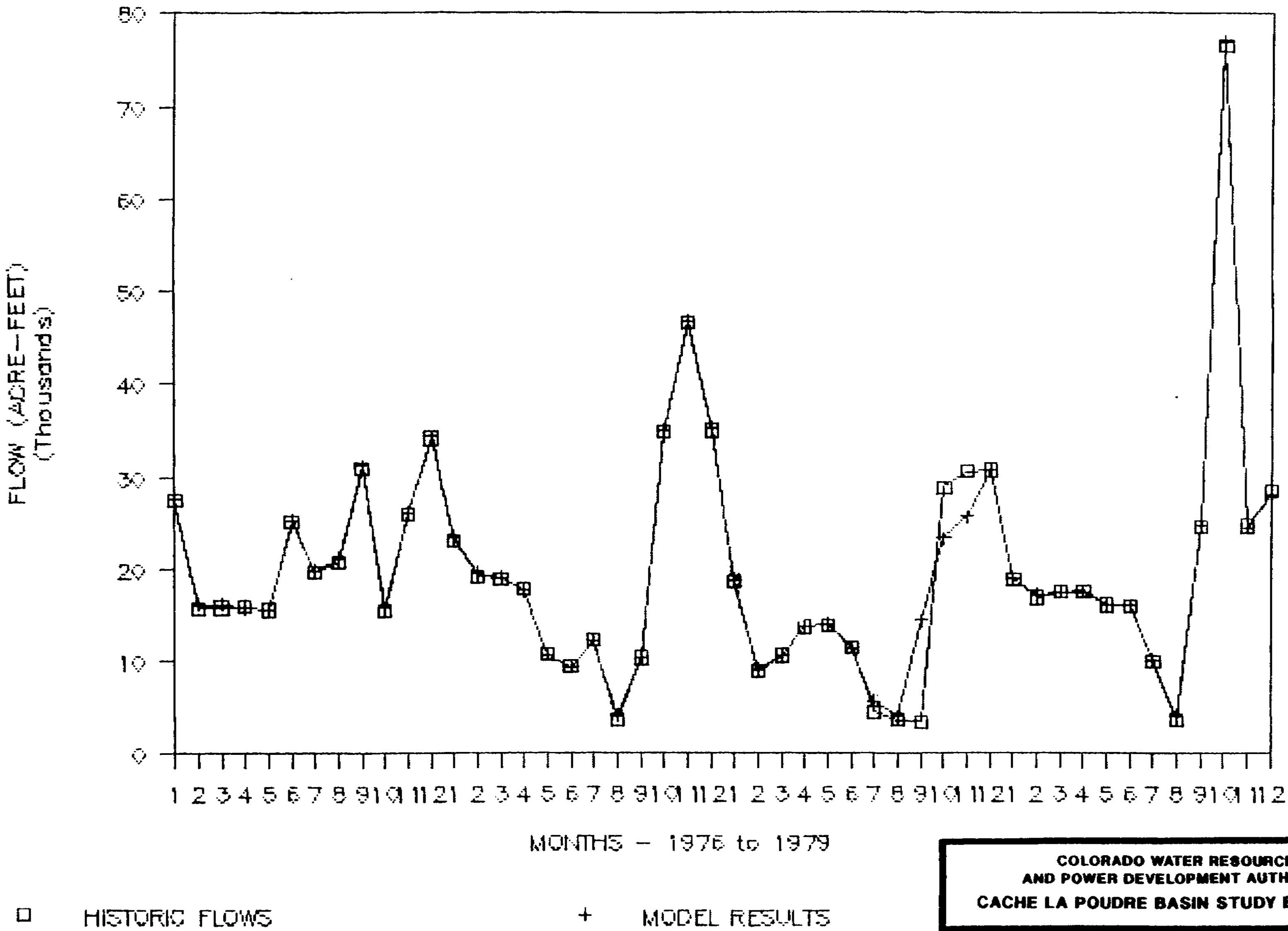
COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

CALIBRATION AT CAMEO GAGE
MODEL LINK 50 ON COLORADO RIVER

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 **FIGURE 10.8**



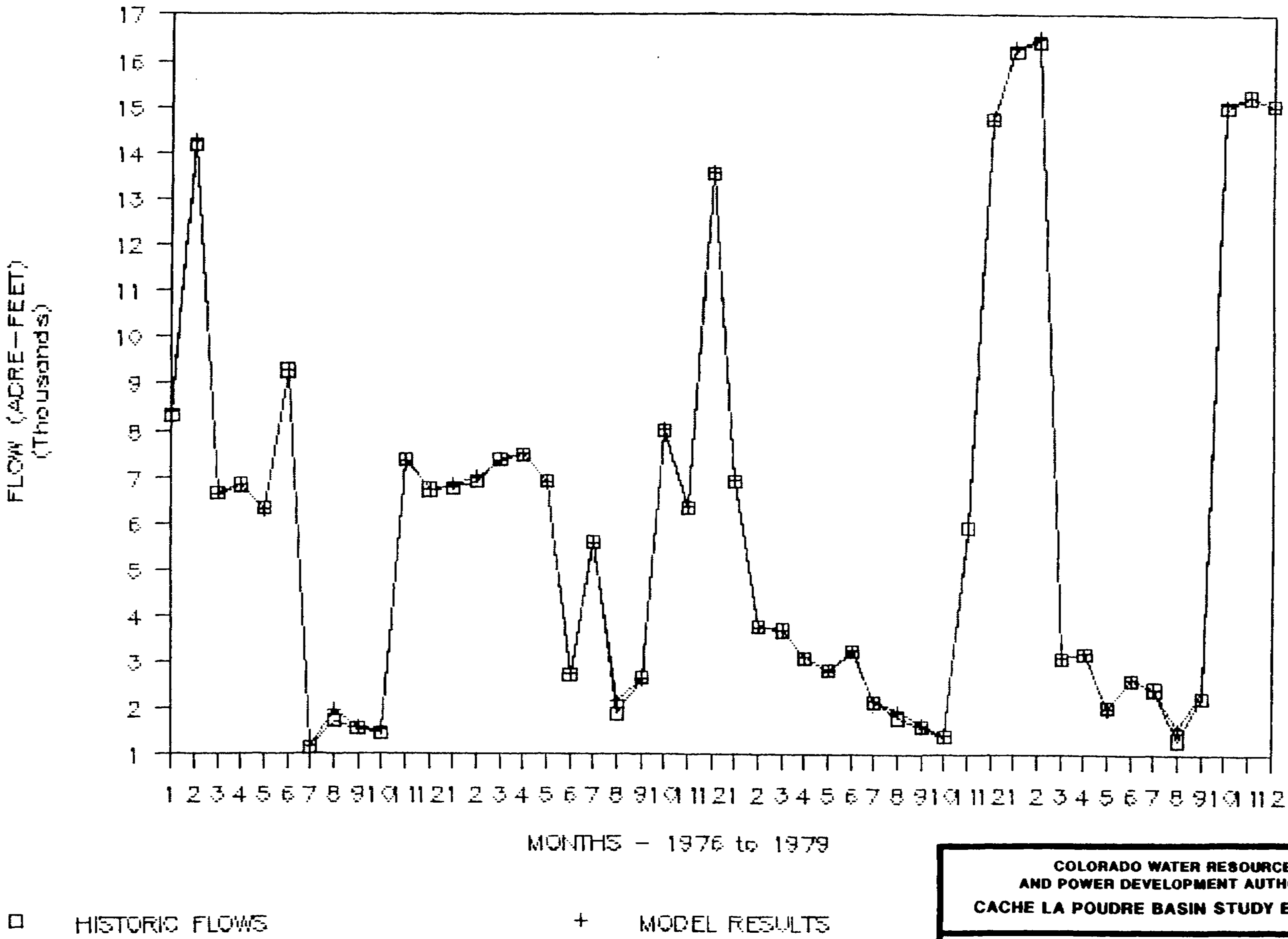
COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

CALIBRATION AT GAGE BELOW GREEN MTN RES.
BLUE RIVER MODEL LINKS 52 & 67

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 FIGURE 10.9



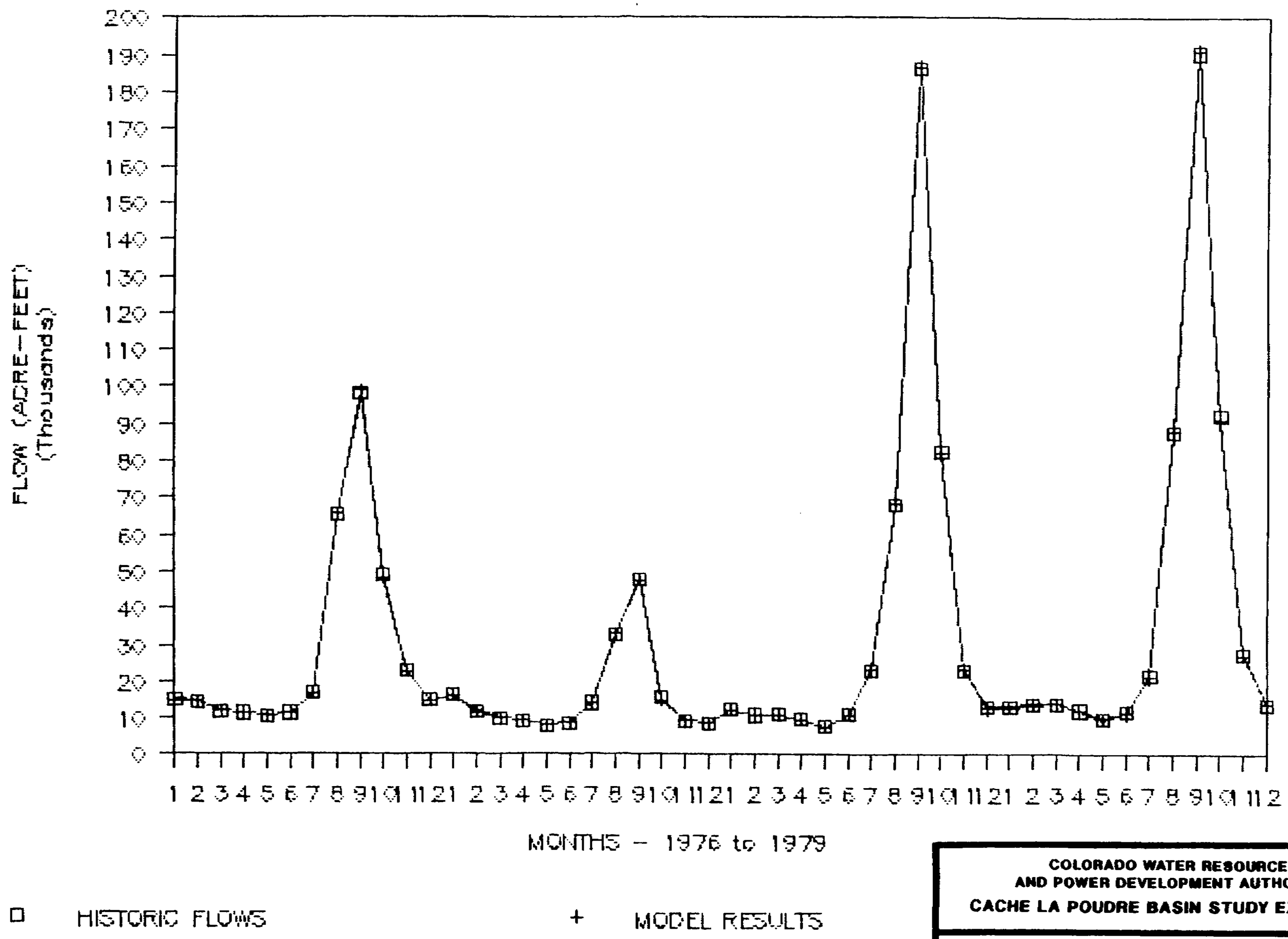
COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

CALIBRATION-GAGE BELOW WILLIAMS FORK RES.
MODEL LINK 2 ON WILLIAMS FORK RIVER

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 **FIGURE 10.10**



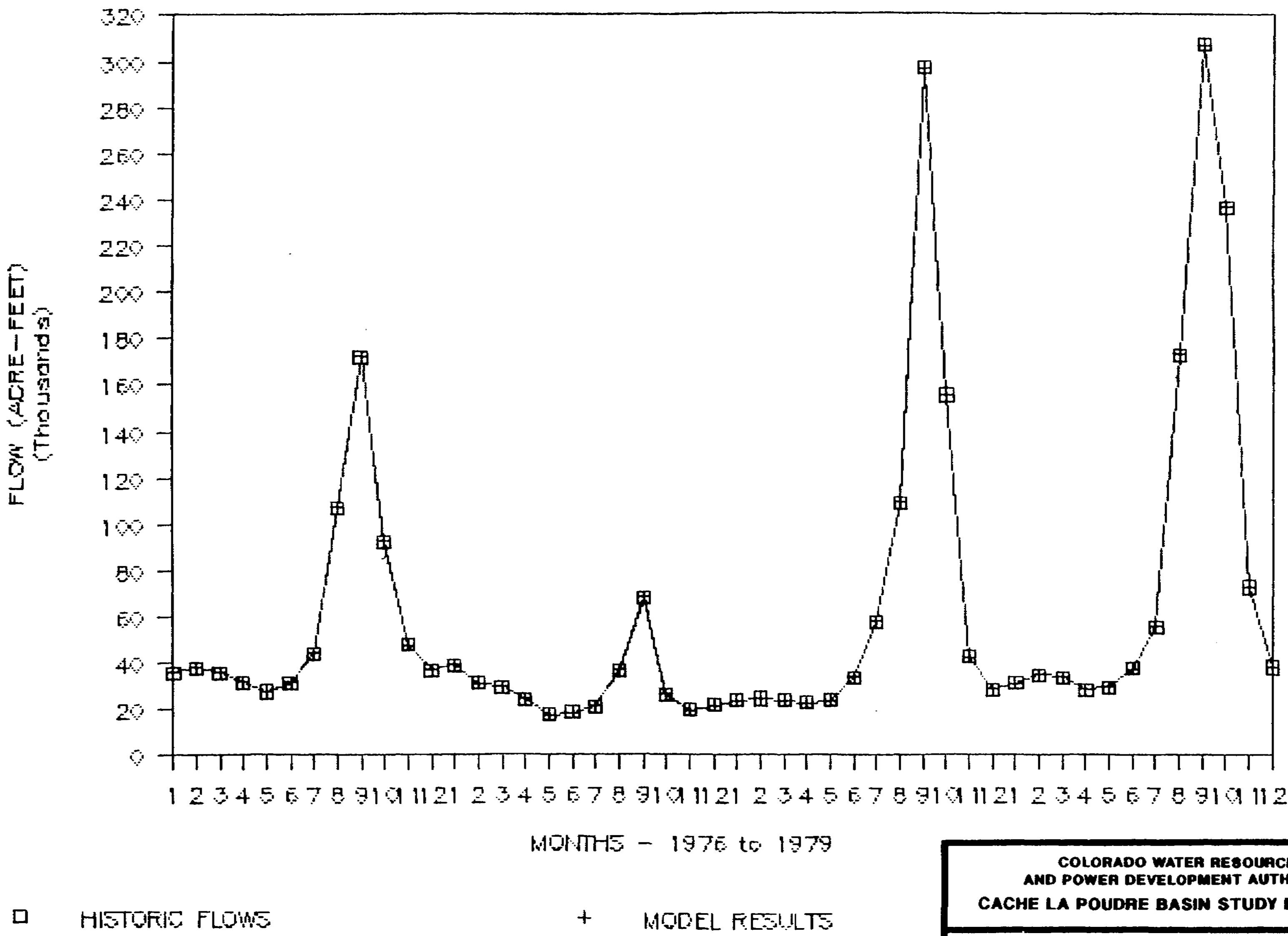
COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY
CACHE LA POUDRE BASIN STUDY EXTENSION

CALIBRATION-GYPSUM GAGE ON EAGLE RIVER
MODEL LINK 40 (NEAR MOUTH OF EAGLE)

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89

FIGURE 10.11



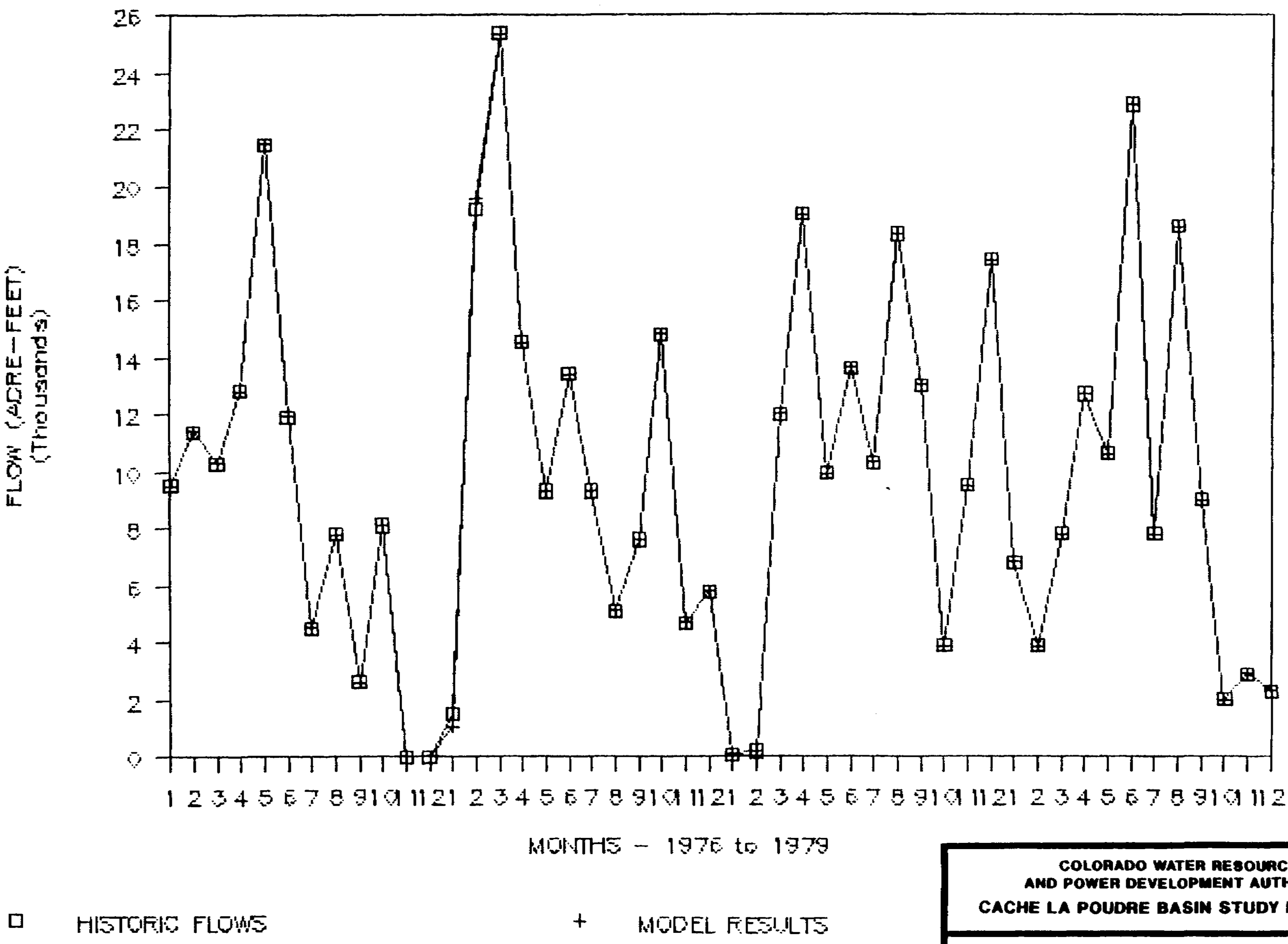
COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

CALIBRATION–GLENWOOD GAGE ON ROARING FORK
LINK 85 (MOUTH OF ROARING FORK RIVER)

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 FIGURE 10.12



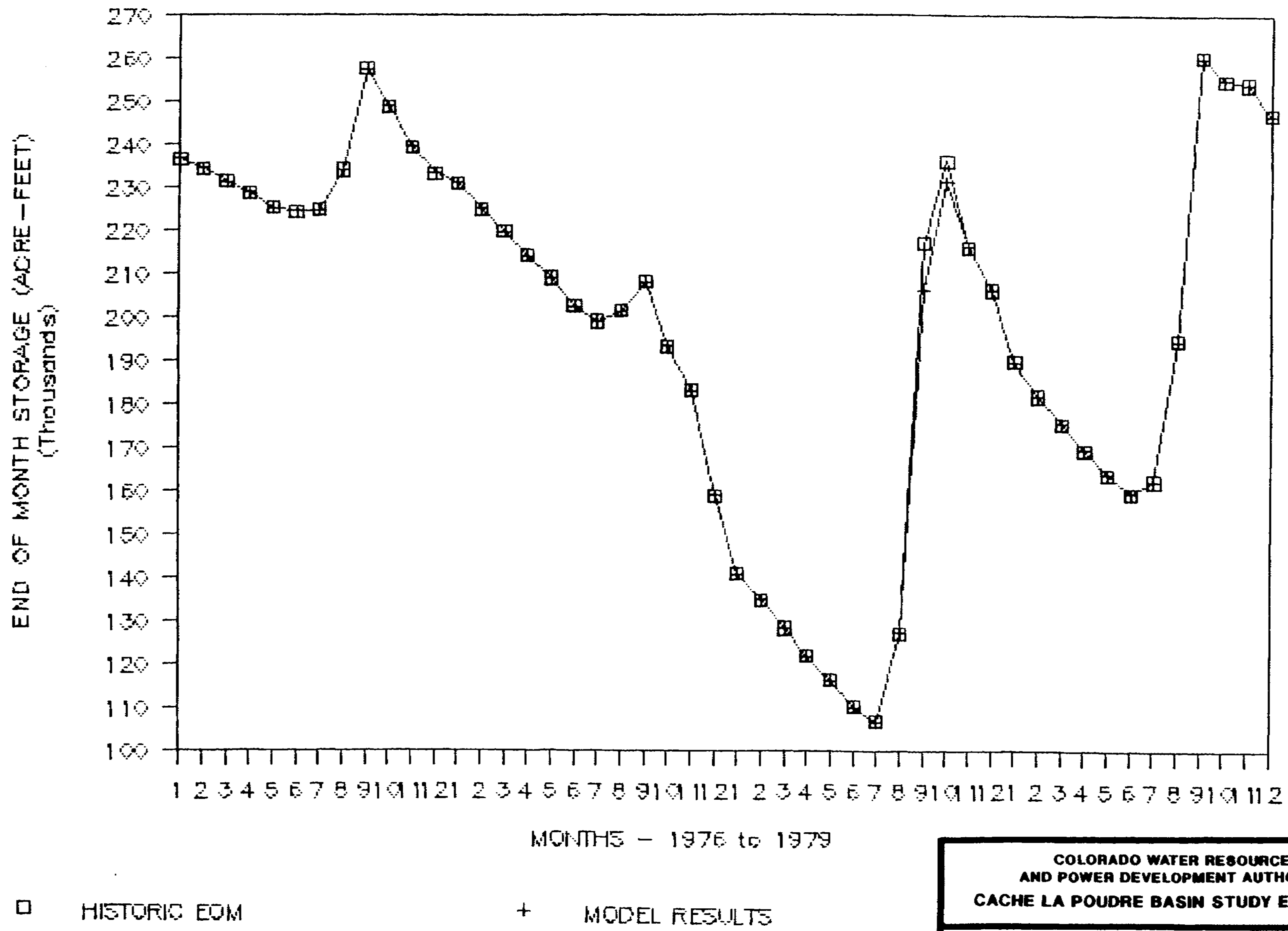
COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

CALIBRATION AT HORSETOOTH RES.INFLOW
MODEL LINK 15

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 FIGURE 10.13



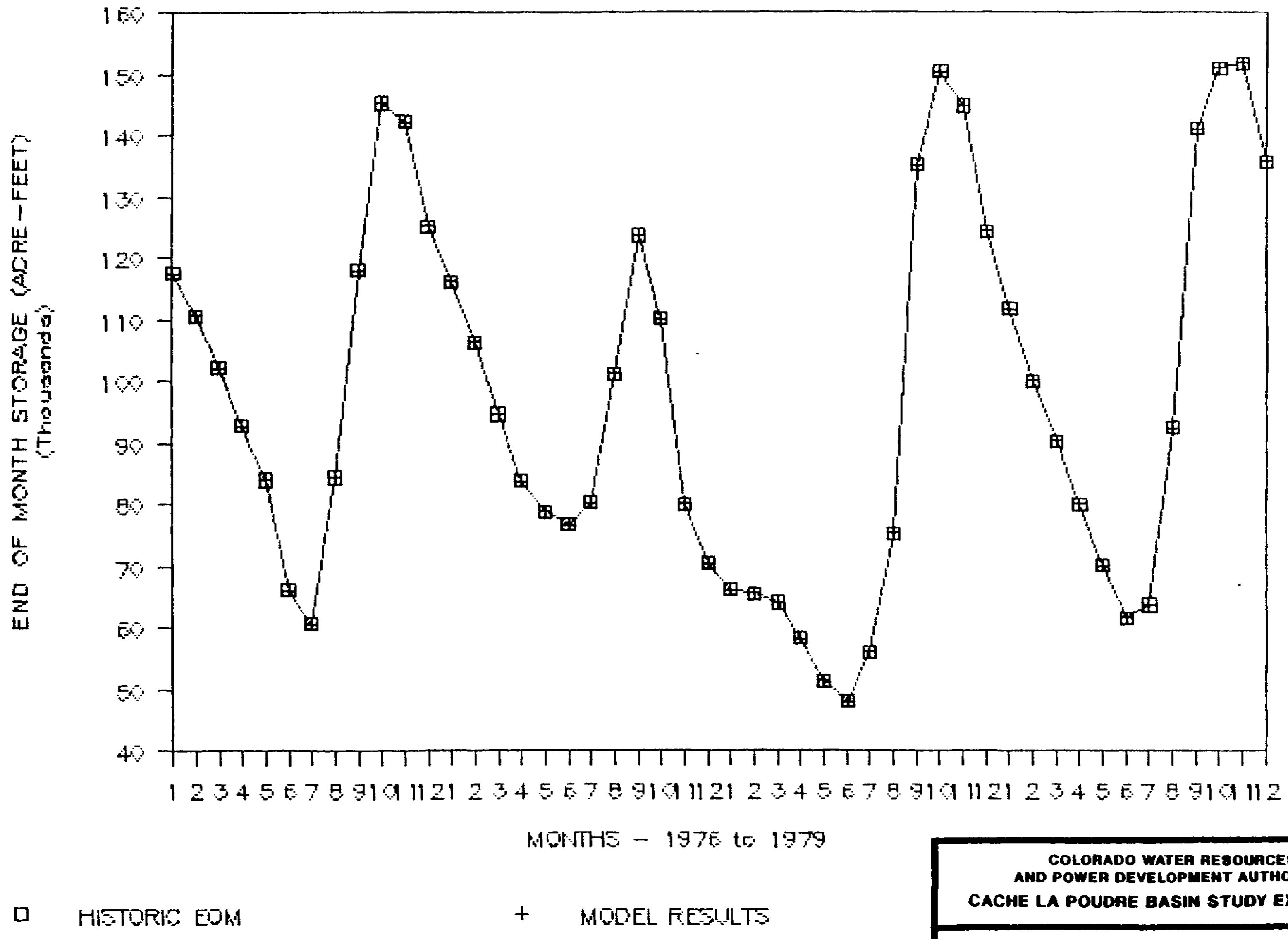
COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

CALIBRATION AT DILLON RESERVOIR
END OF MONTH STORAGE AT MODEL NODE 14

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 FIGURE 10.14



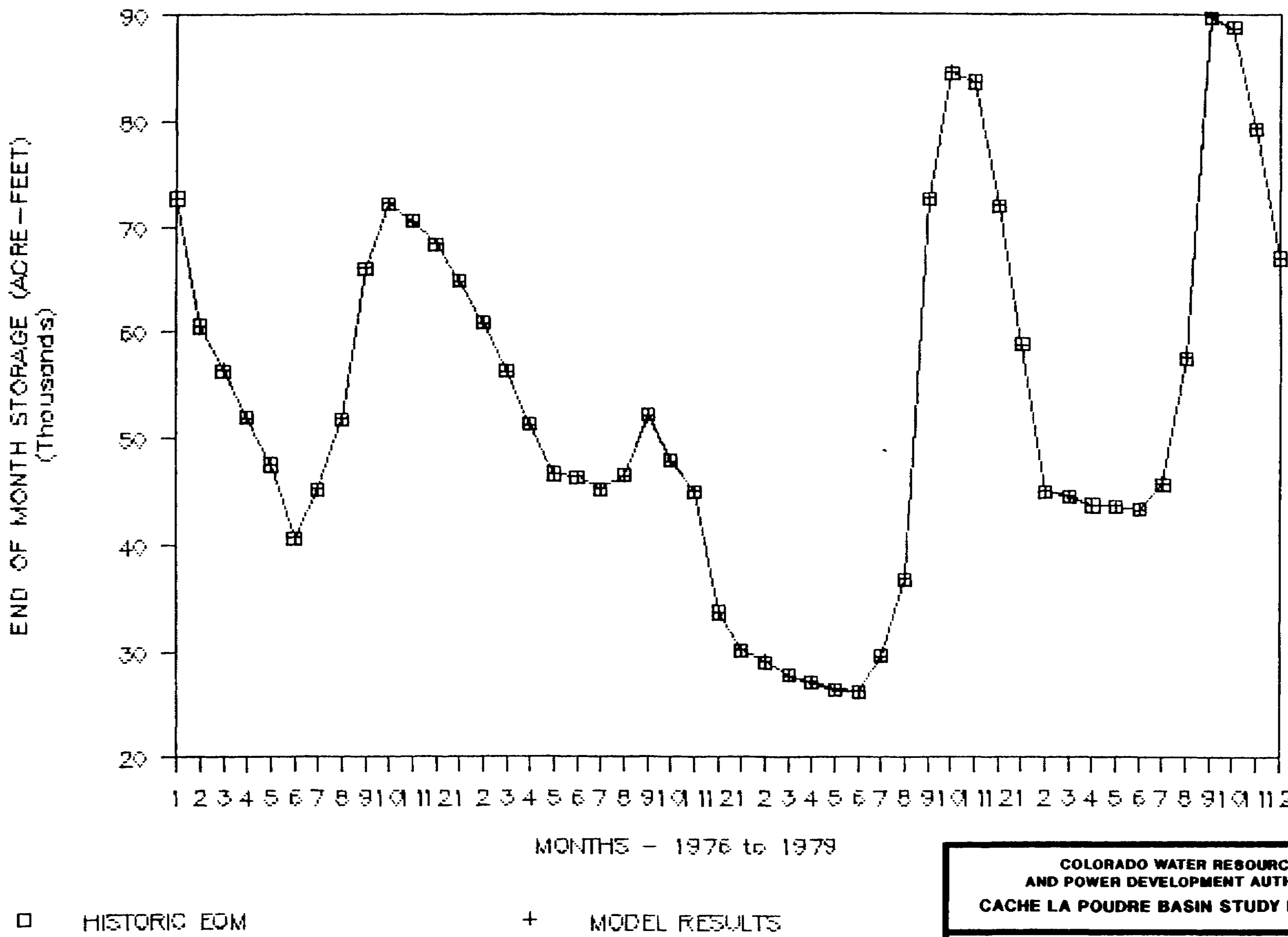
COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

CALIBRATION AT GREEN MOUNTAIN RES.
END OF MONTH STORAGE AT NODE 1

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 FIGURE 10.15



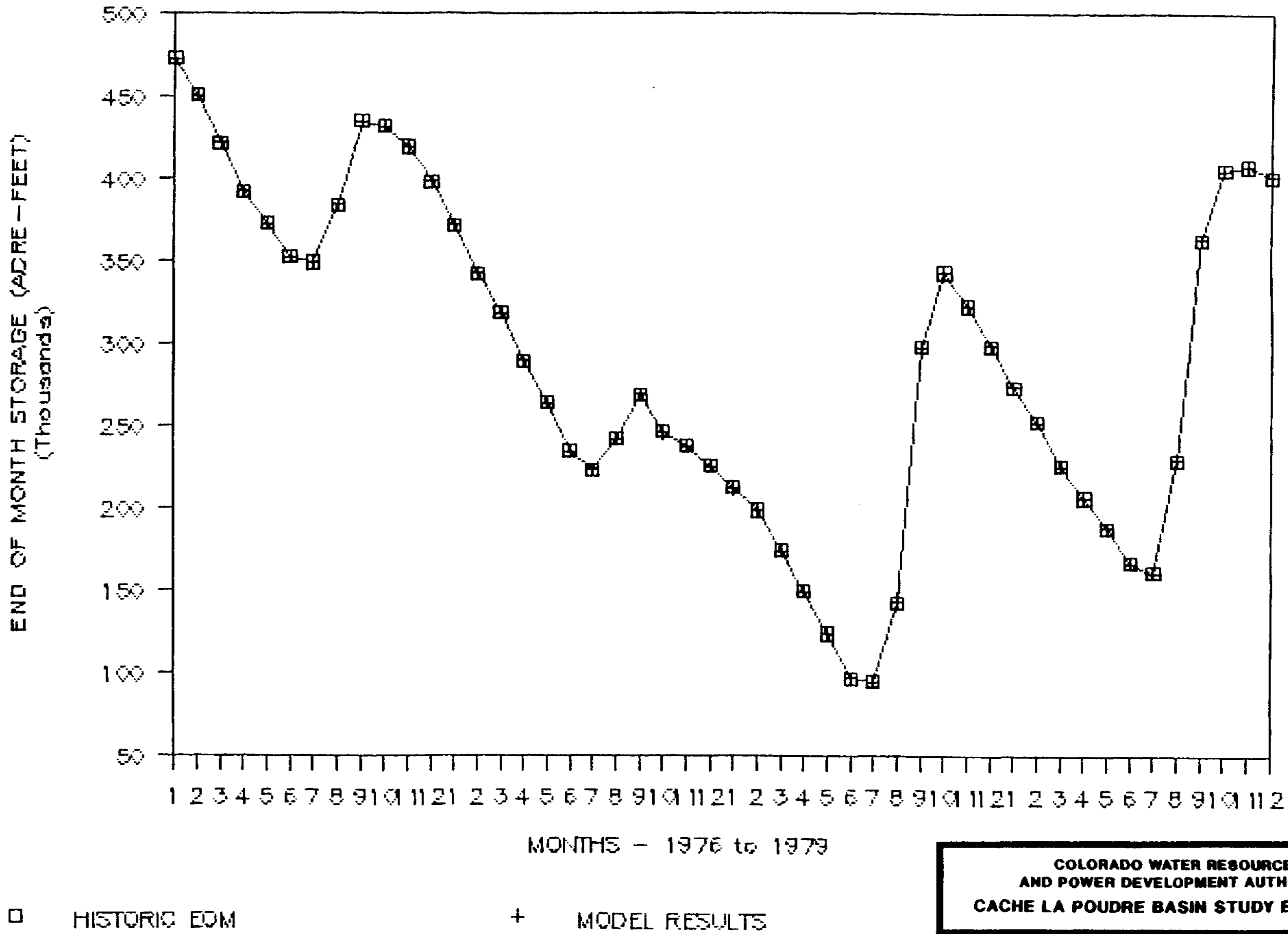
COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

CALIBRATION AT WILLIAMS FORK RES.
END OF MONTH STORAGE AT MODEL NODE 2

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 **FIGURE 10.16**



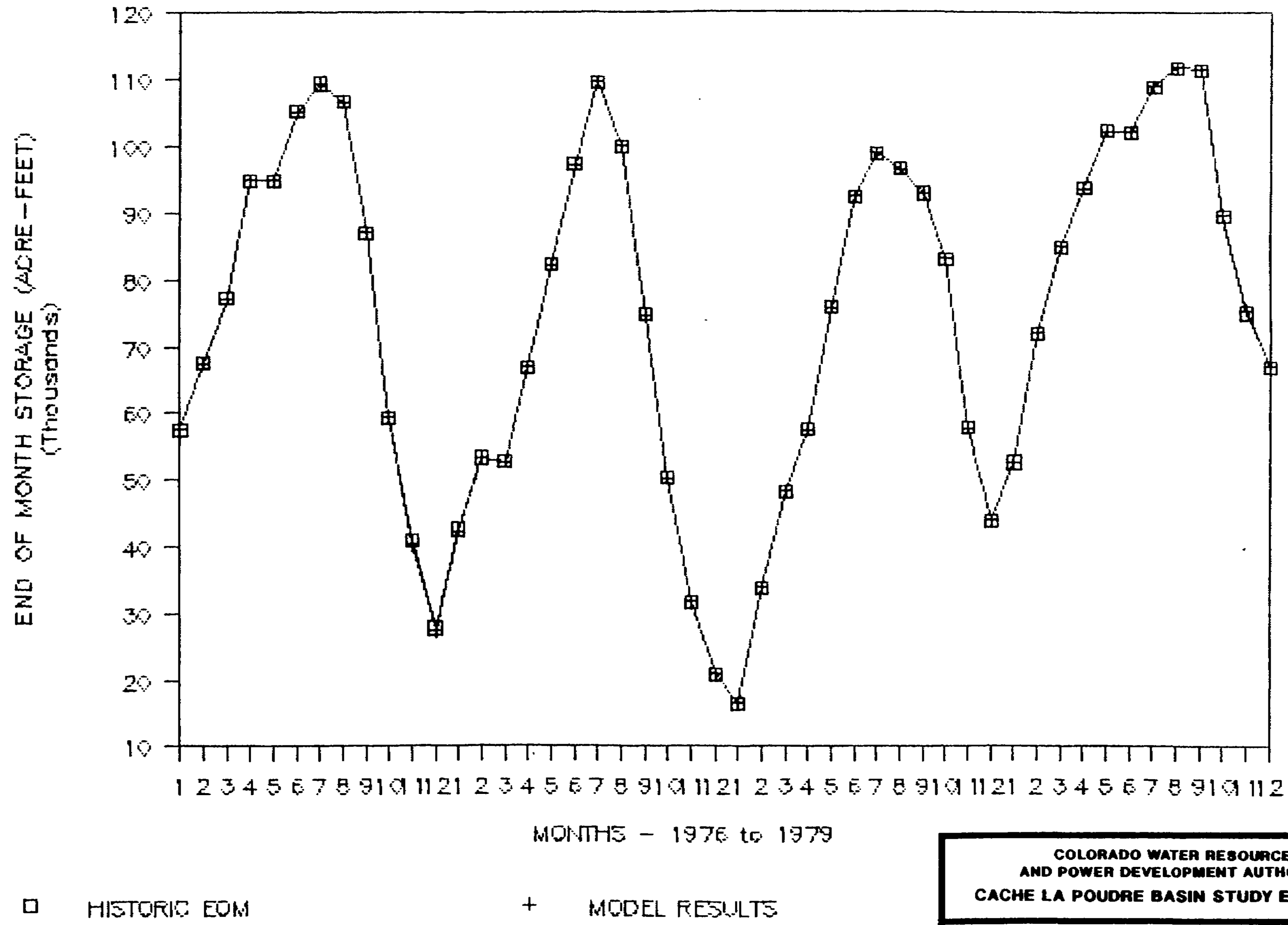
COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

CALBRATION AT GRANBY RES.
END OF MONTH STORAGE AT MODEL NODE 4

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 FIGURE 10.17



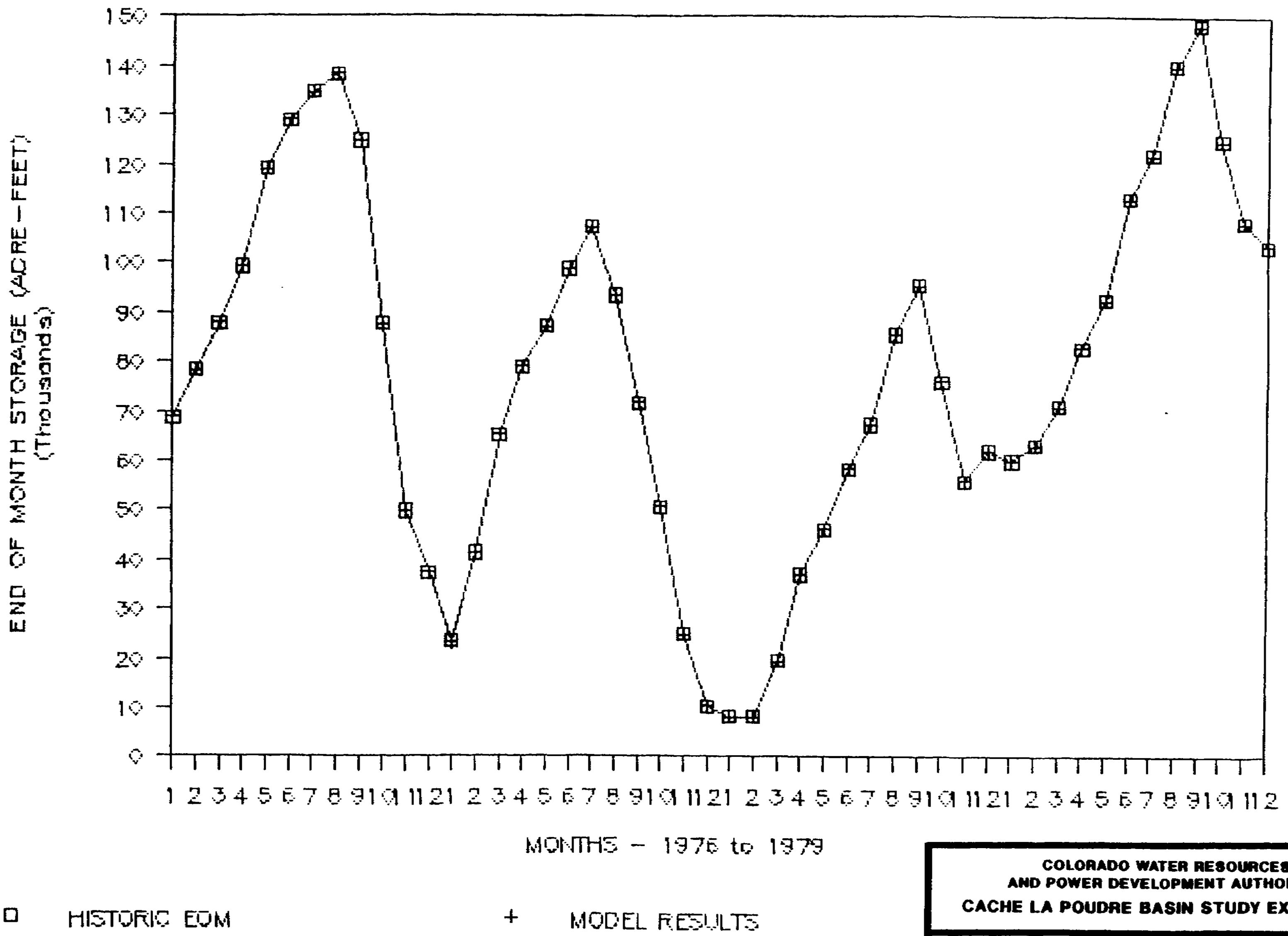
COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

