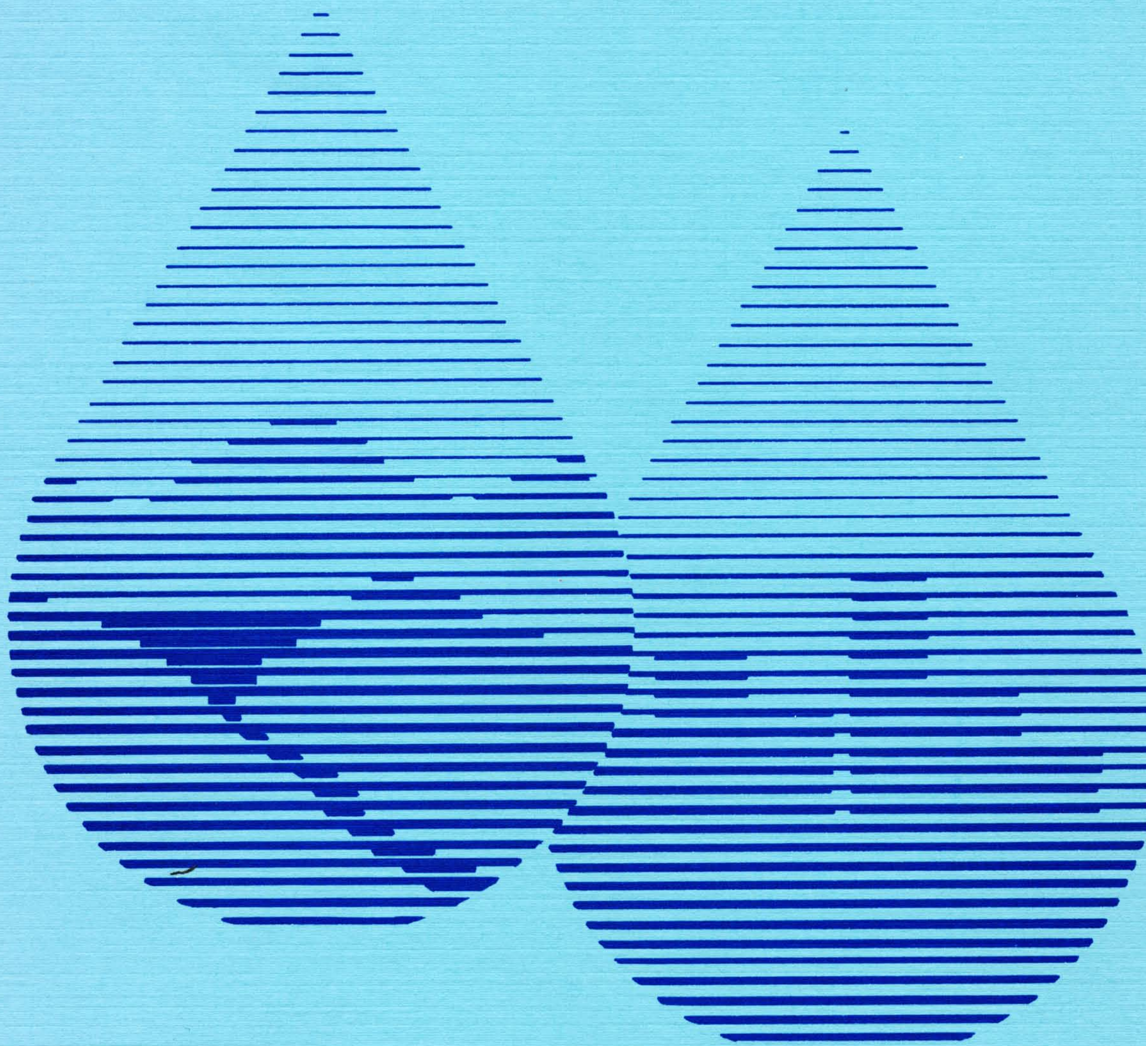
Clear Creek Project

Phase I—Feasibility Study

Step 2—Final Report



COLORADO WATER RESOURCES & POWER DEVELOPMENT AUTHORITY
1981

June 1989

TUDOR ENGINEERING COMPANY

Ralph A. Tudor (1902-1963)

Consulting Engineers and Planners

John Williams–Vice President
Office Manager

621 - 17th Street, Suite 750
Denver, Colorado 80293
(303) 298-8844

June 30, 1989

Mr. Ulrich Kappus, P.E.
Executive Director
Colorado Water Resources and
Power Development Authority
Logan Tower Building
1580 Logan Street, Suite 620
Denver, Colorado 80203

Subject: Clear Creek Project
Submittal of Final Report for Step 2 of the
Phase I - Feasibility Study

Dear Mr. Kappus:

We are pleased to submit this Final Report for the Clear Creek Phase I, Step 2 - Feasibility Studies. A Summary Report is submitted under separate cover. These Step 2 studies complete the Phase I investigation which was performed in two steps. This step of the investigation provides estimates of the new water supply which can be developed in the Clear Creek basin. Firm yield and project cost have been estimated for a range of reservoir sizes at a representative damsite in Clear Creek Canyon.

Results of this study indicate that Clear Creek could be a major source of new water supply for Denver's northern metropolitan area. These investigations have estimated that up to 61,000 acre-feet per year of new firm yield could be developed from water which originates in the Clear Creek basin. The cost of storage and delivery of this new firm yield is estimated to range from $630 to $940 per acre-foot per year based on the project investment cost. To obtain new firm yields of this magnitude, the full cooperation of the Clear Creek water users will be needed to conjunctively manage their water rights so that maximum advantage can be gained from a major new reservoir. The Clear Creek Water Users Alliance has already initiated efforts to expand cooperation and provide greater efficiency in water use on Clear Creek.

The main project features would include a large dam and reservoir located in Clear Creek Canyon, and relocation of that portion of U.S. Highway 6 that runs through the canyon. Conceptual designs and cost estimates were developed during Step 2 investigations for only one of several potential damsites in Clear Creek Canyon. This site, the Centennial damsite located approximately two miles west of Tunnel No. 3, is considered representative of the damsites available in the canyon. To fully develop Clear Creek water, a dam of about 500 feet in height would be needed. Capital costs of approximately $400 million have been estimated for a project of this magnitude, including the cost of relocating U.S. Highway 6. The plans for project development should consider the needs of local communities and users of U.S. Highway 6; our preliminary studies indicate that a project can be developed that will meet these needs.

The Clear Creek Project could provide a major recreational attraction to the Denver metropolitan area and to Clear Creek and Gilpin Counties. Recreational opportunities could include activities such as: camping, hiking, boating, and fishing. Recreational areas could be located along the reservoir and throughout a corridor along Clear Creek Canyon downstream of the dam. Project benefits beyond water supply and recreation may include improvements to existing water quality, flood control to downstream communities, and production of hydroelectric power.

The next step in project development should include further evaluation of the plan for U.S. Highway 6 relocation. The evaluation should consider the long-term needs of the local communities, the highway users, and the Clear Creek water users. Future phases of project planning will require additional investigations to select a specific dam and reservoir site in Clear Creek Canyon, and to identify the environmental and socioeconomic issues to be addressed in an environmental impact statement. As part of future investigations, an advisory committee should be formed to enhance public involvement in the planning stages of this major project.

We appreciate the continued opportunity to conduct these evaluations of the Clear Creek basin. We wish to acknowledge the excellent support and guidance we have received from you and your Project Manager, Ralph Kerr. We look forward to working with you in the future.

Sincerely,

TUDOR ENGINEERING COMPANY

John Williams, P.E.
Vice President

Enclosure: As stated

C E R T I F I C A T E   O F   E N G I N E E R

CLEAR CREEK PROJECT

PHASE I - STEP 2 FEASIBILITY STUDY

This report was prepared by Tudor Engineering Company and our subconsultants, Cheryl Signs Engineering; Leonard Rice Consulting Water Engineers, Inc.; Muller Engineering Company, Inc.; and Woodward-Clyde Consultants. The technical material, data, and analyses contained in this report were prepared by the following professionals:

TUDOR ENGINEERING COMPANY

- Salvatore Todaro
- Robert Toothman
- S.T. Su
- Milton Kramer (Consultant)
- Michael A. Stevens (Consultant)

CHERYL SIGNS ENGINEERING

- Cheryl Signs

LEONARD RICE CONSULTING WATER ENGINEERS, INC.

- Leonard Rice
- Ross Bethel

MULLER ENGINEERING COMPANY, INC.

- Robert Carlson
- Edward Haase

WOODWARD-CLYDE CONSULTANTS

- Allen Gipson, Jr.
- John Black

The technical analyses, data, and documentation developed in this study were prepared under the supervision and direction of John Williams, whose seal as a professional engineer is affixed below.

JOHN WILLIAMS, Tudor Vice President
Registered Professional Engineer
State of Colorado
No. 17394

COLORADO REGISTERED JOHN WILLIAMS 17394 PROFESSIONAL ENGINEER

FINAL REPORT

CLEAR CREEK PROJECT

PHASE I, STEP 2 - FEASIBILITY STUDY

Prepared for:

Colorado Water Resources and Power Development Authority
1580 Logan Street, Suite 620
Denver, Colorado 80203

Prepared by:

Tudor Engineering Company
In Association With:
Cheryl Signs Engineering
Leonard Rice Consulting Water Engineers, Inc.
Muller Engineering Company, Inc.
Woodward-Clyde Consultants

June 1989

<u>TABLE OF CONTENTS</u>

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

LIST OF TABLES

TABLE OF CONTENTS (CONTINUED)

LIST OF TABLES (CONTINUED)

LIST OF TABLES (CONTINUED)

LIST OF FIGURES

Section 1

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

1.0 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

1.1 INTRODUCTION

A Phase I Feasibility Study for the Clear Creek Project was authorized on April 4, 1986, by the Colorado Water Resources and Power Development Authority (Authority) in response to an application submitted by the Clear Creek Water Users Alliance (Alliance). The objective of this investigation was to plan for future development of the water resources of the Clear Creek basin to meet the growing municipal and industrial water supply needs of the existing Clear Creek water users. Other anticipated benefits from this project include improved water quality, a major new recreation area within a short drive of metropolitan Denver, flood control, hydropower, and enhancement of agriculture water supply.

The Phase I studies have been performed in two steps. The Step 1 investigations, completed in November 1987, focused on the identification and evaluation of potential water and hydropower developments and the selection of several preferred alternatives. A broad range of potential projects was screened based on preliminary technical, economic, and environmental analyses. The objective was to distinguish the major differences between alternative plans; provide an indication of viability for each alternative; and to determine if more refined investigations were justified for selected alternatives. The results of the Step 1 study indicated that a reservoir of at least 100,000 acre-feet (af) capacity would be needed to produce a firm water supply yield that is both sufficient in quantity as well as potentially cost effective. Step 1 studies also determined that only reservoir sites within Clear Creek Canyon could provide at least 100,000 af of storage.

The objective of the Step 2 studies was to establish if a Clear Creek Canyon water storage project could: 1) develop on a firm annual basis at least 35,000 af/yr of water native to Clear Creek, 2) at a unit cost competitive with other potential water supplies available to the Alliance members, 3) while providing for the access needs of present and future users of Highway 6 in the canyon. The Step 2 investigations were initiated in April 1988 to focus on these key technical issues associated with the development of the preferred alternatives identified in Step 1. Step 2 studies, documented in this report, have provided estimates of firm water supply yield and project cost for a range of possible water sources and dam sizes related to a main stem storage reservoir in Clear Creek Canyon. Construction costs were estimated for the same range of reservoir sizes and for each of six highway relocation alternatives. Potential user impacts that would result from the relocation of U.S. Highway 6 were also quantified.

1.2 STUDY AUTHORIZATION

Study of the Clear Creek Project began in August 1986 when Tudor Engineering Company (Tudor) entered into a contract with the Authority to carry out the Step 1 investigations. All studies were conducted under the auspices of the Authority. The Authority was created by the General Assembly to provide Colorado with a mechanism to finance water and hydroelectric projects through the issuance of revenue bonds. In addition to financing, the Authority is authorized to assist in the planning, design, and construction of such projects. The Authority initiates water project investigations based on applications received from local project sponsors who are in need of developing additional water supplies and who anticipate a stream of revenue adequate to repay the annual debt service and operation of the project. The Authority staff evaluates the applications received to assess the potential demand for the project, potential project costs and revenues, and major environmental and institutional issues to be addressed. Projects that meet the Authority's criteria are recommended to the Board for either feasibility study, final design and specifications, or for construction financing. The Board determines what, if any, Authority participation is warranted.

The sponsor of the Clear Creek project is the Clear Creek Water Users Alliance, a group of ten entities including municipalities, water companies, water and sanitation districts, and industries who need to develop new water supplies to meet growing demands. The Alliance is a non-profit organization without taxing authority. Membership eligibility in the Alliance includes any individual or legally recognized entity having the lawful right to use water arising in or deliverable into the Clear Creek watershed.

The following Alliance members are participants in the Clear Creek study:

Agricultural Ditch and Reservoir Company
City of Arvada
City of Broomfield
Consolidated Mutual Water Company
Adolph Coors Company
Walt Flanagan & Co., Inc.
Mobile Premix Concrete, Inc.
North Table Mountain Water and Sanitation District
Public Service Company of Colorado
Suburban Sand & Gravel, Inc.

In April 1988, the Authority entered into a second contract with Tudor to provide engineering services for the Step 2 studies. Tudor subcontracted with four other firms to provide specialty services for the Step 2 study: Cheryl Signs Engineering and Leonard Rice Consulting Water Engineers, Inc. (hydrology, water supply, and water rights); Woodward-Clyde Consultants (geology, geotechnical engineering, and groundwater); and Muller Engineering Company, Inc. (highway relocation). Additionally, Tudor utilized the services of two special consultants: Milton Kramer (dam layouts) and Edward McClean (cost estimates).

1.3 STUDY AREA

The Clear Creek basin is located in central Colorado and is bordered by the Continental Divide to the west, and the confluence of Clear Creek and the South Platte River in the City of Denver to the east. The Clear Creek basin is composed of an upper and lower basin. The two basins combine to drain an area of about 575 square miles. The mountainous upper basin, that part of the basin upstream from the mouth of Clear Creek Canyon, provides the major portion of surface water runoff from annual snowmelt. The lower basin is a plains area where the water is used for agriculture and by municipalities and industry. The Clear Creek basin map is shown in Figure 1.1.

There are no major on-stream reservoirs in the Clear Creek basin to regulate and control the flow of the stream. Because most of the unappropriated native flows occur during spring snowmelt, reservoir storage is required in Clear Creek Canyon if these excess native flows are to be conserved for beneficial use by the local water users during periods of low flow.

The existing water supply facilities in the upper basin include transbasin diversion facilities, minor storage reservoirs, tributary wells, and minor water supply diversion structures. Transbasin diversion facilities currently importing water to the Clear Creek basin include Vidler Tunnel, the Eisenhower Tunnel, the Berthoud Pass Ditch, and the Gumlick Tunnel. Importations to the Clear Creek basin through the Gumlick Tunnel from the Williams Fork collection system are exported from the Clear Creek basin through the Vasquez Tunnel to the Fraser River basin. These Williams Fork diversions are subsequently diverted into the Denver Water Department's (DWD) northern system. Water from DWD's northern system is treated at its Moffat water treatment plant.