CALIBRATION AT CARTER LAKE RES.
END OF MONTH STORAGE AT MODEL NODE 11

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 **FIGURE 10.18**



COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY

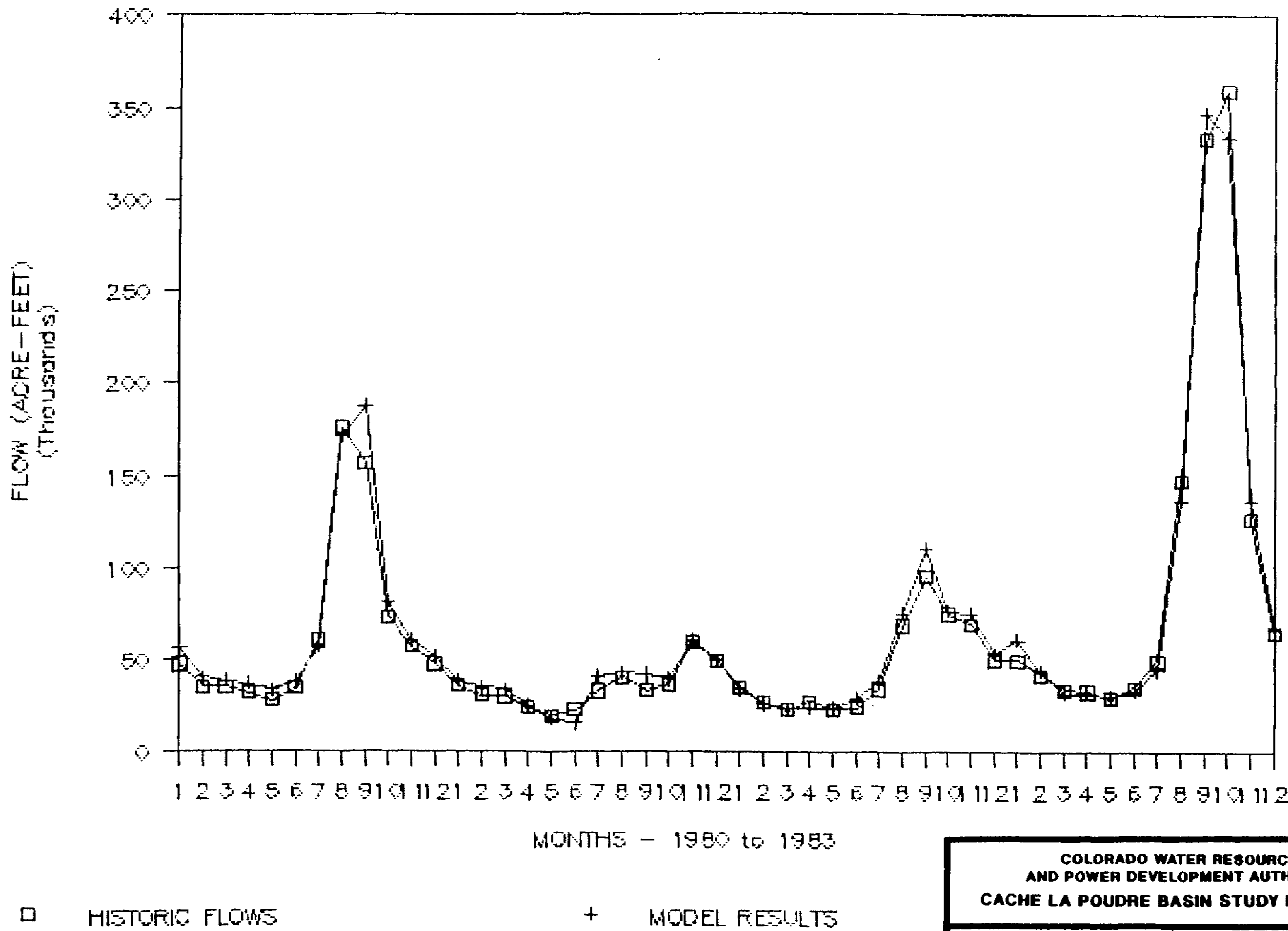
CACHE LA POUDRE BASIN STUDY EXTENSION

CALIBRATION AT HORSETOOTH RES.
END OF MONTH STORAGE AT MODEL NODE 13

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89

FIGURE 10.19



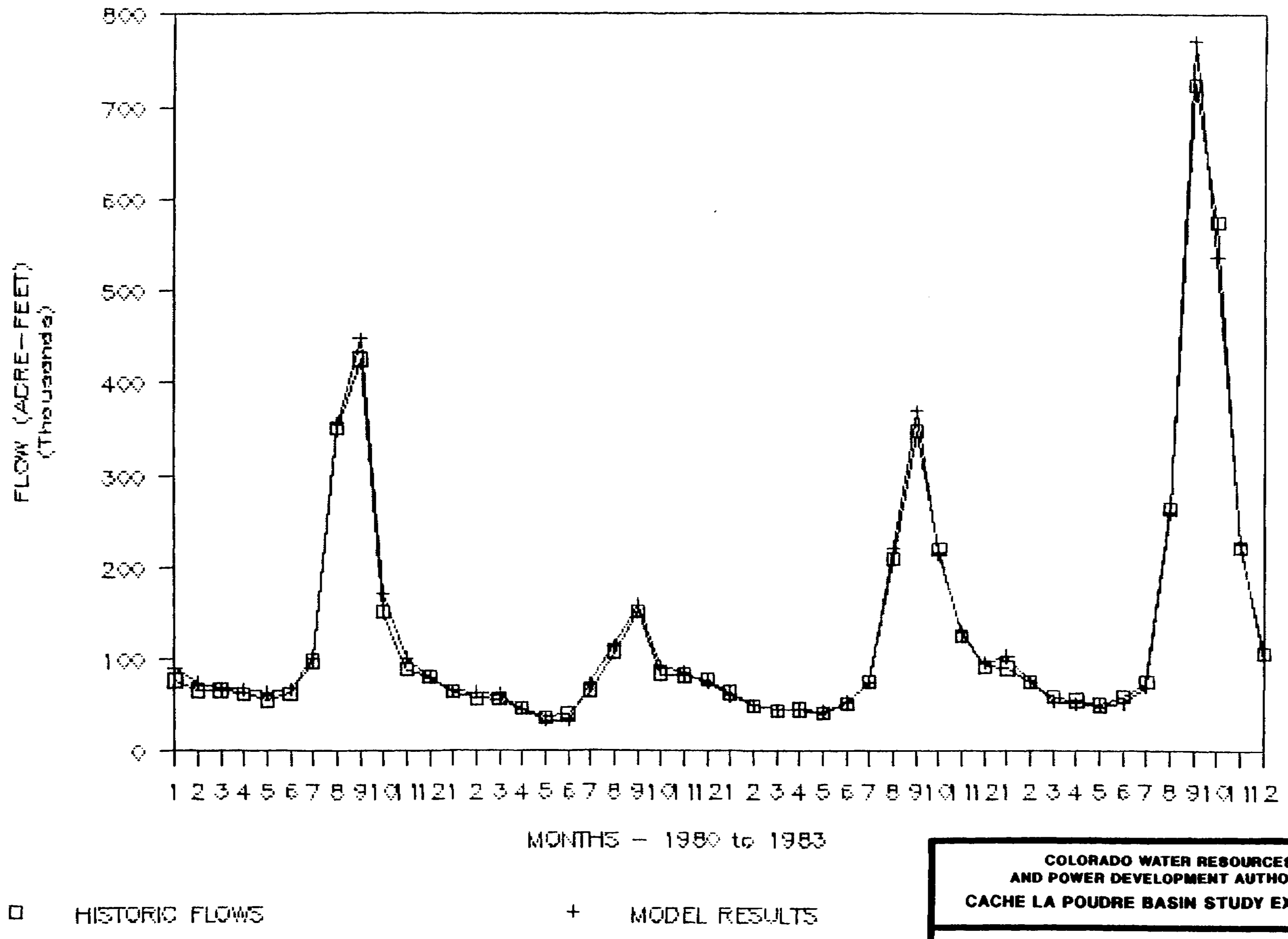
COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

VALIDATION AT KREMMLING GAGE
MODEL LINK 33 ON COLORADO RIVER

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 **FIGURE 10.20**

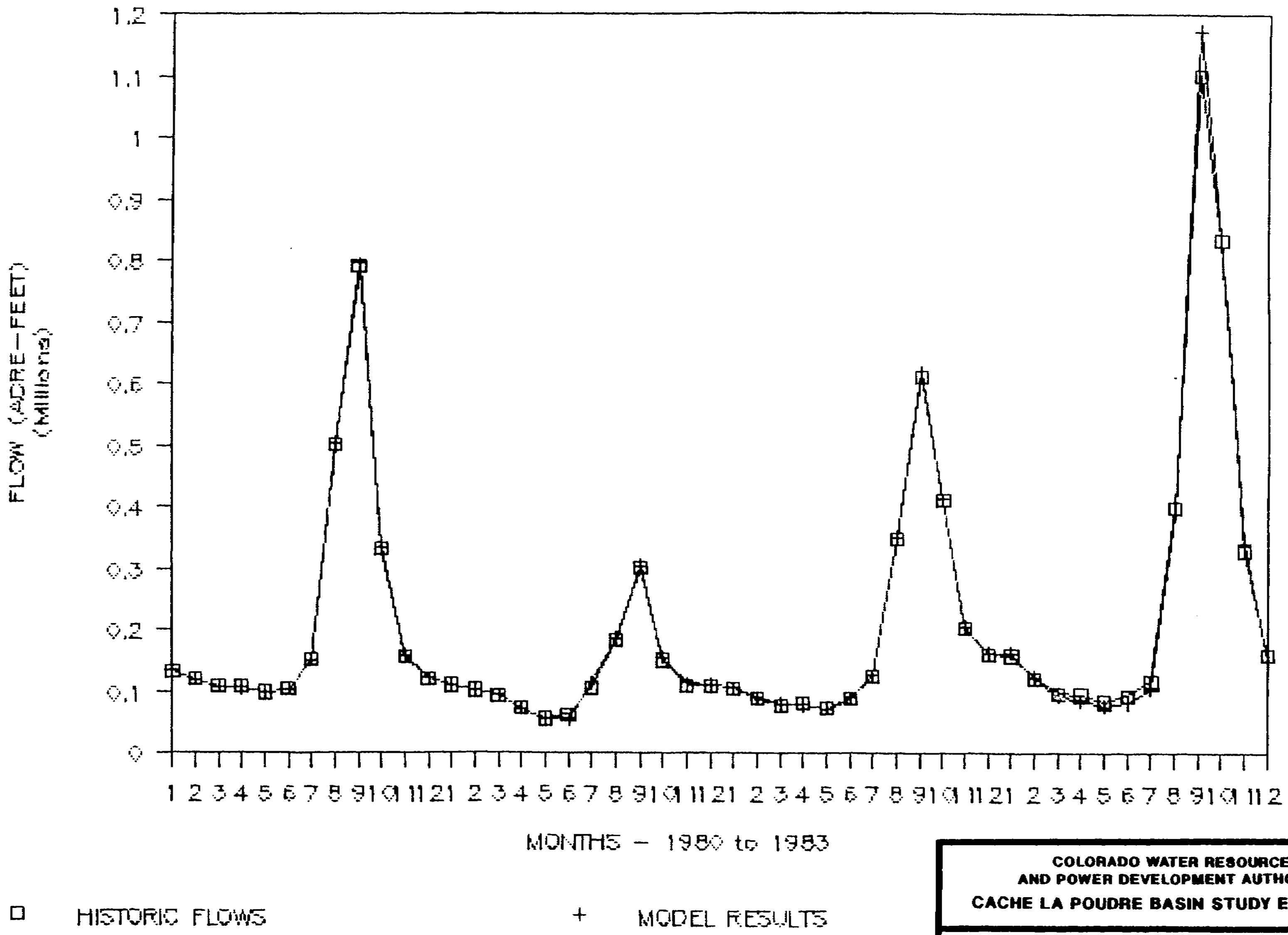


COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY
CACHE LA POUDRE BASIN STUDY EXTENSION

VALIDATION AT DOTSERO GAGE
MODEL LINK 41 ON COLORADO RIVER

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 FIGURE 10.21



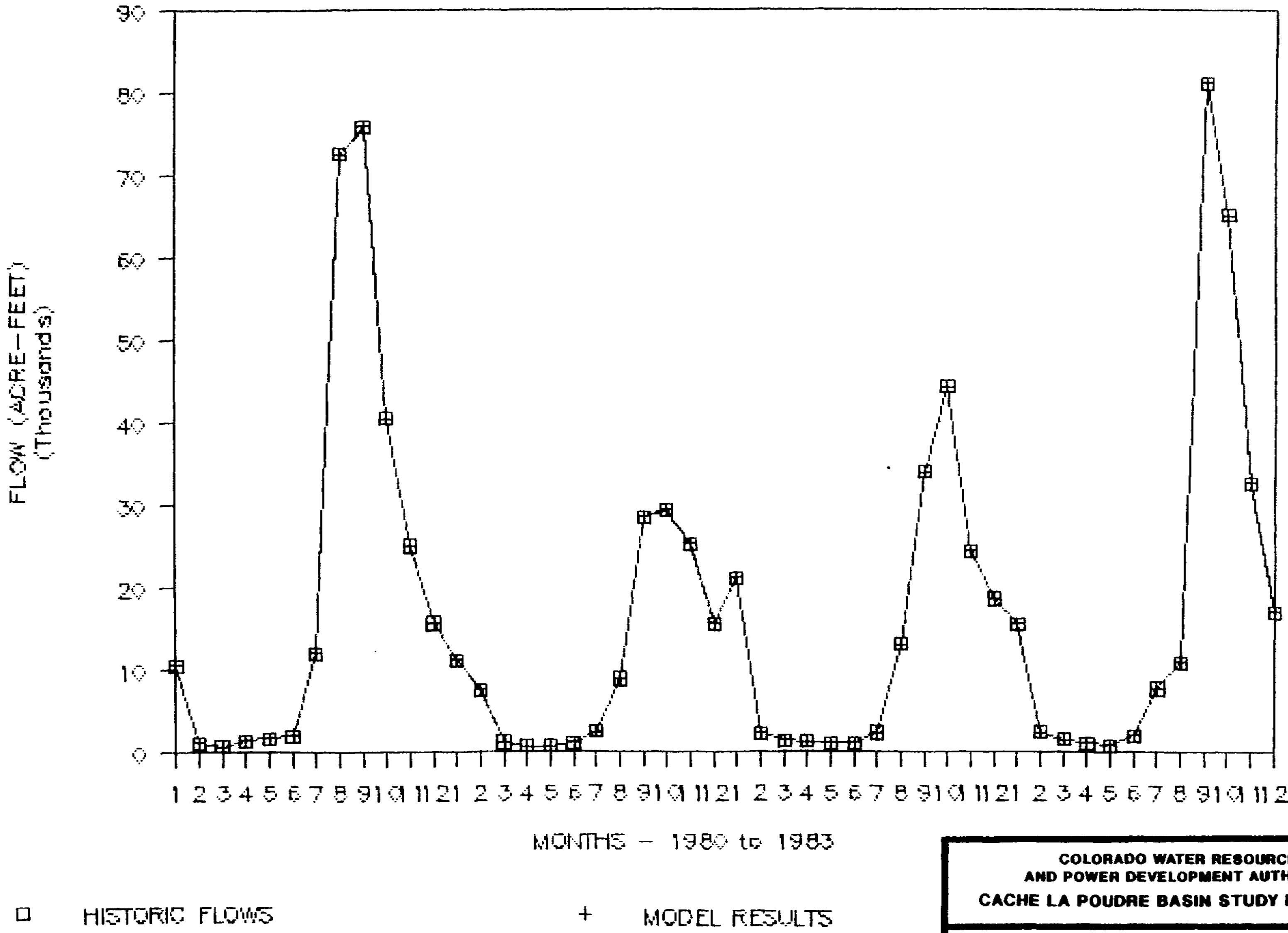
COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

VALIDATION AT GLENWOOD SPRINGS GAGE
MODEL LINK 48 ON COLORADO RIVER

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 **FIGURE 10.22**



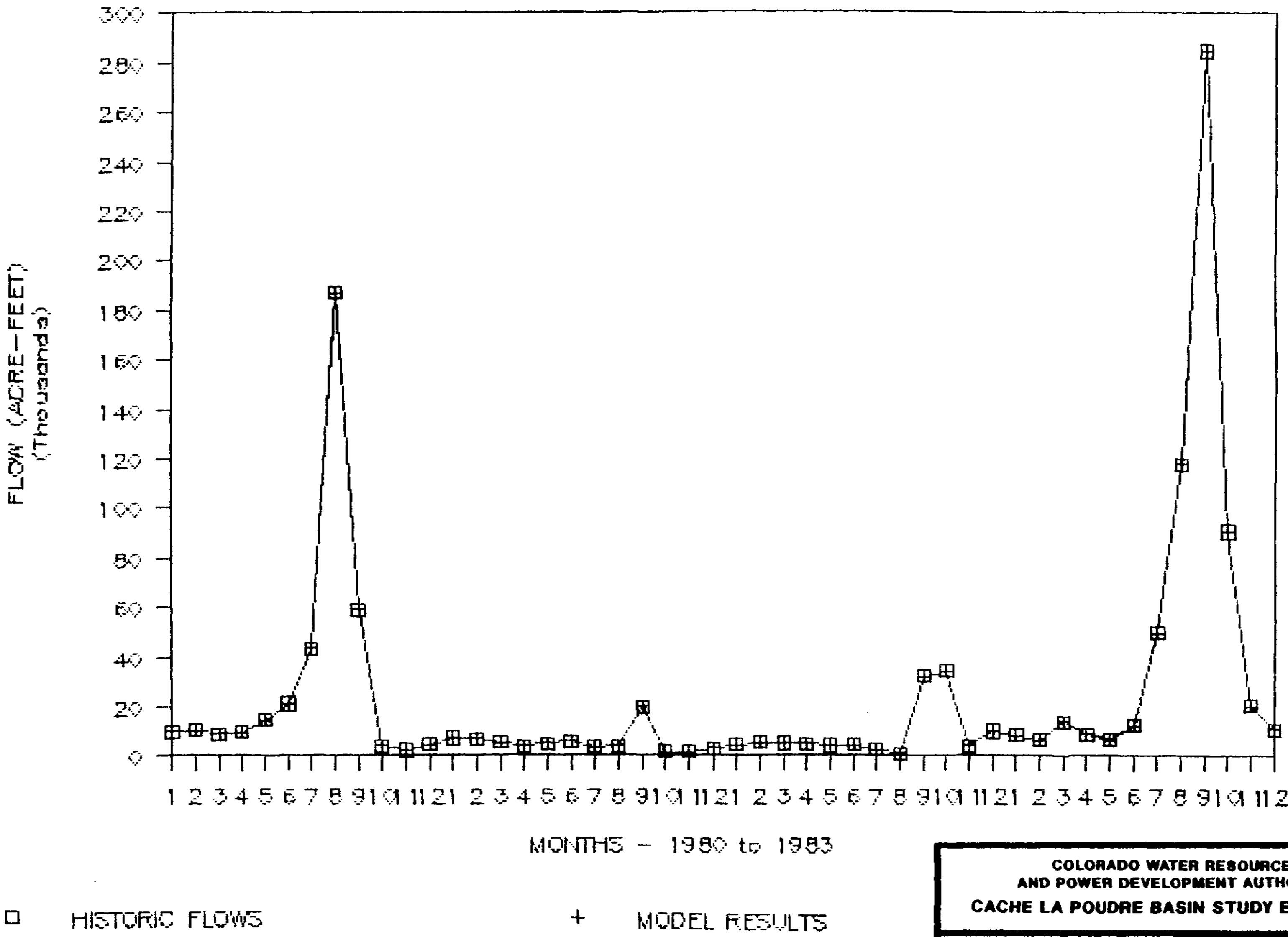
COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

VALIDATION AT BIG THOMPSON RIVER
MODEL LINK 60 AT MOUTH OF CANYON

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 FIGURE 10.23



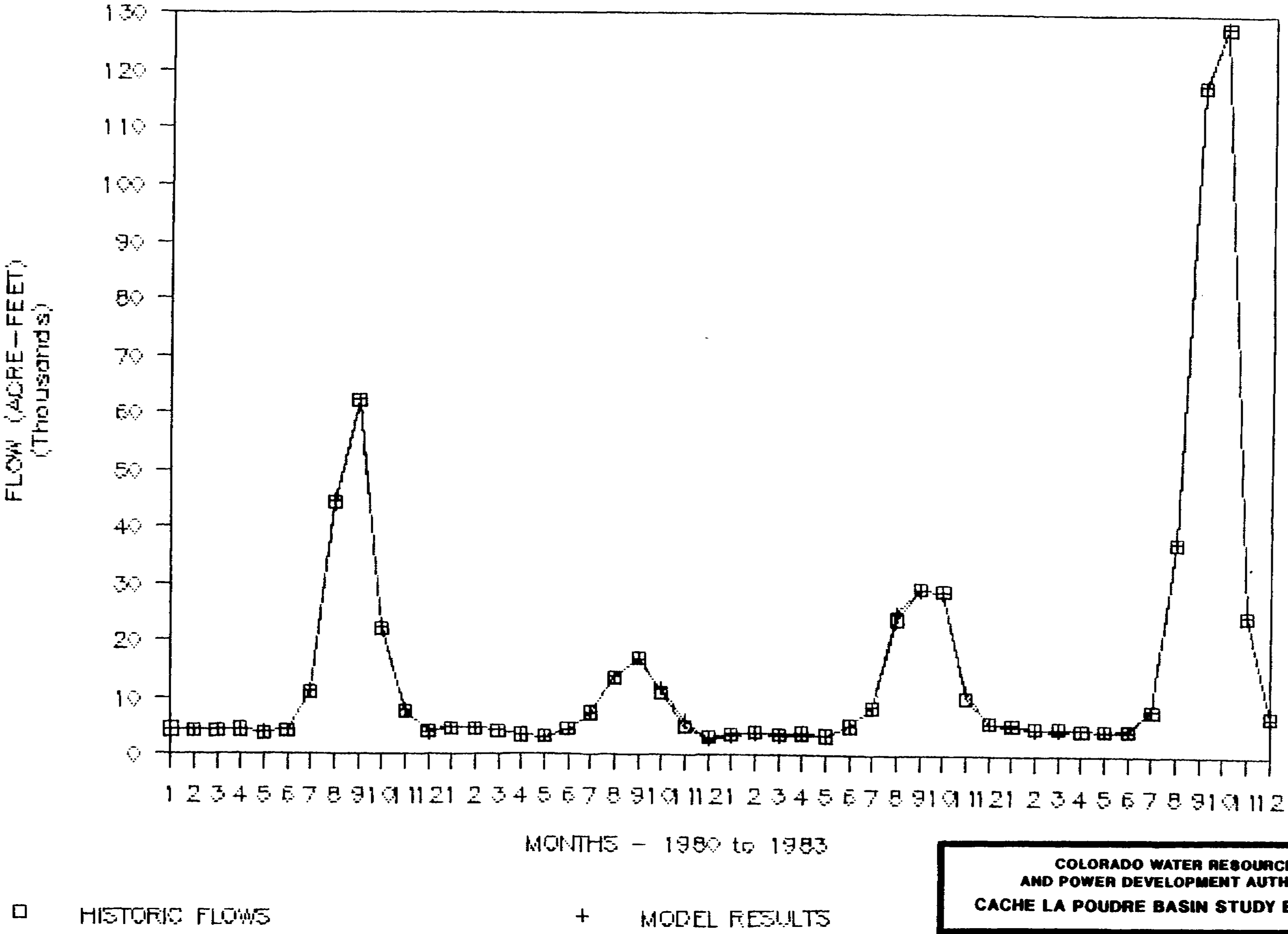
COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

VALIDATION AT GREELEY GAGE
MODEL LINK 57 ON POUDRE RIVER

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 FIGURE 10.24



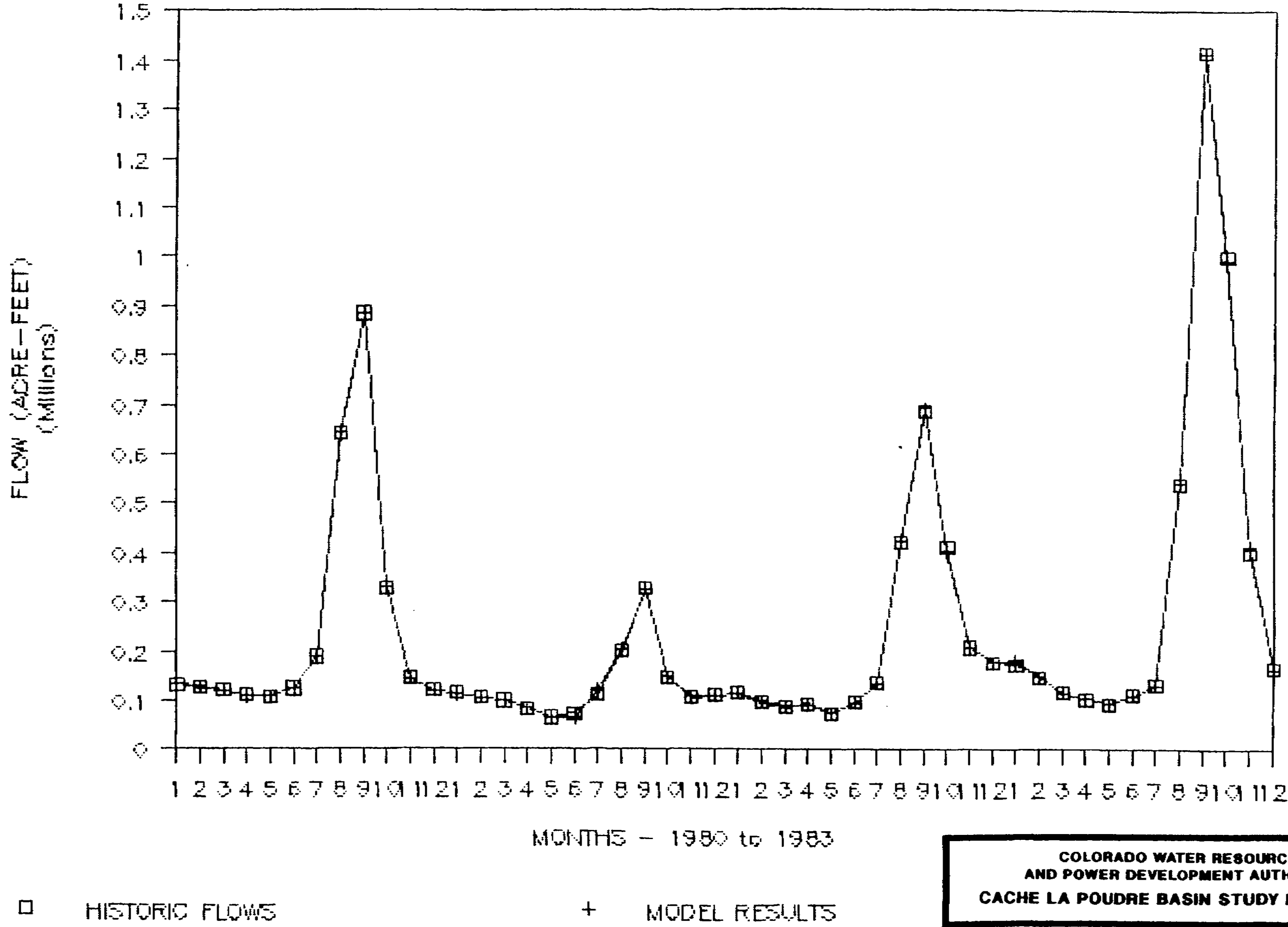
COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

VALIDATION AT HOT SULPHUR SPRGS.GAGE
MODEL LINK 29 ON COLORADO RIVER

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 **FIGURE 10.25**

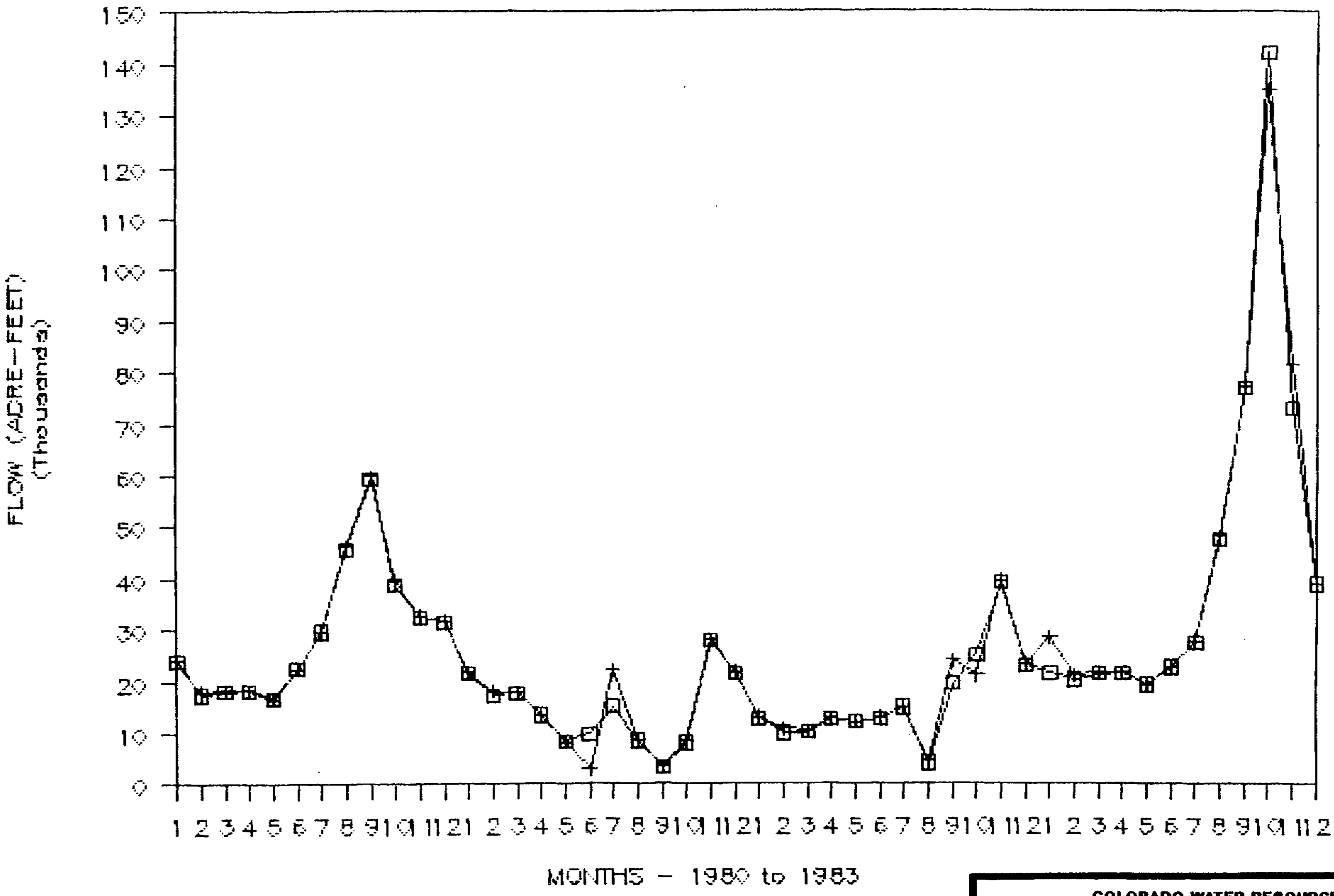


COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY
CACHE LA POUDRE BASIN STUDY EXTENSION

VALIDATION AT CAMEO GAGE
MODEL LINK 50 ON COLORADO RIVER

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 FIGURE 10.26



□ HISTORIC FLOWS + MODEL RESULTS

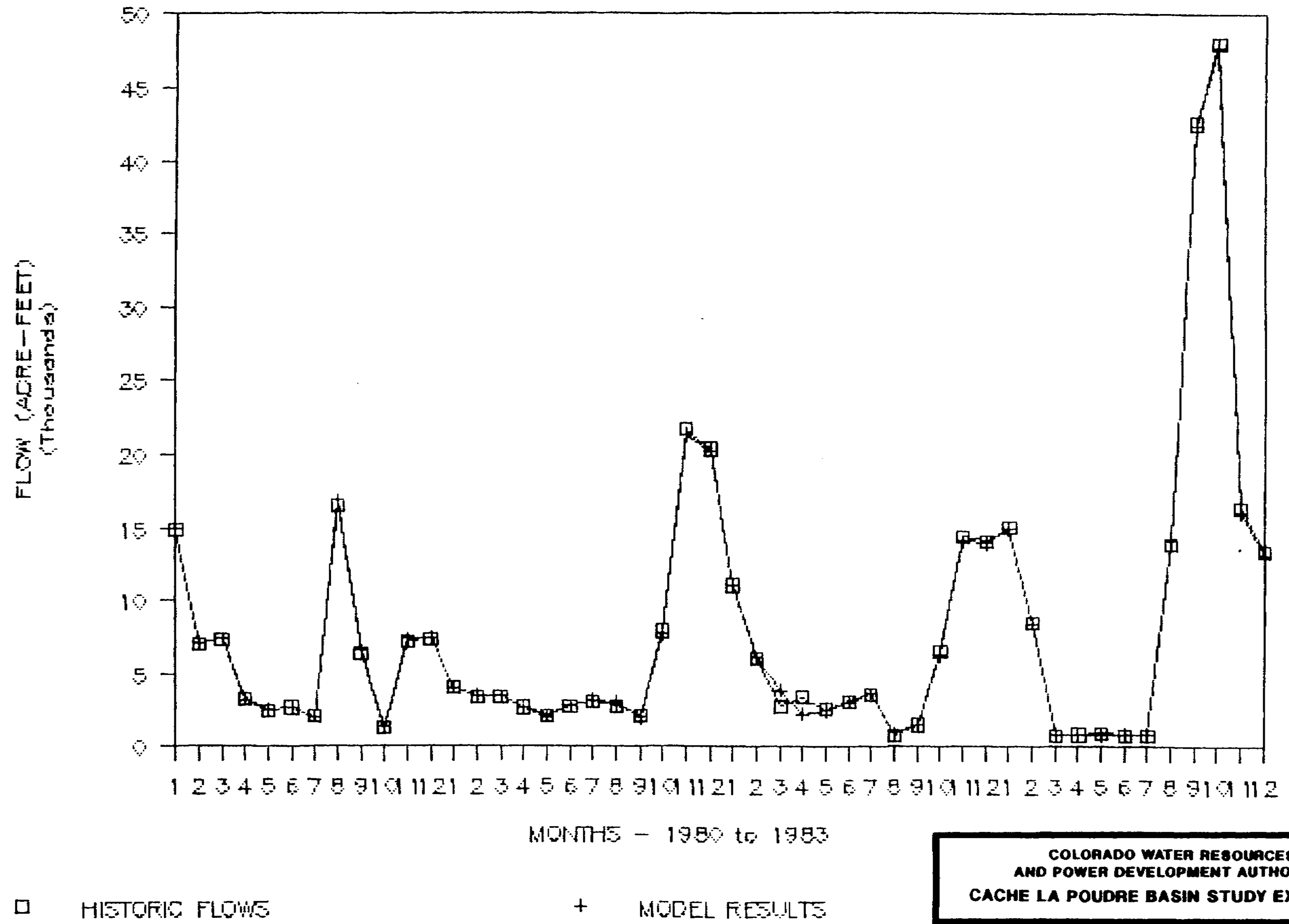
COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

VALIDATION AT GAGE BELOW GREEN MTN.RES.
BLUE RIVER MODEL LINKS 52 & 67

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 FIGURE 10.27



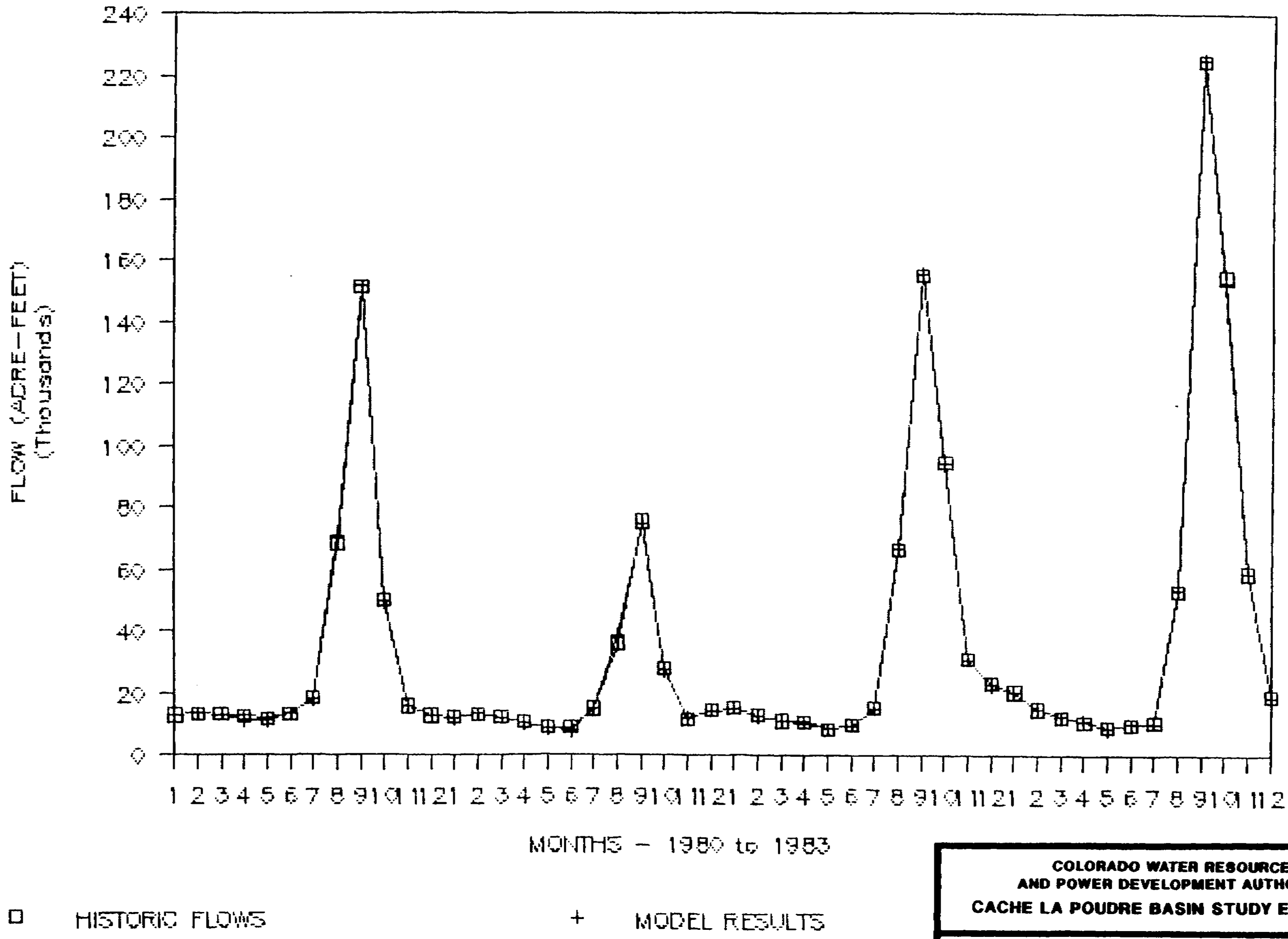
COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

VALIDATION–GAGE BELOW WILLIAMS FORK RES.
MODEL LINK 2 ON WILLIAMS FORK RIVER

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 **FIGURE 10.28**



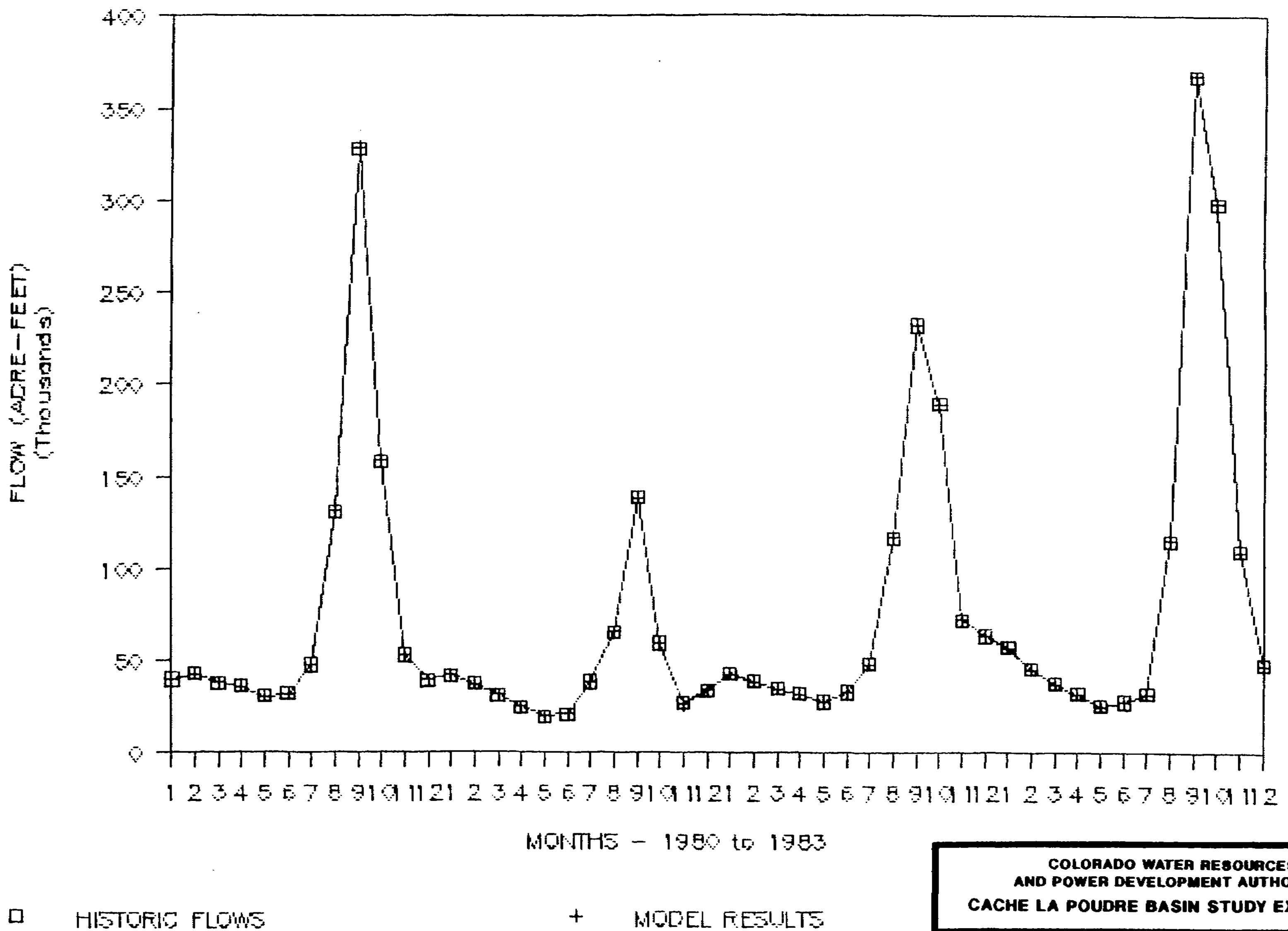
COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

VALIDATION-GYPSUM GAGE ON EAGLE RIVER
MODEL LINK 40 (NEAR MOUTH OF EAGLE)

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 **FIGURE 10.29**



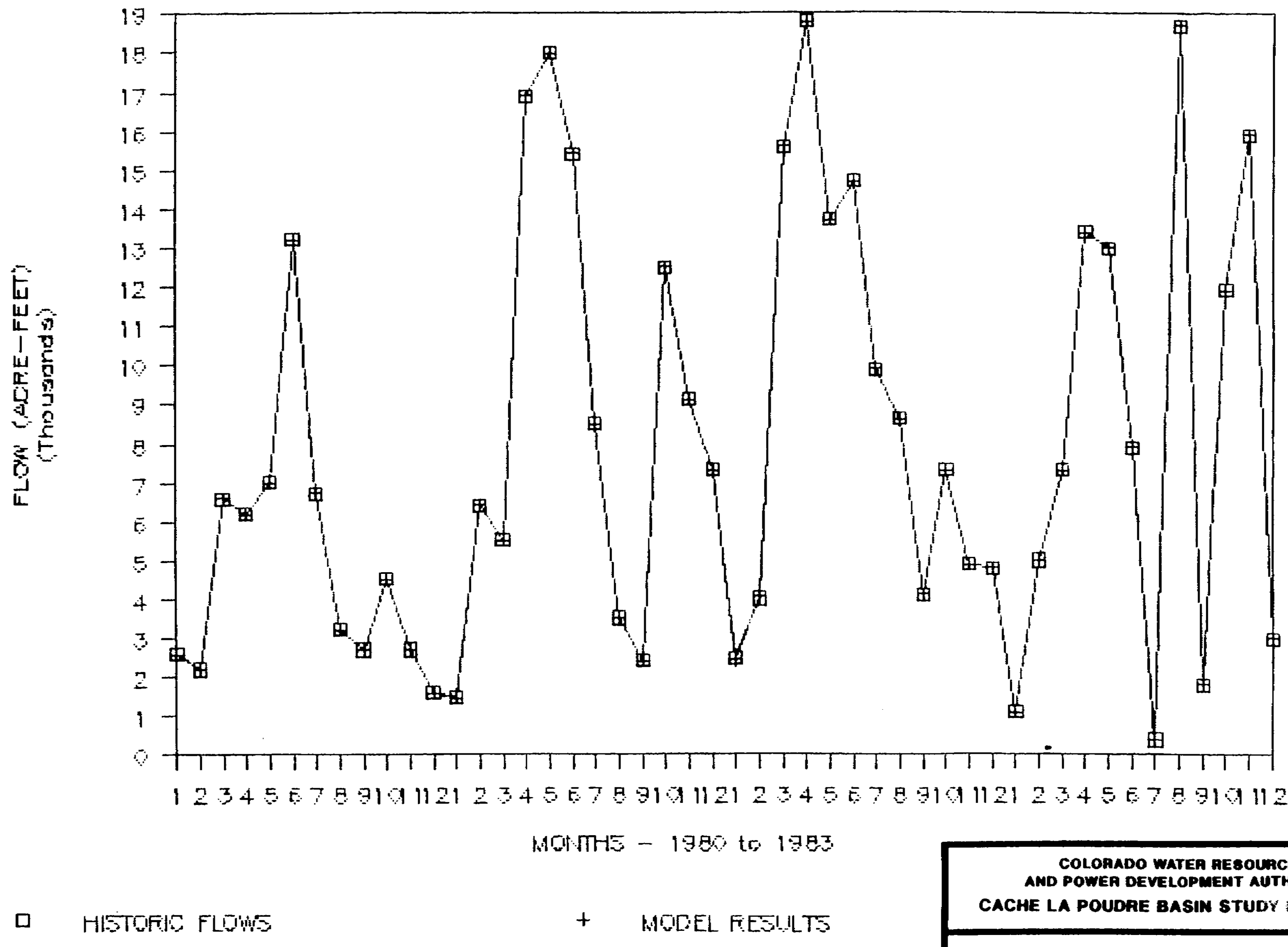
COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

VALIDATION–GLENWOOD GAGE ON ROARING FORK
MODEL LINK 85 (MOUTH OF ROARING FORK)

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 FIGURE 10.30



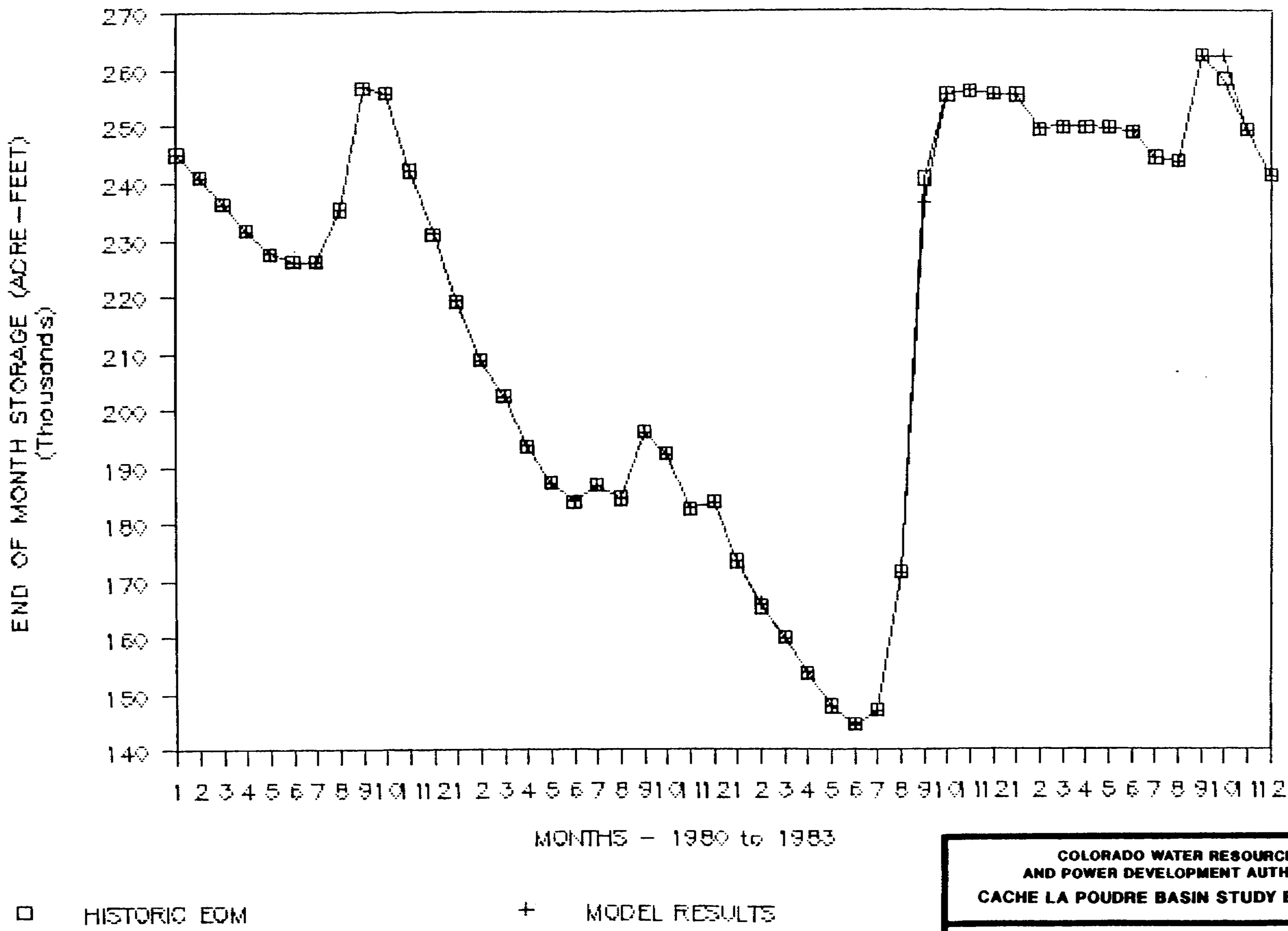
COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

VALIDATION AT HORSETOOTH RES. INFLOW
MODEL LINK 15

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 FIGURE 10.31



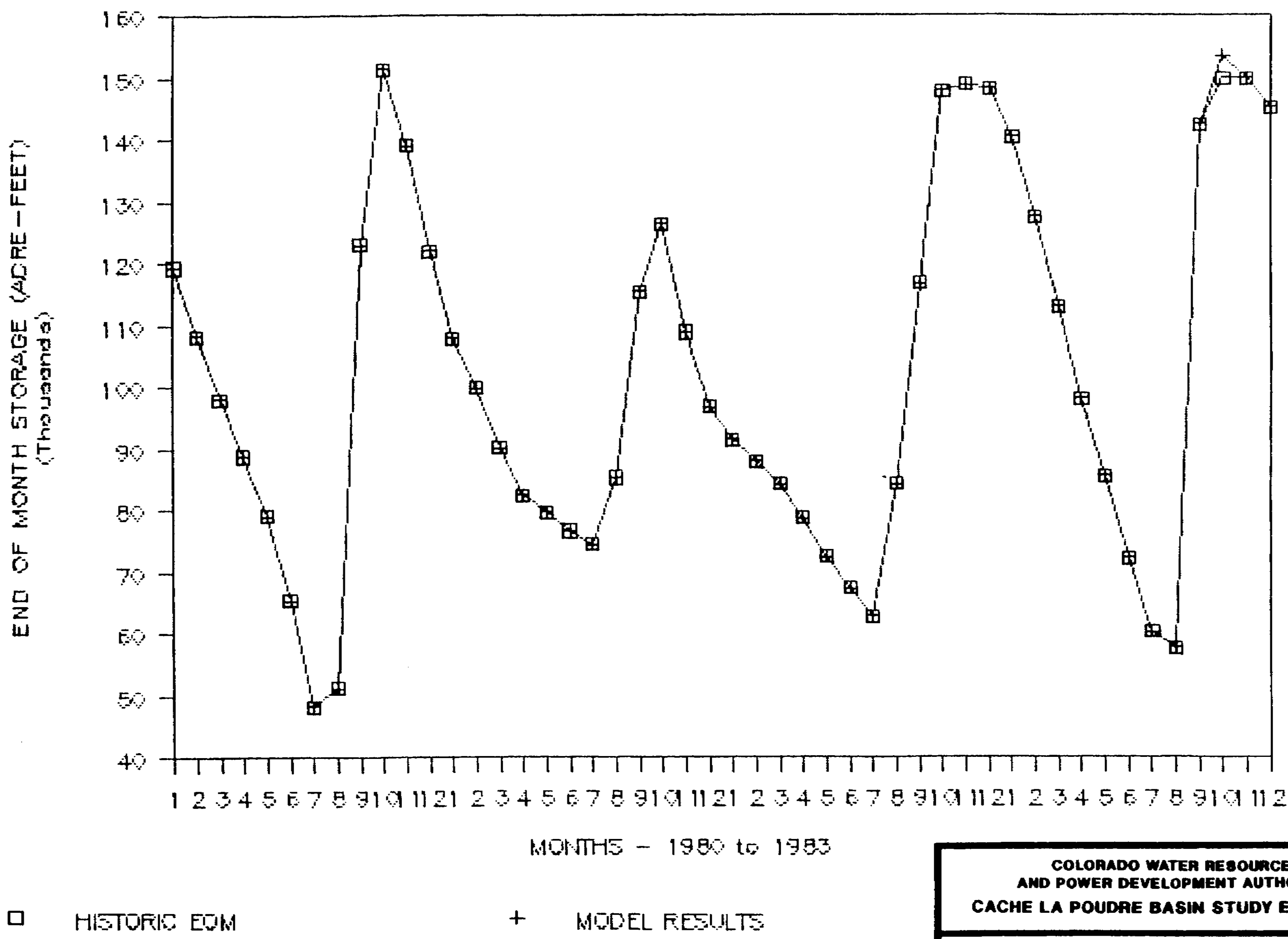
COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

VALIDATION AT DILLON RESERVOIR
END OF MONTH STORAGE AT MODEL NODE 14

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 **FIGURE 10.32**

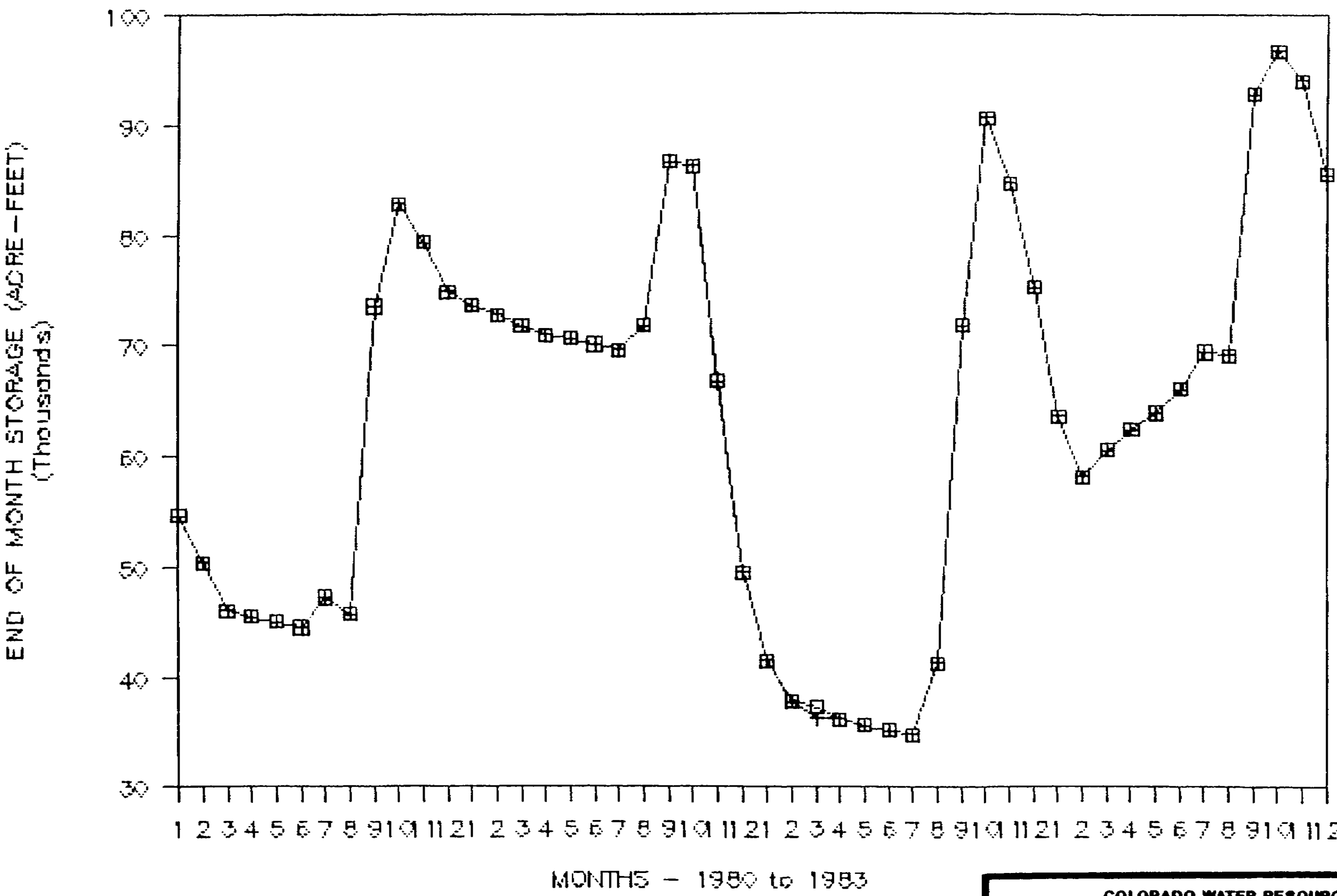


COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY
CACHE LA POUDRE BASIN STUDY EXTENSION

VALIDATION AT GREEN MOUNTAIN RES.
END OF MONTH STORAGE AT MODEL NODE 1

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 FIGURE 10.33



□ HISTORIC EOM + MODEL RESULTS

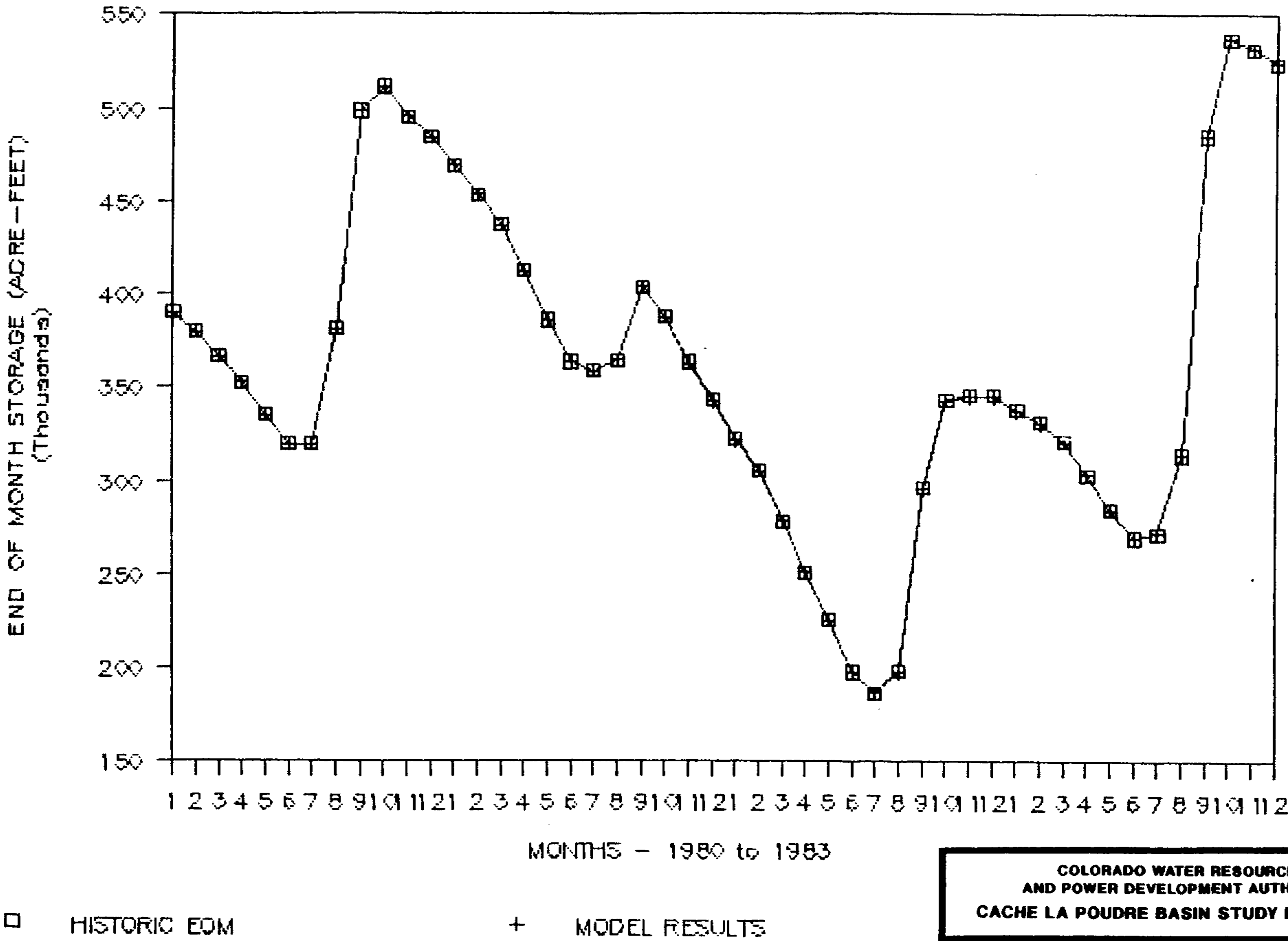
COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

VALIDATION AT WILLIAMS FORK RES.
END OF MONTH STORAGE AT MODEL NODE 2

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 FIGURE 10.34



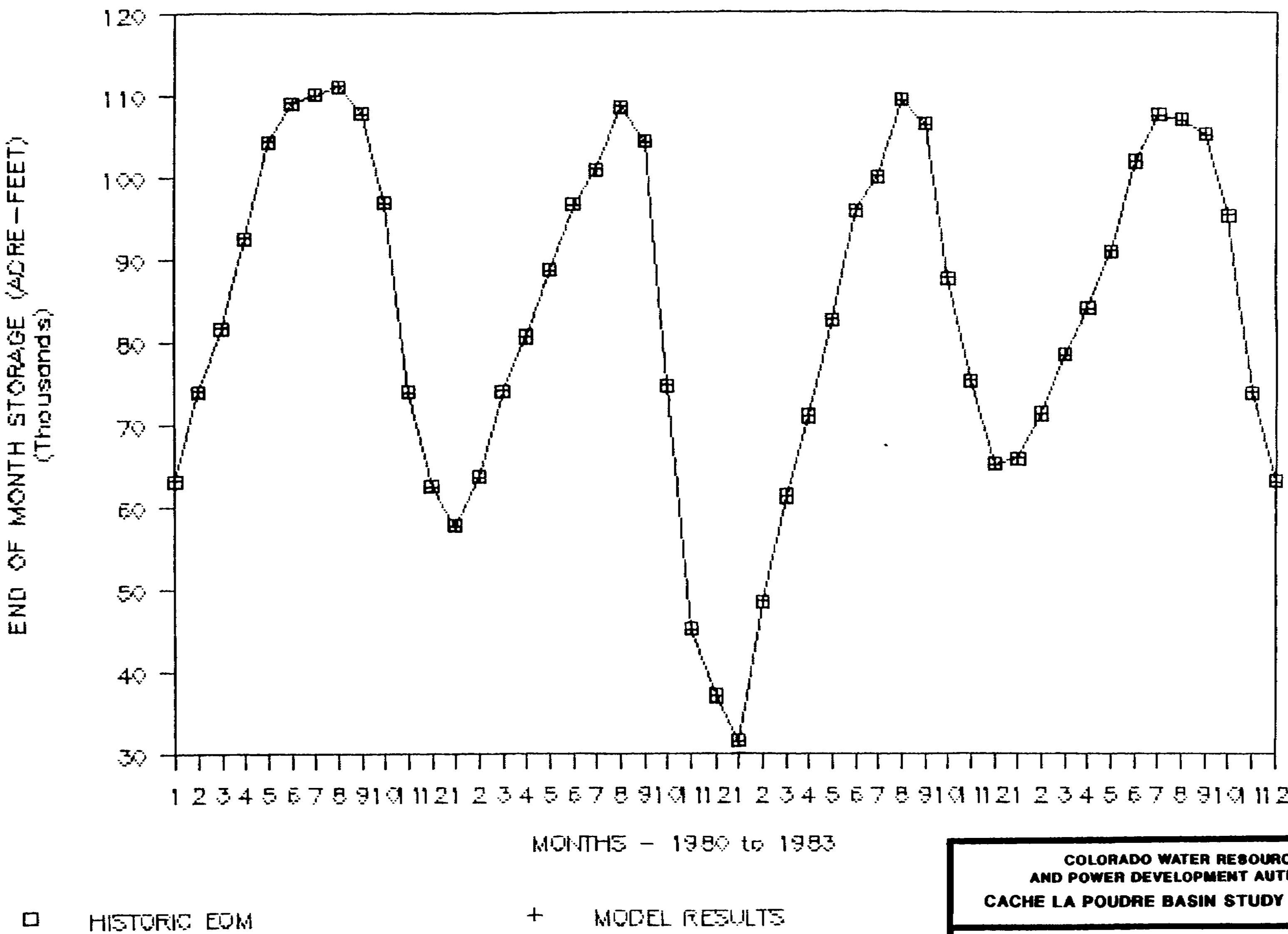
COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

VALIDATION AT GRANBY RESERVOIR
END OF MONTH STORAGE AT MODEL NODE 4

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 FIGURE 10.36



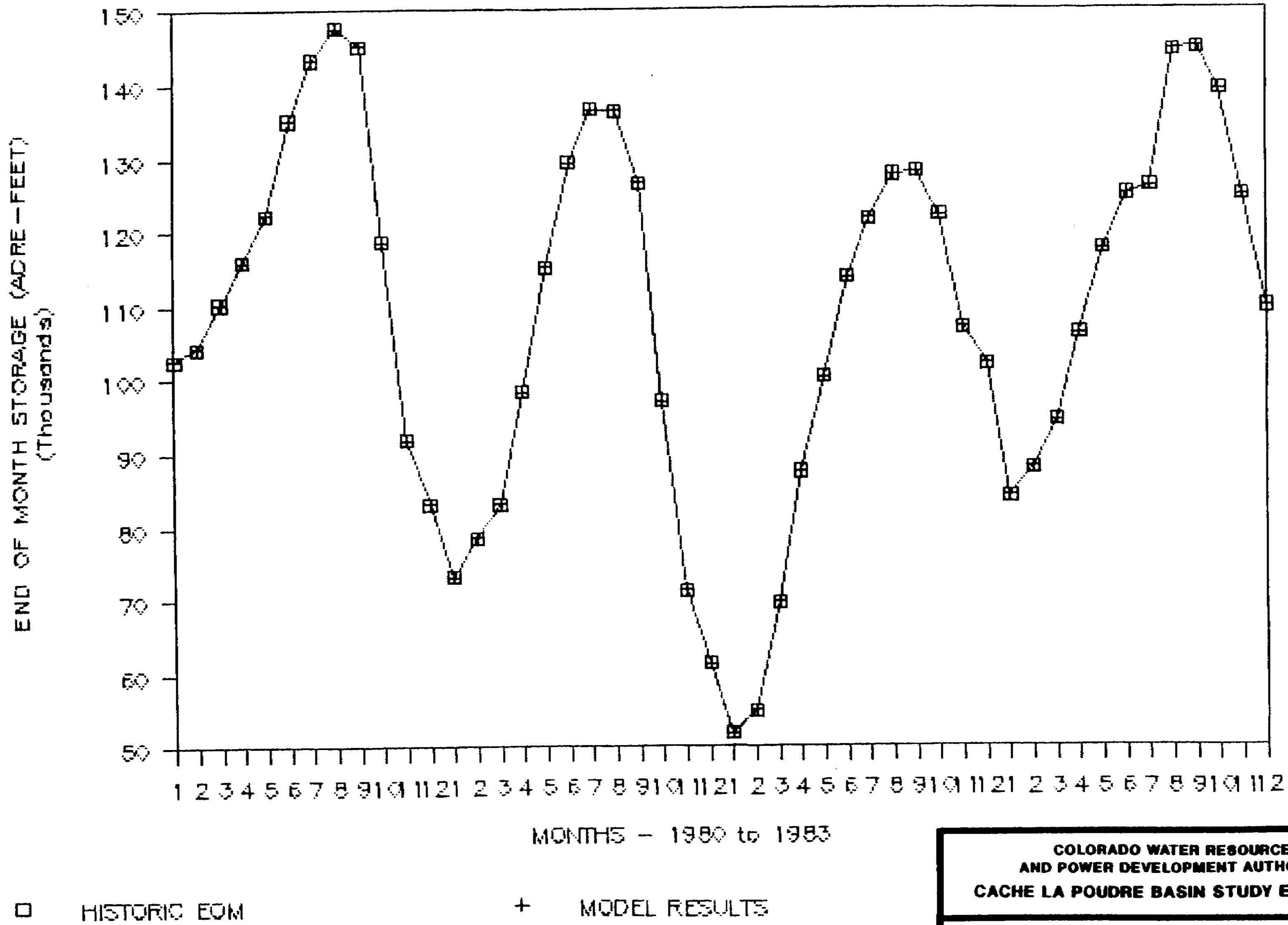
COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

VALIDATION AT CARTER LAKE RESERVOIR
END OF MONTH STORAGE AT MODEL NODE 11

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 FIGURE 10.36



COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY EXTENSION

VALIDATION AT HORSETOOTH RESERVOIR
END OF MONTH STORAGE AT MODEL NODE 13

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

DATE 10/01/89 **FIGURE 10.37**

CHAPTER 11.0

ECONOMIC
ANALYSIS

11.0 ECONOMIC ANALYSIS

11.1 INTRODUCTION

As part of the Cache la Poudre Basin Study Extension, an economic analysis of the proposed Stage 1 project on the Cache la Poudre River was performed. The scope of the economic analysis was limited to the Grey Mountain alternative for Stage 1 of the proposed three-stage Cache la Poudre Project. This chapter describes the components of the economic analysis and the approach used to evaluate the economic performance of the project.

11.1.1 Components of Economic Analysis

The economic analysis consists of three components: assessment of economic effects; estimation of benefits; and determination of financial feasibility. Each task is related to the others, although distinguished by its own scope and purpose.

The economic effects component is described in Section 11.2 and presents projected changes in tangible economic measures stemming from construction and operation of the Stage 1 Cache la Poudre Project. Economic effects encompass monetary and demographic impacts directly and indirectly attributable to the Grey Mountain alternative. Examples include population, employment, income, and business and public sector revenues.

Along with the tangible benefits set forth in Section 11.2, non-tangible benefits and costs are addressed in the benefit-cost, or economic efficiency evaluation presented in Section 11.5. Non-tangible benefits and costs include recreational values. Where possible, quantification of benefits and costs is accomplished, although certain benefits and costs are not amenable to reliable quantification. The latter are described in terms of importance in Section 11.5.

Financial feasibility isolates only those project benefits which can produce revenues to offset the capital and financing costs associated with the Grey Mountain alternative. Estimates of revenue from water and hydropower sales are compared with annual principal and debt service repayment. The financial feasibility of the Grey Mountain alternative is described in Section 11.6.

11.1.2 Economic Study Approach

The Cache la Poudre Basin Study Extension builds upon the economic analyses performed for the Basin Study, completed in 1986 (Harza, 1987). For example, the Basin Study identified a potential need for additional storage in the basin since water shortages encountered during drought conditions could substantially impact the regional economy.

As described in Chapter 7.0, various alternatives for Stage 1 of the Cache la Poudre Project were investigated, leading to selection of the Grey Mountain alternative as the preferred Stage 1 development. The preferred plan selected during the Basin Study involved a mainstem storage reservoir and a major pumped-storage component. Economic benefits of pumped-storage were substantially larger than benefits emanating from additional water to irrigators during drought periods, conventional hydroelectric generation, and lake-oriented recreation. The present Stage 1 configuration does not include a pumped-storage component, and firm yield from storage on the mainstem Cache la Poudre River would be utilized by municipal and industrial entities within or outside of the Cache la Poudre Basin. As described in Chapter 1.0, Stages 2 and 3, respectively, would provide pumped-storage hydroelectric capacity and additional reservoir storage.

With the reformulation of the Grey Mountain alternative as a Stage 1 development, the pattern of project benefits identified in the earlier Basin Study is altered substantially, resulting in different emphasis in the economic studies. Water yields from the Stage 1 development are directed toward the municipal and industrial sectors, assuming drought protection as a secondary benefit. Pumped-storage hydroelectric power generation is not a part of the Stage 1 project, and run-of-river hydroelectric power generation is a relatively minor element. Conversely, gains and losses of recreational resources receive much greater attention in the Basin Study Extension.

Information about project configuration, construction costs, labor and materials, safe water yield, hydroelectric power generation, flood control potential, and estimated effects on regional recreation activities were used as inputs to the economic analyses. Baseline economic, demographic, and fiscal data were obtained from the Colorado Municipal League, Colorado Division of Local Government, the Colorado Departments of Labor and Employment and Revenue, and the U.S. Bureaus of Economic Analysis, Labor Statistics, and the Census.

Estimated costs for the Grey Mountain alternative do not include costs for specific environmental mitigation or enhancements. Whereas the necessity for appropriate mitigation is recognized, the process of obtaining input and eventually concurrence from local, state, and federal natural resource agencies to formulate a mitigation plan has not been initiated. This step is considered premature until potential project participants can be joined together in an initiative to develop the project. To account for the effects of mitigation costs on project feasibility, sensitivity analyses were performed as described in Section 11.5.4.

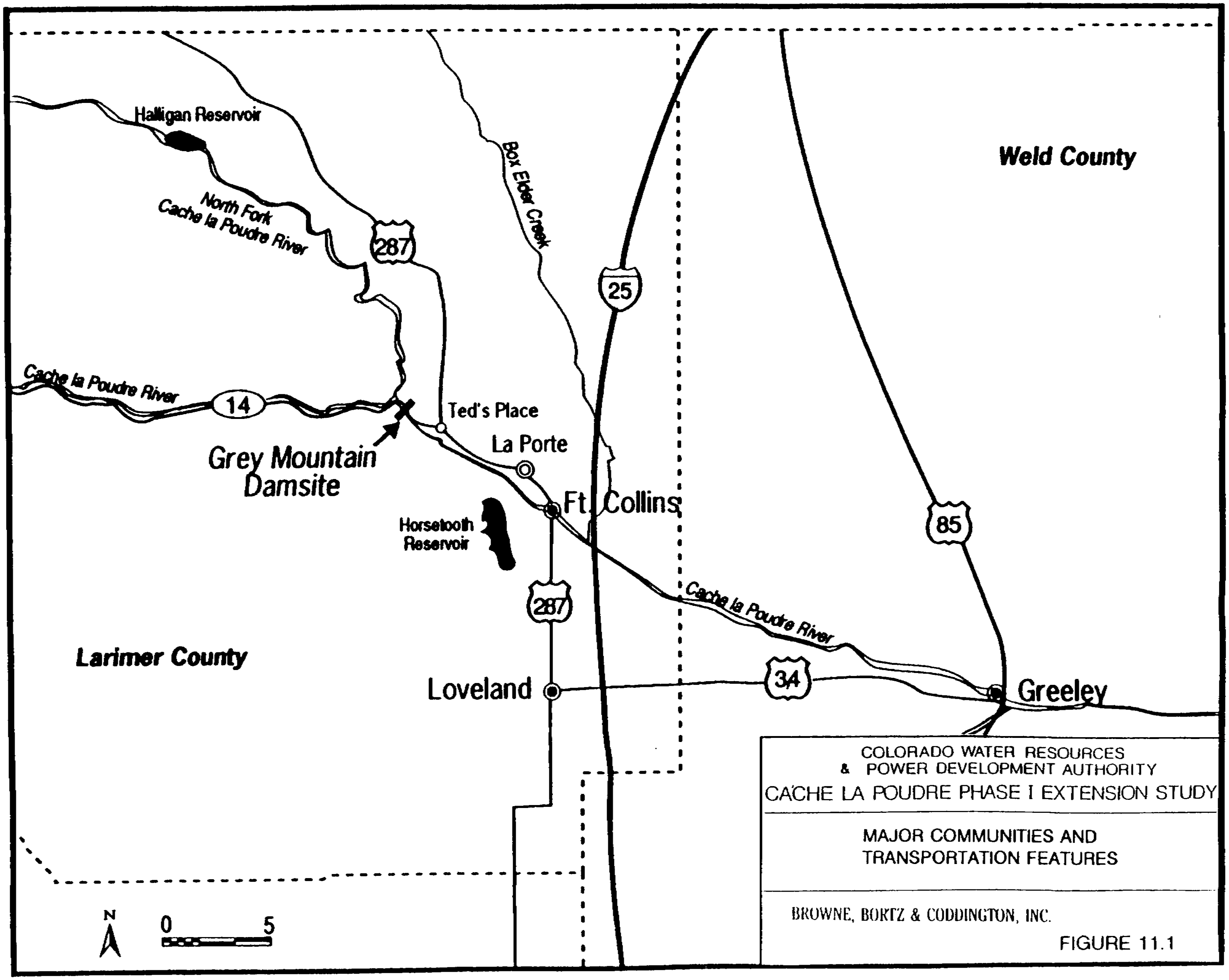
11.2 ECONOMIC ATTRIBUTES OF THE GREY MOUNTAIN ALTERNATIVE

This section describes the characteristics of the Stage 1 Grey Mountain alternative which will likely affect the economic climate of the region. The configuration of the Grey Mountain alternative for Stage 1 of the Cache la Poudre Project is described in Chapter 9.0. The Grey Mountain Damsite is located just below the confluence of the mainstem and North Fork of the Cache la Poudre River as shown on Figure 11.1.

11.2.1 Project Schedule

Construction of the Grey Mountain Dam could not begin until after a number of prerequisite tasks are completed. These tasks and the anticipated time to complete them include:

1. Permitting - 5 to 10 years;
2. Detailed engineering and design - 3 years;
3. Preparation of contract documents - 2 years;
4. Award of construction contracts - 1 year.


Halligan Reservoir
North Fork
Cache la Poudre River
Box Elder Creek
Weld County
287
25
Cache la Poudre River
14
Ted's Place
La Porte
Grey Mountain
Damsite
Ft. Collins
85
Horsetooth
Reservoir
287
Cache la Poudre River
Larimer County
34
Loveland
Greeley
N
0
5
COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY
CACHE LA POUDRE PHASE I EXTENSION STUDY
MAJOR COMMUNITIES AND
TRANSPORTATION FEATURES
BROWNE, BORTZ & CODDINGTON, INC.
FIGURE 11.1

While some of the activities associated with these tasks could be undertaken simultaneously, a minimum period of approximately 10 years would be required before construction could begin. Actual construction of Grey Mountain Dam and associated facilities would require about five years. The reservoir would inundate portions of the existing Colorado Highway 14. Therefore, during the first year of construction, Highway 14 would be relocated, and access roads to the damsite would be constructed. The Highway 14 relocation could follow any of several alternative alignments, as described in Chapter 8.0. Construction of the dam and ancillary facilities could commence in the second year of construction. The dam itself would require approximately three years to build. The fifth and final year of construction activities would involve restoration of areas disturbed by construction activities and disposal of unused excavated materials.

11.2.2 Project Employment and Compensation

The employment and remuneration levels (in 1988 dollars) associated with construction of Grey Mountain Dam and associated facilities, including the highway relocation, are presented below:

TABLE 11.1

Estimated Construction Employment and Compensation
Grey Mountain Alternative

Year of Construction	Average Annual Employment	Total Wages & Salaries (thousands of 1988 dollars)
1	60	$ 1,596
2	260	6,962
3	510	13,576
4	390	10,345
5	120	811

Annual average employment would reach its highest level during the third year of construction with an estimated 510 workers; the five year average employment would be 268 persons. Wages and salaries would be almost $33.3 million over the five year period, excluding fringe benefits and payroll burden.