The existing water supply facilities in the lower basin include diversion structures, ditches, canals, augmentation stations, storage reservoirs, and pump stations. The major diversion and conveyance facilities include the Church Ditch, Farmers High Line Canal, Croke Canal, Agricultural Ditch, Wannamaker Ditch, Slough Association, Fisher Ditch, Clear Creek and Platte River Ditch, Colorado Agricultural, and Rocky Mountain Ditch. The major water supply storages include Standley Lake, Great Western Reservoir, Arvada Reservoir, Maple Grove Reservoir, and the Jefferson Storage system.

There are more than 15 water suppliers in the lower Clear Creek basin that utilize Clear Creek as a source of raw water supply. These water suppliers include agricultural water users, municipal water suppliers, and two major industrial users. The major municipal water suppliers and industrial water users that receive water from Clear Creek include Arvada, Broomfield, Consolidated Mutual, Adolph Coors Company, Golden, Lakewood, Northglenn, North Table Mountain, Pleasant View, Public Service Company, Thornton, and Westminster.

The agricultural use in the basin has steadily declined as urbanization has encroached on the land and the water supply. The irrigated area using Clear Creek as a water supply was reported by the State Engineer's office to be 120,000 acres in 1950. In 1980, agricultural land using Clear Creek for water supply was estimated to be 28,000 acres. The current average annual water demand for agriculture is estimated to be 42,000 af, but the annual firm yield is estimated to be only 25,000 af.

1.4 STRUCTURE OF THE STEP 1 STUDY

The Step 1 investigations of the Phase I Feasibility Study were conducted to make a preliminary evaluation of developing additional water supplies for Clear Creek basin water users. The purpose was to distinguish the major differences between alternative plans, provide an indication of viability for each alternative, and to establish if more refined studies were justified. Seven water supply scenarios were evaluated based on combinations of the following: a junior storage decree on Clear Creek for 110,000 af; capacities of existing diversion facilities; transbasin importations; water rights transfers; and effluent exchanges. Potential water storage and hydropower facilities were identified and were then combined to form 12 alternative water storage projects and 10 multipurpose pumped-storage hydropower projects. Pumped storage hydropower development involves pumping water from a lower reservoir to an upper reservoir with low-cost, off-peak power and later releasing the water to generate power during peak power demand periods. The projects were then screened based on preliminary technical, economic, and environmental analyses.

Technical and institutional issues addressed in the Step 1 study include:

1. Projections of demand for water supply to meet the needs of existing users of Clear Creek water.
2. Availability of native flows to be stored and the possibility of increased yield as a result of innovative water management.
3. Potential storable flows from adjacent basins.
4. Institutional constraints which may limit development of available water.
5. Assessment of water quality effects.
6. Consideration of alternatives to new storage, such as groundwater development and water leasing.
7. Evaluation of the firm water supply yield from new development.
8. Identification of potential storage sites.
9. Identification of potential pumped storage sites.
10. Conventional hydropower in conjunction with potential dams.
11. Environmental and geotechnical issues which could preclude potential development.

The environmental studies conducted during Step 1 were general in nature and relied upon available data and discussions with agency personnel. The objective of those studies was to identify environmental concerns of the alternative projects. The final environmental studies required to construct a major water storage project will require compliance with the National Environmental Policy Act (NEPA).

The Step 1 study made maximum use of previous reports and existing data. Previous studies of Clear Creek and adjacent drainage basins were important sources of data. However, those investigations did not consider the numerous basin-wide factors that were considered in the Step 1 studies. These factors include both the potential benefits and potential constraints to project development such as: the possibilities of transbasin diversions; hydrologic modeling of the basin to estimate available storable flows; assessment of pumped storage hydroelectric potential; and identification of potential environmental constraints and potential environmental enhancements of new water supply projects.

1.5 RESULTS OF THE STEP 1 STUDY

Following is a list of the principal findings of the Step 1 studies. Conclusions and recommendations derived from both the Step 1 and Step 2 study findings are presented in Section 1.8.

1. A large reservoir (at least 100,000 af) on Clear Creek could provide substantial new firm yields in the Clear Creek basin. New firm yields could be derived by: capturing flood waters in the new reservoir; using the reservoir to better manage available water; using the reservoir to store water for a South Platte exchange; and using the reservoir to store water diverted from the Williams Fork basin.
2. Only reservoir sites located in Clear Creek Canyon have sufficient storage capacity to meet the water supply goals of the project. The largest offstream reservoir has a storage potential of only 63,000 af and would require at least five miles of large diameter water supply tunnels to fill the reservoir.

3. Location of a reservoir in Clear Creek Canyon would require relocation of portions of U.S. Highway 6 and the possible relocation of portions of State Highway 119.
4. The cost of highway relocation could be as much as 40 percent of the total project construction cost.
5. Several dam and reservoir sites exist within Clear Creek Canyon. Initial geological studies indicate that suitable geology exists for the construction of a large concrete arch dam and reservoir.
6. Several pumped storage sites exist within the canyon. Pumped storage could be combined with several of the water supply reservoir sites identified in Clear Creek Canyon. The capacity of the pumped storage projects investigated in the Step 1 studies ranged from 110 to 750 megawatts.
7. Clear Creek and many of its tributaries presently contain concentrations of heavy metals that exceed chronic exposure limits for aquatic life. The preliminary analysis performed as part of the Step 1 study indicates that a reservoir on the main stem could support a cold water fishery and would likely improve water quality downstream from the facility.

1.6 STRUCTURE OF THE STEP 2 STUDY

The Step 2 study was structured to develop estimates of firm water supply yield, overall project costs, and unit costs of firm yield for a variety of project configurations and water supply scenarios at a representative dam site in Clear Creek Canyon. An integral part of this study was the formulation and evaluation of alternatives for relocation of U.S. Highway 6, and the potential impact this relocation would have on highway users. Step 2 investigations address the critical technical issues affecting project feasibility. These technical evaluations include:

1. Estimates of water supplies that could be utilized by the project, based not only on storage of flood waters, but also on cooperation by Clear Creek water users at two different levels of user participation; on exchanges to meet water right calls from the South Platte; and on integrated usage of existing storage reservoirs.

2. Estimates of the firm annual water yield that could result from each of seven water supply scenarios for reservoir sizes ranging up to 230,000 af. Each of the seven scenarios utilizes only water native to Clear Creek. However, each scenario is based on the utilization of a different set of water rights.
3. Evaluation of two basic concepts for the relocation of U.S. Highway 6: relocation inside the canyon versus relocation outside the canyon. Three alternatives were identified for each of the two basic concepts. Evaluation of each of these six alternatives included layout of new route alignments, construction costs, and operation and maintenance costs. The change in user costs caused by road relocation was evaluated for each alternative in terms of commuting time, accident rates, and vehicle operation costs.
4. Preparation of dam layouts, cost estimates, and construction schedules for concrete arch dams of 420, 480, and 540 feet in height, corresponding to reservoir sizes of 110,000, 165,000, and 230,000 af, respectively. Cost curves were prepared to identify dam costs throughout the size range stated.
5. Economic and financial evaluations of potential projects for a range of reservoir sizes, combined with each of the six alternatives for highway relocation, and four selected water supply scenarios.

Interim results of the study were provided to the Authority by means of regular meetings, monthly progress reports, and preliminary drafts of chapters for the final report. This procedure provided the Authority an active role in the study process. A public awareness program for the project was provided in the form of two public involvement meetings and the distribution of newsletters. Coverage of the project has also been provided by local press and metropolitan newspapers.

These studies are a preliminary part of a complex process that could lead to the development of a project on Clear Creek. That process includes a detailed environmental analysis that will form the basis of an environmental impact statement (EIS). Other investigations required for an EIS would include issues such as updated projections of demand for water supply; conservation measures and other potential alternatives to a project in Clear Creek Canyon; impact on canyon resources (such as aquatic, aesthetic, botanical, cultural, recreational, and terrestial); cumulative downstream impacts; socioeconomic effects; and identification of mitigation measures.

A graph showing the key steps and potential schedule to develop a project of this size is provided in Figure 1.2. This schedule is presented to indicate a preliminary estimate of the tasks and time to bring a project of the complexity of Clear Creek on-line. The sponsor's need to complete the project, the success of the permitting activities, and the availability of project funding, will each have a significant impact on the actual schedule for implementing the project.

1.7 RESULTS OF THE STEP 2 STUDY

The following is a list of the findings of the Step 2 studies. Conclusions and recommendations from the Step 1 and Step 2 studies are presented in Section 1.8.

1. Water supply scenarios have been identified in which up to 61,000 af/yr of new native water from the Clear Creek basin can be developed. Table 1.1 shows the required reservoir capacity and the maximum firm yield which can be developed for each of the seven water supply scenario studies.
2. The two principal sources of native water supply available for development are storage of flood water and the water savings resulting from enhanced management of existing diversions. The amount of water that can be conserved as a result of enhanced management with a new reservoir would depend on the level of participation by Clear Creek water users.
3. Costs for four representative projects are shown in Table 1.2. Costs for highway relocation (Alternative 6) are included with each of these four projects. The values of firm yield shown in Table 1.2 are the maximum obtainable yields for each of the respective scenarios.

TABLE 1.1

Maximum Firm Yield and Associated Reservoir Capacity

Water Supply Scenario	Project Firm Yield(1) (af/yr)	Required Project Storage(2) (af)
1. AD- Alliance Decree	16,100	158,000
2. AT- Alliance Transfer	6,100	62,000
3. SPX-South Platte Exchange	10,900	59,000
4. AS- Alliance Sources	26,000	180,000
5. ASX-Alliance Plus	38,700	175,000
6. BAM-Basin Management	43,200	230,000
7. BC- Basin Combined	61,000	189,000

(1)Production of firm yield for some scenarios requires acquisition of additional water rights or legal transfers.
(2)Includes 30,000 af for recreation pool and dead storage.

TABLE 1.2

Project Costs
Representative Project - Four Water Supply Scenarios

Scenario	Firm Yield(1) (af)	Unit Cost(2) ($/af/yr)	Annual Cost(3) ($1000)	Construction Cost ($1000)	Capital Cost ($1000)	Investment Cost ($1000)	Reservoir Storage(4) (af)	Dam Height (ft)
AS	26,000	1,262	33,000	274,000	338,000	377,000	180,000	494
ASX	38,700	935	36,000	309,000	375,000	419,000	175,000	489
BAM	43,200	843	37,000	311,000	385,000	429,000	230,000	540
BC	61,000	631	39,000	330,000	400,000	447,000	189,000	502

(1)Maximum firm yield which can be developed for each scenario.
(2)Includes annual debt service plus operation and maintenance per acre-foot of firm yield.
(3)Includes annual debt service plus operation and maintenance.
(4)Storage required to develop maximum firm yield; figure includes 30,000 af for recreation pool.

4. Location of a reservoir in Clear Creek Canyon will require relocation of portions of U.S. Highway 6 and State Highway 119. Options exist for relocating U.S. Highway 6 in the canyon or for routing traffic to a widened I-70. The cost of relocating U.S. Highway 6 within Clear Creek Canyon would be more than double the cost of relocating U.S. Highway 6 to I-70. A direct access through Clear Creek Canyon from Central City to Golden can be maintained for tourism and recreation by the construction of a county road around the reservoir with a connection to the existing U.S. Highway 6.

5. Preliminary evaluations indicate that all six of the roadway relocation alternatives should increase safety for traffic currently using U.S. Highway 6.
6. For highway relocation within the canyon, travel times between Idaho Springs and Denver or Golden are expected to increase by 1 to 3 minutes. Travel times between Black Hawk and Denver or Golden are predicted to change by less than 1 minute. For highway relocation to I-70, travel time between Denver and mountain locations would be reduced 4 to 6 minutes. A 6 to 8 minute increase would be expected between Golden and mountain locations.
7. Damsites exist for the location of a large dam and reservoir in Clear Creek Canyon. The Centennial damsite, shown in Figure 1.1, can provide up to 230,000 af of storage. Initial geological investigations have identified no conditions that would preclude the construction of a major dam and reservoir at this site. Additional field investigations will be required to confirm the suitability of this site. Conceptual designs for various dam heights were prepared for the Centennial site, as listed in Table 1.3.
8. The total construction period of the project would be approximately 5 years. Construction of the road and dam would take place concurrently. Dam construction would require approximately 4.5 years; whereas, road relocations would require approximately 3.5 years.
9. The public involvement program for this study has resulted in the identification of concerns related to project development. Some of these concerns include:
   - The effect of the relocation of U.S. Highway 6 on commuting time from Gilpin County and, in turn, how this may affect residential property values.
   - The relocation of U.S. Highway 6 and the effect on tourist access to Gilpin County.
   - The effect of a reservoir on existing ecosystems of Clear Creek Canyon.
   - The effect of reservoir fluctuations on recreation and aesthetics.
   - The effect of geologic faulting in the proposed reservoir.
   - The effect of heavy metal sedimentation within the reservoir.
   - The effect on the Gilpin County tax base from project land purchases.

TABLE 1.3

Summary of Dams and Reservoirs Studied at the Centennial Site

Dam Crest Elevation (MSL)	Dam Height (ft)	Reservoir Storage (af)	Reservoir Surface Area (acres)
7110	420	110,000	740
7170	480	165,000	960
7230	540	230,000	1,200

1.8 CONCLUSIONS AND RECOMMENDATIONS

The Phase I Feasibility Studies conclude that up to 61,000 af of firm native yield could be developed on Clear Creek. The Clear Creek project could provide other opportunities to the region in addition to a new water supply. Opportunities that could be realized by this project include: a major new source of recreation for the Denver metropolitan area; flood protection for Clear Creek; improvement of Clear Creek water quality; creation of a new flat water fishery; enhancement of the marginal stream fishery; and stimulation of the economies of Gilpin, Clear Creek, and Jefferson Counties.

1.8.1 Conclusions

The Phase I Feasibility Study has provided the evaluation necessary to establish that the Clear Creek project is a viable water supply project. Based on this evaluation, it can be concluded: that the project could develop a sufficient quantity of water native to Clear Creek to justify a project; that a firm water supply can be developed at a cost competitive with other potential water supplies; and that the existing and forecast needs of the users of U.S. Highway 6 in the canyon can be met. The following general conclusions can be drawn from the Phase I Feasibility Studies.

Potential For Development of New Native Clear Creek Water - Project development using only Alliance water rights (Scenario AD) would result in a maximum firm yield of 26,000 af/yr. Development which is based on combining Alliance water rights with South Platte exchanges (Scenario ASX) could increase the firm yield to as high as 38,700 af/yr. Assuming integrated management of water native to the Clear Creek basin (Scenario BAM), firm yield could reach 43,200 af/yr. Integrated management combined with South Platte exchanges (Scenario BC) could provide up to 61,000 af/yr of firm yield. A high level of cooperation between Clear Creek water users would be required to achieve firm yields in excess of 40,000 af/yr.

<u>Demand for Water Supply</u> - The future water demand for the Clear Creek water users is estimated to be in excess of the maximum firm yield of the project (65,000 af). This estimated demand projection has factored in extensive non-structural and conservation measures.

<u>Highway Relocations</u> - Development of a reservoir in Clear Creek Canyon would require relocation of U.S. Highway 6. Relocation would also be required of Highway 119. As an example, one of the six highway relocation alternatives is shown in Figure 1.1. All six highway relocation alternatives would continue to provide direct access through the canyon from Golden to Central City for tourism and for canyon recreation. Implementation of this project would require the resolution of significant issues involving the Colorado Department of Highways and the users of Highway 6 in Clear Creek Canyon. These issues include: the impacts of the project on the highway users and on regional access, highway safety for existing and proposed conditions; and the governmental processes required for relocation of U.S. Highway 6. Based on these preliminary studies, average user costs (based on driving time, mileage and accidents) are expected to increase by about 10 percent. All six of the roadway relocation alternatives are projected to increase safety for traffic currently using U.S. Highway 6.