During the operational phase of the project, a dam operator, assistant operator, and maintenance person would be employed at the site. The dam operators would reside at the project site, while the maintenance person would likely commute. Total annual compensation for the three operations personnel is estimated to be $78,000.

11.2.3 Project Construction Costs

Construction costs for Stage 1 of the Cache la Poudre Project, Grey Mountain alternative, are estimated to be approximately $230 million as follows:

TABLE 11.2

Estimated Construction Costs
Grey Mountain Alternative

Component	January 1988 Construction Cost ($ millions)	Percent of Total
Grey Mountain Dam and Reservoir	$163.9	71.2%
Conventional Hydroelectric Plant	13.9	6.1
Horsetooth-Grey Mountain Conveyance	29.0	12.6
Access Roads	1.9	0.8
Colorado Highway 14 Relocation	21.4	9.3
Total	$230.1	100.0%

Construction of the dam and reservoir account for the largest portion of total costs. The costs associated with construction of the ancillary facilities represent nearly 19 percent of total costs, and Highway 14 relocation costs amount to about nine percent of construction costs. To the extent possible, construction materials, supplies, and labor would be purchased or obtained in northern Colorado.

11.2.4 Project Related Outputs

The Grey Mountain Reservoir will provide for the regulation of native storable flows on the mainstem and North Fork of the Cache la Poudre River and storage of water from the Colorado-Big Thompson (C-BT) and Windy Gap Projects. Other project related outputs include run-of-river hydropower production, flood control, and enhancement of regional water management.

Grey Mountain Reservoir is primarily a water supply facility providing an estimated 185,000 acre feet (af) of active storage and 41,000 af of safe annual yield (see Chapter 10.0). This figure includes an increment of yield from the C-BT and Windy Gap Projects. Diversions from the C-BT and Windy Gap Projects would be imported through existing C-BT conveyance facilities and stored in Horsetooth Reservoir. From Horsetooth, a maximum of about 10,000 af per month, depending on available storage, could be conveyed by pipeline approximately 7.5 miles to Grey Mountain Reservoir as described in Chapter 9.0.

A conventional hydroelectric power facility can be constructed at Grey Mountain Dam. The hydropower component is assumed to have an installed generating capacity of about 24 MW. As described in Chapter 9.0, average annual energy production would be 52 GWh, a portion of which would be used for pumping water between Grey Mountain and Horsetooth reservoirs.

Other potential outputs are incidentally related to construction of Grey Mountain Dam and Reservoir. A mainstem storage facility would substantially reduce the risk of downstream flooding and associated damages. The principal beneficiaries of flood control would be the City of Fort Collins and the Town of LaPorte. Other developed areas in unincorporated Larimer County also would benefit. Hydrologic studies indicate that substantial reductions in peak flood flows can be achieved without allocating a portion of reservoir storage specifically for flood control. Recreational benefits could accrue to the area from lake-oriented opportunities at the reservoir and because of river flow regulation through Fort Collins.

Additional storage in the Poudre Basin will allow for the enhanced management of the region's water supplies. The Grey Mountain Reservoir would increase the capacity for water exchanges among various users in the region, as well as provide for additional drought protection. In addition, the Grey Mountain Reservoir would facilitate management of the Cache la Poudre River's upper reservoirs for improved recreational use if appropriate agreements could be negotiated with reservoir owners to allow for changes in reservoir operations, enhancing fish habitat and recreational opportunities. This could only be achieved with the agreement of existing reservoir owners, however.

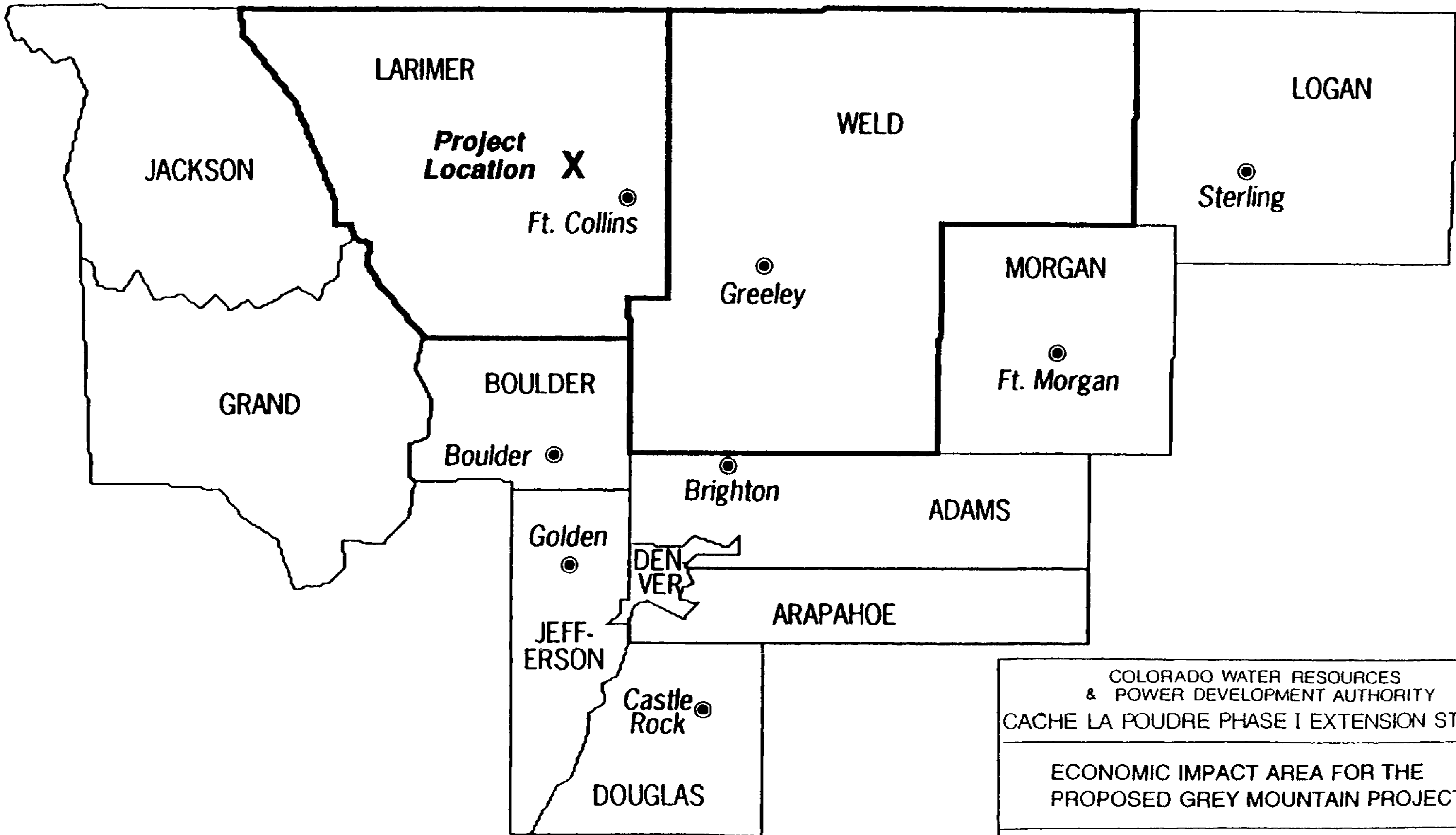
11.2.5 Area of Economic Influence Delineation

As a general rule, the area of economic influence includes those political jurisdictions which will experience economic effects from the project. This area includes communities in which local employees reside, as well as communities in which new in-migrating employees will settle. In addition, those political jurisdictions that will incur substantive financial effects, as a result of tax revenues, are also included in the area of influence.

Determination of the area of economic influence is based upon an analysis of the size and distance of nearby communities and certain labor force characteristics, such as size and skill levels. For the Stage 1 Cache la Poudre Project, the area of economic influence is defined to include the Larimer-Weld County Region (see Figure 11.2). A large majority of the labor force needed to construct the project is expected to reside in the cities of Fort Collins or Greeley and the surrounding urban areas. The primary political jurisdictions expected to incur fiscal impacts are these same cities.

11.2.5.1 Distance, Size and Accessibility of Nearby Communities

The Grey Mountain Damsite is located close to northern Colorado's two largest communities, Fort Collins and Greeley. Several highways provide regional access to the site, including I-25; US Highways 287, 34, and 85; and CO Highway 14. This effectively forms a northern Front Range employee transportation corridor bounded on the west by US Highway 287 and on the east by US Highway 85.



COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY
CACHE LA POUDRE PHASE I EXTENSION STUDY

ECONOMIC IMPACT AREA FOR THE
PROPOSED GREY MOUNTAIN PROJECT

BROWNE, BORTZ & CODDINGTON, INC.
FIGURE 11.2

TABLE 11.3

Size and Distance of Nearby Towns
Grey Mountain Alternative [1]

Community	One Way Driving Distance to Site (miles)	Population
Fort Collins	10	83,588
Greeley	45	62,290
Longmont	47	51,691
Loveland	28	36,111

1 Distances are based on the most direct route to the reservoir site. Population estimates are for 1989 and were obtained from the State demographer.

In addition, there are a number of small communities located in the employee transportation corridor, including La Porte, Ault, Windsor, Timnath, Severance, Platteville, Johnstown, and several other communities.

Based on distance and travel time, Longmont is considered too far to drive for any significant number of construction workers. Furthermore, Longmont is functionally integrated into the Boulder County regional high-tech economy. Given the proximity of Fort Collins to the project area, it will likely experience the bulk of the economic effects. Although Greeley is located approximately 45 miles from the project area, transportation access to the site is highly developed. Furthermore, commuting to jobs in Fort Collins and elsewhere in Larimer County is evident (Colorado Division of Local Government, 1989). Although Loveland clearly has an adequate population base, residents must travel through Fort Collins to reach the construction site.

11.2.5.2 Labor Force Characteristics

With some variation, unemployment rates within the Larimer-Weld County Region have generally declined since 1986. The 1988 unemployment rate in the Fort Collins-Loveland area was 5.8 percent, down from the 6.5 percent rate for 1986 (Colorado Department of Labor and Employment, 1989). The 1988 rate of unemployment in the Greeley area was 6.8 percent, a decrease of 1.6 percentage points from the 1986 level (Colorado Department of Labor and Employment, 1989). While the unemployment rate in the Fort Collins area has been consistently below that of the state, the unemployment rate in the Greeley area has been generally higher.

The labor force in the Larimer-Weld County Region is clearly large and diverse enough to support most of the labor requirements for a major facility such as the Grey Mountain Project. The total labor force in the region numbered more than 162,000 persons in 1988 (Colorado Department of Labor and Employment, 1989). About seven percent of the work force in the region, or more than 11,000 persons, is employed in construction. For purposes of comparison, Grey Mountain Project employment would total about 510 persons during the peak year of project construction.

11.2.5.3 Summary - Project Commuting Patterns

The employment requirements for the Grey Mountain Project are expected to be drawn from the following locations:

TABLE 11.4

Estimated Commuting Patterns

Location	Portion of Direct Project Employment
Fort Collins	70%
Greeley	20
Other	10
Total	100%

Almost all positions are likely to be filled by existing residents of the above communities. No substantial in-migration is expected because of the availability of qualified labor already in the area.

11.3 DESCRIPTION OF THE AREA OF SOCIOECONOMIC INFLUENCE

This section presents the demographic, economic, and infrastructure conditions within the area influenced by construction of the Grey Mountain Project. A description of the area affected as a whole is provided with particular emphasis upon those communities where project employees are expected to live, especially the cities of Fort Collins and Greeley. This description relies heavily on data compiled and published by various Colorado agencies and the U.S. Bureau of the Census. A brief description of the area likely to be inundated by the reservoir is also included. This description relies heavily on data presented in in Chapter 5.0.

11.3.1 Demographic Characteristics

Population levels, age distributions, households, and educational levels are key demographic characteristics relevant to describing the socioeconomic influence area and are described below.

11.3.1.1 Population

The economic influence area of Larimer and Weld Counties is also Colorado State Planning and Management Region 2. The estimated 1989 population in the region was more than 326,000 persons as shown in the table below (Colorado Department of Revenue, 1989):

TABLE 11.5

Larimer-Weld Region Population, 1980-1989

Year	Larimer	Weld	Total
1980	150,081	123,820	273,901
1981	153,673	125,353	279,026
1982	158,523	126,794	285,317
1983	162,579	131,020	293,599
1984	166,222	133,916	300,138
1985	170,449	136,699	307,148
1986	174,636	137,271	311,907
1987	177,903	140,044	317,947
1988	179,783	142,185	321,968
1989	182,979	143,436	326,415

Between 1980 and 1986, population in the region increased by about 38,000 persons, or nearly 14 percent. This translates into an average annual growth rate of 2.2 percent. The rate of population growth between 1986 and 1989 slowed to 1.5 percent per year.

Fort Collins and Greeley are the largest cities in the Larimer-Weld Region. The population in these two communities are shown in Table 11.6 below and accounted for about 45 percent of the total population in the region in 1988 (Colorado Department of Revenue, 1989):

TABLE 11.6

Estimated Population, Fort Collins and Greeley, Selected Years

Year	Fort Collins	Greeley
1980	65,092	53,006
1985	75,270	58,353
1986	77,998	59,012
1987	80,409	60,629
1988	81,718	61,702
1989	83,558	62,290

Annual population growth rates in Fort Collins and Greeley have been relatively steady since 1980 at about 2.9 and 1.9 percent, respectively.

11.3.1.2 Households

According to the 1980 U.S. Census, there were nearly 97,000 households in the region. Average household size was about 2.7 persons (Bureau of the Census, 1983a). At 2.5 persons, household sizes in Fort Collins and Greeley are smaller than in the remainder of the region or Colorado as a whole (Bureau of the Census, 1983a):

TABLE 11.7

Household Characteristics, Fort Collins and Greeley

	Fort Collins	Greeley
Number of households	23,523	19,351
Persons per household	2.5	2.5

11.3.1.3 Age Distribution

Age distributions are important in determining labor force availability for the prime working years and are provided in Table 11.8 below for Fort Collins, Greeley, and the Larimer-Weld Region. (Bureau of the Census, 1983a):

TABLE 11.8

Age Distribution of Larimer-Weld Region

Age Group	Fort Collins Number	Fort Collins Percent	Greeley Number	Greeley Percent	Larimer-Weld Region Number	Larimer-Weld Region Percent
Under 5 years	3,838	5.9	3,912	7.4	20,509	7.5
5 to 24 years	29,324	45.0	21,793	41.1	104,616	38.4
25 to 64 years	27,185	41.8	22,154	41.8	124,046	45.5
65 and over	4,745	7.3	5,147	9.7	23,451	8.6
Total	65,092	100.0%	53,006	100.0%	272,622	100.0%

In Fort Collins and in Greeley, more than 41 percent of the population is between the ages of 24 and 64 years. Compared with other large Front Range communities and Colorado as a whole, the median age of Fort Collins and Greeley residents is relatively young at 25 and 26 years, respectively.

11.3.1.4 Educational Attainment Levels

Educational levels can be a measure of the employability of a population and may indicate the type of work for which the work force is suited. Compared with Colorado as a whole, education attainment in the Larimer-Weld Region is high. This is partially attributable to the presence of two large state universities in the region (Colorado State University in Fort Collins and the University of Northern Colorado in Greeley). More than three-quarters of the population aged 25 years or more are high school graduates. Nearly 25 percent had completed four or more years of college (Bureau of the Census, 1983b).

Educational attainment levels are higher in Fort Collins than in Greeley. More than 85 percent of the population aged 25 year or more are high school graduates, while nearly 40 percent completed four or more years of college. The corresponding figures for Greeley are 74 and 25 percent, respectively (Bureau of the Census, 1983b).

11.3.2 Economic Base of the Influence Area

Economic characteristics of the impact area are described in terms of income levels, income by source, employment patterns, unemployment, and retail sales.

11.3.2.1 Employment Summary

The labor force in the Larimer-Weld Region was estimated to be nearly 162,000 persons in 1988 (Colorado Department of Labor and Employment, 1989):

TABLE 11.9

Labor Force and Employment Characteristics
Larimer-Weld Region

	1985	1986	1987	1988
Labor force	153,177	153,424	158,951	161,731
Total employment	143,998	142,219	147,353	152,239
Total unemployment	9,179	11,205	11,598	10,122
Percent unemployed	6.0%	7.3%	7.3%	6.3%

About 10,100 persons were unemployed in 1988, corresponding to an unemployment rate of 6.3 percent. Unemployment rates for the region have been consistently below state rates, indicating a relatively strong local economy.

Between 1985 and 1988 the region's labor force and employment levels increased by about 5.5 percent. This translates into a modest annual growth rate of about 1.8 percent. The number of unemployed, however, increased by more than 10 percent, or 3.3 percent annually, over the same period.

The rate of labor force participation in the Larimer-Weld Region is comparable to the state as a whole. According to the 1980 Census, the proportion of persons 16 years of age and older in Larimer County in the labor force is 66 percent, while the participation rate in Weld County is about 63 percent (Bureau of the Census, 1983b). Labor force participation rates in the communities of Fort Collins and Greeley are slightly lower than those found in the region as a whole.

11.3.2.2 Employment by Industry

An examination of employment by economic sector shows the strength, degree of diversification, and the importance of certain industries in the local economy. Manufacturing, retail trade, services, and government are the largest employment sectors in the Larimer-Weld Region, as shown in Table 11.10. Included in the government sector is employment by the region's two universities. The breadth and strength of these four sectors points to a healthy local economy with a well diversified economic base.

In 1987, the services sector was the largest employer of any sector in the region, accounting for more than 23 percent of total employment. The retail trade and government sectors accounted for 16.5 and 17.6 percent, respectively, of regional employment. Manufacturing employed 14 percent of the regional work force. At five percent of total regional employment, the importance of the farm sector is evident. This figure compares with 2.3 percent for Colorado and less than one percent for the Front Range Region.

TABLE 11.10

Employment by Sector, Larimer-Weld Region

Sector	1982	1983	1984	1985	1986	1987
Farm	7,915	8,015	7,807	7,595	7,887	7,796
Agricultural Services, Fishery and Forestry	1,605	1,835	2,008	2,079	2,135	2,278
Mining	1,097	1,151	1,311	1,725	1,394	1,310
Construction	8,872	10,069	11,853	11,583	11,675	11,153
Manufacturing	19,667	20,617	21,242	21,384	21,473	21,858
Transportation and Public Utilities	4,340	4,302	4,537	4,682	4,745	4,877
Wholesale Trade	3,950	3,691	3,972	4,059	3,863	3,993
Retail Trade	22,251	22,968	24,394	24,837	24,491	25,369
Finance, Insurance and Real Estate	9,413	9,949	10,824	11,591	12,360	12,595
Services	25,422	27,561	29,535	31,024	33,713	35,488
Government	25,074	25,759	26,037	26,734	26,641	27,095
Total	129,606	135,917	143,520	147,293	150,377	153,812

Source: U.S. Department of Commerce, Bureau of Economic Analysis, Regional Economic Information System, selected years.

11.3.2.3 Employment by Occupation

The 1980 Census data indicate the occupational structure of the Larimer-Weld Region is generally representative of Colorado as a whole and is shown in the table below (Bureau of the Census, 1983b):

TABLE 11.11

Occupational Status of Employed Residents
Larimer-Weld Region, 1980

	Larimer	Weld	Region
Managerial and professional	25.6%	20.1%	23.3%
Technical sales and support	31.2	27.3	29.4
Service	13.1	12.8	13.0
Farming, forestry, and fishing	2.9	9.0	5.5
Precision production, craft, and repair	13.6	14.5	14.0
Operators, fabricators, and laborers	13.6	16.3	14.8
Total	100.0%	100.0%	100.0%

Of the 126,000 employed persons living in the region in 1980, more than 50 percent held jobs traditionally identified as white collar occupations, managerial and professional positions and technical sales and support jobs. Service occupations accounted for 13 percent of the region's jobs. About 29 percent of the work force held traditionally blue collar jobs, such as precision production, craft and repair, operators, fabricators, and laborers.

11.3.2.4 Personal Income

Personal income levels are an important economic indicator in the region. Personal income by source indicates the relative importance of wage and salary income and non-earnings income. Income by industry provides a measure of the relative significance of each individual element of the economy. Per capita and per household income measures are indicative of the purchasing power and economic well being of area residents.

Personal income includes earnings from work, personal dividend income, personal interest income, rental income, and transfer payments. Income is further adjusted by subtracting personal contributions for social insurance. Earnings are adjusted to reflect earnings by place of residence.

In 1986, total personal income in the Larimer-Weld Region exceeded $3.9 billion as shown below (Bureau of Economic Analysis, 1988):

TABLE 11.12

Personal Income by Place of Residence (million dollars)

Income Sources and Adjustments	Larimer County	Weld County	Total Region
Earnings by place of work	$1,479.4	$1,028.9	$2,508.3
Less: personal contributions for social insurance	(83.1)	(54.9)	(138.0)
Plus: residence adjustment	231.8	206.7	438.5
Net Earnings by Place of Residence	$1,628.1	$1,180.7	$2,808.8
Plus: dividends, interest and rents	419.2	206.1	625.1
Plus: transfer payments	272.6	216.0	488.6
Total Personal Income	$2,319.9	$1,602.8	$3,922.5

Work-related earnings comprised nearly 72 percent of regional income in 1986. The positive residence adjustment indicates that a sizable element of the local work force is employed outside the Larimer-Weld region, mostly in the Denver Metropolitan Area. Dividend, interest, and rental income, accounting for about 16 percent of regional income, points out the accumulated wealth of the region as well as royalties from oil and gas production.

Table 11.13 presents work-related earnings by industry for 1986. Two sectors, manufacturing and government, account for roughly 40 percent of total earnings in the region in 1986. Other important sectors include construction, retail trade, and services.

Together, these five sectors generated more than 80 percent of the region's total earnings. Although relatively prominent in Weld County, the farm sector is not a major source of earnings for the region.

TABLE 11.13

Earnings by Economic Sector in 1986, Larimer-Weld Region

Sector	Larimer County Earnings ($ millions)	Larimer County Percent	Weld County Earnings ($ millions)	Weld County Percent	Total Region Earnings ($ millions)	Total Region Percent
Farm	17.5	1.2%	64.0	6.2%	81.5	3.2%
Non Farm	1,479.8	98.8	964.9	93.8	2,444.7	96.8
Private	1,116.2	74.5	787.5	76.5	1,903.7	75.4
Agricultural Services Fishery and Forestry	9.7	0.6	12.1	1.2	21.8	0.9
Mining	11.9	0.8	23.8	2.3	35.7	1.4
Construction	146.1	9.8	108.3	10.5	254.4	10.1
Manufacturing	348.6	23.3	227.0	22.1	575.6	22.8
Transportation and Public Utilities	46.7	3.1	68.1	6.6	114.8	4.5
Wholesale Trade	38.3	2.6	52.9	5.1	91.2	3.6
Retail Trade	167.8	11.2	93.2	9.1	261.0	10.3
Finance, Insurance and Real Estate	66.6	4.4	51.7	5.0	118.3	4.7
Services	280.5	18.7	150.4	14.6	430.9	17.1
Government	363.6	24.3	177.4	17.3	541.0	21.4
Federal, Civilian	50.5	3.4	10.1	1.0	60.6	2.4
Military	6.2	0.4	4.0	0.4	10.2	0.4
State and Local	306.9	20.5	163.3	15.9	470.2	18.6
Total	1,497.3	100.0%	1,028.9	100.0%	2,526.2	100.0%

Source: U.S. Department of Commerce, Bureau of Economic Analysis.

Median annual household income in Larimer County was $17,170 in 1979, while Weld County median household income was $15,800 as shown below (Bureau of the Census, 1983b):

TABLE 11.14

Median Household Income

Region	Annual Income in Dollars
Fort Collins	$15,770
Greeley	14,510
Larimer County	17,170
Weld County	15,800

Household incomes in Fort Collins and Greeley were less than respective county averages. This might reflect the student populations in both these communities.

Per capita income in the Larimer-Weld Region averaged about $12,900 in 1986. During the period between 1981 and 1986, growth in real per capita income was modest at an annual rate of about 1.6 percent as shown in Table 11.15. Per capita income in both counties is below levels for Colorado as a whole (Bureau of Economic Analysis, 1988).

TABLE 11.15

Trends in Real Per Capita Income

	Larimer County	Weld County	Total Region	Colorado
1981	$12,354	$11,446	$11,941	$14,311
1982	12,408	11,456	11,983	14,359
1983	12,684	11,186	12,013	14,527
1984	13,056	11,809	12,500	14,881
1985	13,167	11,781	12,557	14,983
1986	13,390	12,271	12,902	15,230

11.3.2.5 Retail Trade

The retail trade sector is one of the region's largest sectors in terms of employment and earned income. In addition, local jurisdictions such as municipalities derive tax revenues from certain trade transactions. The 1988 volume of retail trade in the region was more than $2.9 billion, as shown below in Table 11.16, the highest level of annual retail sales on record (Colorado Department of Revenue, 1984-1988).

TABLE 11.16

Retail Trade Sales, Larimer-Weld Region (million dollars)

Year	Larimer	Weld	Total
1984	$1,434.0	$1,111.0	$2,545.0
1985	1,564.5	1,118.3	2,682.8
1986	1,617.2	1,044.1	2,661.3
1987	1,642.5	1,095.6	2,738.1
1988	1,763.1	1,226.5	2,989.6

Retail sales in the region increased at an annual rate of 4.1 percent between 1984 and 1988. Percentage growth in Larimer County retail sales was about 2.8 percentage points higher than in Weld County during this period.

11.3.2.6 Inundation Area

Several land ownership classes would be affected by creation of a mainstem reservoir on the Cache la Poudre River, as described in Chapter 5.0, and identified below:

TABLE 11.17

Grey Mountain Alternative, Land Ownership Within Project Boundary

Ownership Class	Acreage	Percent of Total
Federal (Forest Service)	710	32%
State	660	29
Local	330	15
Private	540	24
Total	2,240	100%

As shown above, Federal and State lands would be most affected in terms of acreage lost to inundation. Effects on private landowners would also be substantial. Portions of two subdivisions and 29 private parcels are located within the proposed inundation area. These parcels are relatively undeveloped, with an estimated 60 to 70 residential structures projected to be inundated by the reservoir.

11.3.3 Overview of Infrastructure and Major Area Employers

11.3.3.1 Infrastructure

Public facilities and services within the socioeconomic influence area are concentrated in Fort Collins and Greeley. Both cities own and operate municipal water and sewer systems. The nearest scheduled air service is located at Denver's Stapleton International Airport. Complete bus, railroad, and trucking services are available in Fort Collins and Greeley.

There is a full complement of emergency and protective services in the Larimer-Weld Region. Complete medical services are available in both Fort Collins and Greeley. Located in Fort Collins, Poudre Valley Hospital has 198 beds, while Greeley's North Colorado Medical Center has 326 beds. McKee Medical Center, located nearby in Loveland, has 105 beds.

11.3.3.2 Major Area Employers

As discussed previously, government and manufacturing sectors account for a substantial amount of employment and income in the region. In the Greeley area, government, or public related, employment is provided by the Northern Colorado Medical Center, University of Northern Colorado, Weld County, and Weld County School District No. 6. Food processing and high tech industrial firms also are important employers in the Greeley area.

Monfort of Colorado, Inc. operations in the Greeley area include two feedlots and two meat packing plants. Hewlett-Packard established an assembly plant for computer drive and mass storage mechanisms northwest of Greeley in 1984. Kodak's Colorado Division constructed a major manufacturing facility for photographic paper, X-ray film, and lithographic plates outside of Greeley near the Town of Windsor.

Similar to Greeley, major Fort Collins employers exhibit diversity, but with more emphasis on public sector activities. In addition to Colorado State University, the Poudre Valley R-1 School District, Poudre Valley Hospital, Larimer County, and the City of Fort Collins are major local employers.

Manufacturing employment in the Fort Collins area also is dominated by high-tech industrial firms. Hewlett-Packard also has a manufacturing plant near Fort Collins which produces specialized computers and circuit boards for other Hewlett-Packard plants. The Woodward Governor Company manufactures speed governors and microprocessors for control of high speed rotational equipment. In addition to producing an oral hygiene device, Teledyne Water Pik manufactures shower heads, water purification systems, and smoking withdrawal systems. The Anheuser-Busch Company constructed a brewery near Fort Collins in 1987.

11.4 ECONOMIC EFFECTS OF THE GREY MOUNTAIN ALTERNATIVE

This section presents estimates of potential economic effects to the Larimer-Weld Region attributable to construction and operation of the Grey Mountain alternative. Prompted by purchases of local goods and services during project construction and the disposition of wage and salary income by project employees, the Grey Mountain Project will induce an expansion of local employment, personal income, retail and services sales, and tax revenues. Beneficiaries would include private individuals and businesses within the influence area as well as local political jurisdictions.

Certain effects on existing recreation activities in the area would also arise. Because this topic is of particular concern, it is discussed separately in Sections 11.4.2.5, 11.4.3.4, and 11.4.3.6.

11.4.1 Analytical Guidelines

In order to project potential economic effects, guidelines are presented which form the foundation of the analytical process and properly focus the analysis.

11.4.1.1 In-Migration

Based upon the labor force characteristics described previously, it is assumed that direct and secondary employment opportunities as a result of project construction will be filled almost entirely from within the defined socioeconomic area of influence, or Larimer and Weld Counties. The local labor force is clearly of adequate size and skills. Only jobs which are highly specialized or jobs which entail temporary contract work are likely to cause in-migration to the region. Consequently, impacts on resident population or the rate of household formation are assumed to be negligible.

11.4.1.2 Magnitude of Secondary and Induced Impacts

The potential magnitude of secondary and induced impacts was assessed through input-output analysis of the regional Larimer-Weld economy. This analysis yielded a set of multipliers with which potential secondary and induced impacts were then calculated.

Businesses within a particular sector of the local economy make purchases of intermediate goods and services from local businesses in other sectors in order to produce final goods. These businesses pay their employees wage and salary income with which local purchases of goods and services are also made. Some intermediate goods, however, must be imported from outside the local economy, and a portion of personal income is spent outside the local economy. These outside purchases, or imports, are known as leakage. A local economy characterized by a high degree of interdependence and relatively little leakage will tend to exhibit high earnings and employment multipliers. Generally speaking, a sparsely populated area will exhibit smaller multipliers as compared with more urbanized areas.

The Colorado Division of Local Government (DLG) provided the multipliers used in the analysis. These multipliers are based on the U.S. Bureau of Economic Analysis Regional Input-Output Modeling System (RIMS). The multipliers were derived from interindustry relationships evident at the national level in 1977, which were were disaggregated to individual, county level relationships. These data have been updated to reflect the most recent earnings and employment data available at the state level.

For purposes of this economic impact analysis, the earnings and employment multipliers are assumed to be 1.8 and 2.2, respectively (Division of Local Government, 1989). The employment multiplier, for example, indicates that for each direct construction job, 1.2 additional jobs will be added within the economic influence area.

11.4.1.3 Distribution of Potential Impacts

Since Fort Collins is located nearest the project area, and is also the region's largest city, it is probable that most of the secondary and induced effects will occur in Fort Collins. For purposes of this analysis, it is assumed that 70 percent of the indirect effects will be captured in Fort Collins. Greeley, the region's second largest community, is agriculturally oriented and might capture 20 percent of the indirect effects. These percentages follow the same distribution projected for direct economic effects from the project. A portion of the remaining 10 percent might be captured elsewhere within the Larimer-Weld Region. It should be noted that there is potential for an unknown portion of effects leaking to other Front Range areas such as Metropolitan Denver.

11.4.2 Economic Effects of Grey Mountain Construction

Economic effects attributable to the project will occur during construction of the project facilities. Determination of potential construction-related effects to the Larimer-Weld Region was based largely on construction data presented in Chapter 9.0. As discussed previously, effects will accrue to private individuals and businesses in the form of increased employment, wage and salary income, and retail sales. Local municipalities will also be affected through increased tax revenues.

11.4.2.1 Employment Effects

Relocation of Colorado Highway 14, construction of access roads, construction of the dam and related facilities, and rehabilitation of the area disturbed by construction is expected to require about five years. Direct employment on site is expected to be distributed throughout the region as indicated in the following table:

TABLE 11.18

Average Annual Construction Employment
Grey Mountain Alternative

Year of Construction	Fort Collins	Greeley	Other Region	Total Region
1	42	12	6	60
2	182	52	26	260
3	357	102	51	510
4	273	78	39	390
5	84	24	12	120

Peak employment of 510 persons is projected for the third year of construction. Based on an employment multiplier of 2.2, secondary employment effects would total 610 jobs. These impacts are assumed to be distributed throughout the region in the following fashion:

TABLE 11.19

Regional Distribution of Secondary Employment
Impacts From Peak Construction Activity

Location	Secondary Jobs
Fort Collins	430
Greeley	120
Other in Region	60
Total	610

During the course of project construction, large quantities of cement and other construction materials would be purchased at a cost of nearly $27.4 million. To the extent such purchases are made from within the influence area, additional employment effects may be realized. For purposes of this analysis, it is assumed that project materials can be acquired from within the influence area. From this so-called linked industry effect, there would be additional total employment of 480 jobs throughout the region, including direct and secondary employment.

In sum, direct and project related employment may total nearly 1,600 jobs in the region. It is important to emphasize that these will be jobs largely for existing residents; few new people will migrate to the area directly as a result of the project.

Potential direct and indirect employment is considered important to the extent that it represents a valued economic stimulus to the region. Based on employment estimates for the year 1988, total employment in the region would be increased by less than one percent, indicating that statistically, the project would make only a small contribution. Given the prospects for continued growth in the region, potential employment effects would be modest when construction actually commences. Even so, the perception of enhanced economic development for this region should not be underestimated.

11.4.2.2 Effects on Personal Income

Income effects include direct earnings from employment during project construction, induced income generated through direct employee spending, as well as project-related purchases of goods and services. Through such purchases, indirect jobs are created, and spending related to indirect job earnings further adds to the earnings multiplier. An earnings multiplier of 1.8 is used for this analysis. The interpretation is that a dollar's worth of earnings from direct project employment will generate an additional $.80 in earnings throughout the local economy. This indicates that there is minimal income leakage from the local economy.

Direct project employee compensation is projected to reach $13.6 million by the third year of project construction based on estimates developed by Harza:

TABLE 11.20

Average Direct Annual Wage and Salary Income (thousands)

Year of Construction	Fort Collins	Greeley	Other in Region	Total Region
1	$1,115	$ 318	$ 159	$ 1,592
2	4,874	1,392	696	6,962
3	9,503	2,715	1,358	13,576
4	7,241	2,069	1,034	10,344
5	567	162	81	810

Total direct remuneration would be about $33.3 million over the five-year construction period.

Secondary income effects could total about $28.3 million and are assumed to be distributed throughout the region in the following fashion:

TABLE 11.21

Regional Distribution of Secondary Income Impacts (millions)

Location	Secondary Income
Fort Collins	$19.81
Greeley	5.66
Other in region	2.83
Total	$28.30

Linked industry purchases of construction-related materials may also lead to impacts on area income levels. An estimated $12.3 million in personal earnings is projected to accrue to the regional economy through the purchase of cement and other construction materials. About $5.8 million will accrue to the region as secondary income.

In sum, nearly $74 million in direct and secondary personal income would be injected into the regional economy. This includes direct employee compensation of $33 million for project construction and $41 million in secondary earnings.

11.4.2.3 Retail and Service Sales

By increasing personal income within the economic influence area, the region's level of retail trade and services sales will increase. Though insufficient information is available to track all transactions, retail and services sales can be estimated based upon traditional relationships to personal income.[1] The results are shown in Table 11.22 which follows:

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(1) The general relationship between personal earnings and retail and service sales was developed according to the disposition of personal income as exhibited in the Bureay of Economic Analysis, Survey of Current Business, with adjustments made for local consideration.

TABLE 11.22

Direct and Secondary Retail and Service Sales
(millions)

	Retail Sales	Services Sales
Fort Collins	$21.47	$20.36
Greeley	5.93	5.82
Other in region	2.96	2.91
Total	$30.36	$29.09

Although the projected level of retail sales is only about one percent of recent levels, businesses in the area will gain from construction of the Grey Mountain Project.

11.4.2.4 Municipal Fiscal Effects

The region's municipalities will be affected in the form of additional tax revenues. Fort Collins and Greeley, the two largest incorporated communities in the region, will likely receive most of the projected tax revenues. The current sales tax rate in Fort Collins is 2.75 percent, and the tax rate in Greeley is 3.0 percent (Colorado Municipal League, 1988). Most services in both communities are not subject to taxation. Direct and secondary sales tax revenues were calculated from direct and secondary retail sales as shown below:

TABLE 11.23

Distribution of Direct and Secondary Municipal Sales Tax Revenues
(thousands)

Location	Revenues
Fort Collins	$590
Greeley	178

11.4.2.5 Economic Effects From Recreation Changes During Construction

During the five year construction phase of the Grey Mountain Project, the area's recreational resources would be affected as described in Chapter 5.0. Neglecting mitigation, these economic effects could include reduced business revenues for those supplying goods and services to recreationists, lost tax revenues, reduced personal income levels, and job losses. The potentially affected recreational activities with associated economic affects include:

1. Fishing - There are nearly five miles of stream between Poudre Park and the canyon mouth designated as "Wild Trout" water. Construction would directly affect lower portions of this stretch, possibly leading to congestion in other areas of the region.

2. Whitewater boating - Rafting and kayaking on the river will be directly affected during construction of the dam. Three segments of the river are currently used for boating. Two segments, the Lower Mishawaka and Bridges Runs, would not be affected by construction of the dam. The Filter Plant Run, which accounts for about 90 percent of total whitewater boating activity in the canyon, would be disrupted by construction. Consequently, commercial outfitters offering trips on the river might be substantially affected unless provisions are made for increased use of the two unaffected runs.

3. General attractiveness of the Canyon - During construction, concerns over visual, noise, and traffic disruptions might serve to reduce the attraction of recreational visitors to the Poudre Canyon seeking hiking, sightseeing, picnicking, or related pursuits.

11.4.3 Economic Effects of Grey Mountain Operations

The region would also experience economic effects during the operation phase of the Grey Mountain Project. As opposed to effects attributable to project construction, effects due to project operation likely will be evident throughout the northern Front Range Region. Positive economic effects will be realized in the form of additional water supplies, hydroelectric power generation, flood control, and lake-oriented recreation opportunities. Without mitigation, negative economic effects would arise to the extent that project construction and operation disrupt existing recreational opportunities. Identified briefly in this section, each of these receive detailed examination in subsequent report sections addressing benefits, costs and financial feasibility.

11.4.3.1 Additional Regional Water Supplies

An estimated 41,000 af of annual yield will be made available to the region through construction of a mainstem dam and reservoir. It is assumed that additional water supplies would be used for municipal and industrial (M&I) purposes within Boulder, Larimer, and Weld Counties.

Positive economic effects would accrue to northern Colorado as a result of this increase in water resource availability. Municipal water providers in the region would benefit by avoiding the cost of a more expensive water resource alternative. As a long-term result, area households and businesses would have more discretionary dollars available to spend on goods, services, and investment. A second economic effect would stem from greater water availability to northern Colorado farmers during drought periods. This would result from increased availability of water to municipalities who currently rely on agricultural supplies to avoid shortages during times of drought.

11.4.3.2 Hydroelectric Power Generation

Average annual hydroelectric power production is projected to be 52 GWh. Revenues from power production would be primarily used for project repayment and to defray pumping costs associated with conveying water from Horsetooth Reservoir to the mainstem reservoir.

From the standpoint of economic impacts, the positive contribution from additional generation capacity to the region is similar to that of additional water resources. Businesses and households may benefit to the extent utilities incur lower resource costs. In fact, such economic effects are quite small since the modest increase in electrical energy is spread over a very large capacity and customer base.

11.4.3.3. Flood Control

Potential flood control beneficiaries will be primarily limited to the communities of Fort Collins and LaPorte. A new Flood Insurance Study (FIS) for the area is currently in progress which will be used to identify 10-, 50-

and 100-year flood elevations along the Poudre River. This information will eventually allow calculation of potential reductions in the floodplain due to mainstem reservoir storage. Economic benefits would result in the form of reduced flood insurance rates, increases in property values in the floodplain, and through stimulated economic activity resulting in higher business revenues and employment. A portion of the latter could come in the form of recreational enhancements. Since exhaustive study of the present and potential economic activity within the floodplain has not been accomplished by the City of Fort Collins or Larimer County thus far, a quantification of potential economic effects from flood control is unavailable at this time.

11.4.3.4. Flatwater Recreation Opportunities

The reservoir formed by Grey Mountain Dam would have a surface area of nearly 1,600 acres and store a total of 195,000 af of water at maximum normal operating pool. Given that other reservoirs in the region (e.g., Horsetooth Reservoir and Carter and Boyd Lakes) are currently used by flatwater recreationists to capacity during peak summer months, demand for additional flatwater recreation resources clearly exists, as described in Chapter 5.0. Typical lake-oriented recreation activities would include boating, fishing, camping, and picnicking. The degree to which these activities are accommodated will depend on the development of necessary facilities. A final plan for recreation development at the proposed mainstem reservoir has not been prepared as of the time of this report. However, the need and benefits of flatwater recreation facilities for mitigation and project enhancement are recognized.

Potential recreation uses of the reservoir are identified and quantified in Chapter 5.0 of this report. Estimated annual visits are based on a mix of projected future recreational activities. Included are power and wakeless boating, camping, picnicking, and shoreline angling. A total of 24,000 to 25,000 annual visits are projected after completion of the project. However, because demand for recreation along the Front Range will continue to grow over time, the estimated maximum capacity of 98,000 annual visits would eventually be reached. It is important to note that in terms of economic benefits, these recreational visits must be new to the region. If these visitors would merely leave Horsetooth Reservoir, for instance, to visit a

Grey Mountain Reservoir, there would be no net benefit to the economy, although there would be improvements in the quality of recreation opportunities.

Direct expenditures associated with reservoir recreation can be expressed in dollars per trip or visit. One source indicates a range of $3.00 to $17.00 in direct per trip expenditures (THK Associates, Inc., 1986). Average annual expenditures by boaters, campers, anglers, and picnickers could total about $470,000. Utilizing a composite multiplier of recreation-related economic sectors, total expenditure effects are estimated to be about $800,000. Secondary expenditure effects would be about $330,000. Increases in personal earnings from these expenditures could total $750,000, of which $275,000 would be secondary.

11.4.3.5 Other Effects

Operation and maintenance (O&M) of project facilities would require on-site employment as well as some local purchases of goods and services. A dam operator, assistant operator, and maintenance worker would be employed at the site. Other O&M requirements, such as contract maintenance, dam inspection, and refuse pickup and disposal, are estimated to require the equivalent of two full time workers. Modest purchases of other goods and services would also be needed. However, the regional effects due to project O&M would be relatively negligible and are, therefore, not quantified.

11.4.3.6 Effects of Displaced Recreation Activities

Without effective mitigation, the region would experience negative economic effects due to the loss of some river-oriented and dispersed recreation activities. Inundation of the Poudre Canyon would adversely affect hiking, fishing, and whitewater boating, as described in Chapter 5.0. Nearby communities, principally Fort Collins, would experience some expenditure effects from a reduction in these activities. These effects may be offset to the extent lost recreation opportunities are replaced with equivalent opportunities through mitigation or by alternative activities in the region.

NCWCD, the project sponsor for the Cache la Poudre Project, is committed to the development of an effective mitigation plan as part of continuing efforts to implement Stage 1 of the proposed project. However, as described in Section 11.1.2, the process of obtaining input and concurrence from local, state, and federal natural resource agencies has not commenced. Consequently, the costs for a specific mitigation plan can not be adequately estimated at the present time and have not been included in estimates of overall project cost. Therefore, the economic analyses described herein include recreational opportunities that would be lost without effective mitigation as project costs. As more refined feasibility studies are performed in the future for the Stage 1 project, the net economic effects of mitigation will be incorporated.

A five-mile segment of "Wild Trout" fishing on the Cache la Poudre River would be displaced by the reservoir, and stream fishing activity would be lost in the area inundated by the reservoir. Assuming no mitigation, an estimated 2,600 annual visits would be lost. This translates into an estimated annual loss of $44,150 in direct expenditures made by anglers.[2] Assuming these expenditures would have been made in the Larimer-Weld Region, the multiplier effect would result in losses of retail and service business by as much as $75,500. Total annual personal income losses would be $70,000; secondary income losses would be $25,900.

Currently four commercial outfitters offer whitewater boat trips on three stretches of the river which might be affected by inundation. Shortened runs may no longer be feasible for commercial outfitters but may still appeal to private boaters. In sum, an estimated 5,050 whitewater recreation visits are estimated to be lost through inundation in the canyon, as indicated in Chapter 5.0, assuming no mitigation. For purposes of this analysis, it is assumed that all of the 5,050 whitewater visits lost because of inundation would be commercial rather than private. Current data on expenditures for whitewater boating are not available. Instead, per trip

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(2) The impacts due to the loss of the "Wild Trout" fishery are derived from several sources. Data regarding lost fishing days are presented in Chapter 5.0, and estimates of angler expenditures were derived from BBC, 1988.

expenditures and average per trip guide fees, as reported in a 1980 whitewater boating economic impact study (ERT, Inc., 1980) updated to 1988 price levels are used. Based on these assumptions, direct expenditures are estimated to be $57.00 per trip; guide fees add an additional $37.00 per trip. (A trip is defined as one person having a whitewater boating experience on either a half day of full day trip.) Based on the estimated loss in annual trips, direct whitewater expenditures may be reduced by more than $287,000. Guide fee revenue could be reduced by nearly $187,000. Although a portion of guide fee revenue covers fixed cost items such as boating equipment, it is assumed that fee revenues are disposed of in the same fashion as direct trip expenditures. As a result, the total reduction in regional sales neglecting mitigation is estimated to be $810,000. Secondary effects are estimated to result in additional reductions totaling $336,000. Total reductions in personal income are estimated to be more than $750,000, with reductions from secondary effects totaling $278,000.

Virtually all hiking activity in the portion of the canyon that would be inundated by Grey Mountain Reservoir is concentrated on the Greyrock Mountain Trail, with access provided by a footbridge across the river. The reservoir would inundate the existing trailhead and parking lot. A new trailhead and parking lot would be constructed further up the canyon as part of the project. Assuming new trailhead facilities are constructed prior to reservoir filling, no substantial diminution in hiking activity would be expected. Therefore, economic losses are not quantified.

Sightseeing, picnicking, and camping are prominent recreational activities in the Poudre Canyon. Clearly, activity levels would be affected by the development of the Grey Mountain Project. It is uncertain whether visits would be reduced, substituted with alternative opportunities in the region, or otherwise modified. Therefore, expenditure losses were not quantified.

11.4.3.7 Displaced Properties in the Inundation Area

Based on land use studies conducted for the Basin Study Extension and described in Chapter 5.0, 60 to 70 residential structures would be inundated by the proposed reservoir. Since fair compensation for these losses would be provided by the project sponsor and since relocation in the region is likely, there should be no net dollar losses to property owners or property taxing jurisdictions.

Recreational cabin use would also be lost with inundation. The estimated loss of 2,700 annual visits would not likely produce large regional economic effects since equivalent habitation expenditures (e.g., food, gasoline, etc.) are expected to occur elsewhere in the Larimer-Weld Region.

11.5 BENEFIT-COST ANALYSIS OF GREY MOUNTAIN ALTERNATIVE

The economic feasibility of the Grey Mountain alternative is evaluated in this section using benefit-cost (B-C) analysis. benefits and costs include the economic effects identified in the previous section of this chapter, plus non-dollar and intangible effects stemming from the project. In the B-C analysis, economic effects are further refined to reflect only net contributions or withdrawals from the economic resources of the region. The primary purpose of B-C analysis is to evaluate separable project components on their own merits. Thus, the value of new water supply is evaluated separately from flood control benefits, for example. Conclusions from the B-C analysis, referred to as the economic feasibility of the project, are presented at the end of this section.

11.5.1 Benefit-Cost Analysis Methodology

A number of methodological issues and assumptions should be noted at the outset. These include the accounting stance of the analysis, the appropriate time horizon, relative prices, selection of the appropriate discount rate, data availability, and standards for quantifying costs and benefits associated with the project.

11.5.1.1 Accounting Posture

A regional accounting posture, specifically the northern Colorado region, is employed in the B-C analysis. Project outputs such as water supply, flood control, and flatwater recreation would likely benefit existing and future residents of this region. This differs from the area of economic influence slightly since certain benefits or costs might extend beyond the

Larimer-Weld Region. Although statewide benefits may be realized through a complex chain of market reactions, such a broad perspective is not appropriate at this level of analysis.

11.5.1.2 Time Horizon

The time horizon, or period of analysis, depends upon the nature of project-related benefits and costs. Generally, the time horizon should be of adequate length to capture potentially significant benefits and costs. The time horizon is also limited by the accuracy of available projections. A time horizon of 60 years following the start of construction was assumed for this analysis, with 1988 as the base period for all dollar values. The full impacts upon recreation use patterns occur about 10 years after construction, and the facility's useful economic life should exceed 50 years. The useful life of a dam is dependant on its ability to safely store and deliver water. There are many fully functioning dams in the United States which are nearly 100 years old, and there is no reason to expect that the Poudre Project would not be fully functional 100 years or more following construction. However, a time horizon longer than 50 years would have no appreciable effect on the results of the B-C analysis.

11.5.1.3 Relative Prices

The B-C analysis is based upon constant, 1988 dollars. All dollar figures are discounted back or escalated forward to this year for the purposes of aggregation and comparison of benefits and costs. It is generally assumed that unless specific considerations indicate that relative prices will change, real price relationships would not change during the time horizon of the analysis.

11.5.1.4 Discount Rate

A discount rate is used to convert benefits and costs which occur over time to the present value of the base period (i.e. ,1988). Since benefits and costs are expressed on a constant dollar basis, a real discount rate, as opposed to a nominal rate which incorporates inflationary expectations, was chosen. There are a number of alternative approaches for choosing the appropriate discount rate. Under the opportunity cost of capital approach, the rate of return should reflect displaced private investment and consumption stemming from public sector taxation and borrowing. The social rate of time preference approach attempts to reflect society's weighting of current consumption versus bequests to future generations. Agreement upon this rate is difficult, suggesting that the opportunity cost of capital approach is preferable.

The yield on tax exempt municipal bonds provides a useful source for a discount rate for this study. The yield on municipal bonds indicates a willingness to pay by the public sector and a price for current investment to earn future returns. The 1989 average yield on long term (21 year) municipal bonds was more than 7.2 percent, and rates were slightly lower during the first quarter of 1990. (Vanguard Municipal Bond Funds, Long Term Municipals, 1990). However, various inflation rates during this period were in the 4 to 5 percent range, considered low by longer term standards and future expectations. Also, the unknown bond issuers and the longer time horizon of this study suggest that a higher rate be used. Hence, a discount rate of 8 percent was assumed for the economic analysis. Since the B-C analysis was conducted in real terms, a real discount rate of 3 percent was employed, reflecting an assumption of long-term average annual inflation of 5 percent (Wharton Econometric Forecast Associates, Inc., 1986).

11.5.1.5 Quantification Standards

An attempt was made to quantify all benefits and costs in dollar terms commensurate with this prefeasibility level of study. The major tangible elements have been quantified, but others, while recognized, were not quantified. Those elements not quantified include the following:

(1) Negative impacts on physical environmental resources might exact an economic loss not given to meaningful quantification. Intrinsic values, though real, are not reducible into dollar terms, and mitigation cannot offer an exact replacement for intrinsic losses.

(2) Use of a total mitigation cost at this level of study is inappropriate for the B-C analyses because a fully integrated and approved mitigation plan based on input and consensus of natural

resource agencies has not yet been developed. Cost estimates for a range of alternative mitigation elements have been prepared, as presented in earlier chapters. However, an integrated mitigation plan acceptable to regulatory and special interests remains to be developed.

(3) Another quantification issue relates to the attribution of costs associated with displacement of certain existing recreational activities. With the exception of whitewater boating, a relatively large number of substitute sites for these activities exist in proximity to the northern Colorado region. Travel over greater distances may be necessary to access these sites, and substitute sites may have less appealing attributes. The potential loss in welfare between the existing resource and available substitutes is the ideal measure for the project's recreation costs. However, due to the uncertainty of substitution and the effectiveness of mitigation, this analysis assumes a total loss of the recreational resources in the B-C evaluation. This conservative approach tends to overstate the economic loss because of displaced recreation.

(4) Beyond resource losses, recreational values, and tourist expenditures, a segment of the population in northern Colorado perceives an existence value to the Cache la Poudre inundation area and the river in its current state. The magnitude of this existence value is so uncertain that it is not quantified here. Even so, to those who hold this value, it is substantial and has political ramifications.

(5) On the benefit side, there are a number of economic benefits likely to stem from the project which have not been quantified in this analysis. A major addition to the water supply of a region can have important, pervasive, and long-range effects on the local economy. As a cost factor in the production of goods and services, more supply will mean lower costs for water. This improves economic returns for business enterprises, encouraging

expanded investment, employment, and income. As an irreplaceable input to irrigated agriculture, the mere availability of water, especially during drought periods, could reduce the retirement of productive irrigated lands. Preserving agriculture's role in northern Colorado means that a basic economic sector can continue to stimulate income, employment, and tax revenues. To some, the preservation of agriculture also offers aesthetic or other intrinsic values.

11.5.2 Project Benefits

Four types of annual, project-related benefits have been identified and quantified to the extent possible. These include the project's safe water supply yield, hydroelectric power production, lake-oriented recreation, and gains in personal and business income. Project benefits will be realized beginning in the third year after the start of construction and are long-term in nature. Quantified benefits are accumulated and compared with costs at the end of this section.

11.5.2.1 Safe Yield

The Grey Mountain alternative would provide an estimated 41,000 af of safe annual yield to the region's water supply. It is assumed that the additional water supply would be used for municipal and industrial (M&I) purposes. Although firm purchase agreements have not been negotiated with any water utility, it is assumed that the water supply from the Grey Mountain alternative would be dedicated to beneficial M&I uses along the northern Front Range in Boulder, Larimer, and Weld Counties. There are more than 25 municipal water suppliers in this region as shown in Table 11.24. In addition, several large industrial water users, such as Anheuser-Busch, Monfort, and Kodak, independently have water supplies or receive water service from municipal suppliers.

The annual average water supplies for the entities listed in Table 11.24 currently totals about 244,000 acre feet (af). The annual safe yield of these supplies is approximately 206,000 af (NCWCD, 1990a). Most municipal entities in the region own Colorado-Big Thompson (C-BT) shares; some own direct flow rights, irrigation company stock, or shares in the Windy Gap

Project. Several of the smaller providers receive treated water through arrangements with other water districts and water associations in the region.

Based on water demand projections for M&I uses within the Poudre Basin presented in the Basin Study (Harza, 1987) and current supplies, additional average year water supplies will be needed by some entities by about the year 2000. Additional dry year supplies, or safe yield, will be needed earlier and in larger amounts.

A more recent, preliminary evaluation of municipal water demand along the northern Front Range indicates dry year demands may exceed supplies within areas served by NCWCD by almost 12,000 af in year 2000 and 52,000 af by year 2020 (NCWCD, 1990a). Southern portions of Boulder and Weld Counties add to these shortages by as much as 14,600 af in 2020. These estimates assume no sharing of water supplies among municipalities beyond the arrangements evident in 1990. Recognizing that municipal water resource planners must look as far as 30 to 50 years in the future, the indicated future shortages will spur these water providers to implement more stringent water conservation measures and seek new sources of water. Hence, it is clear that the safe yield from the Grey Mountain Reservoir can be fully utilized within Boulder, Larimer, and Weld Counties.

TABLE 11.24

Municipal and Industrial Water Providers, NCWCD Boundaries, 1988

Provider	County
Ault	Weld
Berthoud	Larimer
Boulder	Boulder
Central Weld County WD	Weld
Dacono	Weld
East Larimer County WD	Larimer
Eaton	Weld
Evans	Weld
Firestone	Weld
Fort Collins	Larimer
Fort Collins/Loveland WD	Larimer
Fort Lupton	Weld
Gilcrest	Weld
Greeley	Weld
LaSalle	Weld
Little Thompson WD	Larimer
Longmont	Boulder
Longs Peak WA	Boulder
Loveland	Larimer
North Weld County WD	Weld
Northern Colorado Water Association	Larimer
Pierce	Weld
Platteville	Weld
Spring Canyon W & SD	Larimer
Wellington	Larimer
West Fort Collins WD	Larimer
Windsor	Larimer

WA: Water Association
WD: Water District
W & SD: Water and Sanitation District

A portion of the safe yield from the Grey Mountain alternative would be available by the end of the fourth year of project construction; the entire yield is projected to be available three years later, two years after the completion of construction. For purposes of this analysis, it is assumed that none of the yield is available to M&I users until two years after construction is completed at which time all of the yield is available. The benefit of the yield is presented as the capitalized value of the water, or the purchase price. Thus, benefits are assumed to be realized in the year in which the full yield is assumed to be available.

Estimating the value of the Grey Mountain Project's estimated safe annual yield requires consideration of several diverse factors which influence the value, or price, of a water right or source of water. These factors generally include the amount of water to be derived from the right or source, its location, the dependability of the water supply, the present and intended uses of the water, overall supply and demand conditions, and individual circumstances of the buyer and seller.

A useful method for measuring the economic value of the safe yield from the Grey Mountain alternative is to evaluate the cost of comparable alternatives potentially available to municipal suppliers in the Poudre Basin. Comparable suppliers ideally are those which exhibit valuation factors enumerated above similar to the Grey Mountain Project (e.g., location, safe yield, storage, etc.). This method assumes that the per af value of the project's safe yield is approximated by the cost per af of comparable alternatives.

In reality, closely comparable water supplies are few in number. There are only a limited number of major water storage, and supply facilities in northern Colorado. Sizable water sources currently being procured by municipalities in northern Colorado are also limited in number. As a result, the estimation process requires identification of somewhat comparable sources and judgement about whether the safe yield from the Grey Mountain Project would be more or less valuable than each "comparable". By examining a number of comparables, sufficient insights can be gained to place a dollar value on the proposed project's safe yield.

For the benefit-cost analysis, four major alternative water sources have been considered in estimating the value of safe yield from the Grey Mountain alternative. These include recent acquisition costs for shares in the C-BT and Windy Gap Projects and the estimated cost of enlarging Halligan Reservoir on the North Fork of the Cache la Poudre River. In addition, as a measure of an entity's willingness to pay for municipal water supplies in northern Colorado, the Northern Project proposed by the City of Thornton was also considered. The cost per af of safe yield of each source is summarized in the following table:

TABLE 11.25

Costs of Comparable Water Supplies

Municipal Beneficiaries	Source of water	Units Transacted	Total Cost (million)	Cost per AF of Safe Yield
Northern Colorado Cities(1)	C-BT	NA	NA	$1,700-$1,900
Estes Park/Superior Metropolitan District(2)	Windy Gap	35	$20.7	$5,900
Greeley/Broomfield(3)	Windy Gap	13	$ 7.9	$6,200
Thornton(4)	Northern Project	283 shares	$60.0	$3,200
Fort Collins/NPIC(5)	Halligan	NA	$18.2	$1,800-$2,300

NA: not applicable

(1) Water Intelligence Monthly, 1990
(2) Greg White, 1990
(3) Craig Harrison, Mark Rybus, 1990
(4) City of Thornton Northern Water Supply Project, 1990
(5) Dennis Bode, 1990

NOTE: Calculations were made to render these diverse water supplies comparable. Capital costs, debt service, pumping, and other annual costs were considered. Future costs were discounted to present values using a three percent real interest rate.

C-BT water is a supplemental supply traded through rental or purchase of shares within the boundaries of the NCWCD. Other irrigation water, including North Poudre Irrigation Company (NPIC) and Greeley-Loveland shares, were also considered. However, the purchase price for these waters tends to be constrained by C-BT prices and thus are adequately represented by C-BT prices. As of 1989, C-BT shares traded at about $1,400 to $1,600 per af. A conversion of 0.7 af per unit is assumed for this analysis. Capitalized costs of annual allotment charges are added to the unit costs. Presently, annual allotment charges for municipalities are $10.50 per unit, or $15 per af assuming 0.7 af per unit. This equals $276 per af in present value terms using a real interest rate of three percent.

The price of C-BT exceeded $3,000 per unit in the early 1980's and reached a low of roughly $500 to $700 per unit when the Colorado economy stagnated and when the Windy Gap Project was completed. The two principal differences between C-BT prices and Grey Mountain water values are the restricting of C-BT transactions within NCWCD project boundaries and its supplemental supply characteristics. Hence, Grey Mountain supplies are likely to be more valuable.

Two sizeable transactions for Windy Gap shares provide a useful benchmark for the value of safe yield from the Grey Mountain alternative. The Windy Gap Project provides M&I water supplies in northern Colorado with an estimated safe yield during moderate droughts of 48,000 af. Shares are traded on a limited basis in northern Colorado. Transactions between Estes Park and the Superior Metropolitan District and between the Cities of Greeley and Broomfield include cash payments, adoption of debt service, and payment for conveyance and pumping costs to Horsetooth Reservoir or Carter Lake. On a fully capitalized basis, Superior Metropolitan District acquired 35 units of Windy Gap at approximately $5,900 per af. Broomfield paid approximately $6,200 per af for 13 units, including the cost of replacement water for Greeley. These figures assume that shares are converted at 100 af per share and include capitalized costs of annual conveyance and pumping charges; presently $45 per af, or $870 per af in present value terms using a real interest rate of three percent.

Windy Gap shares present certain drawbacks for use as a comparable for Grey Mountain Project waters. Because of delivery and other constraints, the market is not well developed for water from the Windy Gap Project. Concern on the part of some utilities regarding the potential need to provide additional storage to enhance yield of Windy Gap shares is evident. This tends to place downward pressure on the value of Windy Gap shares. There have been relatively few transactions, however, to gauge the impact of perceived project yield on willingness to pay.

The City of Thornton's acquisition of Water Supply and Storage Company (WSSC) shares for its proposed Northern Water Supply Project is used to illustrate Thornton's willingness to pay for water supplies in northern Colorado. Thornton purchased approximately 20,000 acres of irrigated farmland and 283 WSSC shares for approximately $60 million. Thornton has estimated the total annual safe yield of its WSSC shares to be 25,900 af (Rocky Mountain Consultants, Inc., 1990). This figure includes 2,900 af of conditional rights on the Poudre River. Other sources estimated the safe, divertable yield at 10,000 to 14,000 af (NCWCD, 1990b). Uncertainties exist about consumptive use, return flow requirements, and costs for conveyance and pumping to eastern slope facilities. Based on yield estimates ranging from 23,000 to 14,000 af, and after deductions in cost for dry land value, Thornton's capitalized cost of water in place for the Northern Project, excluding conveyance costs, would range from about $2,400 per af to $4,000 per af.

Because Thornton has only recently commenced litigation for obtaining a decree for the change-in-use of the WSSC stock purchased, estimates of safe yield should be viewed cautiously. It is possible that the safe yield of the Northern Project will be different than current estimates; and costs could vary substantially.

The City of Fort Collins and the North Poudre Irrigation Company (NPIC) have recently studied the possibility of enlarging Halligan Reservoir. Estimated safe yields and costs are preliminary at this time (Dennis Bode, City of Fort Collins, 1990). If constructed, Fort Collins would likely operate the reservoir to regulate agricultural water converted to municipal use and provide carry-over storage so that additional supplies are available during drought periods. Safe annual yield for the city under this option is estimated to range from 8,000 af to 10,000 af. With a construction cost of approximately $18.2 million, the unit cost to Fort Collins for additional safe yield would range from about $1,800 to $2,300 per af.

Halligan Reservoir is not strictly comparable to the Grey Mountain Project in several respects. Whereas the estimated safe yield of Halligan represents an increase in yield to only the Fort Collins system, the safe yield from the Grey Mountain Project essentially represents a new resource to the region. A second difference is the specialized drought-related use to Ft. Collins versus a more generalized use for Grey Mountain Project waters.

A fifth water source, a project on the Little Thompson River, has been considered and rejected for comparison purposes in this evaluation. The Colorado Water Resource and Power Development Authority funded a study of various storage and water resource development alternatives in the St. Vrain River Basin. One of the alternatives considered, a reservoir on the Little Thompson River, is comparable to the storage component of the Grey Mountain alternative but not the safe yield. The Little Thompson Reservoir would primarily regulate existing supplies while the Grey Mountain Project would develop new supplies. The Little Thompson Reservoir as an element of several project plans identified in the St. Vrain Basin Study (R.W. Beck and Associates, 1986), was initially sized for 16,000 af of active storage in order to deliver 8,000 af on an annual basis. However, recent reformulation of the project and uncertainties about integration of Longmont's Windy Gap waters prevent direct comparison with the Grey Mountain Project. As a result, this project was excluded from further consideration in the B-C analysis.

Considering the above alternatives, a reasonable range of value for the safe yield from the Grey Mountain Project is $3,000 to $4,000 per af. Therefore, a value of $3,500 per af was selected for the benefit-cost analysis. This results in an estimated value for the safe yield from the Grey Mountain Project of $143.5 million.

11.5.2.2 Hydroelectric Power Production

The Grey Mountain alternative, as currently proposed, includes a 24 MW hydroelectric power plant. Average annual energy production was estimated to be 52 GWh, as described in Chapter 9.0, indicating an average plant capacity factor of 25 percent.

The concept of avoided cost is used to determine the economic value of the project's hydroelectric power component. Power benefits are calculated based on Public Service Company of Colorado purchases from cogenerators. According to the Colorado Public Utilities Commission, PSCo pays $18.02 per kW-month and $0.0161 per kWh (Colorado PUC, 1990). Using these figures, annual hydroelectric power benefits are estimated to be $2.15 million.

11.5.2.3 Lake-Oriented Recreation

The reservoir formed by Grey Mountain Dam would provide substantial opportunities for flatwater recreation. As discussed in Chapter 5.0, Horsetooth Reservoir, Carter Lake, and Boyd Lake are currently used to capacity during peak summer months. Thus, the project could redistribute and expand existing lake-oriented recreation in the region, thereby reducing congestion, and possibly adding new users. These recreation benefits are essentially gains to existing and new flatwater recreationists.

Based on the flatwater recreation potential of the reservoir formed by Grey Mountain Dam, as described in Chapter 5.0, estimates of annual visits for an assumed mix of recreational activities have been developed. These activities include power and wakeless boating, camping, picnicking, and shoreline angling. Estimates of initial annual visitations by activity and at maximum capacity have been developed as shown in Table 11.26:

TABLE 11.26

Projected Annual Recreation Visits
Grey Mountain Reservoir

Activity	Utilization (annual visits) Initial	Maximum Capacity
Power boating	12,860	42,880
Wakeless boating	6,340	21,120
Camping	2,400	12,000
Picnicking	2,400	12,000
Shoreline angling	1,000-2,000	10,000
Total	25,000-26,000	98,000

As the population in northern Colorado continues to grow over time, usage of the project's recreational features would reach maximum capacity. For purposes of this analysis, annual visitation was assumed to grow at a rate of roughly two percent per year, which is the historical combined annual population growth rate for Boulder, Larimer, and Weld Counties during the period between 1980 and 1988 (State Demographer, 1989). It is assumed that initial recreational use of the reservoir commences the fourth year after the start of construction, when the reservoir is assumed to be partially filled, and reaches maximum capacity approximately 10 years after construction is completed.

Unit values (UVs) represent the benefits associated with a particular recreation activity beyond direct expenditures necessary to participate in the activity. UVs for each of the five recreational activities are presented in earlier report chapters and have been updated to 1988 dollars using the GNP implicit price deflator for personal consumption expenditures. UVs are summarized as follows:

TABLE 11.27

Assumed Value per Recreational Visit
Grey Mountain Reservoir

Activity	Unit Value Per Visit
Power boating	$32.00
Wakeless boating	20.00
Camping	21.00
Picnicking	20.00
Shoreline angling	16.00

Flatwater recreation benefits were derived by multiplying the estimated number of annual visits by the activity's UV. Lake-oriented recreation benefits are estimated to be about $640,000 annually when project construction is completed. Annual benefits are estimated to be more than $2.4 million when maximum capacity is attained. These benefit estimates are summarized in the following table:

TABLE 11.28

Total Annual Recreation Benefits
Grey Mountain Reservoir

Activity	Average Annual Benefits ($1,000s) Initial	Maximum Capacity
Power boating	$411	$1,372
Wakeless boating	127	422
Camping	50	252
Picnicking	48	240
Shoreline angling	16-32	160
Total	$652-$668	$2,446

11.5.2.4 Personal Income and Business Net Income Benefits

Individuals and business establishments in the northern Colorado region would benefit from the proposed project due to positive effects on personal and business income. Incremental personal income due to direct project employment and incremental net business income due to the purchase of construction related materials are included as direct benefits. Secondary income benefits, both personal and business, occur through the multiplier effect described in Section 11.4.

From Section 11.4 of this report, a total gain of $74 million in personal income is projected to result directly and indirectly from construction of the Grey Mountain alternative. Business net income benefits would arise through the disposition of project wage and salary income, spending of secondary income, and purchases of construction-related materials. These benefits are derived from the ratio of the national average of business profits to total pre-tax business revenues, which is about 0.10 (U.S.Department of Commerce, 1990). Business net income benefits are estimated to total roughly $6.2 million.

11.5.2.5 Local Tax Revenue Benefits

Local governments in the northern Colorado region would benefit from the Grey Mountain Project to the extent that it generates additional tax revenues. Since the project would not lead to in-migration of employees, which could burden existing public infrastructure, additional tax revenues would represent a net gain to local governments. Property tax impacts would be modest. Thus, it is assumed that fiscal benefits totaling $770,000 would occur from additional sales tax revenues induced by the spending of direct and secondary personal income (see Section 11.4.2.4).

11.5.2.6 Flood Control Benefits

As currently proposed, the Grey Mountain Project would provide for reductions in peak flood flows. Principal beneficiaries would be City of Fort Collins, the Town of La Porte, and other unincorporated areas in Larimer County within the current floodplain. Although several drainages, primarily Boxelder Creek, join the Poudre River between Greeley and Fort Collins, the City of Greeley also could benefit to some extent from flood control provided by a mainstem storage reservoir.

According to the Army Corps of Engineers, there have been 30 major floods on the Poudre River during the past 100 years (COE, 1981). Existing reservoirs, except for Seaman and Halligan on the North Fork of the Cache la Poudre River, have little effect on attenuating flood flows.

Although potential benefits are considered to be substantial, flood control benefits could not be quantified for this study. The Flood Insurance Studies (FIS) for Fort Collins and unincorporated Larimer County, performed in 1984 and 1987, respectively, are in the process of being updated. Updated floodplain maps are expected to be available by the end of 1990. At the time of this report, there was substantial disagreement regarding peak flood discharges to be used for estimating floodplain elevations, and there was no consensus as to the areal extent of the 100-year floodplain. As described in Chapter 13.0, available results from the FIS work are not directly usable to evaluate potential reductions in floodplain extent and depth of flooding.

There is also limited information concerning the type and value of land uses currently in what will be designated as the floodplain. A related factor is that neither Fort Collins nor Larimer County have yet developed a comprehensive plan for the floodplain, although a planning effort is contemplated for 1991.

The Grey Mountain Project would provide substantial flood control benefits. The entire 100-year flood, as estimated by the Corps of Engineers, could be stored in Grey Mountain Reservoir without any allocation of storage for flood control. Although flood control benefits have not been quantified, a discussion of the nature of potential benefits is merited. The COE considers three types of flood control benefits: flood reduction; intensification; and location. Flood reduction benefits relate to a reduction in average annual flood damages to existing land uses due to the project. As a point of reference, a 1981 COE report estimates potential average annual flood damages to the communities of LaPorte, Fort Collins, and Greeley resulting from a 100-year flood to be about $1.2 million (updated to 1988 dollars) (COE, 1981). These figures are misleadingly low since damage to streets and utilities, emergency costs, and agricultural losses were excluded and two other forms of flood attenuation benefits were ignored.

The two flood attenuation benefits ignored are location and intensification benefits, which refer to instances where a reduction in the level of flood risk leads to new activities and to increased utilization of existing floodplain resources. Location benefits arise when the reduction in flood risk makes it profitable for new activities to locate in the floodplain. Location benefits can be measured by the increase in net income or property values due to new floodplain uses. Intensification benefits refer to increases in net income due to expansion of existing land uses, rather than changes in existing land uses.

The City of Fort Collins is in the preliminary planning stages for establishing a Heritage Corridor along the Cache la Poudre River where it passes through the city. Various recreational amenities are contemplated which would enhance the usefulness and overall economic contribution derived from activities along the river corridor. A study was prepared in 1989 to explore the possibility of utilizing these lands more productively (Shalkey Walker Associates, Inc., 1989). The study proposed a $14 million capital investment in bike paths, stream improvements, and other enhancements. Although no quantification has been provided thus far, it is clear that the Heritage Corridor would benefit Ft. Collins and Larimer County by:

1. Increasing recreational assets for the community;
2. Stimulating capital expenditures;
3. Stimulating commercial activity;
4. Creating jobs;
5. Increasing income levels; and
6. Raising land values.

These benefits can best be realized with flood flow attenuation that would be provided by a mainstem reservoir below the confluence with the North Fork such as the Grey Mountain Reservoir.

11.5.3 Economic Costs

This section describes the direct and secondary economic costs associated with construction of the proposed Grey Mountain Project. Along with costs directly associated with construction activities, additional costs are incurred because of land and stream inundation and displacement of certain existing recreation activities. Other costs include losses in personal income and business net income. Construction and inundation costs are incurred in the near term, while costs associated with displacing recreation activities tend to occur over a longer term.

11.5.3.1 Project Construction Costs

The total construction cost of Grey Mountain Dam and appurtenant facilities is estimated to be $230.1 million in 1988 dollars. Project construction would require approximately five years, with most of the costs incurred during the third and fourth years.

11.5.3.2 Displaced Recreation Activity Costs

Welfare costs are associated with the inundation of the canyon and the displacement of certain existing recreation activities. Welfare costs are essentially the benefits to recreationists, beyond the actual dollar costs, which would be foregone in the future. Impacted activities include hiking, private recreation cabin use, fishing, whitewater boating, hunting, and picnicking.

The estimated number of displaced annual visits and related unit values due to construction and operation of the Grey Mountain Project were described in previous report chapters and are shown below:

TABLE 11.29

Displacement of Existing Recreational Activities
Grey Mountain Reservoir

Activity	Displaced Annual Visits	Unit Value Per Visit
Recreation cabins	1,400	$ 3.00
Fishing	2,600	16.00
Hiking	19,500	17.00
Hunting	10	52.00
Picnicking	400	20.00
Whitewater boating	5,050	20.00

UVs are updated to 1988 dollars using the GNP implicit price deflator for personal consumption expenditures. The costs associated with displacing recreation activities are obtained by multiplying the number of displaced annual visits for each activity by the respective unit value. These costs are summarized below:

TABLE 11.30

Estimated Displaced Recreation Costs
Grey Mountain Reservoir

Activity	Annual Costs ($1,000 s)(1)
Recreation cabins	$ 4
Fishing	41
Hiking	324
Hunting	(2)
Picnicking	8
Whitewater boating	101

(1) Not additive because losses occur in different years.
(2) Less than $1,000.

There are five privately owned recreation cabins constructed on land leased from the U.S. Forest Service that would be inundated by the reservoir. Forest Service policy does not suggest that the inundated cabins would be relocated to comparable sites. Hence, the loss of the cabins could only be offset through monetary compensation which is included in estimated project costs. Beyond that value, a welfare loss of $4.00 per visit is assumed.

Approximately 6.5 miles of the Poudre River accessible for fishing would be inundated by the proposed project. About one-half of this segment has been designated as "Wild Trout" water by the Colorado Division of Wildlife. As described in Chapter 5.0, an estimated 2,600 fishing visits would be displaced annually. Displaced angling would likely move to other segments of the Poudre River or other fishable streams within the northern Front Range (e.g., Laramie River or North St. Vrain Creek). The diminished welfare associated with fishing at potentially more distant, congested, or lower quality sites is noted in benefit-cost analysis as an indirect cost to the project. To ensure that these costs are not understated, displaced fishing visits were treated as a loss attributable to the Grey Mountain Project without adjustments for opportunities at other potential sites.

The existing Greyrock Mountain trailhead would be inundated by the reservoir. While access to the trail is disrupted, nearly 20,000 annual visits would be eliminated, as described in Chapter 5.0. However, if new access is constructed early in the construction period prior to the filling of the reservoir, displacement would likely be modest. For purposes of the benefit-cost analysis, it is assumed that one year of hiking activity would be lost due to project construction.

Big game hunting occurs in the vicinity of the North Fork of the Cache la Poudre River. As described in Chapter 5.0, an estimated 10 percent of annual hunting activity, or 10 visits, would be displaced by the Grey Mountain Project. This is a relatively minor effect, and displaced hunters would likely have access to substitute sites offering a similar quality of hunting experience. Again to ensure such costs are not understated, the benefit-cost analysis included the total loss in visits as a cost to the project.

Because the proposed project would inundate several miles of river environment, picnicking and general day use, which occur along the river's banks, would also be displaced. The Grey Mountain Project would displace an estimated 400 visits annually (see Chapter 5.0). The nature of the canyon environment (i.e., roaded stream valley) indicates that many substitute sites are available in the proximate region. By assuming a total loss in visits, this again overstates the cost to the project.

Currently, six commercial whitewater outfitters offer full day and half day boating trips on the lower Poudre River during a 60-day period per year, on average, that boating is possible. Private boaters account for an estimated five to ten percent of total boating use. Annual boating use is concentrated on three segments of the lower river: Filter Plant Run; Bridges Run; and Lower Mishawaka Run. Most of the commercial use, about 80 percent, is concentrated on the Filter Plant Run. The entire Bridges Run and the upper half of the Filter Plant Run would be inundated by construction of the project. As described in Chapter 5.0, it is estimated that 5,050 annual visits, or about 80 percent of existing whitewater use, would be displaced by the Grey Mountain Project. Releases from the reservoir could be managed to preserve whitewater boating opportunities on the lower half of the Filter Plan Run, particularly if improvements are made and the run is extended further downstream. Also, the Lower Mishawaka Run could be improved to accommodate displaced boaters. Alternatively, boaters would have to travel substantial distances to substitute sites. For consistency in this analysis, the total number of displaced annual visits are counted as a cost attributable to the project as if no mitigation is provided.

11.5.3.3 Expenditure Losses from Displaced Recreation

The loss of angling and whitewater boating recreation visits to the Poudre Canyon could reduce business revenues, jobs, and personal income. Income losses could occur through reductions in expenditures made by individuals engaging in these recreational activities. As described in Section 11.4.3.6, personal income losses could total about $820,000, including $750,000 from whitewater boating and $70,000 from fishing. Lost business revenues associated with decreased fishing and boating activity could total $880,000. Assuming 10 percent of lost business revenues would be net income (U.S. Department of Commerce, 1990), regional net business income reductions are estimated to be about $88,000.

11.5.3.4 Inundation of Public and Private Property

It was reported in Chapter 5.0 that portions of two subdivisions and 29 private parcels of land lie within the proposed project inundation area. Although these parcels are relatively undeveloped, an estimated 60 to 70 residential structures would be inundated by the reservoir. The homes affected range from small structures in poor condition to relatively large and newer houses. According to knowledgeable realtors and appraisers, home values generally range from $15,000 to $75,000, with a few homes in the

$200,000 to $500,000 range (Realtor Interviews, 1986). An average value of $60,000 was developed for this analysis based on the estimated number of homes in each price category. The total cost of residential structures is therefore estimated to be $4.2 million. When a decision is made to proceed with final design and construction of the Grey Mountain Project privately owned property would be appraised and purchased on the basis of actual value as part of the project cost.

11.5.4 Findings and Conclusions of Benefit Cost Analysis

The summary of the benefit-cost analysis is presented in this section. Tables 11.31 and 11.32 summarize annual benefits and costs incurred throughout the planning horizon. Table 11.33 summarizes the present value of benefits and costs. A real discount rate of three percent is used to translate future benefit and cost streams into 1988 dollars for comparability.

The cost of project construction is the single largest cost item and occurs early in the planning horizon. Annual benefits, on the other hand, are relatively small but are realized over a long period. Flood control benefits are not included in the quantified analysis for the reasons discussed in Section 11.5.2.6. As shown in Table 11.33, quantified benefits exceed costs by more than $45 million on a present value basis for a benefit-cost ratio of 1.22.

TABLE 11.31

Summary of Annual Benefits ($1,000) from the Grey Mountain Alternative

Year After Start of Construction	Direct Benefits: Conv. Hydro	Direct Benefits: Water Supply	Direct Benefits: Flat Water Rec.	Direct Benefits: Flood Control	Secondary Benefits: Personal Income Gains	Secondary Benefits: Business Net Income Gains	Secondary Benefits: Additional Local Tax Revenues	Total Annual Benefits
1	$	$	$	$	$	$	$	$
2								
3				*	22,200	1,862		24,062
4			653	*	18,500	1,551		20,704
5	2,154		666	*	14,800	1,241	768	19,629
6	2,154		693	*	11,100	931		14,878
7	2,154	143,500	736	*	7,400	621		154,411
8	2,154		798	*				2,952
9	2,154		882	*				3,036
10	2,154		995	*				3,149
15	2,154		2,383	*				4,537
20	2,154		2,443	*				4,597
40	2,154		2,443	*				4,597
60	2,154		2,443	*				4,597

* Tangible but unquantified

TABLE 11.32

A Summary of Annual Costs ($1,000) for the Grey Mountain Alternative

Year After Start of Construction	Direct Costs: Const. Cost	Direct Costs: O&M	Secondary Recreational Welfare Losses: Stream Fishing	Secondary Recreational Welfare Losses: White Water	Secondary Recreational Welfare Losses: Hiking	Secondary Recreational Welfare Losses: Other Recreation Losses	Secondary Recreational Welfare Losses: Recreation Cabins	Other Secondary Costs: Residential Structure Inundation	Other Secondary Costs: Business Income Losses	Other Secondary Costs: Personal Income Losses	Total Annual Losses and Costs
1	$23,300	$	$	$	$324	$	$4	$4,200	$	$	$27,828
2	49,170		41	100		8	4				49,323
3	70,620		41	100		8	4				70,773
4	70,620		41	100		8	4		27	246	71,046
5	17,110	360	41	100		8	4		22	205	17,850
6		360	41	100		8	4		18	164	695
7		360	41	100		8	4		13	123	649
8		360	41	100		8	4		9	82	604
9		360	41	100		8	4				513
10		360	41	100		8	4				513
11		360	41	100		8	4				513
12		360	41	100		8	4				513
17		360	41	100		8	4				513
27		360	41	100		8	4				513
47		360	41	100		8	4				513
57		360	41	100		8	4				513

TABLE 11.33

Present Value of Benefits and Costs for the Grey Mountain Alternative

	Millions
Benefits	
M&I Water Supply	$100.65
Conventional Hydro	43.54
Flat Water Rec	40.56
Flood Control	(1)
Personal Income	55.93
Business Income	4.69
Local Tax Revenue	0.57
Subtotal	$245.94
Costs	
Construction	$182.10
O&M	7.28
Inundation	3.52
Lost Recreation	7.25
Personal Income	0.60
Business Income	0.06
Subtotal	$200.81
NET PRESENT VALUE	$45.13

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(1) Tangible benefit but unquantified.