<u>Dam Location and Size</u> - A large dam in Clear Creek Canyon is required to meet the water supply goals of the project (to develop at least 35,000 af of native Clear Creek water). This will require a reservoir with a capacity of 175,000 to 230,000 af. Respective dam heights would range from 490 to 540 ft. Clear Creek Canyon is the only suitable location within the drainage basin that could provide the required storage capacity.

<u>Suitability of Canyon for Construction of Dam and Reservoir</u> - Preliminary geological and engineering studies indicate that suitable dam and reservoir sites

exist within the canyon. Initial studies indicate that a concrete-arch dam would be the dam type best suited to these site conditions because of the competency of dam foundation rock, availability of construction material for production of concrete, and the damsite topography. Preliminary investigations indicate that the Black Hawk Fault and the terrace gravels identified within the Centennial reservoir would not be a seepage path for migration of water from the reservoir. Initial geologic findings are based on interpretation of published data and must be confirmed by detailed field investigation.

Project Capital Costs - The preliminary cost studies show that the two major construction items would be the dam and relocation of U.S. Highway 6. It is anticipated that the capital cost for a Clear Creek project would be approximately $400 million (1988 price level). Capital cost includes total construction cost plus interest during construction. The dam would account for approximately two-thirds of the estimated project construction cost and the road relocation approximately one-third.

Unit Cost of Firm Yield - The three highest yielding water supply scenarios (shown in Table 1.2) could develop Clear Creek water at unit costs ranging from $631 to $935 af/yr. These costs are generally competitive with the unit cost of other firm water supplies which may be available to the Alliance members. The unit cost of firm yield is calculated as the annual debt service of the project plus annual operation and maintenance costs divided by the amount of firm yield.

Construction Schedule - The estimated construction period would be approximately 5 years. Construction activities for the dam and the road relocation would be expected to overlap by approximately 3 years. This overlap would require routing traffic through the canyon along U.S. Highway 6 during dam construction.

Conventional Hydropower - A conventional hydroelectric power plant with a capacity of approximately 12 megawatts could be installed at the base of the proposed dam in Clear Creek Canyon. However, project economic analysis has not considered conventional hydropower in these preliminary studies. The decision to include conventional hydropower as part of the project would depend upon the value of power at the time of project construction.

Flood Control - A major reservoir on Clear Creek would reduce the risk of flooding downstream of the reservoir. This flood protection would occur as a natural consequence of the reservoir's attenuation of flood flows. Additional flood protection could also be added to the project by reserving space within the reservoir dedicated to water storage for flood control. This potential was not evaluated in the present study.

Improved Water Quality - A major reservoir on Clear Creek could improve water quality by reducing the quantity of heavy metals presently in the stream. These water quality improvements could result in decreased treatment costs for downstream water users. This improved water quality could make it possible to establish a cold water fishery in the reservoir and also in Clear Creek downstream of the dam. The outlet works can be designed to control the temperature and oxygen content of the water released from the reservoir to enhance the downstream fishery.

Recreational Opportunities - In addition to the water supply benefits, the project could also provide a major recreational resource. A reservoir in Clear Creek Canyon could provide flat water (reservoir) recreation including activities such as sailboating, windsurfing, fishing, canoeing, and swimming. The reservoir's proximity to I-70 would provide convenient access from the Denver metropolitan area for day use and overnight camping. Recreation at the reservoir could be managed jointly with Golden Gate Canyon State Park so that visitors could camp and hike at both parks in combination with lake and stream recreation at a Clear Creek reservoir.

A recreational corridor could be developed downstream of the dam to the mouth of the canyon. Recreation in the corridor could include hiking, rafting, kayaking, bicycling, wildlife observation, and fishing. Existing recreation within the canyon is limited because of the heavy truck traffic on U.S. Highway 6, very high seasonal variations in existing streamflow, and existing poor water quality conditions. The proposed project could be designed and operated to enhance these conditions.

<u>Enhanced Water Supply for Gilpin and Clear Creek Counties</u> - A reservoir on Clear Creek would provide communities in Gilpin and Clear Creek Counties with the opportunity to exchange water to downstream senior water rights holders. This exchange would allow increased use of Clear Creek water by communities located upstream of the reservoir.

<u>Use of Existing Water Conveyance Systems</u> - The infrastructure for delivery of project water to Clear Creek water users is essentially in place. A reservoir in Clear Creek Canyon would be located above the existing diversion, conveyance, and off-stream storage facilities. The reservoir would permit more efficient utilization of Clear Creek water.

<u>Transbasin Diversions</u> - Water conveyance systems exist to transport water from the Williams Fork drainage to Clear Creek. A Clear Creek reservoir could be used to store any excess Williams Fork spring snowmelt which is available for diversion and cannot currently be stored in the Denver Water Department's northern system. Spills presently experienced in Williams Fork could be conveyed through the existing Gumlick Tunnel into Clear Creek basin. Diversions could be increased from Williams Fork to Clear Creek through Denver's Williams Fork Pumping Collection System or through the Henderson Tunnel. The Henderson Tunnel alternative is presently under study by the Climax Molybdenum Company. A major storage reservoir on Clear Creek could substantially increase the firm yield for these additional Williams Fork diversions.

<u>Pumped Storage Hydroelectric Power</u> - Combining pumped storage hydroelectric power with a water supply project might reduce the cost of water supply. Several possible pumped storage projects were identified within the canyon. Implementation of pumped storage would depend on the local need for peaking energy and upon the ability to incorporate a pumped storage feature with other project goals.

Environmental Issues - The environmental studies conducted to date have provided only a cursory overview of the environmental issues associated with project development. These preliminary studies did not identify any major environmental obstacles to project construction.

1.8.2 Recommendations

These preliminary studies indicate that further work is warranted on the Clear Creek Project, based on the original three objectives for this project: 1) to develop a sufficient quantity of water 2) at a competitive cost 3) while adequately addressing the issue of relocating U.S. Highway 6. Therefore, it is recommended that further investigations be undertaken to evaluate the many other issues and refine these preliminary findings relative to the development of a major water supply project. If the project sponsor, the Clear Creek Users Alliance, decides to proceed with this project, the following recommendations are made for future investigations:

Expand Clear Creek Water Users Alliance - The Alliance should continue to encourage non-member Clear Creek water users to join the Clear Creek Water Users Alliance. An expanded Alliance organization would encourage cooperation between water users to maximize potential yield from a new reservoir. Membership in the Alliance for communities in Gilpin and Clear Creek Counties would give these water users opportunities for more efficient use of their Clear Creek water rights.

U.S. Highway 6 Relocation Studies - Investigations of U.S. Highway 6 relocation should address the concerns of the highway users and identify the alternatives which best meet the needs of the local communities and highway users. These studies should include: origin and destination studies, traffic forecasting for the alternatives, preliminary design studies, environmental issues, and coordination with the Colorado Department of Highways.

Determine the Socioeconomic Impacts of the Clear Creek Project and Develop a Project Plan Compatible with Local Interests - Socioeconomic studies should address the overall effect of the project on local communities. These investigations should identify the effects of the project on the long-range goals of the local communities. Early planning efforts should also identify ways in which the project can benefit these local communities. This early stage of planning should be conducted with the goals of the local communities in mind so that project development would be compatible with these goals.

Overall socioeconomic effects of the project on the local communities should be investigated. Positive and negative effects on the local community should be established. This may include: effect on tourism to Central City, Black Hawk, Golden, and Idaho Springs as a result of lake recreation; effect on business in these communities and the resulting effect on the tax base; effect of the changes in travel time for commuters and tourists; and enhanced local water supply which could encourage local growth.

Selection of a Specific Damsite and Reservoir - One or more specific dam and reservoir sites should be selected in Clear Creek Canyon to provide a storage capacity of at least 200,000 af. Minimum capital cost of the project should be the principal consideration in this selection because environmental, socioeconomic, and legal issues would be similar to most sites in the canyon. The major influences on project cost would include the geology of both the dam and the reservoir, and the cost of the road relocation alternatives. The location of the proposed quarry in the canyon would limit the potential damsites to upstream locations if the quarry is approved by Jefferson County.

Geological Investigations - Additional geological investigations will be required to select and confirm one or more specific dam and reservoir sites. Pertinent geological issues to be addressed during the next level of study should include the potential for reservoir seepage at locations of ancient faults and at gravel terraces within the reservoir.

If the Centennial damsite is the site selected for further investigations, then field studies should be conducted at the Black Hawk Fault to determine the potential for reservoir seepage. Bedrock elevations should also be determined at areas of terrace gravels to determine the maximum recommended reservoir elevation. Site-specific damsite geology should include subsurface investigations to determine rock jointing, weathering, and quality of rock.

Water Quality - Investigation of the effect of a reservoir on the water quality and, specifically, on the concentration of heavy metals should be undertaken to confirm preliminary evaluations made during Step 1 studies. The potential to establish a quality fishery in the reservoir and downstream of the dam should be evaluated based on projected changes in water quality.

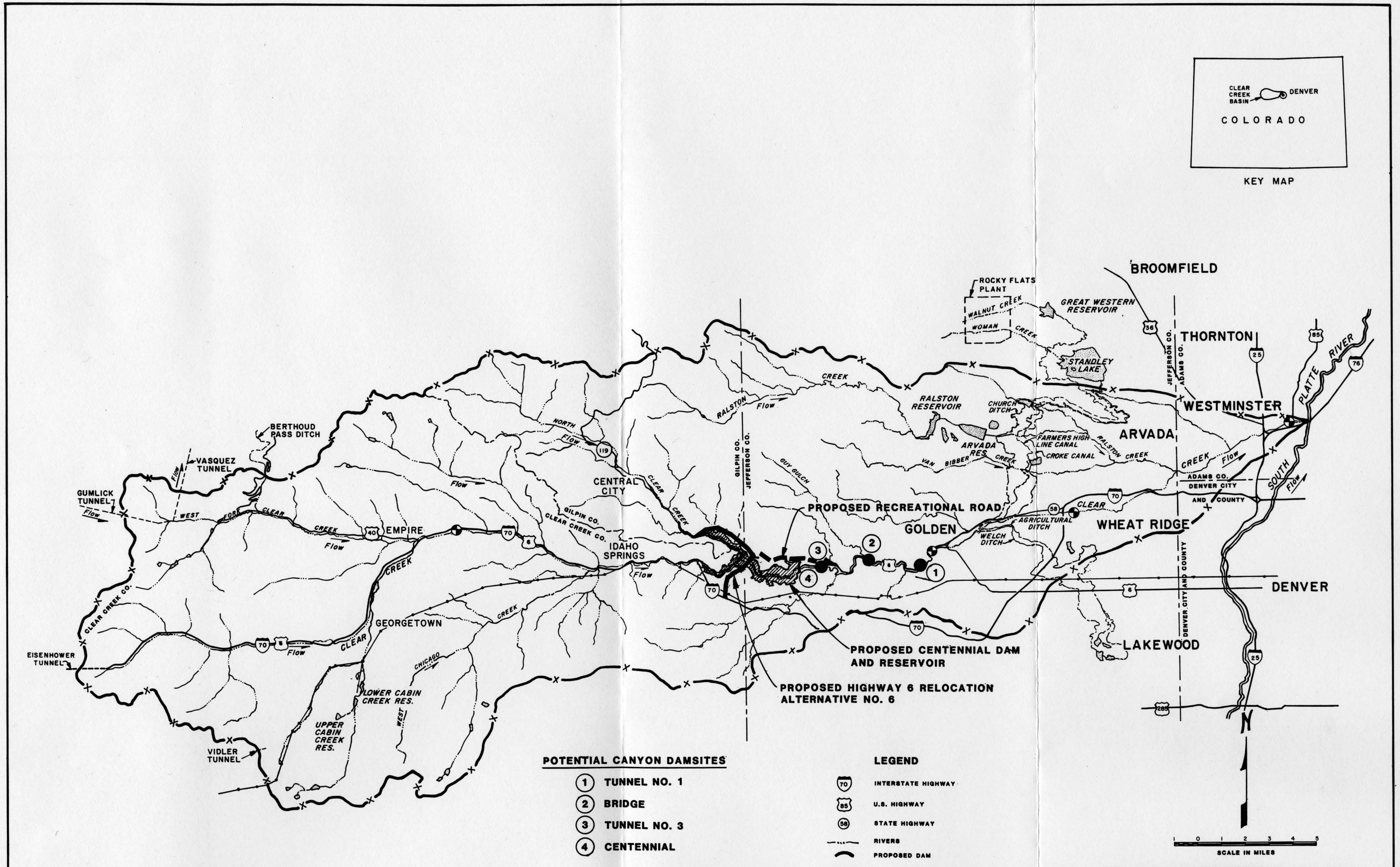
Determine Opportunities for Recreation - Project related recreation facilities would provide a source of local recreation for the Denver metropolitan area and the local mountain communities. These facilities could be planned to complement the existing Golden Gate Canyon State Park facilities and to encourage day trips within Gilpin and Clear Creek Counties. Future studies should address local recreation needs and plans for development to enhance tourism at these local communities. Consideration should be given to recreational opportunities around the reservoir, on the surface of the reservoir, and along the canyon downstream of the dam.

Environmental Studies - If the institutional issues involving water rights and the relocation of U.S. Highway 6 can be resolved, initial environmental studies should be conducted to identify and quantify the environmental issues. These initial investigations would form a basis for scoping the detailed studies necessary for an environmental impact statement (EIS). The EIS is required by the National Environmental Policy Act (NEPA). NEPA "is the major determinant of the time and effort required to obtain government approvals for water development projects in Colorado," according to the Colorado Joint Review Process. NEPA requires federal agencies to evaluate the environmental effects of actions which they may take, including the issuance of permits.

Possibilities for Storing Non-Native Water - Investigations should be undertaken to estimate the potential increase in firm yield of Williams Fork water (existing and potential development) by sharing capacity in a Clear Creek Canyon reservoir. Potential development should consider both the Denver Pumping Collection System and the Henderson Tunnel project to further develop Williams Fork water.

Pumped Storage Hydroelectric Power - The incorporation of pumped storage as part of a water supply project should be further investigated. This investigation should establish physical properties of such a project so that its compatibility with other project goals (water supply, recreation, etc.) can be assessed.

Public Involvement - As part of future project investigations, an advisory committee should be formed to enhance public involvement in the planning stages of this major project. The advisory committee should be composed of those public and private entities whose interests may be affected by such a project.



COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CLEAR CREEK PROJECT

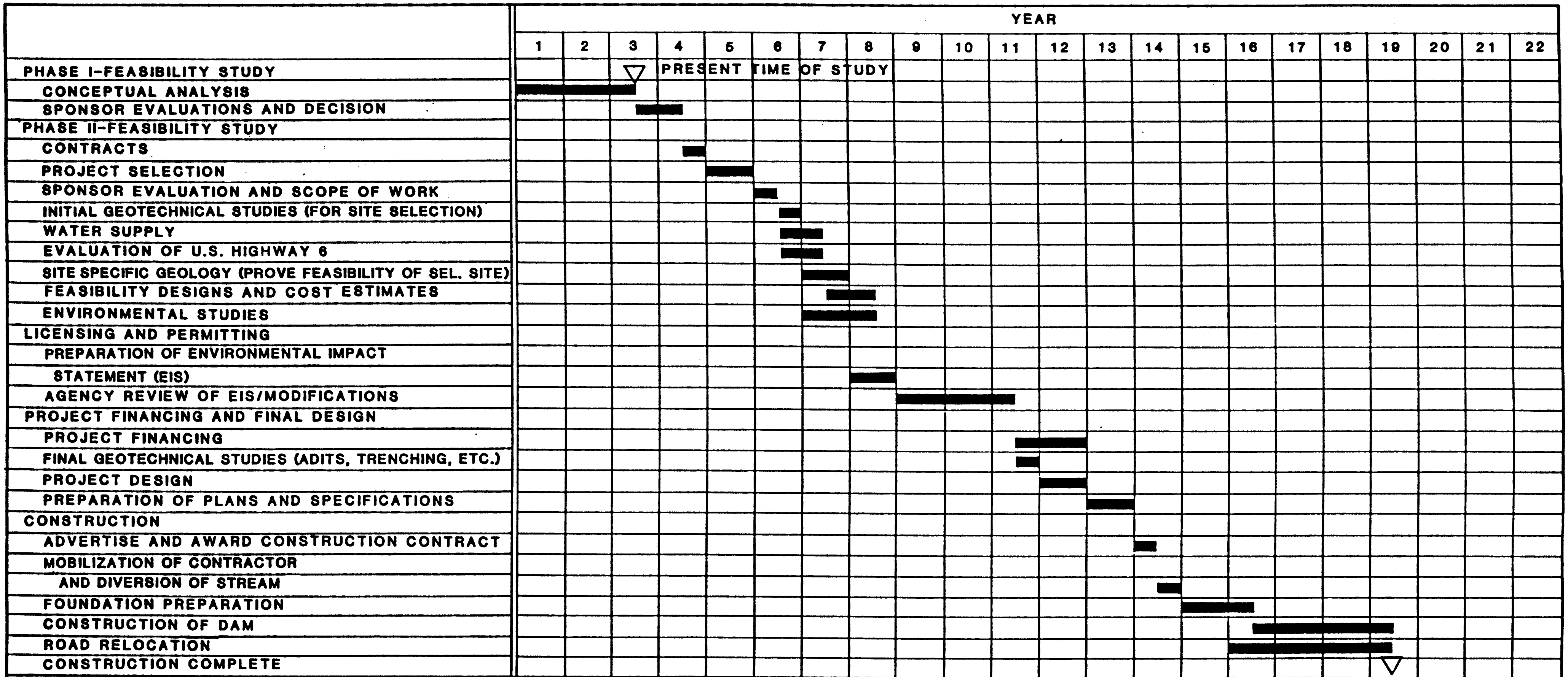
PROJECT AREA MAP

TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
WOODWARD-CLYDE CONSULTANTS
LEONARD RICE CONSULTING WATER ENGINEERS, INC.
MULLER ENGINEERING COMPANY, INC.

DATE: MARCH 1989

FIGURE 1.1

PROJECT DEVELOPMENT: KEY STEPS AND POTENTIAL SCHEDULE (1)



(1) THE ACTUAL SCHEDULE FOR IMPLEMENTING A PROJECT WILL DEPEND UPON THE DEMAND FOR WATER, THE AVAILABILITY OF PROJECT FUNDING, AND THE SUCCESS OF THE PERMITTING ACTIVITIES.

COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CLEAR CREEK PROJECT

PROJECT DEVELOPMENT

TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
WOODWARD-CLYDE CONSULTANTS
LEONARD RICE CONSULTING WATER ENGINEERS, INC.
MULLER ENGINEERING COMPANY, INC.

DATE: JUNE 1989 FIGURE 1.2

Section 2

PROJECT WATER SUPPLY

2.0 PROJECT WATER SUPPLY

2.1 INTRODUCTION

The Clear Creek Project (project) was conceived to increase the municipal and industrial water supply for the northern Denver metropolitan area. The primary component of the project would be a large dam and reservoir in the Clear Creek Canyon at a site yet to be selected.

The project water supplies include the flows which exceed the downstream diversion capacity or demand (flood waters) as well as the downstream direct flow diversions whose yield could be enhanced through project storage (regulated flow). The regulated flow component of the project depends on the level of project participation by Clear Creek water users. This study has been focused on two levels of participation. The first level would be composed of the selected entities that comprise the Clear Creek Water Users Alliance (Alliance). The second level of project participation would be composed of all Clear Creek Basin water users. Seven project water supply scenarios were formulated based on these two levels of project participation. This chapter discusses estimation of the project water supplies and the determination of the relationships between firm yield and required storage for each of the seven supply scenarios.

2.1.1 Background

The foundation for this Step 2 water supply investigation was derived from work previously performed in Step 1 of the Clear Creek Project Phase I Feasibility Study (Authority, 1987). Step 1 included basic data collection on Clear Creek Basin hydrology, existing water supplies and existing water demands, and consideration of that information in a basin simulation model. Section 2.2 includes a discussion of the major assumptions in the Step 1 simulation modeling.

2.1.2 Purpose

The estimation of project water supplies was required for the determination of project firm yield versus storage relationships. The firm yield versus storage relationships were, in turn, an input to the financial analysis described in a subsequent chapter in this report. The firm yield versus storage relationships also were used to reduce the number of project scenarios considered in the project financial analysis to four.

2.1.3 Methodology

The following activities were included in the Step 2 water supply investigation.

1. A review of Step 1 project water sources, resulted in the formulation of the project water supply scenarios indicated in Table 2.1.

TABLE 2.1

Step 2 Project Water Supply Scenarios

Scenario	Project Water Sources
Alliance Decree (AD)	Water available to a 1981 conditional water right owned by the Alliance.
Alliance Transfer (AT)	Alliance sources (excluding Alliance Decree) which can not be effectively regulated with existing Alliance storage.
South Platte Exchange (SPX)	Flows which were modeled as passed from Clear Creek Basin to satisfy South Platte demands. Source availability is dependant on provision of substitute source to South Platte users.
Alliance Sources (AS)	Combination of AD, AT, and partial SPX (SPX as limited by Alliance exchange sources).
Alliance Sources Plus Remaining SPX (ASX)	Combination of AS and remaining SPX.
Basin Management (BAM)	Basin water sources (excluding SPX) which can not be effectively regulated with existing Basin storage.
Basin Combined (BC)	Combination of BAM and SPX.

2. Modification and application of the basin simulation model (model) used in Step 1 to determine the Clear Creek flows available for storage in the project reservoir (storable flows) and flows downstream of the project reservoir that could be utilized by the project on a direct flow basis (downstream flows).
3. Estimation of project firm yield versus storage relationship for the seven water supply scenarios.

This chapter presents summaries of the water supply analyses. More detailed information on assumptions used in the analyses are provided in appendixes. Those appendixes also include detailed output from the analyses.

2.1.4 Results

The firm yield versus storage relationships for each project scenario are the primary products of the project water supply analysis. Project firm yield is defined as the maximum annual supply that can be delivered to a river demand each year of the period from 1947 through 1974. This period of record was the base period used in the Metropolitan Denver Water Supply Systemwide Environmental Impact Statement. Project storage is the amount of storage required to provide the firm yield plus 30,000 acre-feet (af) for a recreation pool and for dead storage.

The estimated maximum project firm yield and the required project storage for each of the seven scenarios are shown in Table 2.2. The maximum project firm yields ranged from approximately 6000 af for the Alliance Transfer project scenario to approximately 60,000 af with full basin management and South Platte exchange. The project firm yields versus project storage relationships are shown in Figure 2.1. The curves in Figure 2.1 are calculated to the point of maximum possible yield for each of the seven water supply scenarios. The addition of incremental storage beyond the end point of each curve will not produce additional firm yield. With the exception of the Alliance Decree scenario, implementation of the scenarios would require institutional changes and water court decrees. The South Platte River Exchange, and combinations using it, would require the acquisition of South Platte water sources.

TABLE 2.2

Maximum Firm Yield and Associated Reservoir Capacity in Acre-Feet

Scenario	Project Firm Yield(1)	Required Project Storage(2)
AD - Alliance Decree	16,100	158,000
AT - Alliance Transfer	6,100	62,000
SPX - South Platte Exchange	10,900	59,000
AS - Alliance Sources	26,000	180,000
ASX - Alliance Plus	38,700	175,000
BAM - Basin Management	43,200	230,000
BC - Basin Combined	61,000	189,000

(1)Production of firm yield requires acquisition of additional water rights or legal transfers, see text.
(2)Includes 30,000 af for recreation pool and dead storage.

2.2 BASIN MODEL

This section describes the basin simulation model used in Step 1 and model modifications made for Step 2. A more detailed description of Step 1 modeling is contained in a previous report (Authority, 1987).

2.2.1 Step 1 Basin Simulation Model

The basin simulation model allocates available water to modeled demands on a daily basis during April through October and on a monthly basis during November, December, January, February, and March. The stream reach modeled was from the gaging station on Clear Creek at Golden (see Figure 2.2) to the Clear Creek confluence with the South Platte. To increase the accuracy of the modeling, this reach was divided into 13 stream sub-reaches in the model.

2.2.1.1 Hydrological Simulation Period

The hydrologic record from 1947 through 1974 was selected for Step 1 simulations of future Clear Creek supplies and demands. The selection was based on inspection of hydrologic records from 1912 through 1985 for the Clear Creek at the Golden gaging station. This station has a drainage area of 400 square miles and records most of the streamflow originating in the Clear Creek Basin. The period from 1947 through 1974 was selected because it included the driest period of record and incorporated large flows at the beginning and end of the simulation period. The mean and standard deviation for the 1947 - 1974 period of record are similar to those for the entire period of continuous record (1912-1988). The selection of the 1947 through 1974 period of record for this analysis is discussed in more detail in the report for Step 1 (Authority, 1987).

2.2.1.2 Land Use

Land use in the Clear Creek Basin downstream of the Golden gaging station factors into calculations of the amount of precipitation runoff and irrigation return flow used in the simulation model. Based on a 1980 census, single-family residential area was estimated at 20,000 acres, urban area (excluding single family residential) was estimated at 11,000 acres, agricultural area was estimated at 5900 acres, and open space area estimated at 48,100 acres. The total classified area was approximately 85,000 acres.

2.2.1.3 Basin Water Supply

In formulating the Step 1 base flow data on which to superimpose demands, the following six major Basin water supply categories were considered:

1. Native flows at the Golden gaging station averaged approximately 158,000 for the 1947-1974 period and represent the largest water source available to Basin water users. Native flows are defined as the flow that is estimated to occur if activities caused by man had not occurred. As discussed in the Step 1 report (Authority, 1987), native flows were estimated by adjusting historic gage records for significant upstream diversions and significant non-tributary inflows. During a simulation, approximately 2000 af were deducted from the modeled flows at Golden to reflect small upstream releases from storage to users downstream of Golden.
2. Irrigation return flow is the water that returns to Clear Creek from the irrigation of agricultural lands or residential lawns in the Clear Creek Basin. The return flow was estimated by applying a 0.0007 af per day (throughout the estimated 214-day irrigation season) factor to each agricultural and residential acre identified by the land use determination. This calculation resulted in approximately 3900 af of average annual irrigation flows in the Step 1 modeling. The irrigation return flows were distributed among the 13 stream reaches based on the irrigated area tributary to each reach.

3. Precipitation runoff to Clear Creek was modeled as 10 percent of the precipitation on single family residential lands and 25 percent of the precipitation on urban lands. Modeled precipitation was derived from the Edgewater and Lakewood precipitation stations. The distribution of precipitation runoff into the 13 stream reaches was made based on estimated land use. Modeled precipitation runoff approximated 4500 af in the Step 1 modeling.
4. Wastewater plant effluent to Clear Creek was modeled from 1) the Coors' General and Process facilities and 2) the Wheat Ridge treatment facility. The Coors' General Wastewater Plant effluent includes effluent from the City of Golden. The amount of effluent modeled in Step 1 was 15.96 cubic feet per second (cfs) or approximately 6800 af per year. Approximately 1600 af of this effluent is produced by the Wheat Ridge treatment facility and is derived from outside the Clear Creek Basin.
5. Ditch augmentation obligations are a percentage of allowable ditch diversions which must be returned to Clear Creek to maintain historic return flows. These are often imposed on ditches being converted to municipal use by court decree. Augmentation obligation percentages were obtained from change-of-use decrees when they were available, or were estimated based on contributing areas to Clear Creek for ditches without change-of-use decrees. Ditch augmentation obligations approximated 15,500 af on an average annual basis in the Step 1 modeling.
6. Transbasin diversions from the Williams Fork Basin were included as a potential water source in the Step 1 modeling. This source would be derived from use of the Denver Water Department's Williams Fork Collection System. An average of 19,700 af per year for the Williams Fork Basin expanded gravity collection system was included in the Step 1 modeling.

The Coors' portion of the wastewater effluent, and the augmentation obligation supplies and the majority of irrigation return flow were derived through the use of the other water supply categories and, therefore, represent reuse supplies. The water supplies available in the Step 1 modeling are summarized in Table 2.3.

TABLE 2.3

Step 1 Modeled Water Supplies
(Average (1947-74) Annuals in Acre-Feet)

Source	Supply
First Time Use Supplies	
Native Flows at Golden	155,600
Wheat Ridge Wastewater Effluent	1,600
Precipitation Runoff	4,500
Williams Fork Transbasin Diversions (Expanded Gravity Collection System)	19,700
Re-use Supplies	
Irrigation Return Flow	3,900
Coors' Wastewater Effluent	5,100
Ditch Augmentation Obligations	15,500
Total	205,900

Two miscellaneous sources included in the modeling, but not included in the above table, are the precipitation contribution to Standley Reservoir and the Ralston Creek inflows to Arvada Reservoir.

2.2.1.4 Water Demands

In estimating project water supply, it was necessary to formulate a reasonable level of demand for water rights senior in priority to the Alliance Decree. The demand formulation was influenced by whether the right was absolute or conditionally decreed and whether the right was direct flow or storage related as discussed below.

Diversions for absolute decreed water rights historically used for irrigation were generally simulated to match historic amounts and patterns. This philosophy is consistent with most change-of-use cases decreed by the Water Court. Monthly diversion limitation factors which varied for dry, average, and wet hydrologic conditions were assigned to each modeled ditch. Conditional water right demands were not constrained to historic diversion levels, but were typically constrained by conveyance, storage, or future demand constraints.

Two levels of conveyance constraints representing existing and future capacities were formulated and used in the Step 1 modeling. Ditch losses were based on historical information or experience and varied from 2 to 35 percent of diversions.

The four existing storage systems modeled were 1) Arvada Reservoir owned by Arvada, 2) Great Western Reservoir owned by Broomfield, 3) Jefferson Storage System owned by Coors, and 4) Standley Reservoir with multiple ownership. Demands were typically imposed on these reservoirs to approximately match the available reservoir supplies. The Step 1 demand on Jefferson Storage was limited to that required to maintain a firm annual Coors demand of approximately 14,200 af. Modeled diversions to storage which exceeded the available reservoir capacity were assumed to be available for project use.

Historic water demands on the Clear Creek Basin from the South Platte River were modeled by not allowing diversions by Clear Creek water rights junior in priority to a "calling" water right on the South Platte. The South Platte calling priorities were derived from inspection of the South Platte water administration records.

To quantify the proposed project South Platte River water exchange, it was necessary to model previously decreed water exchanges for Coors and Arvada. The modeled project exchange was the amount of water passing under call through the gaging station near Golden to the South Platte River.

2.2.1.5 Step 1 Project Scenarios

The project scenarios formulated for the Step 1 project firm yield analysis are presented in Table 2.4.