A sensitivity analysis has been conducted to determine the effects of variations in key benefit/cost assumptions upon economic feasibility. Total project costs were increased to reflect uncertainties about mitigation, lost recreation and other values, or other unexpected costs. Total project benefits were decreased to reflect uncertainties about water values, hydroelectric power revenues or other project benefits. Finally, the discount rate of 3 percent (real rate) was varied to reflect uncertainties about interest rates. All of these variations are considered less likely than the base case described in this chapter, but in the unlikely event that these deviations occur, the B-C ratio would be affected. The results of this sensitivity analysis are depicted in the table below:

TABLE 11.34

Sensitivity Analysis of the B-C Ratio for the Grey Mountain Project

Variable Modified From Base Case	Benefit-Cost Ratio
Total Costs + 10%	1.12
Total Costs + 20%	1.03
Total Costs + 10%, Total Benefits - 10%	1.01
Real Discount Rate @ 4%	1.13
Real Discount Rate @ 5%	1.06

Present value benefits would exceed costs by at least $26 million if all base case costs are increased by 10 percent, or if the real discount rate is raised to 4 percent. Benefits slightly exceed costs under the more extreme assumptions of a 20 percent increase in costs and a 5 percent real discount rate.

The results of the sensitivity analysis suggest that the economic feasibility of the Grey Mountain Project would remain positive even if key assumptions are incorrect and adverse.

This preliminary feasibility level analysis indicates that the Grey Mountain Project is economically feasible since benefits exceed costs. It should be noted that benefits are conservatively estimated and costs are liberally estimated. This further emphasizes the positive conclusion about the economic feasibility of the Grey Mountain Project.

11.6 FINANCIAL FEASIBILITY OF GREY MOUNTAIN ALTERNATIVE

The financial feasibility of the Grey Mountain alternative is examined in this section. The focus is upon the project construction costs and potential revenue streams to offset annual repayment obligations. Direct project costs are annualized through debt financing assumptions. Vendable project benefits are isolated from other economic benefits and annualized for comparison with annual revenue requirements to ascertain whether or not the project costs can be repaid.

This analysis is performed on both a real (constant) and nominal dollar basis. The real dollar analysis utilizes constant 1988 dollars in all instances, assuming inflation affects all costs and rates similarly. The nominal dollar analysis was benchmarked to 1988, and rates and costs were inflated at 5 percent to reflect future dollars.

There are several reasons for conducting the financial analysis in both nominal and real terms. Because debt financing is assumed, potential project sponsors must repay bondholders in future, inflated dollars. Inflationary expectations are reflected in the nominal interest rate assumed for the bond issue, as well as project construction costs and any rates and charges which might be levied to repay the project. A constant dollar analysis recognizes that inflation and nominal interest rates affect both the revenue and expenditure components. By using real rates and constant dollars, a financial analysis suitable for decision-making purposes, though not debt issuance, can be produced.

11.6.1 Annual Revenue Requirements

Annual revenue requirements are composed of capital and operating costs. Through the application of debt financing assumptions, an annual schedule of dollar requirements, in both constant and current dollars, is presented.

11.6.1.1 Project Features and Costs

Project features and construction costs are identified in Section 11.2.3 of this report and discussed in detail in other portions of Chapter 16.0. The initial step in the financial feasibility study is to develop a schedule of costs by year of the project.

Constant 1988 dollar construction cost of the Grey Mountain alternative is estimated to be $230.1 million (see Chapter 9.0). The cost of constructing the dam alone is $163.9 million. The Horsetooth conveyance system has an estimated cost of $29.0 million. The hydropower component is estimated to cost $13.9 million. Construction of access roads and realignment of Colorado Highway 14 is estimated to cost $23.3 million. Considering the effects of inflation, total construction costs would total about $342 million by the end of the construction period.

Facilities would be constructed to provide lake-oriented recreation opportunities, although detailed plans have not yet been established. As discussed in Chapter 5.0, boat launch access, which would capture the largest potential recreational use of the reservoir, is estimated to cost nearly $400,000. The estimated cost of a 20-unit, semi-primitive campground would be about $160,000. The construction of 10 picnic units and parking for 15 cars is estimated to cost $40,000. The total cost of recreational facilities development near the reservoir would be more than $600,000.

Based on current plans, construction of Grey Mountain Dam and appurtenant facilities would require five years. During the first year, a portion of Colorado Highway 14 would be relocated, and access roads to the damsite would be constructed. Construction of the dam would begin in the second year and would require three years to complete. Construction of the powerhouse and the Horsetooth conveyance facilities would proceed concurrently, beginning in the third year of project construction, and would require two years to complete. The last year of construction would be devoted to restoration of disturbed areas near the project site.

Annual O&M costs are estimated to be $360,000 in constant 1988 dollars, as discussed in Chapter 9.0. This includes personnel costs, materials and supplies. On a current dollar basis, which includes the effects of inflation, annual O&M costs will increase from $620,000 when project operations begin to approximately $2.6 million by the end of the repayment period.

11.6.1.2 Financing Assumptions

Capital costs of the project are assumed to be fully met through a single revenue bond issue with a 30-year term and an 8 percent nominal interest rate. For the constant dollar analysis, capital and O&M costs were expressed in constant 1988 dollars, and a real interest rate on the bonds, exclusive of inflation, was applied. Assuming a 5 percent inflation rate, the real interest rate utilized in this financial analysis was 3 percent. For the nominal analysis, capital and O&M costs were inflated at 5 percent annually, and the nominal rate of 8 percent on the bonds was applied. Section 11.5 of this report provides the rationale for selecting the 8 percent nominal rate and the 5 percent inflation rate.

Other financing assumptions were necessary to account for interest during construction, the bond reserve fund, bond issuance costs, and insurance. For purposes of this analysis, interest costs incurred during the five-year construction period were assumed to be included in the single bond issue. Realistically, interest during construction would be provided through separate, short-term financing. The bond reserve fund was assumed to be one year's debt service payment. Bond issuance and insurance costs were assumed to be 1.5 percent of the total bond issue.

This set of financial assumptions is conservative since other, more favorable financing alternatives might contribute in part to the project's financial support. These other alternatives could include grants or loans from various state or federal agencies. For instance, the Colorado Water Resources and Power Development Authority has a loan program based on long term bonds at very favorable interest rates. The Colorado Water Conservation Board (CWCB) also has the ability to provide 5 percent interest rate loans for up to 50 percent of project costs. The Wolford Mountain Project (formerly the Muddy Creek Project) will be financed in part by a $13 million loan from the CWCB, the largest loan it has issued. Monies from the Colorado Department of Local Affairs and the State's Fish and Wildlife Mitigation grant funds might also be available. At the federal level, the Bureau of Reclamation and the Farmer's Home Administration have programs which might apply to the Grey Mountain Project. It should be emphasized, however, that the state and federal financing alternatives generally target smaller water projects supported by smaller communities or rural areas. Such avenues might be possible if the smaller communities in the Cache la Poudre River Basin demonstrated commitment to a mainstem storage project such as the Grey Mountain Project.

One federal financing source which deserves particular consideration is the U.S. Army Corp of Engineers (COE). An important potential benefit of the Grey Mountain Project is flood control, and the COE has indicated an interest in jointly supporting projects which have flood control along with other benefits and sponsors. The profile of the Grey Mountain Project appears to fit the broad criteria for COE participation. The COE has also conducted preliminary flood control evaluations in the Poudre Basin. Potential drawbacks to involving the COE include lengthy evaluation periods, loss of local control, and compliance with the agency's procedures.

Table 11.35 provides a schedule of revenue requirements for the evaluation. A bond issue totalling about $265 million would be required to finance the Grey Mountain alternative. This includes $230.1 million for construction costs, $17.5 million for interest charges during construction, $3.9 million for bond issuance and insurance costs, and a bond reserve fund of $13.5 million. Annual debt service would be $13.5 million. Interest earned annually on the bond reserve fund would amount to about $400,000, more than offsetting O&M costs. Total annual revenue requirements would amount to an estimated $13.5 million.

TABLE 11.35

Annual Revenue Requirements for Grey Mountain Alternative

(millions of constant dollars)

	CAPITAL COSTS AND DEBT								ANNUAL PAYMENTS			
YEAR AFTER CONST. BEGINS	CONST. COSTS	INTEREST DURING CONST.	BOND RESERVE FUND	BOND ISSUANCE COSTS	TOTAL	CUMULA-TIVE TOTAL	OUT-STANDING PRINCIPLE	INTEREST EXPENSE	DEBT SERVICE	O & M COSTS	INTEREST ON RESERVE	TOTAL REVENUE REQUIRED
1	$ 23.3	$ 0.3	$	$	$ 23.6	$ 23.6	$	$	$	$	$	$
2	49.2	1.4			50.6	74.2						
3	70.6	3.3			73.9	148.1						
4	70.6	5.5			76.1	224.2						
5	16.4	7.0			23.4	247.6						
6			13.5	3.9	17.4	265.0	265.0	8.0	13.5	0.36	0.4	13.5
7							259.5	7.8	13.5	0.36	0.4	13.5
8							253.8	7.6	13.5	0.36	0.4	13.5
9							247.9	7.4	13.5	0.36	0.4	13.5
10							241.8	7.3	13.5	0.36	0.4	13.5
11							235.5	7.1	13.5	0.36	0.4	13.5
12							229.1	6.9	13.5	0.36	0.4	13.5
13							222.4	6.7	13.5	0.36	0.4	13.5
14							215.6	6.5	13.5	0.36	0.4	13.5
15							208.5	6.3	13.5	0.36	0.4	13.5
16							201.2	6.0	13.5	0.36	0.4	13.5
17							193.7	5.8	13.5	0.36	0.4	13.5
18							186.0	5.6	13.5	0.36	0.4	13.5
19							178.1	5.3	13.5	0.36	0.4	13.5
20							169.9	5.1	13.5	0.36	0.4	13.5
21							161.5	4.8	13.5	0.36	0.4	13.5
22							152.8	4.6	13.5	0.36	0.4	13.5
23							143.9	4.3	13.5	0.36	0.4	13.5
24							134.6	4.0	13.5	0.36	0.4	13.5
25							125.2	3.8	13.5	0.36	0.4	13.5
26							115.4	3.5	13.5	0.36	0.4	13.5
27							105.3	3.2	13.5	0.36	0.4	13.5
28							95.0	2.8	13.5	0.36	0.4	13.5
29							84.3	2.5	13.5	0.36	0.4	13.5
30							73.3	2.2	13.5	0.36	0.4	13.5
31							62.0	1.9	13.5	0.36	0.4	13.5
32							50.3	1.5	13.5	0.36	0.4	13.5
33							38.3	1.1	13.5	0.36	0.4	13.5
34							26.9	0.8	13.5	0.36	0.4	13.5
35							13.2	0.4	13.5	0.36	0.4	13.5
36							0.0	0.0	13.5	0.36	0.4	13.5
TOTAL	$230.1	$17.5	$13.5	$3.9	$265.0	$ ---	$ ---	$140.8	$418.5	$11.20	$12.4	$418.5

TABLE 11.36
Annual Revenue Requirements for Grey Mountain Alternative
(millions of current dollars)

YEAR AFTER CONST. BEGINS	CAPITAL COSTS AND DEBT: CONST. COSTS	INTEREST DURING CONST.	BOND RESERVE FUND	BOND ISSUANCE COSTS	TOTAL	CUMULATIVE TOTAL	OUT-STANDING PRINCIPLE	INTEREST EXPENSE	ANNUAL PAYMENTS: DEBT SERVICE	O & M COSTS	INTEREST ON RESERVE	TOTAL REVENUE REQUIRED
1	$ 31.2	$ 1.2	$	$	$ 32.4	$ 32.4	$	$	$	$	$	$
2	69.2	5.4			74.6	107.0						
3	104.3	12.7			117.0	224.0						
4	109.6	22.3			131.9	355.9						
5	26.7	29.5			56.2	412.1						
6			40.8	6.8	47.6	459.7	459.7	36.8	40.8	0.60	3.3	38.1
7							455.8	36.5	40.8	0.60	3.3	38.1
8							451.4	36.1	40.8	0.70	3.3	38.2
9							446.7	35.7	40.8	0.70	3.3	38.2
10							441.6	35.3	40.8	0.70	3.3	38.2
11							436.0	34.9	40.8	0.80	3.3	38.3
12							430.1	34.4	40.8	0.80	3.3	38.3
13							423.6	33.9	40.8	0.90	3.3	38.4
14							416.7	33.3	40.8	0.90	3.3	38.4
15							409.2	32.7	40.8	1.00	3.3	38.5
16							401.0	32.1	40.8	1.00	3.3	38.5
17							392.3	31.4	40.8	1.10	3.3	38.6
18							382.8	30.6	40.8	1.10	3.3	38.6
19							372.6	29.8	40.8	1.20	3.3	38.7
20							361.6	28.9	40.8	1.20	3.3	38.7
21							349.6	28.0	40.8	1.30	3.3	38.8
22							336.8	26.9	40.8	1.30	3.3	38.8
23							322.9	25.8	40.8	1.40	3.3	38.9
24							307.8	24.6	40.8	1.50	3.3	39.0
25							291.6	23.3	40.8	1.60	3.3	39.1
26							274.1	21.9	40.8	1.60	3.3	39.1
27							255.2	20.4	40.8	1.70	3.3	39.2
28							234.7	18.8	40.8	1.80	3.3	39.3
29							212.7	17.0	40.8	1.90	3.3	39.4
30							188.8	15.1	40.8	2.00	3.3	39.5
31							163.1	13.0	40.8	2.10	3.3	39.6
32							135.3	10.8	40.8	2.20	3.3	39.7
33							105.3	8.4	40.8	2.30	3.3	39.8
34							72.9	5.8	40.8	2.40	3.3	39.9
35							37.8	3.0	40.8	2.50	3.3	40.0
36							0.0	0.0	40.8	2.70	3.3	40.2
TOTAL	$341.0	$71.1	$40.8	$6.8	$459.7	$ ---	$ ---	$765.2	$1,264.8	$43.60	$102.3	$1,206.1

Table 11.36 shows that the effects of inflation would increase the size of the bond issue by $194.7 million to $459.7 million. Annual debt service would total approximately $40.8 million. Annual interest earned on the bond reserve fund would be $3.3 million. Because of escalating O&M costs, total revenue requirements would increase from $38.1 million to $40.2 million by the end of project repayment.

11.6.2 Projected Revenues for Repayment

Although the Grey Mountain alternative offers a number of project benefits, only water sales to M&I users and hydroelectric power generation are presumed to be vendable and therefore relevant to project repayment. Recreation, flood control, and regional economic benefits are not readily amenable to a bond repayment pledge, although there may be alternative funding mechanisms such as grants and low-interest loans for these project purposes that would lessen the size of the bond issue.

11.6.2.1 Water Tap Fees and User Charges

For purposes of this analysis, it is assumed that M&I water suppliers in Boulder, Larimer, and Weld Counties would participate in the Grey Mountain Project and would sell their portion of the safe yield from the project to future and existing residents and businesses within their jurisdictions. Two common forms of revenue, tap fees and user charges, are assumed for this repayment analysis.

The tap fee or user charge revenues, which might be forthcoming from the M&I sector in return for the safe yield of the Grey Mountain Project, cannot be estimated with certainty. There are numerous M&I water suppliers of varying sizes in the Cache la Poudre River Basin and in the surrounding region which might ultimately agree to participate in the proposed project. The need for the project yield to serve anticipated households and businesses coming into the region is demonstrated in Section 11.5 on an aggregate basis. However, the mix of actual project participants is not known at this time. Further, the mix between tap fees and user charges is in part based upon the pricing and development policies of the individual suppliers.

Tap fees and user charges of the largest communities in the Poudre Basin, Fort Collins and Greeley, are indicative of the extent to which repayment from future growth might occur. Single family unit tap fees range from roughly $1,600 to $2,300 in Fort Collins and Greeley. Greeley charges an additional $1,000 for units outside the city limits. Both cities require developers to also contribute water rights or cash to support their development.

Water charges in the Basin are relatively low. The Fort Collins service area is essentially unmetered, but wholesale treated water customers are charged about $.90 per 1,000 gallons. Within the City of Greeley, $1.15 per 1,000 gallons is charged for the first 10,000 gallons consumed, and additional water usage is charged at a rate of $.97 per 1,000 gallons. Water charges outside the city are double the in-city charges.

Water tap fees and water charges exhibit a wide range among other municipal suppliers in the Basin. Tap fees and user charges for other selected Basin suppliers are shown below.

TABLE 11.37

Tap Fees and User Charges, Selected Municipal Suppliers

Supplier	Tap Fees	User Charges(1)
Ault	$ 860	N.A.
Elco	3,500	$1.33 per 1,000 gal
Eaton	2,100(2)	N.A.
Fort Collins/Loveland	1,500	N.A.
Mead	4,500	$.80 per 1,000 gal
Spring Canyon	4,000	$1.21 per 1,000 gal(3)
Wellington	2,700	$1.30 per 1,000 gal
West Fort Collins Water District	2,750	$1.25 per 1,000 gal
Windsor	2,200(2)	$1.40 per 1,000 gal

(1) Excludes initial gallonage or "fixed" portions of user charges.
(2) Developer is also required to contribute water rights at 3 af per acre of development.
(3) Assumes 20,000 gallons of consumption per month.

Source: Interviews with water suppliers, May 1990.

The above water suppliers do not explicitly levy charges to fund water acquisitions. The Fort Collins/Loveland Water District and North Weld County Water District, on the other hand, charge an additional $.35 per 1,000 gallons to existing and future water users to offset the costs of new water right acquisitions.

Water resource acquisitions are traditionally funded through a combination of user charges and tap fees. The range of fees and charges currently evident in the Basin suggest that suppliers could add $1,000 to $2,000 to existing tap fees and up to $.40 per 1,000 gallons in user charges and still remain competitive with other entities. Recognizing these amounts as upper limits, the feasibility analysis tests whether or not these amounts would be sufficient, coupled with hydropower generation revenues, to meet annual repayment requirements.

Tap fee and user charge assumptions are applied to household demand forecasts contained in the Basin Study (Harza, 1987). Each new household is assumed, for instance, to pay an additional $1,000 to access safe yield from the proposed Grey Mountain Project. New commercial and industrial customers would pay equivalent amounts. A modest increase in user charges of $.15 per 1,000 gallons consumed is assumed for illustrative purposes, recognizing that the balance of tap fees and user charges is an individual supplier decision.

11.6.2.2 Power Revenues

As identified in Section 11.2.4 and quantified in Section 11.5.2.2, hydrogeneration would produce annual revenues for the project. The 24 MW hydroelectric power plant would produce 52 GWh annually. Pumping Windy Gap and C-BT water from Horsetooth Reservoir to the mainstem reservoir would require about 12 GWh of electrical energy per year, leaving 40 GWh which could be sold. In constant 1988 dollars, and assuming current market conditions continue in the future, revenues from hydrogeneration could amount to $1.65 million annually. This assumption is believed to be conservative, since it is believed that power market conditions are expected to improve during the next decade.

11.6.3 Financial Feasibility Determination

Tables 11.38 and 11.39 compare potential revenues from the project with annual revenue requirements in terms of constant and current dollars, respectively. As shown in Table 11.38, annual and cumulative deficits are evident for a brief period at the beginning of project operations and at the end of project repayment. The current dollar analysis in Table 11.39 shows a revenue shortfall only at the beginning of project operations. In addition, a cumulative surplus of more than $400 million is evident by the end of the repayment period. Serial bond issues and other financial structuring measures can be taken to alleviate these temporary shortfalls or reduce surpluses through smaller borrowing or more modest water rates.

Based upon water tap fees of $1,000 per single family equivalent and user charges of $.15 per 1,000 gallons (both in addition to current charges), the project is financially feasible. That is, if annual hydrogeneration revenues are added to water revenues from the M&I sector, total project revenues will exceed revenue requirements from the bond issue plus O&M costs. In fact, the current dollar, or nominal, analysis shows that future increases in user charges and tap fees will not necessarily have to keep pace with inflation to ensure project repayment. As water or power charges are increased, the rate of the return on the project can be enhanced. A sensitivity analysis was conducted to test the financial feasibility determination. Real interest rates were assumed to increase to 4 percent. Should this occur, annual revenue requirements would increase to $15.8 million under the constant dollar version and $38.1 to $40.2 million under the nominal dollar version. Total revenues would be assumed to increase to meet revenue requirements.

These revenues would be arranged for and contracted prior to proceeding with the bond issue or the development. Hence, the project would remain financially feasible unless real interest rates rose appreciably higher than the 3 percent level.

In conclusion, the Grey Mountain alternative is financially feasible based upon the foregoing assumptions and analyses. These conclusions are

TABLE 11.38

Comparison of Project Revenues with Revenue Requirements
(millions of constant dollars)

YEAR AFTER CONSTRUCTION BEGINS	ANNUAL REVENUES				TOTAL REVENUE REQUIRED	ANNUAL SURPLUS/ DEFICIT	CUMULATIVE SURPLUS/ DEFICIT
	POWER REVENUES	WATER CHARGES	TAP FEES	TOTAL REVENUES			
1	$	$	$	$	$	$	$
2							
3							
4							
5	1.7			1.7		1.7	1.7
6	1.7			1.7	13.5	(11.8)	(10.1)
7	1.7	4.3	8.8	14.8	13.5	1.3	(8.8)
8	1.7	4.4	10.2	16.3	13.5	2.8	(6.0)
9	1.7	4.5	10.2	16.4	13.5	2.9	(3.1)
10	1.7	4.6	10.2	16.5	13.5	3.0	(0.1)
11	1.7	4.7	10.2	16.6	13.5	3.1	3.0
12	1.7	4.8	10.2	16.7	13.5	3.2	6.2
13	1.7	4.9	10.2	16.8	13.5	3.3	9.5
14	1.7	5.0	10.2	16.9	13.5	3.4	12.9
15	1.7	5.1	10.2	17.0	13.5	3.5	16.4
16	1.7	5.1	10.2	17.0	13.5	3.5	19.9
17	1.7	5.2	10.2	17.1	13.5	3.6	23.5
18	1.7	5.3	6.5	13.5	13.5	0.0	23.5
19	1.7	5.4	6.5	13.6	13.5	0.1	23.6
20	1.7	5.4	6.5	13.6	13.5	0.1	23.7
21	1.7	5.5	6.5	13.7	13.5	0.2	23.9
22	1.7	5.5	6.5	13.7	13.5	0.2	24.1
23	1.7	5.6	6.5	13.8	13.5	0.3	24.4
24	1.7	5.7	6.5	13.9	13.5	0.4	24.8
25	1.7	5.7	6.5	13.9	13.5	0.4	25.2
26	1.7	5.8	6.5	14.0	13.5	0.5	25.7
27	1.7	5.9	6.5	14.1	13.5	0.6	26.3
28	1.7	5.9	4.2	11.8	13.5	(1.7)	24.6
29	1.7	5.9	4.2	11.8	13.5	(1.7)	22.9
30	1.7	6.0	4.2	11.9	13.5	(1.6)	21.3
31	1.7	6.0	4.2	11.9	13.5	(1.6)	19.7
32	1.7	6.0	4.2	11.9	13.5	(1.6)	18.1
33	1.7	6.1	4.2	12.0	13.5	(1.5)	16.6
34	1.7	6.1	4.2	12.0	13.5	(1.5)	15.1
35	1.7	6.2	4.2	12.1	13.5	(1.4)	13.7
36	1.7	6.2	4.2	12.1	13.5	(1.4)	12.3
Total	$54.4	$162.8	$213.6	$430.8	$418.5	$12.3	

TABLE 11.39

Comparison of Project Revenues with Revenue Requirements
(millions of current dollars)

YEAR AFTER CONSTRUCTION BEGINS	ANNUAL REVENUES				TOTAL REVENUE REQUIRED	ANNUAL SURPLUS/ DEFICIT	CUMULATIVE SURPLUS/ DEFICIT
	POWER REVENUES	WATER CHARGES	TAP FEES	TOTAL REVENUES			
1	$	$	$	$	$	$	$
2							
3							
4							
5	2.7			2.7		2.7	2.7
6	2.8			2.8	38.1	(35.3)	(32.6)
7	3.0	7.8	15.8	26.5	38.1	(11.5)	(44.1)
8	3.1	8.3	19.2	30.6	38.2	(7.6)	(51.7)
9	3.3	8.9	20.2	32.4	38.2	(5.8)	(57.5)
10	3.4	9.6	21.2	34.2	38.2	(4.0)	(61.5)
11	3.6	10.2	22.3	36.1	38.3	(2.2)	(63.7)
12	3.8	11.0	23.4	38.2	38.3	(0.1)	(63.8)
13	4.0	11.7	24.5	40.2	38.4	1.8	(62.0)
14	4.2	12.5	25.8	42.5	38.4	4.1	(57.9)
15	4.4	13.4	27.1	44.9	38.5	6.4	(51.5)
16	4.6	14.3	28.4	47.3	38.5	8.8	(42.7)
17	4.8	15.3	29.8	49.9	38.6	11.3	(31.4)
18	5.1	16.3	20.1	41.5	38.6	2.9	(28.5)
19	5.3	17.3	21.1	43.7	38.7	5.0	(23.5)
20	5.6	18.4	22.1	46.1	38.7	7.4	(16.1)
21	5.9	19.5	23.3	48.7	38.8	9.9	(6.2)
22	6.2	20.7	24.4	51.3	38.8	12.5	6.3
23	6.5	22.0	25.6	54.1	38.9	15.2	21.5
24	6.8	23.3	26.9	57.0	39.0	18.0	39.5
25	7.1	24.8	28.3	60.2	39.1	21.1	60.6
26	7.5	26.3	29.7	63.5	39.1	24.4	85.0
27	7.9	27.9	31.2	67.0	39.2	27.8	112.8
28	8.3	29.5	21.0	58.8	39.3	19.5	132.3
29	8.7	31.1	22.1	61.9	39.4	22.5	154.8
30	9.1	32.9	23.2	65.2	39.5	25.7	180.5
31	9.6	34.8	24.3	68.7	39.6	29.1	209.6
32	10.0	36.7	25.5	72.2	39.7	32.5	242.1
33	10.5	38.8	26.8	76.1	39.8	36.3	278.4
34	11.1	41.0	28.2	80.3	39.9	40.4	318.8
35	11.6	43.3	29.6	84.5	40.0	44.5	363.3
36	12.2	45.8	31.0	89.0	40.2	48.8	412.1
Total	$202.7	$673.4	$742.1	$1,618.2	$1,206.1	$412.1	

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CHAPTER 12.0

ENVIRONMENTAL
EVALUATION

12.0 ENVIRONMENTAL EVALUATION

The environmental studies concentrated on the elements believed to have the greatest overall effect on project feasibility. Summaries of the studies are provided in the five subsections that follow.

12.1 AQUATIC RESOURCES

The aquatic resource studies consisted of a literature review, fish population inventories, macroinvertebrate population inventories, a fisheries habitat evaluation, a study for a species of special concern (Johnny darters), evaluations of project effects, and identification of potential mitigation measures.

The aquatic resources study area extended from an upstream boundary on the mainstem at the confluence with Joe Wright Creek, and an upstream study boundary for the North Fork at an elevation of 5680 feet. The downstream boundary of the study area was at the western limit of the Fort Collins urban growth area, approximately 0.5 miles east of Taft Hill Road.

Eleven fish species were identified in the mainstem and North Fork of the Cache la Poudre River. In the mainstem, brown trout and rainbow trout were dominant. In the North Fork, these trout species as well as certain warm-water species were found. High densities of yellow perch and white suckers were also found at various locations in the North Fork.

Average density of trout populations in the mainstem ranged from 1,020 to 2,310 trout per ac. The average biomass for these populations ranged from 33 to 106 lb/ac. Lowest density and biomass estimates were reported at the downstream extent of the study area, where flow depletion and habitat degradation presently exist.

Species of special concern (Johnny darters) were found only in the North Fork. The presence of a variety of size classes indicated natural reproduction.

Johnny darters represented eight to ten percent of the total fish sampled in the North Fork.

A total of 47 macroinvertebrate taxa were collected. Macroinvertebrate populations in the mainstem consisted of clean water aquatic insects typically found in rivers; North Fork invertebrate populations included species associated with pools and standing water.

The primary effects on fish distribution and abundance from construction of the Stage 1 reservoir would be inundation of approximately 7.5 miles of existing stream habitat on the mainstem and 7.5 miles of existing habitat on the North Fork. Approximately 7.5 miles of existing Johnny darter habitat in the North Fork also would be inundated, although Johnny darter populations would remain in the North Fork upstream of the proposed reservoir, and could become established along the edges of the reservoir where shallow, sandy areas would develop.

Macroinvertebrate populations would be expected to change within the reservoir area from essentially stream-dwelling insects to those associated with ponds or lakes. Specifically, non-insect groups would become more prevalent. Reservoir operation could result in increased trout food production downstream as it has in other Colorado streams, and a more stable, though less diverse, invertebrate community.

The fish habitat evaluation was based on: (1) Instream Flow Incremental Methodology (IFIM) studies, (2) instream temperature studies, and (3) stream and reservoir habitat studies. The IFIM results indicated that spawning habitat for both brown and rainbow trout was probably the limiting factor for existing populations in the Poudre River. However, more spawning habitat was probably available than indicated from the habitat study because of the likely existence of small, unmeasurable pockets of sands and gravels. Studies for post-project conditions conducted for downstream reaches potentially affected by operation of the proposed project differed depending on the quantity and timing of water released from the reservoir.

For reservoir releases associated with the minimum bound of post-project river flows, overall fish habitat increased moderately during May and June because of reductions in peak flow. For the reservoir releases estimated to result in the maximum bound of post-project river flows, overall fish habitat increased significantly relative to pre-project conditions during March, April, September and October for both brown and rainbow trout. Juvenile brown and rainbow trout habitat was considerably enhanced for the assumed maximum bounding flows, as was habitat for brown trout fry. Comparisons between post-project habitat downstream of the Grey Mountain and Poudre Damsite alternatives for the mainstem reservoir showed that habitat increases for both rainbow and brown, adult and juvenile trout, under the maximum bounding reservoir releases, were consistently greater for the Grey Mountain alternative than for the Poudre alternative. This occurred because the larger reservoir storage capacity associated with the Grey Mountain alternative afforded the potential for larger releases from the reservoir.

River water temperature studies indicated that pre-project mean monthly water temperatures in the Poudre River were not generally detrimental to trout survival under most hydrologic and meteorologic conditions. However, at certain times during summer months when releases to the river from the Hansen Canal were not being made, temperatures were significantly higher than optimum for either brown or rainbow trout for short periods. With-project summer river water temperatures were predicted to be lower than pre-project conditions, mainly due to the potential for lowering river water temperatures by releasing colder water from the mainstem reservoir. Conversely, predicted with-project winter river water temperatures were slightly higher than pre-project temperatures because of the heat retention in the large volume of reservoir water. Predicted with-project river water temperatures during July and August of hot dry years were significantly improved over pre-project conditions and overshadowed the negative effects of lower river water temperatures during spring months.

Potential mitigation measures for trout and species of special concern were considered in three categories: (1) in-kind mitigation, (2) land or access acquisition, and (3) biomass or standing crop replacement. In-kind mitigation was considered for effects due to inundation along segments of the mainstem and North Fork and in association with predicted habitat changes downstream of the mainstem reservoir. Inundation would transform as much as 15 miles of stream habitat to reservoir habitat. Approximately half of the stream habitat lost through inundation could be offset through habitat increases downstream resulting from reservoir releases. Mitigation for the remaining loss of stream habitat could potentially be provided upstream of the proposed mainstem reservoir through flow modifications to reduce summer flows and increase winter flows. Upstream flow modifications would be achieved through changes in the operation of existing upstream reservoirs. It is conceivable that flow changes in the upstream reaches, coupled with habitat increases below the proposed reservoir, could fully mitigate the inundation impacts.

Mitigation to offset loss of trout biomass in inundated reaches of the Cache la Poudre River could be provided by stocking fingerling trout in the reservoir. Potential mitigation for water temperature effects would vary, depending on the downstream reaches evaluated. Below Taft Hill Road, expected reservoir water releases at temperatures between 5 and 10°C could provide substantial relief from high river water temperatures during summer months below the Larimer County Canal diversion. However, the colder water temperatures associated with releases from the mainstem reservoir might suppress trout growth rates between either damsite and the Larimer County Canal diversion.

From the perspective of habitat availability, the Grey Mountain Damsite alternative for the mainstem reservoir would be preferable to the Poudre Damsite alternative because of greater improvements in downstream habitat. However, increases in downstream habitat would be offset to some extent by the greater loss of habitat to inundation. Overall, there is significant potential for preserving and possibly enhancing aquatic resources, particularly when reservoir releases are maximized.

12.2 BOTANICAL RESOURCES

The botanical resource studies involved cover type mapping, field sampling, identification and documentation of plant species and associations of special concern, evaluation of project effects, and identification of potential mitigation measures.

The botanical resources study area was defined in consultation with state and federal natural resource agencies and consisted of 39,489 acres. The study area was continuous and incorporated the potential inundation areas for all three stages of the Cache la Poudre Project, buffer zones surrounding each potential inundation area, and substantial border areas for use as potential mitigation.

The entire 39,489-acre study area was cover typed and mapped. Of the 16 cover types identified in the study area, the 4 most abundant types were mountain shrub (34 percent), grasslands (26 percent), open canopy forest (17 percent), and closed canopy forest (15 percent). The remaining 8 percent of the study area was composed of riparian, palustrine, riverine, lacustrine, agriculture, developed, disturbed, and rock/talus types.

A mainstem reservoir formed by constructing a dam at the Poudre Damsite would affect 1,589 acres of vegetation consisting of mountain shrub (698 acres), upland forest (539 acres), grassland (269 acres), and riparian (83 acres). A mainstem reservoir formed by constructing a dam at the Grey Mountain Damsite would affect 2,037 acres containing mountain shrub (972 acres), upland forest (630 acres), grassland (334 acres), and riparian (101 acres). The acreage of upland cover types affected by either alternative represents about 5 percent of the respective current totals in the study area. In a regional context, the most significant effects of the project on vegetation would be the inundation of riparian areas. Regionally, rivers and riparian cover types comprise a small amount of area and are relatively scarce. Due to their proximity to water, riparian cover types are valuable to wildlife in that they are conducive to high productivity and species diversity. However, the riparian vegetation in the project areas has been degraded due to heavy grazing, development, recreational activities, and the proximity to Highway 14.

A total of five plant species of special concern were identified by the Colorado Natural Areas Program as potentially occurring in or near the study area. These species included Colorado butterfly weed (Guara neomexicana), Bell's twinpod (Physaria bellii), Larimer aletes (Aletes humilis), purple-stem cliff-break (Pellaea atropurpurea), and prairie goldenrod (Solidago ptarmicoides). All potential habitats for these species in the study area were searched, but only the Larimer aletes was located. In addition to the known population of this species at the summit of Grey Rock Mountain, Larimer aletes was also found at the base of some massive granite boulders on Grey Rock Mountain. Construction of either project alternative for Stage 1 of the Cache la Poudre Project would not affect this species. No plant associations of special concern or natural non-riverine wetlands were identified in the study area.

The most important effect on botanical resources from the proposed project would be loss of riparian cover types adjacent to the mainstem and North Fork of the Cache la Poudre River. Mitigation for these losses could include creation of wetland areas with seepage or spill water from irrigation or from other sources. Losses of upland cover types could also be mitigated through reclamation of other areas. All of the mitigation measures required for botanical resources could be accomplished in conjunction with wildlife mitigation measures.

12.3 CULTURAL RESOURCES

The cultural resources investigations consisted of background research to identify known prehistoric or historic sites of significance, inventory of areas and recording of potentially significant sites that would be directly affected by the proposed project, evaluation of the identified resources based on the significance criteria of the National Register of Historic Places (NRHP), assessment of the nature and degree of project effects on the significant sites, and identification of potential mitigation measures. Two basic types of cultural resource studies were undertaken. Class I investigation consisted of researching existing records to ascertain if portions of the current project area have been inventoried previously and to determine the location, nature, and significant qualities of known cultural resources. Class III investigation consisted of intensive pedestrian inventory conducted for the purpose of discovering, recording, and evaluating sites within a defined impact area. Because of data availability, Class I investigation was conducted for a contiguous 82-square-mile (52,480 acres) area encompassing facilities associated with all three of the proposed project stages. Class III investigation was conducted only within the mainstem reservoir inundation area and an associated narrow buffer zone identified specifically for the cultural resources study.

Class I investigation indicated that 39 previously recorded prehistoric and historic sites exist in the general project vicinity. Class III inventory of 6,390 acres within the proposed mainstem reservoir area of the Grey Mountain alternative, and associated buffer zone, led to the identification of 29 of these sites. Another site was known to exist within the survey area. However, the landowner would not allow access to the site. In addition to prehistoric and historic sites, 18 isolated finds were recorded of which 8 were determined to be prehistoric and 10 were historic.

Of the 30 sites identified during the Class III inventory, 10 are prehistoric and 20 are historic. Prehistoric sites include open lithic scatters and camps with lithic and ground stone artifacts, hearths, and stone circles, and rock shelters containing deeply stratified deposits. Historic sites consist of homesteads, miscellaneous structural remnants, mines, canals, and an inactive water filtration plant owned by the City of Fort Collins. All recorded historic sites post-date 1880.

Six of the 29 newly recorded sites are assessed as eligible for inclusion in the NRHP. All 18 isolated finds are assessed as ineligible for the NRHP. All 6 significant (NRHP eligible) sites would be partially or wholly inundated by reservoir waters (at normal reservoir surface elevation of 5630 feet) regardless of which mainstem damsite alternative is constructed.

Mitigation in the form of data retrieval is recommended at all 6 significant sites. For the 4 prehistoric sites, recommended mitigation measures consist of partial excavation, with efforts concentrated in prehistoric activity areas or, in the case of rock shelters, in undisturbed areas where stratified deposits are known to occur. Mitigation at one historic site, a homestead, should consist of small-scale excavation in combination with mapping, photodocumentation, and additional archival research. At the remaining historic site, a water filtration facility, mitigation should consist of full recording to Historic American Engineering Record (HAER) standards accompanied by photodocumentation and production of a complete narrative.

12.4 RECREATION, AESTHETIC, AND LAND USE RESOURCES

The recreation, aesthetic, and land use studies consisted of inventorying existing conditions (based primarily on literature review and existing agency file data), a survey of whitewater boating guides to determine use patterns and flow requirements, a survey of recreationists to supplement existing data, identification of potential direct and indirect project effects, and identification of potential mitigation measures.

The studies were conducted within a primary study area and a larger surrounding area, termed the secondary study area. The primary study area encompassed approximately 34,000 acres in the immediate vicinity of the proposed project facilities. The larger secondary study area, consisting essentially of all of Larimer County, was used to provide a regional perspective for the recreation studies. Recreation resources beyond the boundaries of the secondary study area were also considered where necessary for providing proper context in the evaluation process.

The most notable recreation attraction in the surrounding region is Rocky Mountain National Park, which is located south of the Poudre Canyon. The canyon itself is surrounded by lands and waters in the Arapahoe-Roosevelt National Forest that offer many opportunities for hiking, angling, sightseeing, and other forms of dispersed recreation opportunities. Forest Service camping and picnicking facilities within the primary study area receive approximately 4,000 annual visits. Two existing river access sites near the canyon mouth operated by CDPOR provide additional facilities for day-use activities. Use of these sites totals over 50,000 visits per year. Much of the land adjacent to Highway 14 and the river is accessible to the public for dispersed recreation. By volume, the most popular recreational activity within the study area is sightseeing, which accounts for an estimated 207,000 visits per year. Other major activities include hiking on the Greyrock Mountain National Recreation Trail (19,500 annual visits), whitewater boating on several sections of the Poudre River (6,000 visits), and stream angling (4,700 visits).

Without mitigation, the Grey Mountain alternative would displace a total of 9,460 user visits each year, excluding temporary hiking displacements. Loss of an estimated 5,050 whitewater boating visits would account for most of the displaced visits. Projected angling losses amount to 2,600 annual visits. Indirect effects of the Grey Mountain alternative through downstream flow changes might increase the whitewater boating loss slightly, but would probably not have an adverse effect on desired flow levels for angling.

Without mitigation, the Poudre alternative for the mainstem reservoir would displace less than half the number of long-term annual visits predicted for the Grey Mountain alternative. The primary difference in displacement effects relates to whitewater boating. Although the Poudre alternative, like the Grey Mountain alternative, would inundate the Bridges whitewater run, the Poudre alternative would leave the more heavily used Filter Plant run essentially intact and floatable. The total number of recurring losses projected for the Poudre alternative is 4,380 annual visits. Angling would be most affected, with an estimated 1,900 visits per year displaced to other locations. Altered streamflows associated with the Poudre alternative could indirectly lead to an additional annual loss of about 50 whitewater boating visits.

Potential options were identified to mitigate recreation losses and to take advantage of recreation opportunities provided by the mainstem reservoir.

Potential recreation facilities that would address these objectives were identified. Options include relocation of the Greyrock Mountain Trailhead, new and replacement river access sites for whitewater boating and fishing, boat chutes at diversion dams to provide a new whitewater run, and facilities at or near the proposed reservoir to support flatwater boating, camping, and picnicking.

Based on estimates of potential use of these new facilities, either alternative could result in a net increase in projected annual visitation in the study area. The additional whitewater boating opportunities proposed would fully mitigate the lost activity on the Bridges and/or Filter Plant runs. Overall, the projected net change for the Grey Mountain alternative could be a gain of nearly 17,600 annual visits. A net increase of over 21,100 visits could be associated with the Poudre alternative.

Existing visual resources were characterized on the basis of Forest Service inventory data, slope and landform information from topographic maps, vegetation mapping conducted for other study tasks, and preliminary field observations and photography. Expected project effects from the Grey Mountain and Poudre alternatives were assessed according to the degree of landscape change that would occur, and the visibility of this change. The compatibility of the appearance of project features with the visual management objectives of the Forest Service were also reviewed.

Highway 14, which parallels the Cache la Poudre River, is the primary viewing location. The sensitivity of viewers using the highway and other recreation user groups to visual change is presumed to be high, as indicated by the assignment of sensitivity Level 1 to virtually all Forest Service lands within the primary study area. Motorists traveling up the canyon would view the Grey Mountain Dam for a distance of approximately 0.5 mile immediately south of the damsite. Travelers in the opposite direction would probably be able to view the dam at a distance of 0.5 to 1 mile. In addition to views from the highway, dispersed recreationists on and along the river would be able to view the dam for up to about 0.5 mile downstream. The visual change created by the Grey Mountain

Reservoir would be larger in area, extending approximately 6 miles upstream from the damsite to near Poudre Park. The portions of the reservoir visible from Highway 14 would appear as a narrow lake flanked by steep canyon walls. The reservoir would increase the visual diversity of the study area, although viewers would likely have divided preferences for lake versus river settings.

The visual effects of the Poudre alternative would be very similar to those of the Grey Mountain alternative. Views of the dam would be possible for at most 0.75 mile to the south, and might be limited to 0.25 mile. Travelers approaching the dam from the west would have very transitory views as they passed opposite and above the dam.

A number of potential mitigation measures that could be implemented for either alternative were identified. These measures were for the types of visual effects identified, and were not based on detailed site-specific analysis of simulated project appearance.

Land use studies indicated that approximately 40 percent of the study area is national forest land and 43 percent is owned by private individuals. Other land owners with river frontage include the CDOW, City of Fort Collins, and City of Greeley. There are four subdivisions in the study area, most of which are only partially developed.

Either of the two alternative damsites considered for the mainstem reservoir would inundate developed properties on the flatter riverside areas in the canyon. Either alternative would require acquisition or easements for approximately 1,800 to 2,200 acres of land. Most of the land required for the mainstem reservoir is used for grazing. Approximately one-third of the land needed for project development would consist of Forest Service lands, one-third would be State Land Board holdings, and the remainder would be divided between municipal lands and private holdings. Most of the municipal land is at the site of an inactive water treatment facility owned by the City of Fort Collins. Two of the four existing subdivisions would be inundated along with an estimated 60 to 70 homes, cabins, and outbuildings. The two project alternatives differ very little with respect to displacement of developed land uses. However, the Poudre alternative would not require acquisition of one of the two ranch/farmstead properties located between the two damsites. Several utilities and Colorado Highway 14 would require relocation.

The proposed project would shift some dispersed recreational activity onto some lands not currently managed for that purpose, but would not require significant changes in land management. Little change in access patterns would occur because of the reservoir, and new access resulting from the proposed project would not be significant. Therefore, no significant indirect land use effects are expected.

12.5 WILDLIFE RESOURCES

Wildlife resource studies included a literature search, cover type mapping, field surveys for bald and golden eagles, and a habitat evaluation using the U.S. Fish and Wildlife Service's Habitat Evaluation Procedure (HEP) for seven evaluation species. Each evaluation species represented a broader group of species characteristic of a specific habitat type. The HEP was used to determine project effects and to estimate the effectiveness of potential mitigation measures.

The wildlife resources study area was coincident with the study area used for botanical resources. A total of 39,489 acres was cover typed and mapped. Both the Poudre and the Grey Mountain alternatives would have negative effects on the seven wildlife evaluation species studied as part of the HEP. Disturbance from historical grazing, recreation, roads, and housing developments influenced the quality of habitat available in the project areas for all the evaluation species except the Abert squirrel and black-capped chickadee. Habitat quality for all species was similar for both project areas as well as the land in the study area outside the project areas. Habitat losses would be highest for mule deer; intermediate for black-capped chickadee, Abert squirrel, and western meadowlark; and lowest for song sparrow, great blue heron, and beaver. Specialists, such as the beaver, song sparrow, and Abert squirrel, depend on specific habitats to meet their life requisites and would be more affected by the proposed project than generalists.

One federally-listed endangered species, the bald eagle, was observed in the project area. The proposed mainstem reservoir would inundate trees presently used by bald eagles for perching and intermittent roosting at night. The loss of these trees would affect the seven bald eagles observed wintering in the project area, which represent about one percent of the population of bald eagles wintering in Colorado. A Biological Assessment and close coordination with the U.S. Fish and Wildlife Service will be required for this species under Section 7(c) of the Endangered Species Act.

Aerial surveys conducted on May 8, 1987 identified five active and four alternate golden eagle nest sites in the study area. The proposed reservoir would not affect any of the active or alternate nest sites but it would reduce the amount of available foraging and nesting habitat for the golden eagle. All nests in the study area are in rock talus habitat and approximately 14 and 22 acres of this habitat type below the ridgetops would be inundated by the Poudre and Grey Mountain alternatives, respectively. In addition, about 1,310 and 1,734 acres of potential foraging habitat would be inundated by the Poudre and Grey Mountain alternatives, respectively.

Mitigation for project effects should concentrate on improving the habitat quality to increase the capacity of the remaining habitats to support wildlife. Potential improvements to the habitat quality were developed for the 7 evaluation species, thereby reflecting wildlife use of each habitat type in the study area.

CHAPTER 13.0

TECHNICAL EVALUATION

13.0 TECHNICAL EVALUATION

Stage 1 of the Cache la Poudre Project would provide additional water supplies for use within the service area of the Northern Colorado Water Conservancy District. In addition to its primary water supply and water management functions, the project would also provide the capability to produce electrical energy, if a conventional hydroelectric power plant is constructed in conjunction with a mainstem storage dam. Project construction would reduce downstream flooding because of the flood attenuation afforded by reservoir storage.

13.1 RESERVOIR STORAGE AND YIELD

The Grey Mountain alternative for the mainstem reservoir would provide a total storage volume of 195,000 af. Reservoir simulation studies, described in Chapter 10.0 of this report, indicate a safe (zero shortage) yield of 41,000 af/yr assuming an initial storage volume of 150,000 af. Reservoir simulation studies further show that a substantial volume of storage could be allocated to flood control without reducing safe yield. Further studies during the full feasibility phase should be based on a more extensive hydrologic data base and should consider tradeoffs between safe yield and storage allocated for flood control.

13.2 HYDROELECTRIC POWER GENERATION

A hydroelectric powerplant could be constructed as part of the Stage 1 Project. As described in Chapter 9.0 of this report, a conventional hydroelectric powerplant could have an installed capacity of about 18 to 24 megawatts (MW) for the Grey Mountain alternative. The capacity range depends on how releases from the reservoir are made. Withdrawal of water directly from the reservoir via an intake/pipeline arrangement would result in lower installed capacity (Case A). If all reservoir outflows, except extreme flood flows, could be passed through the hydroelectric powerplant, installed capacity would be greater (Case B). Hydroelectric capacity associated with the Poudre alternative for the mainstem reservoir would be lower because of the lower dam height and operating head at the Poudre site.

For Case A, an installed capacity of 17,700 kilowatts (kW) was selected based on the analyses described in Chapter 9.0. Energy production was estimated to be an average of 39 GWh per year for Case A flow conditions, indicating an average plant capacity factor of 25 percent. For Case B, the installed hydroelectric generating capacity would be 23,900 kW. Average annual energy production for Case B flow conditions would be about 52 GWh per year (25 percent plant capacity factor).

Hydroelectric generating capacity and energy production estimates presented above are preliminary and applicable to the Grey Mountain alternative. Hydroelectric power studies should be refined during subsequent detailed feasibility studies of the Stage 1 Project to determine the optimum installed generating capacity for the conventional hydroelectric powerplant.

The Stage 1 Cache la Poudre Project could also involve construction of a conveyance pipeline from Horsetooth Reservoir to the Stage 1 Storage Project. For the Grey Mountain alternative, the pipeline would be 7.5 miles long and would include two 8400 HP pumping stations to lift water a maximum of 200 feet between the two reservoirs. Pumping energy requirements are expected to average about 12 GWh per year to convey C-BT and Windy Gap water from Horsetooth Reservoir to storage in Grey Mountain Reservoir. This represents about 31 percent of the Case A energy production and 23 percent of the Case B energy production. Pumping from Horsetooth Reservoir to a Stage 1 mainstem reservoir normally would occur during the months of December to May, as shown in Table 13.1. Maximum pumping normally would be in the February to April period, which accounts for about 80 percent of the average annual pumping requirement.

Generation from a conventional hydroelectric powerplant at a Stage 1 mainstem reservoir would occur primarily during the March-October period and be greatest in the May to July high streamflow period. Over 80 percent of average annual generation could be expected in the May to July period. Therefore, direct offsetting of pumping energy requirements by conventional hydroelectric energy generation would not be possible. However, it should be possible for NCWCD, as owner and operator of the proposed project, to obtain a credit for summer energy production which would in turn be used against pumping energy required earlier in the year.

TABLE 13.1

Comparison of Pumping Energy Requirements With Potential Hydroelectric Energy Production (For 1954 - 1983 Historic Flow Conditions)

Month	Required Pumping Energy(1)	Energy Produced at Conventional Hydro Plant		Hydro Energy Less Pumping Energy(4)	
		Case A(2)	Case B(3)	Case A	Case B
	(GWH)	(GWH)	(GWH)	(GWH)	(GWH)
Jan	1.2	-	-	-1.2	-1.2
Feb	1.8	-	-	-1.8	-1.8
Mar	3.2	0.1	0.1	-3.1	-3.1
Apr	4.9	1.3	1.6	-3.6	-3.3
May	0.8	9.2	11.1	8.4	10.3
Jun	0.1	13.3	18.2	13.2	18.1
Jul	-	9.3	12.2	9.3	12.2
Aug	-	3.8	5.5	3.8	5.5
Sep	-	1.3	2.4	1.3	2.4
Oct	-	0.4	0.5	0.4	0.5
Nov	-	-	-	-	-
Dec	0.3	-	-	0.3	-0.3
Total	12.3	38.7	51.6	26.4	39.3

(1) Pumping energy required for the 7.5-mile long Horsetooth-Grey Mountain conveyance pipeline.

(2) New water yield produced by the reservoir is supplied by a pipeline from the reservoir, and is not available for power production.

(3) New water yield from reservoir is available for power production.

(4) Hydro plant energy production less pumping energy for the Horsetooth-Grey Mountain conveyance pipeline.

Preliminary studies by NCWCD indicate that releases from the reservoir might be timed to provide hydroelectric generation during peak electrical demand periods each day. For example, a full day's volume of water could be released during a 12-hour period that matches the peak electrical demand period. This type of operation would further enhance the value of energy produced by a conventional hydroelectric installation. The effect of alternative flow release patterns on recreational opportunities (especially boating and fishing) are discussed in general terms in the recreation sections of this report. It is currently envisioned that this flow release pattern would have a positive effect on boating because the peak daily demands for power generation and boating are coincident. However, hourly reservoir operation studies to analyze water supply, power production, and recreational effects are beyond the scope of the present Basin Study Extension, but would properly be considered during the detailed feasibility phase of project implementation.

13.3 FLOOD CONTROL POTENTIAL

The potential for a mainstem reservoir to alleviate downstream flooding and associated flood damages was recognized during the initial Basin Study (Harza, 1987). However, this potential was not quantified. The major beneficiary of flood control afforded by a mainstem reservoir would be the City of Fort Collins and the Town of LaPorte, a small community northwest of Fort Collins. Developed areas of the Poudre River floodplain in unincorporated Larimer County might also benefit. Some reduction in flood peaks could also be expected further downstream in Greeley. However, flood discharges of the Poudre River in Weld County and at Greeley could be influenced substantially by Boxelder Creek and other drainages that join the Poudre River between Fort Collins and Greeley. Therefore, any benefits from a mainstem reservoir on Poudre River flooding in Greeley and unincorporated Weld County were not considered at this preliminary level of study.

The purposes of the flood control analyses conducted during the Cache la Poudre Basin Study Extension were to:

(1) Determine the effects of mainstem storage on downstream flood discharges (undertaken during Task 16);

(2) Estimate potential monetary benefits that might be derived from flood control in a mainstem reservoir (undertaken during Task 18 - Socioeconomic Benefit Studies); and

(3) Consult with the U.S. Army Corps of Engineers (COE) to determine interest in cost-sharing for a potential flood control component of a mainstem storage facility (undertaken during Task 18 - Socioeconomic Benefit Studies).

Analyses were based primarily on available data supplemented by limited new investigations undertaken during the Basin Study Extension.

13.3.1 Available Data

Data that are readily available for flood control evaluations along the Poudre River can be grouped into three categories:

(1) Hydrologic data, consisting primarily of COE-supplied data from "1981 Special Study on Flood Hazard, Dam Safety, and Flood Warning" (COE, 1981).

(2) Floodplain information including flood stage-frequency relationships and flood profiles; flood inundation mapping for the 100-year flood; and related historical data on flood hazards contained in flood insurance studies for the City of Fort Collins, unincorporated areas of Larimer County, the City of Greeley, and unincorporated area of Weld County.

(3) Data concerning flood damages contained in the above-referenced COE report supplemented by discussions with City staff from Fort Collins regarding floodplain planning and management.

Application of available data in identifying potential flood control benefits associated with a reservoir on the mainstem Cache la Poudre River is described in subsequent sections of this chapter.

Efforts during Task 16 concentrated on assessing possible flood control benefits as they relate to the Fort Collins area. Based on earlier studies (COE, 1981), about three-fourths of the average annualized flood damages in urban floodplain areas of the lower Poudre Basin would occur in Fort Collins.

13.3.2 Flood Control Potential of Mainstem Storage Reservoir

A storage reservoir on the mainstem Cache la Poudre River would provide increased levels of flood protection for downstream communities, particularly Fort Collins and LaPorte, as well as areas of unincorporated Larimer County within the Cache la Poudre floodplain. A flood insurance study sponsored by the Federal Emergency Management Agency (FEMA) covering Fort Collins and unincorporated Larimer County is nearing completion after several years of study and review. Results from this study will supersede an earlier study and will provide data needed to regulate development within the 100-year floodplain, as well as estimated flood elevations corresponding to the postulated 10-, 50-, 100- and 500-year flood events. Maps showing the 100- and 500-year flood boundaries and the floodway will be published. The floodway is defined as the floodplain area needed to discharge the 100-year flood without an appreciable rise in 100-year flood elevations. Development within the 100-year floodplain can be allowed provided that development is protected from flooding and such development does not encroach into the defined floodway. At the time of this report, the flood insurance study had not been finalized. During discussions with City staff in Fort Collins, it was learned that the hydraulic studies performed to define the 100-year floodway and floodplain along the Cache la Poudre River were very complex because of "split flow" situations where a portion of the flood flow leaves the main floodplain and flows overland to rejoin the river further downstream. Because of this level of complexity, it was not possible to define a "with-project" floodplain during the Cache la Poudre Basin Study Extension. Furthermore, definitive data on historic flood damages in the Cache la Poudre River floodplain are not available. The City of Fort Collins plans to undertake a detailed floodplain management study in the near future, following finalization of the FEMA-sponsored flood insurance study.

A 100-year flood hydrograph at the mouth of Poudre Canyon was obtained from Corps of Engineers report entitled "Hydrologic Analysis of the Cache la Poudre River Basin (COE, 1988). The hydrograph has a peak discharge of 15,100 cfs and a duration of about 22.5 hours, as shown on Figure 13.1. With Grey Mountain Reservoir the 100-year flood peak would be reduced to about 7700 cfs, a 49 percent reduction, without any specific allocation of storage for flood control. The reduction in peak discharge was calculated using a reservoir flow-routing program and an assumed starting reservoir water surface level at El 5630 (maximum normal water surface). Allocation of storage specifically for flood control would further reduce or even eliminate the 100-year flood peak. The entire 100-year flood as estimated at the mouth of Poudre Canyon, would be stored in Grey Mountain Reservoir if about 12,000 af were allocated for flood control (maintain normal maximum reservoir at El 5622). As indicated in Chapter 10.0, up to 35,000 af of dedicated flood control storage could be provided without reducing the safe water supply yield provided by Grey Mountain Reservoir. Although the previously cited Corps of Engineers report did not provide a 500-year flood hydrography, it is estimated that the 500-year flood volume as estimated at the Canyon Mouth could also be completely stored without reducing the safe yield of Grey Mountain Reservoir.

It should be noted that normal operation of the reservoir for water supply will result in the reservoir level being near its maximum normal water surface elevation much of the time. One purpose of a mainstem storage facility would be to capture native flood flows and to store these flows for beneficial use. Therefore, storage space for flood flows will be available a large percentage of the time.

Figure 13.2 is excerpted from National Recreation Area (NRA) Study for the Cache la Poudre River (Shalkey Walker, 1989). It shows the 100-year flood boundary along the Cache la Poudre River, as mapped in 1988, from Taft Hill Road to near County Road 32. This map also indicated the 100-year floodway area; however, the updated FEMA-sponsored study will amend these flood boundaries. As shown on Figure 13.2, the 100-year floodplain within the boundaries of the NRA Study is fairly extensive. In fact the 100-year floodplain mapped in 1988 is outside of the NRA Study boundary at several locations. With flood control afforded by a mainstem reservoir, the size of the 100-year floodplain could be reduced significantly especially if dedicated flood control storage would be provided in the reservoir. Only tributary inflows below the Canyon Mouth would remain uncontrolled and contribute to flooding.

13.3.3 Potential Flood Control Benefits

Reduction of peak flood discharges at the mouth of the Poudre Canyon would reduce the depth and extent of overbank flooding in downstream floodplain areas. As noted previously, beneficial effects would be greatest in the Fort Collins area.

Data contained in the "old" flood insurance study reports for unincorporated Larimer County and the City of Fort Collins (Flood Emergency Management Agency, FEMA, 1987 and 1984, respectively) were used to estimate the effects of a mainstem storage reservoir on downstream flood levels. These reports provide flood frequency versus river elevation relationships at many locations along the mainstem Cache la Poudre River. These relationships are for existing conditions in the Poudre Basin and can be used to determine how flood elevations could be lowered if flood regulation is provided by a mainstem storage reservoir.

Potential reductions in the 10-, 50- and 100-year flood elevations along the Poudre River in the vicinity of Fort Collins are indicated in Table 13.3. Results in Table 13.3 are for the case where only incidental flood control is provided by a mainstem storage reservoir (i.e., storage is not allocated specifically for flood control). Locations referenced in Table 13.3 are identified on Figure 13.3. With allocation of 12,000 af of flood control storage, the entire 100-year flood could be stored and flows in the Poudre River would be within the streambanks at least in segments upstream from major tributaries such as Boulder Creek.

TABLE 13.2

Effect of Mainstem Storage on 100-Year Flood Elevations (No Storage Allocated for Flood Control)

Condition	Location in Fort Collins: Highway 14	College Avenue
100-Year Flood		
Without Project Elev. (ft)	4934.5	4966.6
With Project Elev. (ft)	4933.3	4963.4
Reduction (ft)	1.2	3.2
50-Year Flood		
Without Project Elev. (ft)	4934.0	4965.8
With Project Elev. (ft)	4932.5	4962.3
Reduction (ft)	1.5	3.5
10-Year Flood		
Without Project Elev. (ft)	4932.8	4962.9
With Project Elev. (ft)	4930.3	4956.5
Reduction (ft)	2.5	6.4

Note: 1. "With project" case is based on Grey Mountain Dam with a maximum NWS El. 5630.

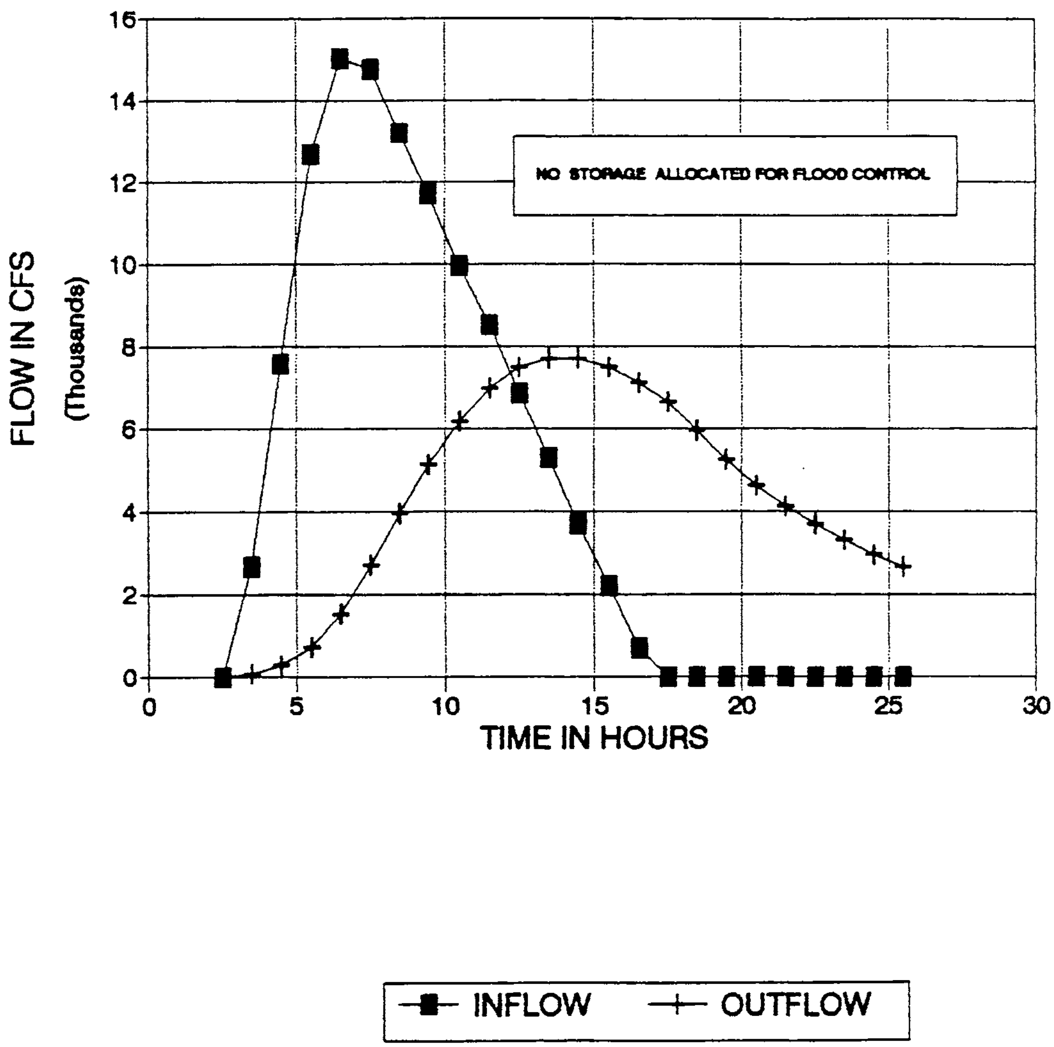
2. Elevations were estimated form elevation-discharge relationships obtained from the Fort Collins flood insurance study reports (FEMA, 1984).

13.4 REFERENCES

Federal Emergency Management Agency, FEMA (1981-84). Flood Insurance Studies for Fort Collins and Unincorporated Larimer County.

Harza Engineering Company, January, 1987. Cache la Poudre Water and Hydropower Resources Management Study, Volumes I and II.

U.S. Army Corps of Engineers (COE), 1981. Special Study on Flood Harzard, Dam Safety and Flood Warning.



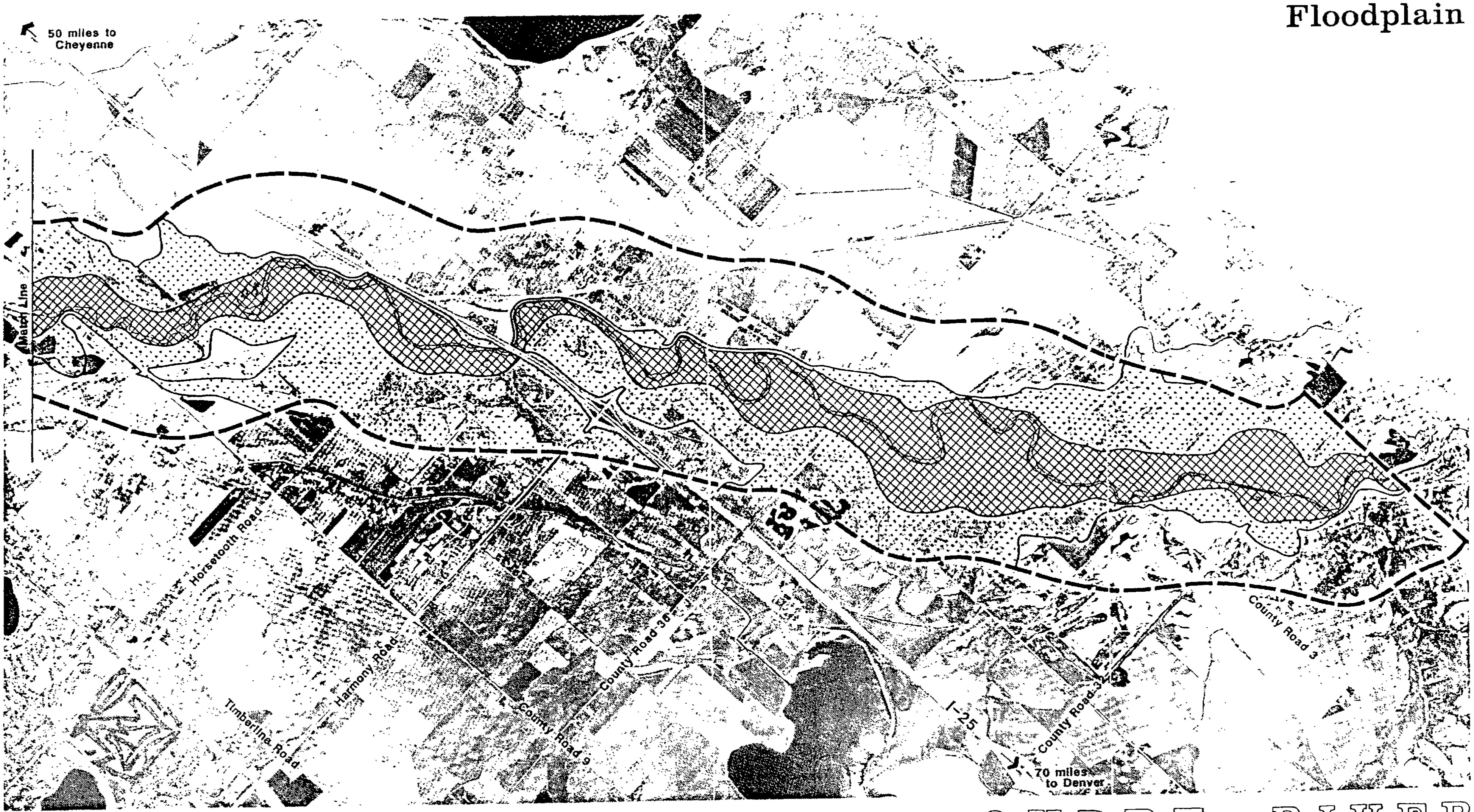
COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY
CACHE LA POUDRE PHASE I EXTENSION STUDY

100-YEAR FLOOD AT GREY MTN
ROUTING STUDY RESULTS

HARZA ENGINEERING COMPANY

DATE 10/27/88 FIGURE 13.1

Floodplain



CACHE LA POUDRE RIVER

National Recreation Area Study

City of Fort Collins, Colorado   Larimer County, Colorado

Scale in Feet 0 1000 5000 NORTH

Shalkey Walker Associates, Inc.   July 1989

FIGURE 13.2

Legend

Source: City of Fort Collins Stormwater Utilities; Larimer County Planning Department, 1988

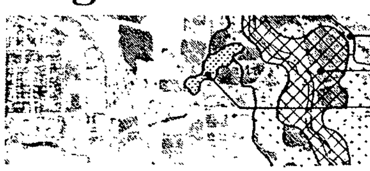
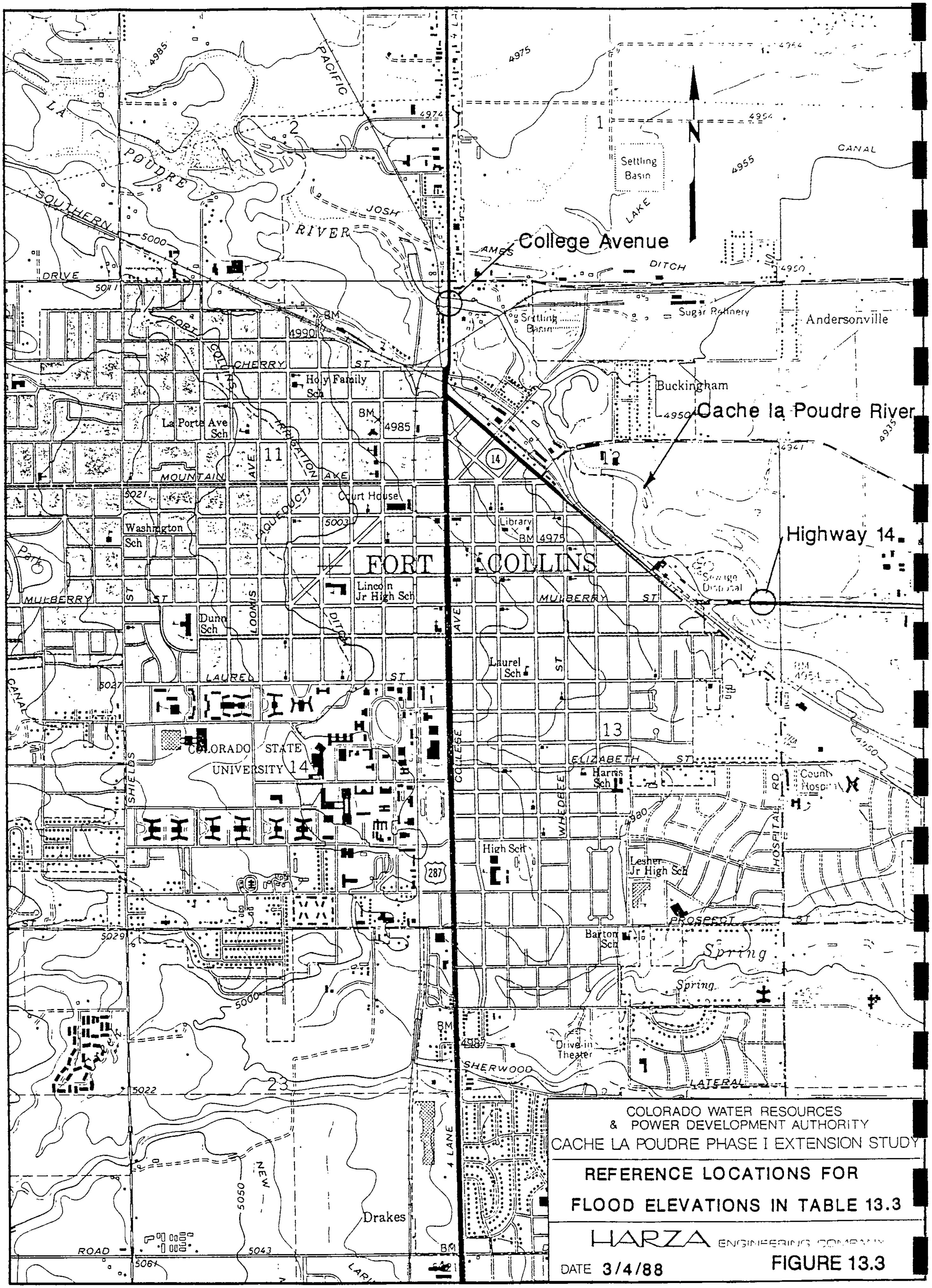


FIGURE 13.2



COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY
CACHE LA POUDRE PHASE I EXTENSION STUDY

REFERENCE LOCATIONS FOR FLOOD ELEVATIONS IN TABLE 13.3

HARZA ENGINEERING COMPANY

DATE 3/4/88

FIGURE 13.3

CHAPTER 14.0

ECONOMIC EVALUATION

14.0 ECONOMIC EVALUATION

14.1 INTRODUCTION

As part of the Cache la Poudre Basin Study Extension, an economic evaluation is provided of the Grey Mountain alternative, proposed as Stage 1 of the Cache la Poudre Water and Power Project. The economic evaluation consists of three components: assessment of economic effects; estimation of benefits; and determination of financial feasibility. The economic effects component projects tangible, dollar denominated effects and demographic effects directly and indirectly attributable to the project. The benefit-cost element, or economic efficiency evaluation, includes the tangible economic effects plus intangible benefits and costs. Non-quantifiable economic impacts are described in qualitative terms. The financial feasibility assessment compares revenues from vendable project outputs with annual revenue requirements assuming debt financing of the project.

14.2 ECONOMIC EFFECTS ASSESSMENT

The economic effects assessment includes an identification of the economic attributes of the proposed Grey Mountain alternative, a description of the current economic and demographic climate of the area, and an estimation of the project's economic impacts.

14.2.1 Economic Attributes of the Grey Mountain Alternative

Construction of the Proposed Grey Mountain Dam and associated facilities would require about five years. Because of permitting and other requirements, a period of at least 10 years would be required before construction could actually begin.

The area of economic influence is defined as the Larimer-Weld County region. A large majority of the employees are expected to reside in the cities of Fort Collins and Greeley or in other nearby urban areas.

The nearby towns, their size and distance to the proposed project site are set forth in the following table:

TABLE 14.1

Size and Distance of Nearby Towns
Grey Mountain Alternative(1)

Community	One Way Driving Distance to Site (Miles)	Population
Fort Collins	10	83,588
Greeley	45	62,290
Longmont	47	51,691
Loveland	28	36,111

(1) Distances are based on the most direct route to the reservoir site. Population estimates are for 1989, obtained from the State demographer.

In addition, there are a number of small communities located in the employee transportation corridor, including Ault, Windsor, Timnath, Severance, Platteville, and Johnstown. Figure 14.1 depicts the location of the project with respect to major towns, roads, and other landmarks.

The employment and remuneration levels associated with the construction of Grey Mountain Dam and associated facilities would be substantial. Annual average employment, would reach its highest level in the third year of project construction, with an estimated 510 workers. Direct wages and salaries from construction would amount to more than $33 million over the five year period, excluding fringe benefits and payroll burden:

TABLE 14.2

Estimated Construction Employment and Compensation
Grey Mountain Alternative

Year of Construction	Average Annual Employment	Total Wages and Salaries (thousands of 1988 dollars)
1	60	$1,596
2	260	6,962
3	510	13,576
4	390	10,345
5	120	811

The Grey Mountain alternative is estimated to cost approximately $230 million (1988 dollars) which is attributable primarily to construction of the dam. To the extent possible, construction materials, supplies and contract services would be purchased in northern Colorado.

14.2.2. Project Related Outputs

Stage 1 of the Cache la Poudre Project, not limited to Grey Mountain alternative only, would be primarily a water supply facility. The Grey Mountain alternative for the Stage 1 project would have an active storage of 185,000 acre feet (af) and a safe annual yield of 41,000 af, based on historical hydrology. A 24 megawatt conventional hydroelectric power facility would produce about 52 GWh annually. A portion of the annual energy production, about 12 GWh, would be used to convey water by pumping from Horsetooth Reservoir to Grey Mountain Reservoir. Other potential outputs or benefits include flood control, enhanced regional water supply management, and drought protection.

14.2.3 Description of the Economic Influence Area

Almost all of the construction workers are expected to reside in the cities of Fort Collins or Greeley. Furthermore, most of these individuals would be drawn from the existing labor force.

Demographic conditions indicate a growing population base, although increases have moderated in recent years. Since 1980, Fort Collins and Greeley have grown at about 2.9 percent and 1.9 percent, respectively. In 1980, these two cities had an average persons per household of 2.5. The age distribution indicates a relatively young population, with a median age of between 25 and 26 years. Education attainment in the region is high, attributable primarily to the presence of two large state universities in Fort Collins and Greeley.

The Larimer-Weld region had a labor force of more than 160,000 persons and an unemployment rate of about 6 percent in 1988. Regional employment levels increased less than 6 percent between 1985 and 1988. The distribution of employment by economic sector indicates a substantial degree of diversification, with manufacturing, retail trade, services, and government being the largest employment sectors.

Personal income levels in the Larimer-Weld region exceeded $3.9 billion in 1986. Per capita personal income in the Larimer-Weld region averaged about $12,900 in 1986, and growth between 1981 and 1986 amounted to about 1.6 percent annually. Per capita income for the Larimer-Weld region has been lower than that of the state as a whole, however.

In terms of employment and earned income, the retail trade sector is one of the region's largest sectors. In 1988, the volume of retail trade was more than $2.9 billion, an increase of more than $500 million, or 4.1 percent annually, from 1984.

Over 2,200 acres would be inundated by the Grey Mountain Reservoir, about 60 percent of which would be federal or state lands. However, an estimated 60 to 70 residential structures would be inundated by the reservoir.

14.2.4 Economic Effects of the Project

Economic effects of the Grey Mountain alternative on the Larimer-Weld region would stem from construction employment and disposition of wage and salary income, purchases of local goods and services, and indirect effects as those purchases circulate through the local economy. Beneficiaries would include private individuals, businesses, and local political jurisdictions. Effects on existing and future recreational activities would be evident during both construction and operation of the project.

14.2.4.1 Employment Effects

Primary and induced employment effects related to the construction of the Grey Mountain alternative are estimated to total approximately 1,600 jobs. This includes approximately 610 induced job opportunities as construction workers spend wage and salary income and other retail and service employees are required. In addition, about 280 jobs would be created through the purchase of construction related materials. Approximately 70 percent of the new jobs would be evident in the Fort Collins area, 20 percent in the Greeley area, and the remainder throughout the Larimer-Weld region. It is important to recognize that these jobs would be largely for existing residents; few new people are expected to migrate to the area directly or indirectly as a result of the Grey Mountain Project.

During project operations, three people are anticipated to be employed directly at the Grey Mountain Reservoir.

14.2.4.2 Personal Income Effects

The construction of the Grey Mountain Project would generate nearly $74 million in direct and secondary personal income in the Larimer-Weld region. This includes $33 million in direct worker compensation, as well as $41 million in secondary earnings. Based upon the projected commuting patterns of construction workers and wage and salary income per worker, a breakdown of direct wage and salary income is provided below:

TABLE 14.3

Average Direct Annual Wage and Salary Income (thousands)

Year of Construction	Fort Collins	Greeley	Other Region	Total Region
1	$1,115	$ 318	$ 159	$ 1,592
2	4,874	1,392	696	6,962
3	9,503	2,715	1,358	13,576
4	7,241	2,069	1,034	10,344
5	567	162	81	810

14.2.4.3 Effects Retail and Service Sales

As shown below, the commercial base in the Larimer-Weld region would be positively impacted by the construction of the Grey Mountain Project:

TABLE 14.4

Direct and Secondary Retail and Service Sales

	Retail Sales	Services Sales (millions of dollars)
Fort Collins	$21.47	$20.36
Greeley	5.93	5.82
Other in region	2.96	2.91
Total	$30.36	$29.09

These increases in business revenues would stem from personal consumption expenditures by direct project employment and secondary employment and by expenditures made by other businesses in the region.

14.2.4.4 Fiscal Impacts on Municipalities

Positive impacts would accrue primarily to the region's largest incorporated communities, Fort Collins and Greeley. During the construction of the project, Fort Collins is projected to receive $590,000 in additional sales tax revenues, while Greeley is projected to receive $178,000 in additional sales tax revenues. These monies would be forthcoming in large part from retail purchases made by direct and secondary employees. Other minor tax revenues are also possible, as well as modest cost increases for local governments.

14.2.4.5 Other Economic Effects from the Construction and Operation of the Project

During construction and operation of the Grey Mountain Project, there would be certain effects on the area's recreational resources which, in turn, would produce economic effects. Any declines in recreation visitor days for fishing, whitewater boating or other recreation activities in the Poudre Canyon area would lead to declines in business revenues for those businesses serving recreationists, tax revenues, personal income levels, and possibly in the level of employment. Increased recreation visitor days for activities such as flatwater boating would produce the opposite effects. Both positive and negative effects would be reduced or eliminated to the extent that site specific visits are replaced or substituted by visits to other recreational destinations within the area of economic influence. To provide conservation in the economic analysis, it was assumed that recreational losses and gains would be total, excluding the mitigating effects of substitution.