TABLE 2.4

Step 1 Project Scenarios

	Project Water Supply
Junior Decree Current	Alliance 1981 conditional decree with current facilities' capacities.
Junior Decree Future	Alliance 1981 conditional decree with future facilities' capacities.
Alliance Transfer	Transfer of selected Alliance water rights to project storage combined with Junior Decree scenario.
Junior + Williams Fork Imports	The Junior Decree Current supply combined with transbasin diversions from the Williams Fork Basin with the existing Water Department collection system.
Junior + Williams Fork Imports	The Junior Decree Future supply combined with transbasin diversions from the Williams Fork Basin with the expanded Water Department collection system.
Basin Management	Management of water available at Clear Creek near Golden gaging station.
South Platte Exchange	Effluent exchange using full Clear Creek Basin's exchange potential with South Platte.

2.2.2 Step 2 Model Modifications

Additional data availability, new assumptions, and reformulation of the project water supply scenarios justified Step 2 modifications to the basin simulation model. These modifications are described in this section.

2.2.2.1 Land Use

Because the precipitation runoff and irrigation return flow sources depend on the modeled land use classification, it was believed to be more reasonable in Step 2 to model future rather than current land use patterns.

To estimate future land use downstream of the Clear Creek gaging station at Golden, the Step 1 open use and agricultural lands were examined to identify lands that could be developed. Lands consisting of flood plains, parks, or lakes were assumed to remain in open or agricultural use. Areas with steep topography or lands where it would be difficult to provide utility service were also assumed to remain in open or agricultural use. The remaining open and agricultural lands were assumed to develop to residential and urban land uses in a ratio similar to that which existed in 1980. No future date was assigned to the estimated land use acreage. A comparison between Step 1 and Step 2 land use acreage is presented in Table 2.5.

Incorporation of the assumed future land uses in the modeling made relatively little difference in the storable flow or firm yield results of the study. The diversion to the Alliance Decree increased on the average by approximately 100 af per year when future rather than current land use patterns were modeled.

2.2.2.2 Basin Water Supply

Five of the Step 1 Basin water supply categories were included in the Step 2 modeling effort. The sixth, the Williams Fork transbasin diversion, was excluded from Step 2 analysis because of the unavailability of this supply to the project.

In addition to the changes made to sources caused by changing the land use pattern, the following modifications to the modeled sources were made and produced the water supplies indicated in Table 2.6.

TABLE 2.5

Comparison of 1980 and Future Clear Creek Land Uses(1)
(Values in Acres)

Step	Residential	Urban	Agricultural	Open
1 (1980)	19,998	11,040	5,857	48,120
2 (Future)	31,348	17,033	2,912	33,722

(1)Excludes land upstream of Ralston Reservoir.

TABLE 2.6

Step 2 Modeled Water Supplies
(Average (1947-74) Annuals in Acre-Feet)

	Supply
First Time Use Supplies	
Native Flows at Golden	155,600
Wheat Ridge Wastewater Effluent	1,600
Precipitation Runoff	6,900
Re-use Supplies	
Irrigation Return Flow	5,100
Coors' Wastewater Effluent	7,600
Ditch Augmentation Obligations	17,900
Total	194,700

1. The wastewater effluent to Clear Creek was increased from 15.96 cfs to 21.86 cfs based on recent information on Coors' future development level.
2. Because the Church Ditch is the highest elevation ditch north of Clear Creek, it captures considerable runoff from upstream lands. The runoff available to Great Western Reservoir from the Church Ditch is estimated by Broomfield engineers to average 1400 af per year. Inclusion of this source in the modeling reduced the modeled demand for Clear Creek supplies. A summary of the resulting Step 2 water supplies is shown in Table 2.6.

2.2.2.3 Demand

Based on information received from Clear Creek water users, a set of probable future capacities of the existing basin facilities was established for the Step 2 modeling. This set of capacities replaced the two sets (current and future) of capacities used for basin facilities in the Step 1 modeling. Additional modifications to the Step 1 demand data are presented in the following list.

1. A Northglenn junior priority decree for a 13,440 af enlargement of Standley Reservoir was modeled.
2. A decree for 50 cfs owned by the City of Broomfield was added because it is senior in priority to the Alliance Decree.
3. Thornton's pending application for an exchange from South Platte River sources to Clear Creek structures was modeled because it could reduce the amount available under the project's South Platte River Exchange. The

maximum exchange potential was assumed to be 2 cfs in April, 41 cfs in May, 63 cfs in June, 47 cfs in July, 3 cfs in August, and 1 cfs in September.

4. Pending changes to a winter exchange of water from Jefferson Storage with the Croke Canal required the removal of this exchange in the Step 2 modeling.
5. The demands on Arvada, Great Western, Jefferson Storage, and Standley reservoirs were adjusted to better match the water supplies available in the Step 2 modeling.

2.2.2.4 Project Water Supply Scenarios

Significant differences occur in the definition of some of the project water supply scenarios from Step 1 to Step 2. These differences are indicated in Table 2.7.

2.3 STORABLE AND DOWNSTREAM FLOWS

Estimates of the water available to the seven project scenarios are required to estimate project firm yields and storage requirements. Water availability to a given scenario's water rights has been differentiated based on whether the water originates upstream or downstream of project storage. Water availability originating upstream of a project storage site in the Clear Creek Canyon has been designated as "storable flows." Water availability which originates downstream of a project storage site in the Clear Creek Canyon has been designated as "downstream flows." The sum of the storable and downstream flow components results in the total water availability in the Clear Creek Basin for a given scenario of water rights.

Five of the scenarios (AT, AS, ASX, BAM, and BC) include water rights presently being used in the Basin. Therefore, a portion of the water availability estimated for these scenarios would have been available with or without project storage. The "total firm yield" estimated for these scenarios will include a combination of existing firm yield and "net" or project firm yield. A methodology is presented in Section 2.4 to explain how the project (net) firm yield for each scenario is derived from the total firm yield.

TABLE 2.7

Comparison of Step 1 and Step 2 Project Scenarios

Step 1 Scenario	Step 2 Modification
Junior Decree Current	Not included in Step 2.
Junior Decree Future	Renamed Alliance Decree.
Alliance Transfer	Removed Alliance Decree source from this scenario. Also removed existing storage restrictions on use of transferred water rights.
Junior + WF Current	Not included in Step 2 since Williams Fork source not available.
Junior + WF Future	Not included in Step 2 since the Williams Fork source not available.
Basin Management	Step 2 project supplies include 12 months of flow to reflect storage capture of winter flows and also includes flow downstream of project reservoir.
South Platte Exchange	Added consideration of Thornton Exchange.
	Added Alliance Sources scenario.
	Added Alliance Sources plus the Remaining South Platte Exchange scenario.
	Added Basin Combined scenario.

The following sections describe the methodology and results of the storable and downstream flow generation for the seven project scenarios. Detailed monthly tabulations of the storable flow and downstream flow for the seven project scenarios may be found in the appendixes.

2.3.1 Methodology

Two simulations were performed to determine the storable and downstream flows for the Step 2 project scenarios. These simulations differed in the modeled capacity of Standley Reservoir. Standley Reservoir was placed at its existing storage level of 42,700 af for those scenarios which included Basin Management because it was believed that Standley Reservoir would not be enlarged if project storage was made available to Standley owners. For the non-Basin

Management project scenarios, it was assumed that Standley Reservoir would be enlarged to its proposed capacity of 62,500 af.

Various utility programs were used to summarize model output in estimating storable and downstream flows. For example, the following equations were used to estimate the storable and downstream flows for the Alliance Sources scenario:

Alliance Sources Storable Flow = ADF + ATU + ASPX

where
- ADF is the modeled available flow to the Alliance Decree
- ATU is the modeled allowable Alliance depletions upstream of the Reno and Juchem Ditch.
- ASPX is the modeled South Platte Exchange limited to estimated available Alliance exchange sources.

Because the project reservoir would be located upstream of the Clear Creek gaging station at Golden, the storable flows at the reservoir site were limited to 95 percent of the flow reported at the Golden gaging station. This relationship of reservoir inflow to downstream gaged flow is based on historic runoff per square mile relationships for stream gaging stations on Clear Creek and Ralston Creek.

2.3.2 Alliance Decree

The Alliance Decree was appropriated on December 10, 1981, and adjudicated on December 31, 1981. Operation of this water right in the model resulted in an average annual storable flow of approximately 21,400 af as shown in Table 2.8. No downstream flow was available to this project scenario because no water rights other than the 1981 appropriation are a part of this scenario.

TABLE 2.8

Alliance Decree - Storable and Downstream Flows
Annual Values in Thousand Acre-Feet

	Storable Flow	Downstream Flow	Total
Average Annual (1947-74)	21	0	21
Minimum Year (1950,51,..)	0	0	0
Maximum Year (1957)	92	0	92

2.3.3 Alliance Transfer

The Alliance Transfer scenario would provide storage to regulate water divertible under existing Alliance water rights (excluding the Alliance Decree). The storable flows consist of the depletions available for transfer to project storage. For this analysis it has been assumed that depletions associated with the Alliance water rights upstream of and including the Reno and Juchem Ditch are transferable to project storage. The Alliance Transfer downstream flows consist of allowable Alliance depletions with water rights downstream of the Reno and Juchem Ditch.

The annual sum of the Alliance Transfer storable and downstream flows ranged from 13,800 af to 47,100 af and averaged 29,400 af (see Table 2.9). As explained earlier, these flows include water which is currently used to produce the existing Alliance firm yield and were used to determine total firm yield for the scenario. Explanation is provided in Section 2.4 ("Firm Yield") of the methodology used to determine the "net" or project firm yield from the total firm yield value.

2.3.4 South Platte River Exchange

An exchange opportunity with the South Platte River occurs when a South Platte River demand for water restricts diversion by Clear Creek ditches. The storable flow for the South Platte Exchange scenario is the estimated amount of water that occurs at the Clear Creek gaging station at Golden which is passed from the Clear Creek Basin to the South Platte River demand. This water would become available for use in the project if a non-Clear Creek Basin replacement source of water is provided to the South Platte River demands. Although a replacement source of water was not identified in this investigation, some consideration of the cost of a replacement source was included in the project financial analysis. The South Platte Exchange storable flows are summarized in Table 2.10. The estimated remaining exchange potential ranged from approximately 2000 af to 44,000 af and averaged approximately 18,000 af. No downstream flow component was included in this scenario.

TABLE 2.9

Alliance Transfer - Storable and Downstream Flows
Annual Values in Thousand Acre-Feet

	Storable Flow	Downstream Flow	Total
Average Annual (1947-74)	24	5	29
Minimum Year (1954)	9	5	14
Maximum Year (1947)	42	5	47

TABLE 2.10

South Platte Exchange - Storable and Downstream Flows
(Annual Values in Thousand Acre-Feet)

	Storable Flow	Downstream Flow	Total
Average Annual (1947-74)	18	0	18
Minimum Year (1954)	2	0	2
Maximum Year (1953)	44	0	44

The South Platte River demands on Clear Creek were quantified by reach as shown in Table 2.11. Demands whose reach could not be identified were placed in an "unidentified" reach.

TABLE 2.11

Estimated Water Passed from Clear Creek to South Platte Demand (by River Reach) (Values in Thousand Acre-Feet per Year)

Reach(1)	Amount Passed Under Call		
	Average	Minimum	Maximum
Upstream of Clear Creek(2)	4	0	20
Clear Creek to Big Dry Creek	4	0	19
Big Dry Creek to St. Vrain	1	0	4
St. Vrain to Big Thompson	0	0	0
Big Thompson to Cache La Poudre	1	0	3
Cache La Poudre to District 64	4	0	17
District 64	1	0	9
Unidentified	3	0	23
Total	18		

(1) Reaches identified by confluence of each named creek with the South Platte River.

(2) Caused by Burlington Ditch demand which is not currently administered against Clear Creek.

2.3.5 Alliance Sources

The Alliance Sources scenario is a composite of the Alliance Decree scenario, the Alliance Transfer scenario, and a portion of the South Platte River Exchange scenarios. The South Platte Exchange was limited to the estimated availability of Alliance South Platte replacement sources. The replacement source quantified was the effluent and lawn return flows generated by use of Alliance allowable depletion water, estimated as 66 percent of municipal and Coors' industrial uses. This Alliance source was equally distributed throughout the year and compared with the potential South Platte Exchange. The estimated South Platte Exchange available (storable flow) with Alliance replacement sources is summarized in Table 2.12.

Combining the individual scenario values from Tables 2.8, 2.9, and 2.12 provides the storable and downstream flows for the Alliance Source as shown in Table 2.13. The range of storable and downstream flow is from 16,000 af to 134,000 af and the annual average is approximately 54,000 af. It is important to note that these flows include water that is currently used to produce the existing Alliance firm yield.

2.3.6 Alliance Sources Plus Remaining South Platte Exchange

The storable and downstream flows for the Alliance Sources Plus Remaining South Platte Exchange are summarized in Table 2.14. The annual sum of the storable and downstream flows ranges from 16,000 af to 140,000 af and averages 68,000 af. These flows include water that is currently used to produce the existing Alliance firm yield.

While South Platte replacement sources in addition to those available from the Alliance have not been identified, consideration of the cost of acquiring the replacement sources is contained in the financial analysis.

TABLE 2.12

Potential South Platte Exchange (Storable Flow) with Alliance Sources in Thousands of Acre-Feet

	Alliance S. Platte Exchange Potential
Average Annual (1947-74)	3
Minimum Annual (1954)	2
Maximum Annual (1962)	5

TABLE 2.13

Alliance Sources-
Storable and Downstream Flows
(Annual Values in Thousand Acre-Feet)

	Storable Flow	Downstream Flow	Total
Average Annual (1947-74)	49	5	54
Minimum Year (1954)	11	5	16
Maximum Year (1949)	129	5	134

TABLE 2.14

Alliance Sources Plus Remaining South Platte Exchange-
Storable and Downstream Flows
(Annual Values in Thousand Acre-Feet)

	Storable Flow	Downstream Flow	Total
Average Annual (1947-74)	63	5	68
Minimum Year (1954)	11	5	16
Maximum Year (1957)	135	5	140

2.3.7 Basin Management

In the Basin Management scenario, Clear Creek Basin water, excluding historic flows required by South Platte River demands, is managed without regard to ownership or the prior appropriation system. This scenario assumes that historic levels of return flows of Clear Creek diversions to non-Clear Creek Basins will be maintained by using effluent derived from Clear Creek sources and discharged at the Metropolitan Denver Sewage Disposal Plant No. 1 and the Big Dry Creek wastewater plants belonging to Clear Creek users (Broomfield, Westminster, and Northglenn).

Table 2.15 summarizes the storable and downstream flows estimated for the Basin Management scenario. The annual sum of the storable and downstream flows ranges from 77,000 af to 267,000 af and averages 160,000 af. These flows include water that is currently used to produce the existing Basin firm yield.

2.3.8 Basin Combined

The Basin Combined scenario is a composite of the Basin Management scenario and the South Platte Exchange scenario. Storable and downstream flows estimated for this scenario are summarized in Table 2.16 and average 178,000 af per year.

TABLE 2.15

Basin Management-
Storable and Downstream Flows
(Annual Values in Thousand Acre-Feet)

	Storable Flow	Downstream Flow	Total
Average Annual (1947-74)	149	11	160
Minimum Year (1954)	58	19	77
Maximum Year (1957)	263	4	267

TABLE 2.16

Basin Combined-
Storable and Downstream Flows
(Annual Values in Thousand Acre-Feet)

	Storable Flow	Downstream Flow	Total
Average Annual (1947-74)	149	29	178
Minimum Year (1954)	58	21	79
Maximum Year (1957)	263	40	303

These flows include water that is currently used to produce the existing Basin firm yield.