The loss in whitewater boating opportunities following project construction is conservatively estimated to result in an $810,000 reduction in regional sales and an income loss of more than $750,000. Reductions in stream fishing visitor days could lead to $75,500 reduction in business revenues and a $70,000 loss in personal income. Direct and indirect expenditures associated with flatwater and other recreation opportunities at Grey Mountain Reservoir could lead to an increase in regional commercial sales of about $800,000 and personal income gains of approximately $750,000.

An estimated 60 to 70 residential structures would be inundated by construction of the project. Assuming fair compensation by the project sponsor, there should be no dollar loss to the property owners or taxing jurisdictions. Recreational cabin use within the inundation area will be lost, although regional economic effects would be negligible since associated expenditures would occur elsewhere within the Larimer-Weld region.

As part of ongoing efforts to implement Stage 1 of the Cache la Poudre Project, NCWCD, the project sponsor, is committed to the development of an effective mitigation plan. Costs associated with specific mitigation actions have not been developed, as the process of obtaining input and concurrence from the necessary resource agencies has not commenced. Costs for effective mitigation will be incorporated in detailed feasibility studies to be carried out in the future.

Operation of the Grey Mountain Project would produce several beneficial effects for the region. The increase in water availability would have a positive effect on northern Colorado since municipal providers could avoid the cost of more expensive water development alternatives, resulting in more discretionary dollars to spend by area households and businesses. Farmers in the region would benefit from greater water availability during drought periods. Hydroelectric generation would similarly have a positive, but more limited, effect on the region. Businesses and households may benefit from hydroelectric power generation to the extent that utilities incur lower resource costs. Flood control benefits would also improve the economic base of the region in the form of reduced flood insurance rates, increased property values, higher business revenues, and gains in employment. Although substantial, these regional economic benefits attributable to the project have not been quantified in dollars.

14.3 BENEFIT COST ANALYSIS OF THE GREY MOUNTAIN ALTERNATIVE

The economic feasibility, or benefit-cost, analysis of the Grey Mountain alternative incorporates the economic effects described above plus non-dollar and intangible effects of the project. Certain methodological considerations and assumptions are important in order to properly interpret the results of the analysis:

1. Only benefits and costs which will likely accrue to existing and future inhabitants of northern Colorado are considered in the analysis;

2. The time horizon for consideration of benefits and costs is 62 years;

3. The benefit-cost analysis is performed in constant, 1988 dollars;

4. The discount rate of 8 percent, composed of a five percent inflation rate and a 3 percent real interest rate, was assumed;

5. Although an attempt to quantify all benefits and costs is made, a number of tangible and potentially significant benefits and costs are not quantified due to lack of supporting data or insupportable underlying assumptions.

14.3.1 Economic Benefits of the Grey Mountain Alternative

Quantified project benefits include the project's safe yield, hydroelectric power generation, lake-oriented recreation, and gains in personal and business income. Most of these benefits would not be realized until the fifth year after the start of construction, but they would continue for a long period of time.

14.3.1.1 Safe Yield

The Grey Mountain alternative would provide 41,000 af of safe annual yield assuming historical hydrological conditions. It is assumed that the additional water supply would be used for municipal and industrial (M&I) purposes. Although purchase agreements have not been negotiated with any water utility, it is assumed that this beneficial use would occur along the Northern Front Range in Boulder, Larimer, and Weld Counties. Recent water resource planning studies conducted for this region indicate the need for at least this amount of additional water supply.

The value of the project's safe yield is assumed to be approximated by the per acre foot cost of comparable alternatives. Although closely comparable water supplies are limited in number, several alternative sources of water were evaluated including the C-BT and Windy Gap Projects, Thornton's proposed Northern Water Supply Project, and enlargement of Halligan Reservoir. This comparative analysis resulted in estimated costs ranging from $1,400 to $6,100 per acre foot of water supply. A value of $3,500 per acre foot of safe yield for the Grey Mountain Project was used, resulting in a total benefit to the region of $143.5 million.

14.3.1.2 Hydroelectric Power

As part of the Grey Mountain Project, a conventional 24 megawatt hydroelectric power plant is planned. Based upon projected load factors and power value, annual net hydroelectric benefits are assumed to be $2.15 million.

14.3.1.3 Lake-Oriented Recreation

Existing reservoirs in the region are currently used to capacity during peak summer months. Thus, flatwater recreation benefits would accrue to the region as a result of constructing the Grey Mountain Project. Assuming some development around the reservoir, annual visitations by activity have been projected as shown below.

TABLE 14.5

Projected Annual Recreation Visits
Grey Mountain Reservoir

Activity	Utilization (annual visits) Initial	Maximum Capacity
Power boating	12,860	42,880
Wakeless boating	6,340	21,120
Camping	2,400	12,000
Picnicking	2,400	12,000
Shoreline angling	1,000-2,000	10,000
Total	25,000-26,000	98,000

Based on the estimated number of annual visits to Grey Mountain Reservoir, and the assumed benefit per visit (represented by a unit value), total annual flatwater recreation benefits are projected. Annual recreation benefits are estimated to be approximately $640,000 when project construction is completed and are projected to increase to $2.4 million when maximum capacity is attained. Most of these benefits would be attributable to power boating.

14.3.1.4 Personal Income and Business Net Income Benefits

Individuals and business establishments in northern Colorado would benefit from the proposed project to the extent that new personal and business income would be generated within the regional economy. As discussed earlier, a total of $74 million in personal income would be added to the region, directly and indirectly attributable to construction of the Grey Mountain Project. Business net income, assuming 10 percent profit on pre-tax revenue, would amount to roughly $6.2 million.

14.3.1.5 Local Tax Revenue Benefits

Local governments would benefit by an estimated $770,000 in additional sales tax revenues as a result of constructing the Grey Mountain Project. Additional costs or other revenues are likely to be quite modest since little or no in-migration of personnel is anticipated.

14.3.1.6 Flood Control Benefits

According to the Army Corp of Engineers (COE), there have been 30 major floods on the Cache la Poudre River during the past 100 years. As currently planned, the Grey Mountain Project could store the entire volume of water associated with a flood event having a recurrence interval of 100-years without reducing the estimated safe annual yield. Principal beneficiaries of the resulting reductions in flood damages would be Fort Collins, the Town of La Porte, and other unincorporated areas in Larimer County.

Although potential flood control benefits are considered to be substantial, such benefits could not be quantified for this study. Early COE estimates of annualized average flood damages of $1.2 million per year are believed to considerably understate potential damages, since damages to streets and utilities, emergency costs, agricultural losses, and other considerations were excluded. In addition, flood control would protect more highly valued uses of the floodplain which could provide substantial benefits to the City of Fort Collins. The City of Fort Collins, in cooperation with other entities, is planning to develop a Heritage Corridor along the Poudre River, wherein a variety of amenities are contemplated for increasing the overall contribution derived from activities along the river corridor. (Shalkey Walker Associates, Inc., 1989). Property values, job opportunities, income levels, and the commercial base of the area could all improve with flood protection, such as would be provided by the Grey Mountain Project. Detailed feasibility studies will include thorough evaluation of flood control associated with storage on the mainstem Cache la Poudre River.

14.3.2 Economic Costs of the Grey Mountain Alternative

Economic costs consist mostly of direct construction costs and the displacement of certain existing recreation activities. Construction costs are short term in nature, while displaced recreation could represent a long term loss.

Project construction costs are estimated to total $230.1 million in 1988 dollars. Construction costs would be incurred during a five-year period.

Other costs would be incurred due to inundation of the Poudre Canyon and the consequent displacement of certain existing developed and dispersed recreation activities. Displaced annual visits and unit values by type of activity are used to calculate costs, as summarized in the following table:

TABLE 14.6

Estimated Displaced Recreation Costs, Grey Mountain Reservoir

Activity	Annual Costs ($1,000s)(1)
Recreation cabins	$ 4
Fishing	41
Hiking	324
Hunting	(2)
Picnicking	8
Whitewater boating	101

(1) Not additive because losses occur in different years.
(2) Less than $1,000.

Hiking losses, if incurred, would only be temporary, if access to the Grey Mountain trailhead is disrupted during the construction period. In total, whitewater boating costs represent the largest potential recreational loss, since more than 5,000 annual visits, concentrated primarily on the Filter Plant Run, could be permanently lost without mitigation.

Without mitigation, reductions in expenditures made by recreationists could lead to losses in personal income and net business income within the region. Personal income losses could amount to approximately $820,000, and net regional business income reductions could approximate $88,000.

The reimbursement to property owners for the 60 to 70 residential properties that would be inundated by the reservoir, would cost approximately $4.2 million based on estimated fair market values.

14.3.3 Summary and Conclusions from the Benefit Cost Analysis

Annual benefits and costs are discounted using a real interest rate of 3 percent. The present value of costs and benefits and the benefit-cost ratio are presented in Table 14.7. Present value benefits exceed costs by $45 million, producing a benefit-cost ratio of 1.22.

A sensitivity analysis, reflecting uncertainties about mitigation and project benefits and costs, was performed by varying project benefits and costs and the discount rate. Estimated project costs were increased by 20 percent, benefits were decreased by 10 percent, and the discount rate was increased to 5 percent. The analysis indicated that the Grey Mountain Project would be economically feasible given reasonable increases in costs and the real interest rate.

The benefit-cost analysis indicates that the Grey Mountain Project is economically feasible, since the present value of benefits exceeds costs. It is reiterated that in this analysis, benefits were conservatively estimated while costs were liberally estimated.

14.4 FINANCIAL FEASIBILITY OF THE PROJECT

The financial feasibility analysis focuses upon project construction costs and potential revenue streams to offset annual repayment obligations. The analysis is conducted on both a real (constant) and nominal dollar basis. The real dollar analysis utilizes 1988 dollars in all instances. The nominal dollar analysis was benchmarked to 1988, and rates and costs were inflated at five percent annually to reflect future dollars.

14.4.1 Annual Revenue Requirements

Annual revenue requirements are composed of capital and operating costs. Through the application of debt financing assumptions, an annual schedule of dollar requirements, in both constant and current dollars, is developed.

TABLE 14.7

Present Value of Benefits and Costs for the Grey Mountain Alternative

Benefits	Millions
M&I Water Supply	$100.65
Convention Hydropower	43.54
Flat Water Recreation	40.56
Flood Control	(1)
Personal Income	55.93
Business Income	4.69
Local Tax Revenue	0.57
Subtotal	$245.94
Costs	
Construction	$182.10
O&M	7.28
Inundation	3.52
Lost Recreation	7.25
Personal Income	0.60
Business Income	0.60
Subtotal	$200.81
NET PRESENT VALUE	$ 45.13

(1) Tangible benefit but unquantified.

A schedule of revenue requirements for the constant dollar evaluation was prepared incorporating a total project construction cost of $230.1 million to be expended over a five year period. Annual O&M costs are assumed to be $360,000. Capital costs are assumed to be fully met through a single bond issue with a 30 year term and a 3 percent real interest rate. The bond issue would total about $265 million including interest during construction, bond issuance and insurance costs, and a bond reserve fund. Accounting for debt service, interest on the bond reserve fund, and O&M costs, total annual revenue requirements are estimated to be $13.5 million.

A separate estimation of revenue requirements was developed on a nominal basis, assuming bond rates of eight percent. This showed that the effects of inflation would increase the size of the bond issue by $194.7 to $459.7 million. Annual debt service would increase by $27.3 million to $40.8 million. Annual revenue requirements would be $38.1 million, increasing to $40.2 million by the end of the project repayment period.

These revenue requirements are intended to be realistic but conservative, since other more favorable financing alternatives might help support the project. Alternative sources of financing might include the Colorado Water Resources and Power Development Authority, the Colorado Water Conservation Board, the Colorado Department of Local Affairs, and Colorado Fish and Wildlife Mitigation grant monies. At the federal level, the Army Corp of Engineers (COE), the Bureau of Reclamation, or the Farmer's Home Administration might be potential sources of support. Only the COE programs appear to be directly applicable to federal financing for the Grey Mountain Project as it is presently configured, although elements of the project or local government support might create other federal or state financing opportunities.

14.4.2 Projected Revenues for Repayment

Although the Grey Mountain Project offers a number of project benefits, only water sales to municipal and industrial (M&I) users and hydroelectric power generation are presumed to be vendable and, therefore, relevant to project repayment. Water tap fees and user charges represent a logical vehicle for repayment from the M&I sector. Coupled with power revenues which would be sold at market rates, the M&I participants could establish water revenues sufficient to simply repay the project.

Tap fee and user charge requirements cannot be estimated with certainty at this point in time. Specific water suppliers who might support the Grey Mountain Project have not been identified, and the mix of tap fees and user charges would depend upon the philosophies of individual suppliers. As an indication of reasonable tap fees and user charges, a brief examination of prevailing rates within the Cache la Poudre River Basin was conducted, which indicated a wide range within this region. For example, single family unit tap fees in Fort Collins and Greeley range from $1,600 to $2,300, respectively. In contrast, the Town of Mead charges $4,500 for a single family tap. User charges range from $0.80 per 1,000 gallons to $1.40 per 1,000 gallons.

Most providers do not explicitly levy charges to fund water acquisitions. The Fort Collins/Loveland Water District and North Weld County Water District, however, charge $0.35 per thousand gallons to water users to offset the costs of new water right acquisitions. Based upon the foregoing, the revenue repayment projections assume an additional $1,000 per single family tap equivalent and a $0.15 per thousand gallon user charge as commitment toward project repayment for the constant dollar evaluation. Tap fees and user charges are inflated at an annual rate of 5 percent under the current dollar evaluation. These figures are considered reasonable in comparison with present rates and fees charged by potential project beneficiaries in the Cache la Poudre Basin.

Power sales revenues would be obtained from the 24 MW conventional hydroelectric power plant constructed as part the of the Grey Mountain Project. In constant 1988 dollars, and assuming current market conditions continue in the future, net revenues from hydropower generation would amount to $1.65 million annually.

14.4.3 Financial Feasibility Determination

Tables 14.8 and 14.9 provide a comparison of potential revenues and annual revenue requirements in terms of constant and current dollars, respectively. Because of the revenue fluctuations from tap sales, annual and cumulative deficits are evident for a brief period at the beginning of project operations. These disappear and are followed by surpluses after the tenth year following the start of project construction. Serial bond issues and other financial structuring measures could be taken to alleviate these temporary shortfalls. Table 14.9 shows a revenue shortfall only at the beginning of project operations. Surpluses could be reduced through smaller borrowing or more modest water rates.

A sensitivity analysis was conducted to test the financial feasibility determination. An increase in the real interest rate to four percent would increase annual revenue requirements by $2.3 million to $15.8 million under the constant dollar analysis and $5.3 million under the nominal dollar version.

Based upon, water tap fees of $1,000 per single family equivalent and user charges of $.15 per 1,000 gallons (both in addition to current charges), the project is financially feasible. That is, if annual hydrogeneration revenues are added to water revenues from the M&I sector, the total project revenues will exceed the revenue requirements for the bond issue and O&M costs. As water or power charges are increased, the rate of return on the project can be enhanced. In conclusion, the Grey Mountain Project is financially feasible based upon the foregoing assumptions and analyses.

TABLE 14.8

Constant Dollar Comparison of Project Revenues with Revenue Requirements (millions)

YEAR AFTER CONSTRUCTION BEGINS	ANNUAL REVENUES: POWER REVENUES	ANNUAL REVENUES: WATER CHARGES	ANNUAL REVENUES: TAP FEES	ANNUAL REVENUES: TOTAL REVENUES	TOTAL REVENUE REQUIRED	ANNUAL SURPLUS/ DEFICIT	CUMULATIVE SURPLUS/ DEFICIT
1	$	$	$	$	$	$	$
2							
3							
4							
5	1.7			1.7		1.7	1.7
6	1.7			1.7	13.5	(11.8)	(10.1)
7	1.7	4.3	8.8	14.8	13.5	1.3	(8.8)
8	1.7	4.4	10.2	16.3	13.5	2.8	(6.0)
9	1.7	4.5	10.2	16.4	13.5	2.9	(3.1)
10	1.7	4.6	10.2	16.5	13.5	3.0	(0.1)
11	1.7	4.7	10.2	16.6	13.5	3.1	3.0
12	1.7	4.8	10.2	16.7	13.5	3.2	6.2
13	1.7	4.9	10.2	16.8	13.5	3.3	9.5
14	1.7	5.0	10.2	16.9	13.5	3.4	12.9
15	1.7	5.1	10.2	17.0	13.5	3.5	16.4
16	1.7	5.1	10.2	17.0	13.5	3.5	19.9
17	1.7	5.2	10.2	17.1	13.5	3.6	23.5
18	1.7	5.3	6.5	13.5	13.5	0.0	23.5
19	1.7	5.4	6.5	13.6	13.5	0.1	23.6
20	1.7	5.4	6.5	13.6	13.5	0.1	23.7
21	1.7	5.5	6.5	13.7	13.5	0.2	23.9
22	1.7	5.5	6.5	13.7	13.5	0.2	24.1
23	1.7	5.6	6.5	13.8	13.5	0.3	24.4
24	1.7	5.7	6.5	13.9	13.5	0.4	24.8
25	1.7	5.7	6.5	13.9	13.5	0.4	25.2
26	1.7	5.8	6.5	14.0	13.5	0.5	25.7
27	1.7	5.9	6.5	14.1	13.5	0.6	26.3
28	1.7	5.9	4.2	11.8	13.5	(1.7)	24.6
29	1.7	5.9	4.2	11.8	13.5	(1.7)	22.9
30	1.7	6.0	4.2	11.9	13.5	(1.6)	21.3
31	1.7	6.0	4.2	11.9	13.5	(1.6)	19.7
32	1.7	6.0	4.2	11.9	13.5	(1.6)	18.1
33	1.7	6.1	4.2	12.0	13.5	(1.5)	16.6
34	1.7	6.1	4.2	12.0	13.5	(1.5)	15.1
35	1.7	6.2	4.2	12.1	13.5	(1.4)	13.7
36	1.7	6.2	4.2	12.1	13.5	(1.4)	12.3
Total	$54.4	$162.8	$213.6	$430.8	$418.5	$12.3	

TABLE 14.9

Nominal Dollar Comparison of Project Revenues with Revenue Requirements (millions)

YEAR AFTER CONSTRUCTION BEGINS	ANNUAL REVENUES: POWER REVENUES	ANNUAL REVENUES: WATER CHARGES	ANNUAL REVENUES: TAP FEES	ANNUAL REVENUES: TOTAL REVENUES	TOTAL REVENUE REQUIRED	ANNUAL SURPLUS/ DEFICIT	CUMULATIVE SURPLUS/ DEFICIT
1	$	$	$	$	$	$	$
2							
3							
4							
5	2.7			2.7		2.7	2.7
6	2.8			2.8	38.1	(35.3)	(32.6)
7	3.0	7.8	15.8	26.5	38.1	(11.5)	(44.1)
8	3.1	8.3	19.2	30.6	38.2	(7.6)	(51.7)
9	3.3	8.9	20.2	32.4	38.2	(5.8)	(57.5)
10	3.4	9.6	21.2	34.2	38.2	(4.0)	(61.5)
11	3.6	10.2	22.3	36.1	38.3	(2.2)	(63.7)
12	3.8	11.0	23.4	38.2	38.3	(0.1)	(63.8)
13	4.0	11.7	24.5	40.2	38.4	1.8	(62.0)
14	4.2	12.5	25.8	42.5	38.4	4.1	(57.9)
15	4.4	13.4	27.1	44.9	38.5	6.4	(51.5)
16	4.6	14.3	28.4	47.3	38.5	8.8	(42.7)
17	4.8	15.3	29.8	49.9	38.6	11.3	(31.4)
18	5.1	16.3	20.1	41.5	38.6	2.9	(28.5)
19	5.3	17.3	21.1	43.7	38.7	5.0	(23.5)
20	5.6	18.4	22.1	46.1	38.7	7.4	(16.1)
21	5.9	19.5	23.3	48.7	38.8	9.9	(6.2)
22	6.2	20.7	24.4	51.3	38.8	12.5	6.3
23	6.5	22.0	25.6	54.1	38.9	15.2	21.5
24	6.8	23.3	26.9	57.0	39.0	18.0	39.5
25	7.1	24.8	28.3	60.2	39.1	21.1	60.6
26	7.5	26.3	29.7	63.5	39.1	24.4	85.0
27	7.9	27.9	31.2	67.0	39.2	27.8	112.8
28	8.3	29.5	21.0	58.8	39.3	19.5	132.3
29	8.7	31.1	22.1	61.9	39.4	22.5	154.8
30	9.1	32.9	23.2	65.2	39.5	25.7	180.5
31	9.6	34.8	24.3	68.7	39.6	29.1	209.6
32	10.0	36.7	25.5	72.2	39.7	32.5	242.1
33	10.5	38.8	26.8	76.1	39.8	36.3	278.4
34	11.1	41.0	28.2	80.3	39.9	40.4	318.8
35	11.6	43.3	29.6	84.5	40.0	44.5	363.3
36	12.2	45.8	31.0	89.0	40.2	48.8	412.1
Total	$202.7	$673.4	$742.1	$1,618.2	$1,206.1	$412.1	

CHAPTER 15.0

CONCLUSIONS AND RECOMMENDATIONS

15.0 CONCLUSIONS AND RECOMMENDATIONS

15.1 INTRODUCTION

The Cache la Poudre Basin Study Extension evaluated environmental, technical, and economic aspects of developing a water supply reservoir on the mainstem of the Cache la Poudre River downstream of the confluence with its North Fork.

Environmental assessments concentrated on seven types of resources judged to have the greatest potential effect on overall project feasibility. The seven resource categories in alphabetical order were: (1) aesthetic, (2) aquatic, (3) botanical, (4) cultural, (5) land use, (6) recreational, and (7) wildlife.

Technical evaluations prepared during this Extension Study refined the evaluations prepared during the initial Basin Study completed in January 1987. A new hydrologic computer model was developed to provide a more detailed assessment of the availability of water for the project; highway relocation, conventional hydroelectric power generation, and flood control opportunities were evaluated in more detail; and project costs were updated.

The economic analysis consisted of three components: assessment of economic effects; estimation of project benefits; and preparation of financial feasibility analyses. The primary differences between these economic analyses and those prepared in the earlier Basin Study are the absence of project revenues from a pumped storage hydroelectric project and increased focus on municipal water supply, the water-based portion of the area's recreational industry, expenditures during construction, flood control benefits, effects on area employment, and project funding sources.

Conclusions reached in relation to the environmental, technical, and economic assessments are summarized below.

15.2 ENVIRONMENTAL CONCLUSIONS

Based on the environmental assessments performed for the seven resources judged to be the most critical in terms of potentially affecting project feasibility, the environmental effects of constructing either the Poudre or Grey Mountain alternatives to form a mainstem reservoir will obviously be significant. However, while the environmental effects may be substantial, none appear to represent fatal flaws in terms of proceeding with plans for constructing a mainstem reservoir. This is demonstrated by the fact that there are a number of positive environmental effects, or environmental enhancements, that would result from construction and operation of the proposed mainstem reservoir, and all of the negative environmental effects identified thus far can be adequately offset through reasonable levels of mitigation. Therefore, there are no indications at this time that the feasibility of Stage 1 of the Cache la Poudre Project will be solely dependent on any environmental factors.

Conclusions related to the seven resources assessments conducted as part of the Extension Study are briefly presented in the following subsections. Recreation, land use, and aesthetic resources are discussed in a single section due to their interrelated nature.

15.2.1 Aquatic Resources

The primary effects on fish distribution and abundance would be the result of transforming up to 15 miles of stream habitat to reservoir habitat. Habitat downstream of the project could be improved by scheduled reservoir releases to mitigate a portion of the lost stream habitat. Potential flow modifications upstream of the project could offset the remainder of the project's effect on habitat availability.

15.2.2 Botanical Resources

The most important effect on botanical resources would be loss of riparian vegetation in the reservoir area. Potential mitigation measures involve the creation of new wetland areas. The study area was searched for five plant species identified by the Colorado Natural Areas Program as species of special concern that potentially could occur in or near the study area. It was concluded that project construction would not affect The Larimer aletes; the only such species identified in the project area.

15.2.3 Cultural Resources

Six of the twenty-nine newly recorded cultural resource sites were assessed as eligible for inclusion in the National Register of Historic Places. Mitigation for all six sites would include data retrieval. Five of the sites could receive partial excavation.

15.2.4 Recreation, Aesthetics and Land Use

Without mitigation, the recreational effects of project development would include the displacement of up to 8,460 user visits each year. The Poudre alternative would displace less than half the number of visits as the Grey Mountain alternative with the primary difference attributable to effects on whitewater boating. Mitigation measures might include trailhead relocation; new river access sites for whitewater boating; boat chutes at diversion dams; and new boating, camping, and picnicking facilities. With these facilities, a net increase of nearly 17,600 annual visits could result.

Primary effects of the project on the aesthetics of the study area were assessed according to the degree of landscape change and the visibility of the change. Selection of appropriate mitigation measures will depend on site-specific simulation of project appearance when a project alternative is chosen.

The project would shift some dispersed recreational activity onto other lands and would require acquisition of up to 2,200 acres of land. This land is presently held in approximately equal portions by: the federal government; the State Land Board; and municipal and private entities.

15.2.5 Wildlife Resources

Project effects on wildlife resources were analyzed using a Habitat Evaluation Procedure in accordance with local, state, and federal agency input. Mitigation for habitat losses will generally concentrate on improving the habitat quality of other habitats in the study area. One federally-listed endangered species, the bald eagle, was observed. A biological assessment and close coordination with federal agencies will be required in addressing project effects on this species.

15.3 TECHNICAL CONCLUSIONS

Hydrologic assessments indicated that a safe yield of 41,000 af/yr could be provided from a 195,000 af reservoir assuming an initial storage volume of 150,000 af. Reservoir releases would support a hydroelectric powerplant at the dam with an installed capacity of 18 to 24 MW depending on whether municipal water deliveries are passed through the powerplant. Flood routing studies concluded that an 82 percent reduction (17,400 cfs to 3,100 cfs) in the 1-in-100-year flood at the mouth of Poudre Canyon would be accomplished with only 10,000 af of reservoir storage allocated to flood control. A 50 percent reduction (to 8,700 cfs) could be accomplished without any storage specifically allocated to flood control.

Alternatives for relocating Colorado Highway 14 in the vicinity of the project were evaluated. The cost of the alternatives (including contingencies and engineering and administrative costs) ranged from $21.4 to $43.1 million for the Rist Canyon and Poudre Canyon Alignment A alternatives, respectively.

Using the Rist Canyon alternative, the total construction cost of the Grey Mountain alternative was estimated to be approximately $230 million at January 1988 price levels. The major cost components of the project are as follows:

	Cost ($ Million - Jan. 1988)
Grey Mountain Dam and Reservoir	$ 163.9
Hydroelectric Powerplant (24 MW)	13.9
Horsetooth-Grey Mountain Conveyance	29.0
Access Roads	1.9
Route 14 Relocation	21.4
Total	$ 230.1

15.4 ECONOMIC CONCLUSIONS

The calculated benefit-cost ratio for the Grey Mountain alternative was 1.22 based on a real discount rate of three percent. Flood control benefits, while substantial, were not included because of a lack of available data. Mitigation costs were also not included in the benefit-cost analysis because potential mitigation measures have not been combined into an overall plan with the concurrence of regulatory agencies. The flood control benefits and the mitigation costs will tend to offset each other in the benefit-cost computation.

Sensitivity analyses were prepared to reflect variations in benefits and costs. Costs could increase by 20 percent and, with no increases in project benefits, the benefit-cost ratio is still greater than 1.0.

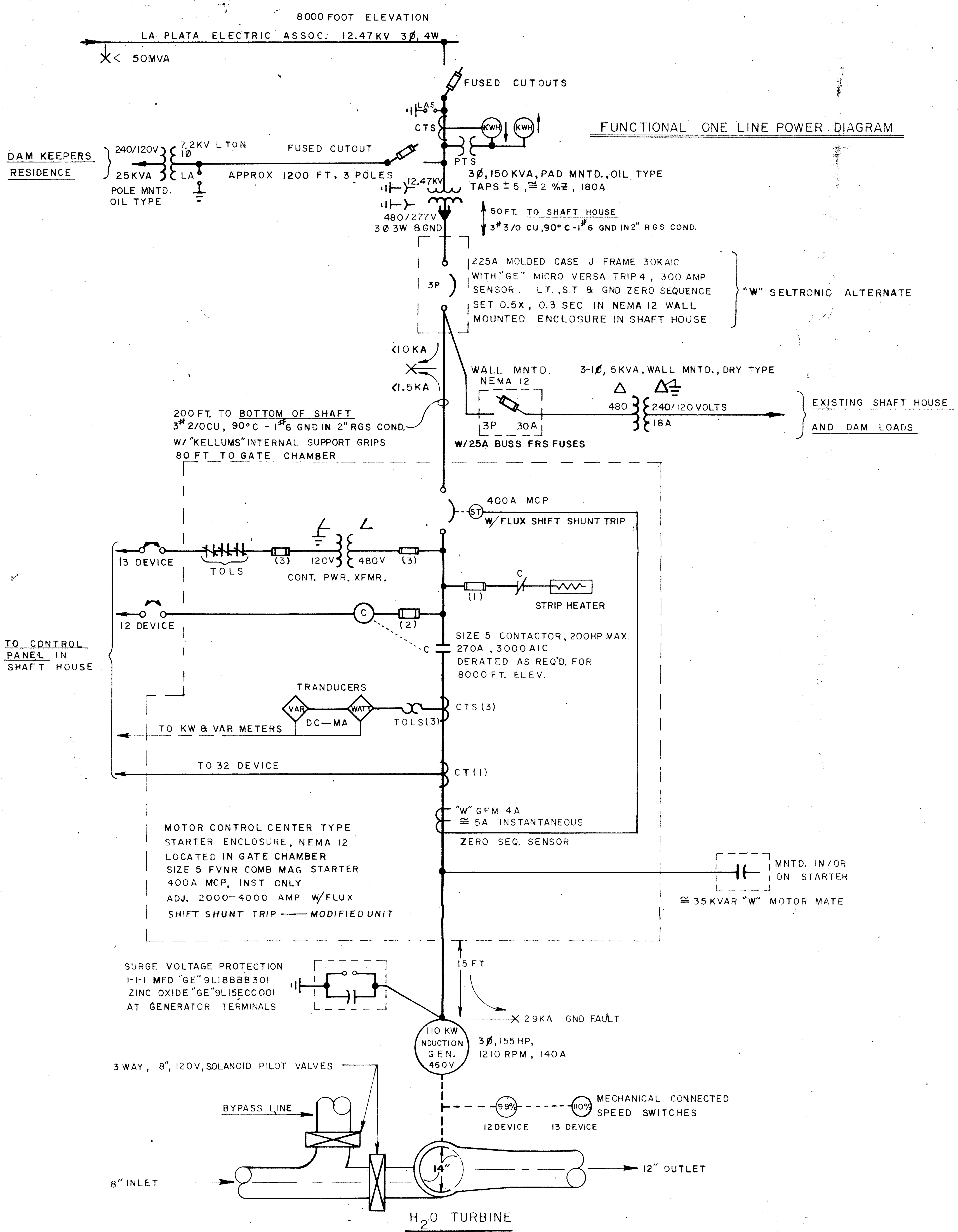
The Grey Mountain alternative is financially feasible assuming new water tap fees are increased by $1,000 per single family equivalent and user charges are increased by $0.15 per $1,000 gallons.

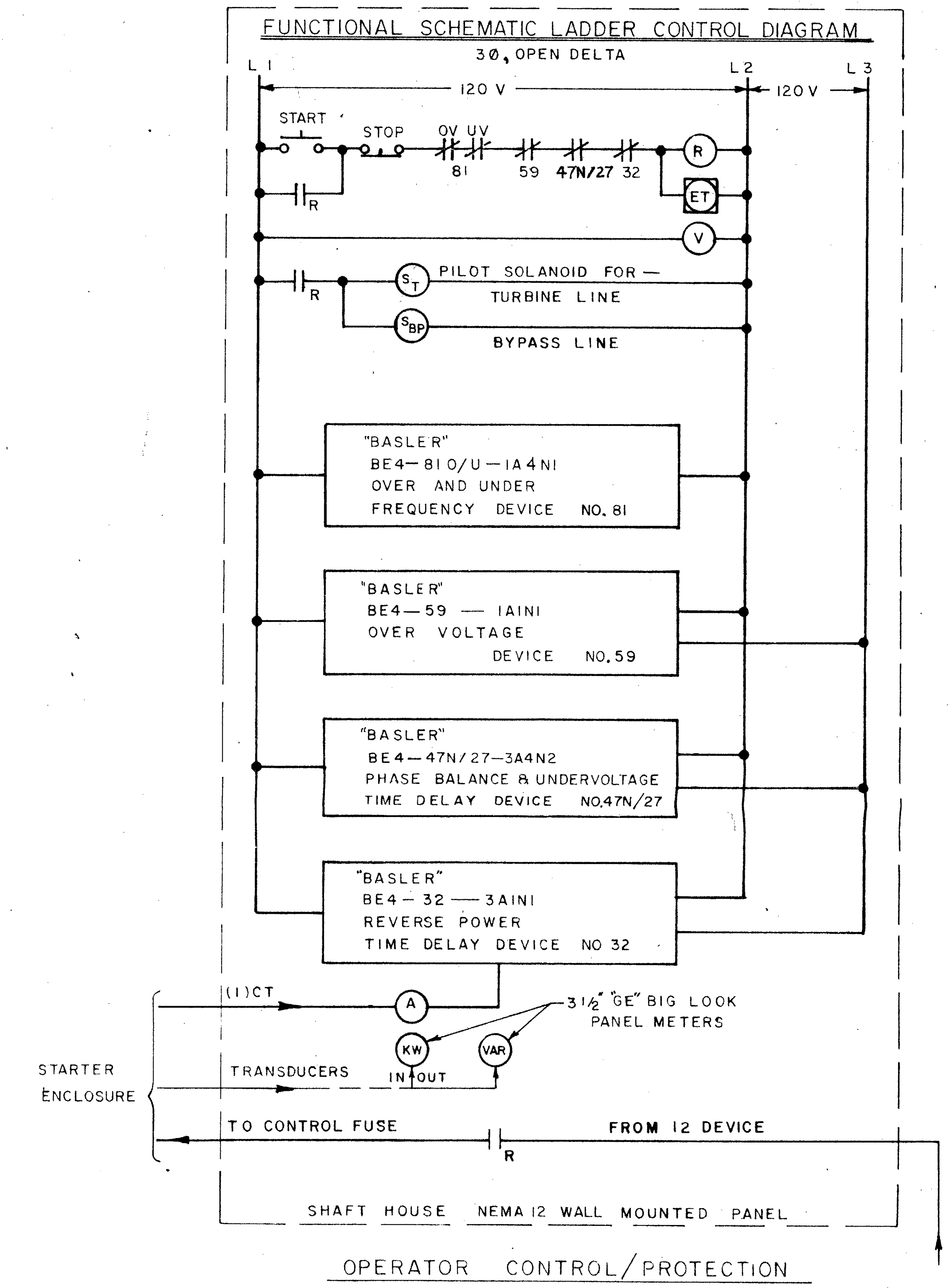
15.5 RECOMMENDATIONS

The preceding sections indicate that either of the two alternatives for a water supply project on the mainstem of the Cache la Poudre River is feasible based on the environmental, engineering, hydrologic, and economic evaluations. Although the Grey Mountain alternative was selected to evaluate project costs, considerable information has been developed on the relative effects of the Poudre and Grey Mountain alternatives.

It is recommended that the results of this Extension Study be reviewed with regulatory agencies and with potential purchasers of the water supply developed by the project. The report should also be reviewed with entities that may be interested in other project benefits, such as flood control and hydropower benefits.

Potential measures to mitigate project effects were listed in the preceding sections for each of the seven resources that have been considered. The measures will not, however, be refined and evaluated in the context of a single comprehensive mitigation plan until additional information is available regarding detailed operation of the project to meet the specific needs of the entities purchasing the water supply and electrical energy output from the project. Therefore, an iterative approach to project refinement is recommended. Potential participants in the project should be surveyed regarding their needs, the project refined accordingly, and then regulatory agencies consulted regarding the mitigation of project effects. In addressing these issues, specific environmental and technical analyses may be needed to adequately distinguish between the effects, costs, and benefits of the project alternatives. Many of these potential study refinements are listed in the main body of the report.





NOTES

LTR	DESC.	DATE	APP.
A	REVIEW MODIFICATIONS	7/20/85	

REVISIONS

DRAWN LINES & ASSOC
CHECK
APP
DATE 7/1/85

DICK SITTNER ENGINEERING, INC.

HARRIS WATER ENGINEERING CO.

LEMON DAM HYDROELECT

PRELIMINARY ELECTRICAL PWR. & CONT.

SIZE	DWG NO	REV
D	PE 001	A

SCALE NONE | SHEET 1 OF 1

SUPERSEDES PAGE 14 OF APPENDIX Q.1

CALCULATED RETURN FLOWS TO THE POUDRE RIVER FROM THE CANYON GAGE TO THE FORT COLLINS GAGE

(mean monthly cfs per mile)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Total
Ave	1.90	1.26	1.18	1.18	1.24	1.01	1.31	2.81	-0.79	3.79	5.06	4.51	24.45
1954	2.56	0.97	0.94	0.94	1.04	0.94	0.97	2.14	-8.62	2.83	4.70	-0.91	8.51
1955	2.00	1.09	1.06	1.06	1.17	1.06	1.09	1.31	-7.22	1.41	1.18	1.02	6.21
1956	1.12	1.19	1.15	1.15	1.27	1.15	1.19	3.19	-7.48	1.95	3.76	4.06	13.70
1957	1.81	1.46	1.41	1.41	1.56	1.41	1.46	1.47	8.14	0.30	0.42	0.42	21.25
1958	0.18	1.25	1.21	1.21	1.34	1.21	1.25	4.13	-6.27	3.96	5.51	5.51	20.50
1959	2.41	1.43	1.38	1.38	1.53	1.38	1.43	2.49	2.82	1.58	2.19	2.19	22.20
1960	0.96	1.01	0.98	0.98	1.08	0.98	1.01	2.09	-0.97	4.32	6.01	6.02	24.48
1961	2.63	1.37	1.32	1.32	1.46	1.32	1.37	3.11	-0.51	3.71	5.16	5.16	27.42
1962	2.26	1.13	1.10	1.10	1.22	1.10	1.13	6.16	-4.26	2.43	3.38	3.38	20.13
1963	1.48	1.12	1.08	1.08	1.20	1.08	1.12	1.73	-11.28	5.32	7.40	7.41	18.74
1964	3.24	1.15	1.11	1.11	1.23	1.11	1.15	1.92	-8.00	5.93	8.24	8.25	26.42
1965	3.61	1.13	1.09	1.09	1.21	1.09	1.13	1.11	4.02	2.58	3.59	3.60	25.22
1966	1.57	1.01	0.98	0.98	1.08	0.98	1.01	1.15	-9.29	7.20	10.02	10.03	26.70
1967	4.38	1.28	1.24	1.24	1.37	1.24	1.28	0.68	-2.70	4.41	6.14	6.14	26.68
1968	2.68	1.31	1.27	1.27	1.41	1.27	1.31	2.54	3.99	4.67	6.50	6.51	34.74
1969	2.85	1.14	1.11	1.11	1.22	1.11	1.14	1.81	-5.21	3.74	5.21	5.21	20.44
1970	2.28	1.12	1.08	1.08	1.20	1.08	1.12	1.63	-1.34	2.63	3.66	3.67	19.22
1971	1.60	1.43	1.38	1.38	1.53	1.38	1.43	3.21	5.74	3.63	5.04	5.05	32.80
1972	2.21	1.00	0.97	0.97	1.08	0.97	1.00	2.53	-1.43	6.54	9.10	9.11	34.06
1973	3.98	1.31	1.26	1.26	1.40	1.26	1.31	3.47	-2.65	3.81	5.30	5.31	27.03
1974	2.32	1.39	1.34	1.34	1.49	1.34	1.39	5.76	-1.48	3.28	4.57	4.57	27.31
1975	2.00	1.19	1.15	1.15	1.28	1.15	1.19	3.63	0.59	0.88	3.88	2.92	21.00
1976	1.77	1.42	1.26	0.94	1.24	0.82	0.85	-2.76	-2.00	1.29	6.14	4.62	15.61
1977	2.24	1.45	0.85	0.86	1.22	0.28	0.64	1.36	-4.16	4.01	2.87	4.53	16.16
1978	-0.75	1.19	0.92	1.14	0.79	0.66	-0.02	-2.94	-6.73	-1.35	4.02	1.68	-1.39
1979	2.79	1.23	1.57	1.61	1.67	1.24	1.69	-0.20	-4.04	0.06	3.46	3.22	14.31
1980	0.50	2.54	0.98	0.95	1.86	0.05	4.09	14.33	-2.81	2.37	3.57	5.20	33.62
1981	0.98	1.52	0.87	1.87	0.97	0.40	-0.03	6.92	6.49	2.97	3.70	3.03	29.70
1982	1.96	0.86	1.48	1.14	1.63	0.68	0.78	2.75	11.71	1.31	1.30	4.19	29.79
1983	-2.64	1.24	1.73	1.18	-0.56	0.52	4.80	7.56	31.17	25.87	15.65	4.28	90.81
Min	-2.64	0.86	0.85	0.86	-0.56	0.05	-0.03	-2.94	-11.28	-1.35	0.42	-0.91	-1.39
Max	4.38	2.54	1.73	1.87	1.86	1.41	4.80	14.33	31.17	25.87	15.65	10.03	90.81
Sdev	1.35	0.29	0.21	0.21	0.40	0.33	0.92	3.11	8.02	4.51	2.92	2.36	14.84

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