2.4 FIRM YIELD

The primary products of the project water supply investigations are the estimated firm yields which can be generated by each of the seven project scenarios. **Project firm yield is defined as the maximum annual supply which can be delivered to a demand on the river each year of the 1947 through 1974 period.** Because the firm yield of a project will vary with the amount of project storage provided, curves of the firm yield versus storage are required in subsequent financial evaluations of the project.

2.4.1 Methodology

The firm yield versus storage relationships for each of the seven project scenarios were derived by applying a computerized mass balance procedure to the previously discussed storable and downstream flows. The analysis was performed on a monthly basis for the 1947 - 1974 hydrologic simulation period.

The firm yield analyses assumed the project demand was located at the confluence of Clear Creek and the South Platte River and had a pattern similar to existing municipal and industrial Clear Creek water use. In the calculation of firm yield, the downstream flows were assumed to be the first source available to the demand. Project storage water produced by the storable flows was next used to satisfy demand shortages.

Because the storable and downstream flows for the AT, AS, ASX, BAM, and BC scenarios include flows that are part of the present basin firm yield, the firm yields derived from these flows will include an existing firm yield component that is additional to the project firm yield. Therefore, the next section of this report describes the estimation of the existing Alliance firm yield, and the existing Basin firm yield, and the adjustment of the derived (or total) firm yields and storage to obtain project (or net) firm yields and the corresponding required project storage.

The estimated project storage requirements include 30,000 af for dead storage and a recreation pool. Water to fill this 30,000 af of capacity was not included in the firm yield calculations. However, storage contents on which the evaporation losses were charged during the firm yield analyses included the 30,000 af pool.

When reporting selected values from the firm yield versus storage relationships, a ratio of the active storage requirements to the associated firm yield is also reported. This acre-foot of storage per acre-foot of firm yield is useful in comparing various scenarios and storage levels within a scenario.

2.4.2 Existing Alliance and Basin Firm Yield

As previously discussed, estimates of the existing Alliance firm yield and existing Basin firm yield are needed to derive project firm yields. The firm yield estimates for the project scenarios, except AD and SPX, include existing firm yield water supplies which would be available even if the project were not implemented. Therefore, the existing system firm yields had to be excluded in deriving project firm yields.

The existing Alliance firm yield was estimated by adding the modeled firm yield from the existing Alliance storage to the dry year (1954) allowable direct flow depletions for Alliance sources which have no associated storage regulation. The existing Alliance firm yield is estimated to be 21,600 af with 17,250 af of existing Alliance storage.

The existing Basin firm yield was estimated by adding the modeled firm yield from the existing Basin storage to the 1954 allowable direct flow depletions for Basin sources which are not regulated. The existing Basin firm yield is estimated to be 96,000 af with an existing Basin storage of 60,000. It was estimated that this firm yield and storage translates into an existing firm yield of 108,000 af if the demands were at the river and did not suffer conveyance losses. The associated storage required to develop 108,000 af of firm yield at the river is estimated to be 75,000 af. The Basin scenario firm yields were reduced by the 108,000 af to estimate project firm yields. A corresponding reduction of 75,000 af was made to the Basin scenario storage requirements.

2.4.3 Alliance Decree

The maximum project firm yield for the Alliance Decree scenario is estimated to be 16,000 af if approximately 156,000 af of project storage is provided. Table 2.17 presents estimated firm yields a range of storage levels. Additional points on the firm yield versus storage relationship can be derived from Figure 2.1.

TABLE 2.17

Alliance Decree,
Selected Project Yields and Storage Requirements

Project Firm Yield(af)	Required Project Storage (af)	Active Storage/ Yield Ratio
8,000	71,000	5.1
12,000	97,000	5.6
16,100	158,000	8.0

2.4.4 Alliance Transfer

The maximum project firm yield for the Alliance Transfer scenario is estimated to be approximately 6000 af if approximately 62,000 af of project storage is provided. Additional points on the firm yield versus storage relationship can be derived from Table 2.18 or Figure 2.1.

2.4.5 South Platte Exchange

The maximum project firm yield for the South Platte Exchange scenario is estimated to be approximately 11,000 af if approximately 59,000 af of project storage is provided. Additional points on the firm yield versus storage relationship can be derived from Table 2.19 or Figure 2.1.

2.4.6 Alliance Sources

The maximum Alliance Sources scenario project firm yield is estimated to be 26,000 af if approximately 180,000 af of project storage is provided. Additional points on the firm yield versus storage relationship can be derived from Table 2.20 or Figure 2.1.

TABLE 2.18

**Alliance Transfer,
Selected Project Yields and Required Project Storage**

Project Firm Yield(af)	Required Project Storage (af)	Active Storage/ Yield Ratio
3,000	45,000	5.0
6,100	62,000	5.2

TABLE 2.19

**South Platte Exchange,
Selected Project Yields and Storage Requirements**

Project Firm Yield(af)	Required Project Storage (af)	Active Storage/ Yield Ratio
5,000	38,000	1.6
10,900	59,000	2.7

TABLE 2.20

Alliance Sources
Selected Project Yields and Storage Requirements

Project Firm Yield(af)	Required Project Storage (af)	Active Storage/ Yield Ratio
13,000	74,000	3.4
26,000	180,000	5.8

2.4.7 Alliance Sources Plus Remaining South Platte Exchange

The maximum project firm yield for the Alliance Sources Plus remaining South Platte Exchange is estimated to be 39,000 af if approximately 175,000 af of project storage is provided. Additional points on the firm yield versus storage relationship can be derived from Table 2.21 or Figure 2.1.

Each reservoir capacity - demand point on the firm yield versus storage curve would create a unique set of reservoir contents, elevations and surface areas if operated for the 1947 through 1974 historic period. Figure 2.3 shows the reservoir contents, elevations, and surface areas for a 175,000 af project reservoir (ASX scenario) with an annual demand approximating 39,000 af.

2.4.8 Basin Management

The maximum project firm yield for the Basin Management scenario is estimated to be 44,000 af if approximately 237,000 af of project storage is provided. Additional points on the firm yield versus storage relationship can be derived from Table 2.22 or Figure 2.1.

TABLE 2.21

Alliance Sources Plus Remaining South Platte Exchange
Selected Project Yields and Storage Requirements

Project Firm Yield(af)	Required Project Storage (af)	Storage/Yield Ratio
20,000	70,000	2.0
30,000	107,000	2.6
38,700	175,000	3.7

TABLE 2.22

Basin Management,
Selected Project Yields and Storage Requirements

Project Firm Yield(af)	Required Project Storage (af)	Storage/Yield Ratio
22,000	108,000	3.5
33,000	161,000	4.0
44,000	237,000	4.7

Each reservoir capacity - demand point on the firm yield versus storage curve would create a unique set of reservoir contents, elevations and surface areas if operated for the 1947 through 1974 historic period. Figure 2.4 shows the reservoir contents, elevations, and surface areas for a 230,000 af project reservoir (BAM scenario) with an annual demand approximating 43,200 af.

2.4.9 Basin Combined

The maximum project firm yield for the Basin Combined scenario is estimated to be 61,000 af if approximately 189,000 af of project storage is provided. Additional points on the firm yield versus storage relationship can be derived from Table 2.23 or Figure 2.1.

Each reservoir capacity - demand point on the firm yield versus storage curve would create a unique set of reservoir contents, elevations, and surface areas if operated for the 1947 through 1974 historic period. Figure 2.5 shows the reservoir contents, elevations, and surface areas for a 189,000 af project reservoir (BC scenario) with an annual demand approximating 61,000 af.

2.4.10 Summary

The Step 2 water supply analysis has indicated the potential for developing considerable amounts of firm yield by the Clear Creek project. Table 2.24 summarizes the maximum firm yields and associated storage requirements estimated for each of the seven project scenarios. Figure 2.1 presents the estimated firm yield versus required storage relationships for the seven project scenarios investigated. The following observations were drawn from the analyses:

1. With the approximate capacity (230,000 to 240,000 af) of the reservoir site being investigated in Step 2, one can maximize the firm yield of any project scenario.
2. The low storage/yield ratios for those scenarios which include a South Platte River exchange indicate that the most dependable source which could be developed is the South Platte River exchange. The availability and cost of replacement sources to enable the South Platte River exchange have not yet been investigated.
3. The diversity of the various water sources combined in a scenario, has produced firm yield synergy (that is, a combination in which the whole is greater than the sum of the parts). An example of this synergy is that the Basin Combined scenario has a greater firm yield than the sum of the firm yields for the Basin Management and South Platte Exchange scenarios.

TABLE 2.23

Basin Combined, Selected Project Yields and Storage Requirements

Project Firm Yield(af)	Required Project Storage (af)	Active Storage/ Yield Ratio
30,000	79,000	1.6
45,000	122,000	2.0
61,000	189,000	2.6

TABLE 2.24

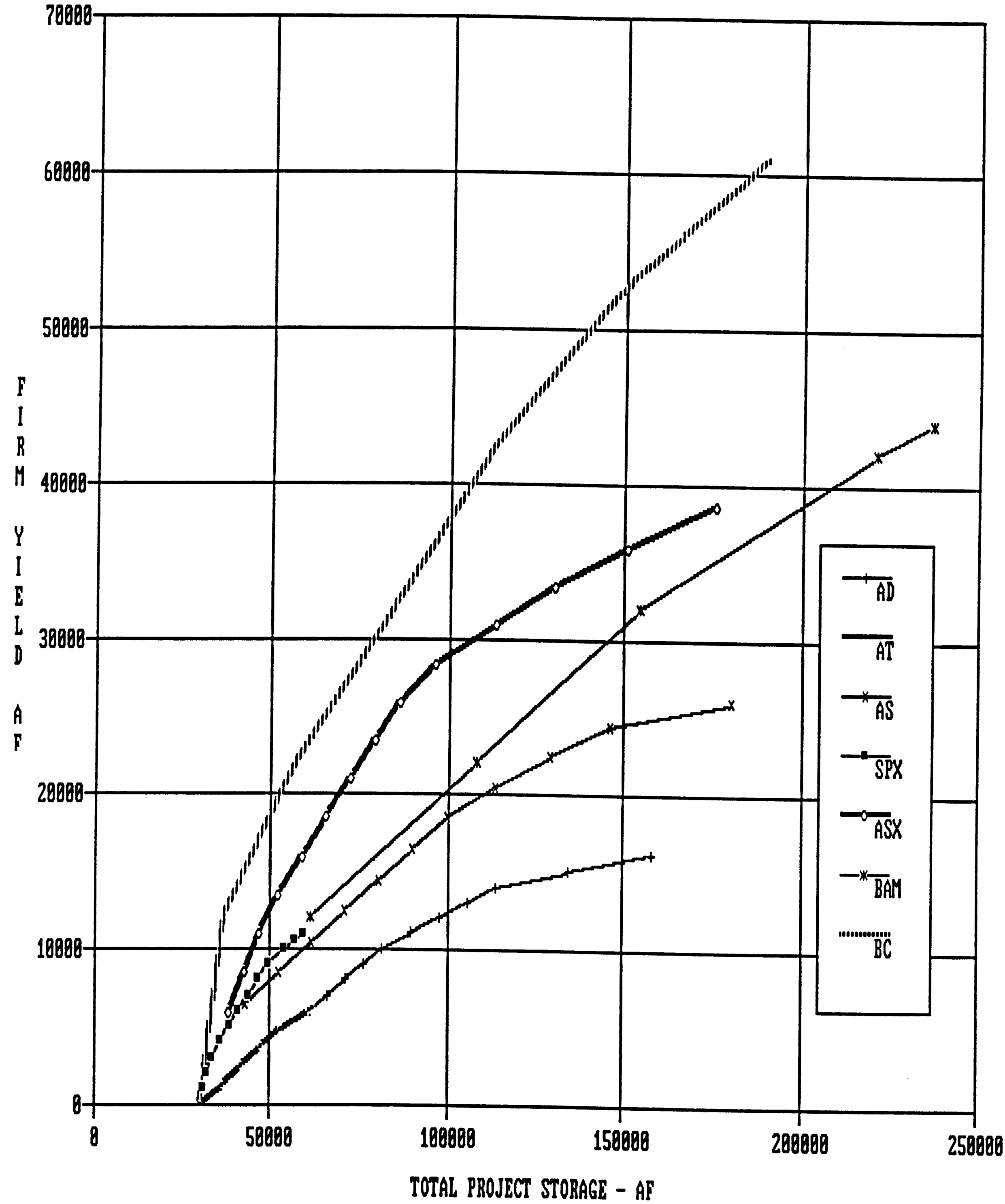
Maximum Firm Yield - Storage Requirement Summary for Seven Clear Creek Project Scenarios

Scenario	Project Firm Yield(1)	Total Project Storage (2)	Active Storage to Firm Yield Ratio
AD - Alliance Decree	16,100	158,000	8.0
AT - Alliance Transfer	6,100	62,000	5.2
SPX - South Platte Exchange	10,900	59,000	2.7
AS - Alliance Sources	26,000	180,000	5.8
ASX - Alliance Plus SPX	38,700	175,000	3.7
BAM - Basin Management	43,200	230,000	4.6
BC - Basin Combined	61,000	189,000	2.6

(1)Production of firm yields may require acquisition of additional water rights or legal transfers, see text.
(2)Includes 30,000 af for recreation pool and dead storage.

The water supply analysis has also indicated that a large project reservoir could create a very high use efficiency of Clear Creek water sources. This is illustrated in Figure 2.6 which compares estimates of the available project water supply (after adjustment for supplies efficiently used in the Basin) with the estimated maximum project firm yield. On the average, maximum firm yield averages 80 percent of the available project supply.

Because of the complexity of the Clear Creek Basin, the storable flow and firm yield analyses have relied on simplifications of basin operation. Because of the difficulty of considering potential water use inefficiencies or potential in-stream flows downstream of project facilities (which may be maintained by project releases), consideration of these aspects are deferred to subsequent investigations of project water supply. For these reasons, the Step 2 water supply evaluations should be considered preliminary but suitable for use as the basis for more detailed investigations of project feasibility.



COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY

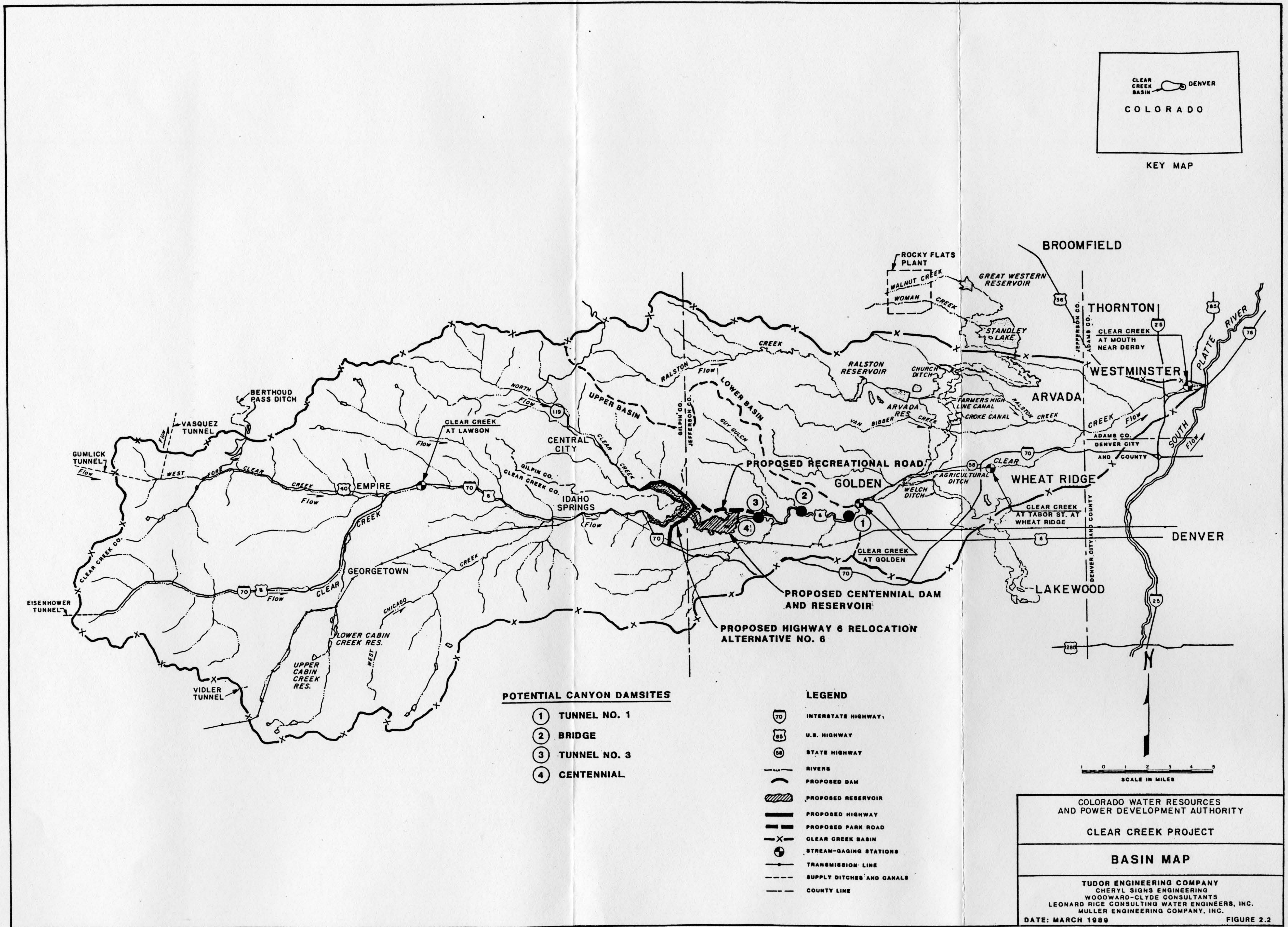
CLEAR CREEK PROJECT

FIRM YIELD
VS. TOTAL STORAGE

TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
WOODWARD-CLYDE CONSULTANTS
LEONARD RICE CONSULTING WATER ENGINEERS, INC.
MULLER ENGINEERING COMPANY, INC.

DATE: MARCH 1989

FIGURE 2.1



COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

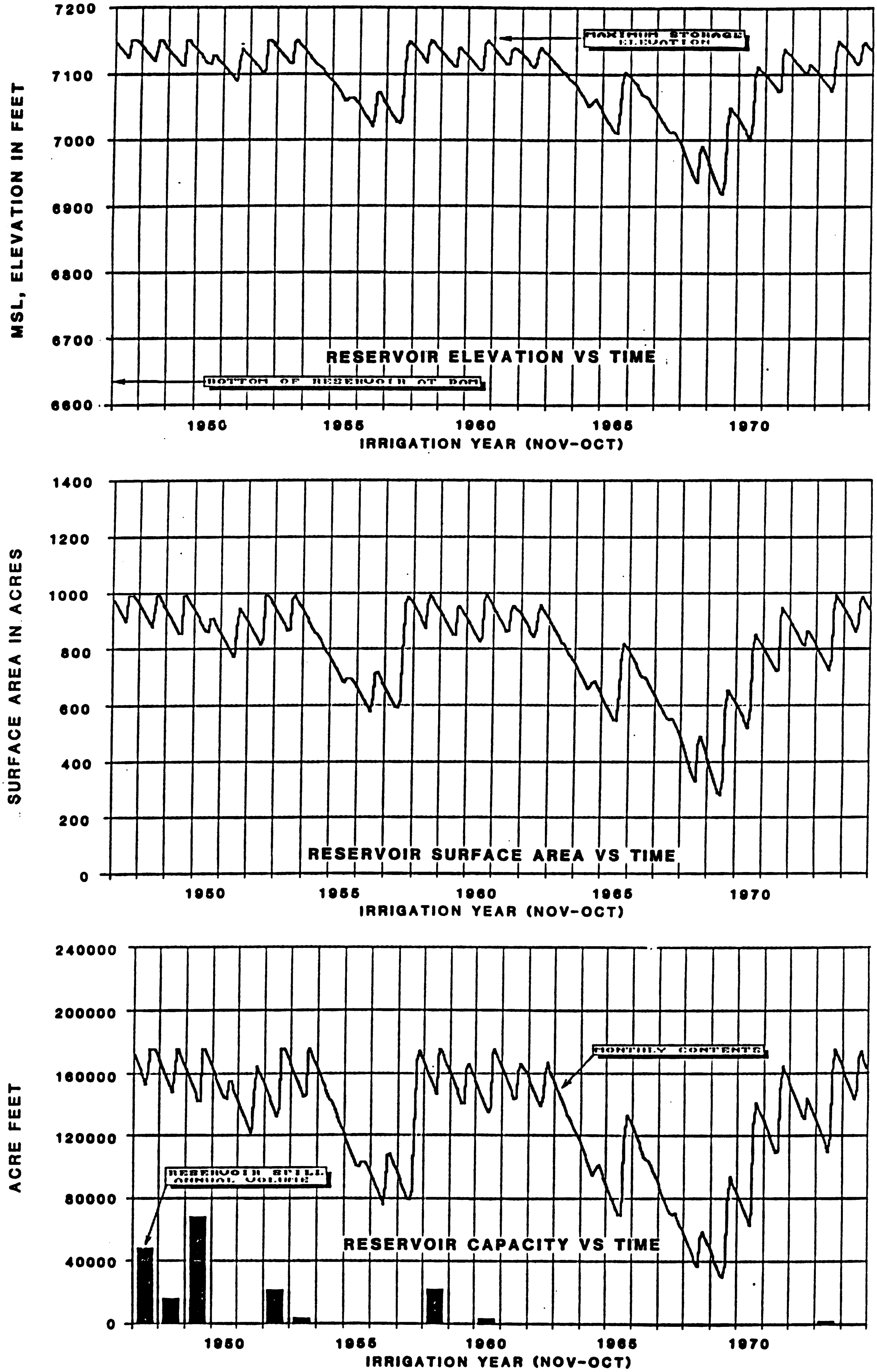
CLEAR CREEK PROJECT

BASIN MAP

TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
WOODWARD-CLYDE CONSULTANTS
LEONARD RICE CONSULTING WATER ENGINEERS, INC.
MULLER ENGINEERING COMPANY, INC.

DATE: MARCH 1989

FIGURE 2.2



NOTE:

GRAPHS SHOW MONTHLY RESERVOIR OPERATION WITH RESERVOIR INITIALLY FULL, FOR THE ALLIANCE SOURCE PLUS SOUTH PLATTE EXCHANGE WITH:

RESERVOIR CAPACITY = 175,000 AF

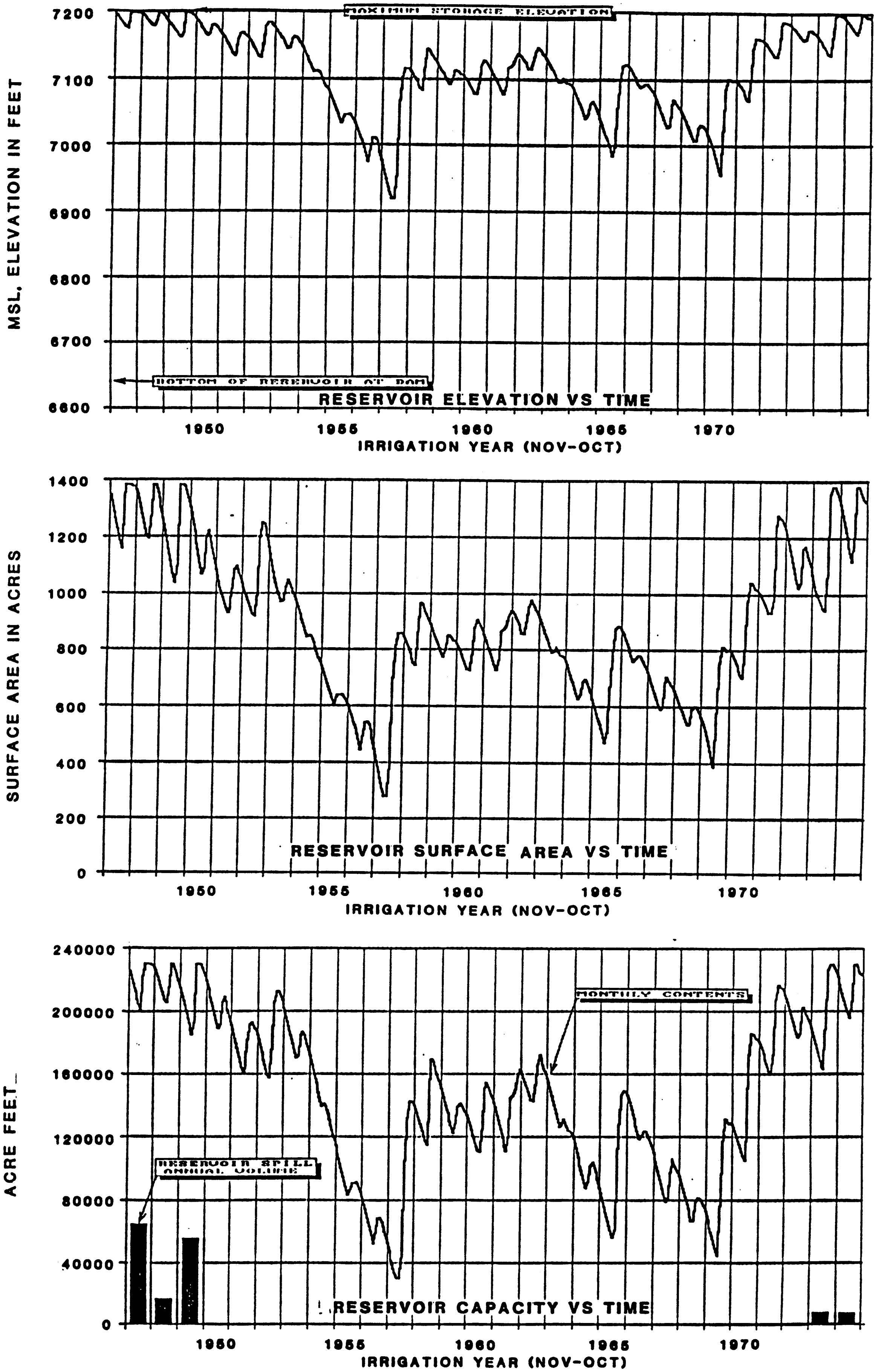
FIRM YIELD = 38,700 AF/YR

COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY
CLEAR CREEK PROJECT

RESERVOIR OPERATION
ALLIANCE SOURCE PLUS
SOUTH PLATTE EXCHANGE

TUDOR ENGINEERING COMPANY
CHENYL SIGNS ENGINEERING
WOODWARD-CLYDE CONSULTANTS
LEONARD RICE CONSULTING WATER ENGINEERS, INC.
MULLER ENGINEERING COMPANY, INC.

DATE: MARCH 1988 FIGURE 2.3



NOTE:

GRAPHS SHOW MONTHLY RESERVOIR OPERATION WITH RESERVOIR INITIALLY FULL, FOR THE BASIN MANAGEMENT SCENARIO WITH:
RESERVOIR CAPACITY = 230,000 AF
FIRM YIELD = 43,000 AF/YR

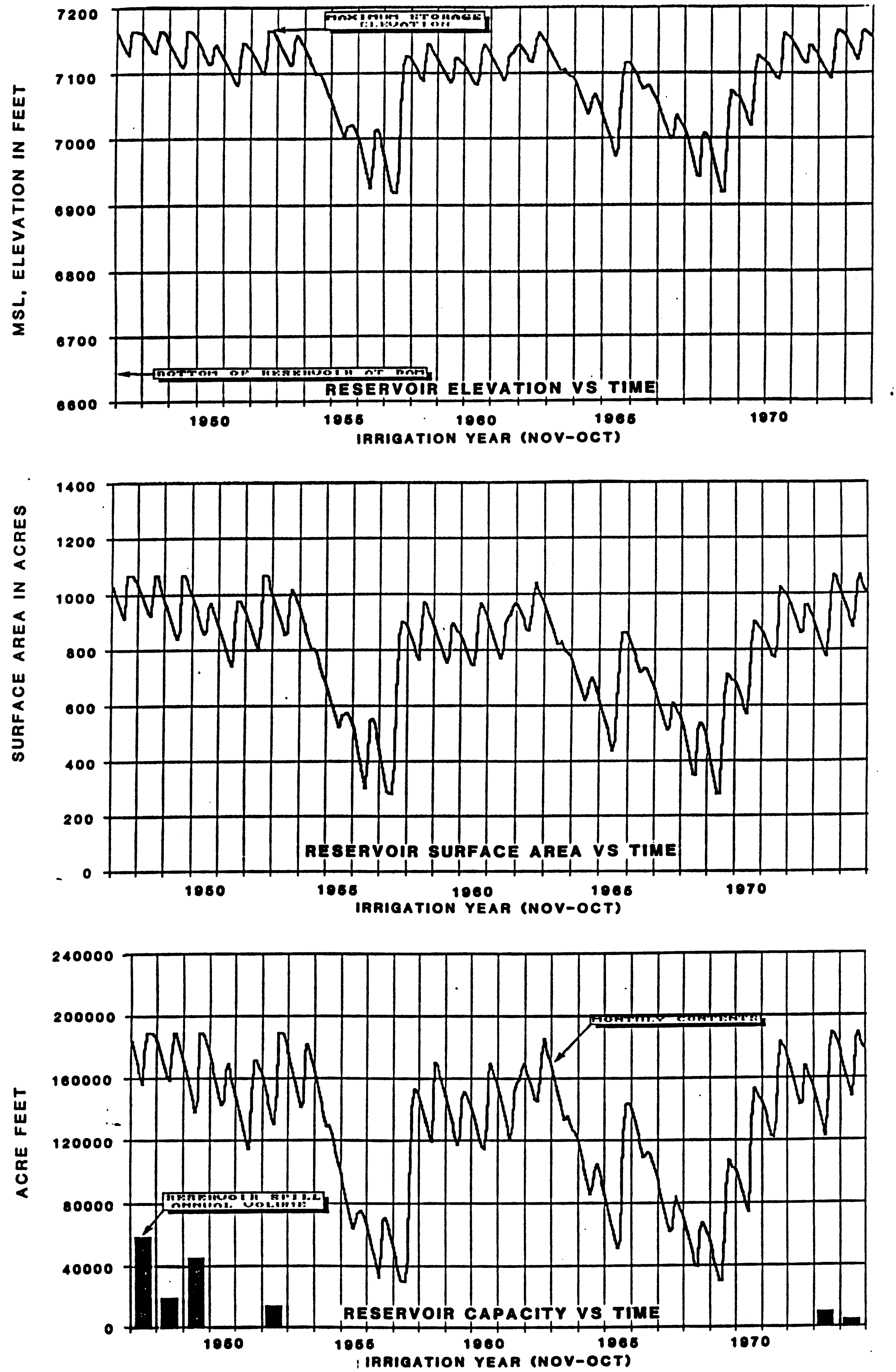
COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CLEAR CREEK PROJECT

RESERVOIR OPERATION
BASIN MANAGEMENT SCENARIO

TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
WOODWARD-CLYDE CONSULTANTS
LEONARD RICE CONSULTING WATER ENGINEERS, INC.
MULLER ENGINEERING COMPANY, INC.

DATE: MARCH [illegible] FIGURE 2.4



NOTE:

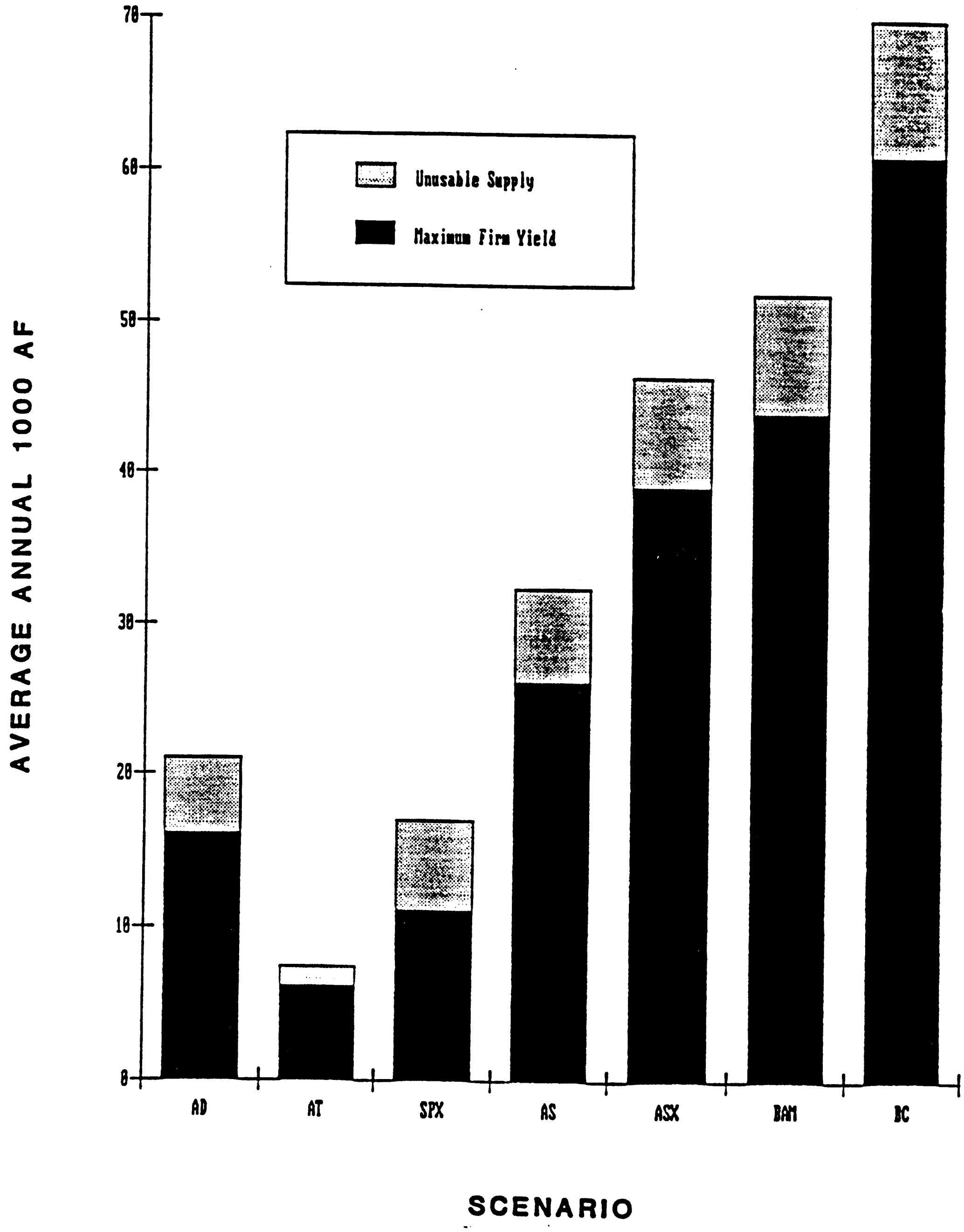
GRAPHS SHOW MONTHLY RESERVOIR OPERATION WITH RESERVOIR INITIALLY FULL, FOR THE BASIN COMBINED SCENARIO WITH:
RESERVOIR CAPACITY = 189,000 AF
FIRM YIELD = 61,000AF/YR

COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY
CLEAR CREEK PROJECT

RESERVOIR OPERATION
BASIN COMBINED SCENARIO

TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
WOODWARD-CLYDE CONSULTANTS
LEONARD RICE CONSULTING WATER ENGINEERS, INC.
MULLER ENGINEERING COMPANY, INC.

DATE: MARCH 1989 FIGURE 2.5



COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY
CLEAR CREEK PROJECT

PROJECT WATER SUPPLY
USE EFFICIENCIES

TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
MULLER ENGINEERING COMPANY, INC.
WOODWARD-CLYDE CONSULTANTS

DATE: AUGUST 1988 FIGURE 2.6

Section 3

U.S. HIGHWAY 6 EVALUATION

3.0 U.S. HIGHWAY 6 EVALUATION

3.1 INTRODUCTION

3.1.1 Purpose

The purpose of the U.S. Highway 6 evaluation was to identify alternatives for the relocation of the highway should a dam be built in Clear Creek Canyon. Construction costs and annual operation and maintenance costs were estimated for each roadway relocation alternative. In addition to construction costs and annual costs, each roadway relocation alternative was analyzed to determine the cost to the users of the highway. User costs for each roadway relocation alternative were then compared to the user costs of the highway without the project. The project area and U.S. Highway 6 corridor is shown in Figure 3.1.

3.1.2 Summary of Investigations

This initial section of the chapter summarizes the findings of the road relocation studies. These findings are presented under the following subject headings:

- Evaluation of Existing Roadways
- Roadway Relocation Alternatives
- User Costs
- Travel Time

A summary of the results of these highway relocation studies is then presented to guide the integration of these investigations into the overall project.

3.1.2.1 Evaluation of Existing Roadways

The major east-west routes in the area of U.S. Highway 6 were evaluated for existing traffic characteristics, future traffic characteristics, capacity, and safety. The three east-west routes in the corridor are U.S. Highway 6, I-70, and Golden Gate Canyon road. The primary sources of data for these evaluations were the Colorado Department of Highways (CDOH) and Jefferson County Department of Highways and Transportation.

Traffic volumes on U.S. Highway 6 in Clear Creek Canyon are currently below half the capacity of the highway and, based on historical patterns, can be expected to stay below capacity for the next 20 years. 1987 average annual daily traffic (AADT) volumes were 5200 vehicles per day with a projected volume of 7280 at year 2007, based on historical growth.

Based on 1986 accident data (CDOH, 1986), accident rates along U.S. Highway 6 in Clear Creek Canyon are about twice the average throughout the rest of Colorado. CDOH summaries of traffic accident experience for 1986 and 1987 (CDOH, 1988a) show 157 accidents in Clear Creek Canyon and 81 more along U.S. Highway 6 between S.H. 58 and the Sixth Avenue/I-70 interchange, for a total of 238 accidents. Projected annual accidents for existing conditions in the study area are 81 property damage only accidents, 73 injury accidents and 4 fatalities.

To reduce the high accident rate, it is estimated that approximately $11.1 million would be required to widen shoulders and replace bridges in Clear Creek Canyon to meet current CDOH design standards. This does not include widening the tunnels.

Traffic volumes on I-70 range from the Sixth Avenue interchange to the bottom of Floyd Hill (U.S. 6 interchange). During periods of peak usage, I-70 operates at capacity from Sixth Avenue to S.H. 74 (Evergreen Exit) and traffic volumes taper off to the west. Projections over the next 20 years show that during periods of peak usage, the capacity of I-70 will be exceeded in the entire length from the base of Floyd Hill (U.S. 6 interchange) to Sixth Avenue. The 1986 accident rates for various segments of I-70 (CDOH, 1986) range from about 0.33 to 1.5 times the Colorado average for rural interstate highways. There were 355 accidents on I-70 between U.S. Highway 6 (base of Floyd Hill) and Sixth Avenue during 1986 and 1987 (CDOH, 1988a).

Existing accident data for Golden Gate Canyon Road are limited because the road is not a part of the state highway system. Traffic volumes are quite low. They range from about 400 vehicles per day at the west end (CDOH, 1988b) to 1700 vehicles per day on the east end, according to the Jefferson County Department of Highways and Transportation. Accident data are available only for the westerly 6.6 miles (S.H. 46) where the accident rate is double the

Colorado average for non-federal aid state highways (CDOH, 1986). In 1986 and 1987, the 6.6 mile segment had 16 accidents with 3 fatalities (CDOH, 1988a).

3.1.2.2 Roadway Relocation Alternatives

The roadway relocation alternatives were developed using two basic concepts. The first concept was to relocate U.S. Highway 6 within Clear Creek Canyon by raising it above the water elevation of the proposed Centennial reservoir. The second concept was to relocate U.S. Highway 6 from Clear Creek Canyon to the parallel segment of I-70 stretching from the base of Floyd Hill to the I-70/Sixth Avenue interchange. Because the present intersection of U.S. Highway 6 and State Highway 119 (S.H. 119) would be within the reservoir area, both concepts included a major relocation of S.H. 119 in Gilpin County to connect directly to I-70.

From the two basic concepts, six alternatives were developed, including three alternative relocations in Clear Creek Canyon (designated Alternatives 1, 2, and 3) and three alternative relocations of U.S. Highway 6 from Clear Creek Canyon to I-70 (Alternatives 4, 5, and 6). The major differences in the six alternatives are based on the method of connecting S.H. 119 to I-70. Alternatives 3 and 4 make this connection by means of a tunnel to the Hidden Valley interchange of I-70. Alternatives 2 and 5 also utilize a tunnel, but connected to the interchange at the base of Floyd Hill. Alternatives 1 and 6 connect S.H. 119 to I-70 using a bridge across the reservoir, linking directly to the existing I-70 interchange at the top of Floyd Hill.

All six alternatives would provide full access to I-70. Alternatives 1, 2, and 3 would provide tourist access through Clear Creek Canyon on the relocated highways. Alternatives 4, 5, and 6 would provide tourist access on the existing road through Clear Creek Canyon below the dam, connected to a new county road around the reservoir. Estimated construction costs for the alternatives are shown in Table 3.1.

TABLE 3.1

Estimated Construction Costs For Centennial Reservoir Highway Relocation

Alternative No.	Largest Centennial Reservoir[1]	Smallest Centennial Reservoir[2]
1	$232,000,000	$218,000,000
2	$264,000,000	$249,000,000
3	$259,000,000	$244,000,000
4	$108,000,000	$108,000,000
5	$112,000,000	$112,000,000
6	$ 84,000,000	$ 84,000,000

(1)Largest Reservoir - 230,000 af.
(2)Smallest Reservoir - 110,000 af.

The alternatives are as follows (see Figures 3.2 through 3.7):

1. Relocate 13 miles of U.S. Highway 6 within Clear Creek Canyon, including two bridges over the reservoir near the U.S. Highway 6/S.H. 119 intersection. Relocate S.H. 119 within North Clear Creek Canyon, connecting to I-70 at the top of Floyd Hill (the existing Floyd Hill interchange).
2. Relocate 13 miles of U.S. Highway 6 within Clear Creek Canyon. Relocate U.S. Highway 6 through a tunnel from S.H. 119 to the U.S. Highway 6/I-70 interchange at the base of Floyd Hill. Reconstruct U.S. Highway 6/I-70 interchange to full direction interchange.
3. Relocate 13 miles of U.S. Highway 6 within Clear Creek Canyon. Relocate U.S. Highway 6 through a tunnel from S.H. 119 to the Hidden Valley/I-70 interchange.
4. Redirect U.S. Highway 6 commuter and truck traffic from Clear Creek Canyon to I-70. Relocate S.H. 119 through a tunnel to the Hidden Valley/I-70 interchange.
5. Redirect U.S. Highway 6 commuter and truck traffic from Clear Creek Canyon to I-70. Relocate S.H. 119 through a tunnel to the U.S. Highway 6/I-70 interchange at the base of Floyd Hill. Reconstruct the U.S. Highway 6/I-70 interchange at the base of Floyd Hill to a full directional interchange.
6. Redirect U.S. Highway 6 commuter and truck traffic from Clear Creek Canyon to I-70. Relocate S.H. 119 to I-70 at the Floyd Hill Interchange. This alternative includes a bridge over the reservoir.

3.1.2.3 User Costs

User costs were estimated for the various roadway relocation alternatives and the existing system under a no-action alternative. User cost factors considered were vehicle operating costs, value of time of drivers and passengers, and accident costs. Vehicle operating costs and value of time costs would increase from 1 percent to 21 percent with all six of the roadway relocation alternatives, with the highest increases in the three Alternatives (4, 5, 6) that relocate U.S. Highway 6 to I-70. All six of the roadway relocation alternatives are projected to reduce accident rates and thus save 31 percent to 74 percent in the costs of accidents. The largest accident cost savings would be in the alternatives that reconstruct U.S. Highway 6 in Clear Creek Canyon.

Total annual user costs in 1988 dollars, under a no-action alternative are estimated to be $16.2 million. For Alternatives 1, 2, and 3, total annual user costs would be approximately 10 percent less than a no-action alternative. An increase of approximately 10 percent is expected for Alternatives 4, 5, and 6.

Based on 1987 traffic data (CDOH 1988b), approximately 470 trucks use U.S. Highway 6 daily. The number of trucks would increase to about 660 in the year 2007.

3.1.2.4 Travel Time

A travel time study was conducted to estimate the average changes in travel time that could be expected under the various roadway relocation alternatives. Table 3.2 shows the changes that might be expected in travel time between Denver and Black Hawk, Golden and Idaho Springs, and Golden and Black Hawk. The changes in travel time are for traffic currently using U.S. Highway 6 under average daily driving conditions in good weather.

Average travel time between Black Hawk or Idaho Springs and Denver (via Sixth Avenue) is expected to decrease by about 4 to 6 minutes under highway relocation Alternatives 4, 5 and 6. For the same alternatives, average travel time to Golden is expected to increase by approximately 6 to 8 minutes. However, construction of the proposed W-470 might reduce this increase in driving time between Golden and mountain destinations.

TABLE 3.2

Average Changes in Travel Time (in Minutes) for Traffic Currently Using U.S. Highway 6

	Trips Between		
	Denver and Black Hawk	**Golden and Idaho Springs**	**Golden and Black Hawk**
Alternative 1	0	+3	-1
Alternative 2	0	+2	-1
Alternative 3	0	+1	-1
Alternative 4	-4	+6	+8
Alternative 5	-5	+6	+6
Alternative 6	-4	+6	+8

3.1.3 Summary of Results

The following results are summarized from the U.S. Highway 6 evaluation:

1. Implementation of Alternative No. 6 would be the most cost effective method for relocation of U.S. Highway 6. The key components of this alternative include (see Figures 3.2 through 3.7):
   - relocating U.S. Highway 6 from Clear Creek Canyon to I-70,
   - relocating the S.H. 119 and U.S. Highway 6 intersection to I-70 at the Floyd Hill interchange (located at the top of Floyd Hill), and
   - constructing a new roadway to connect with S.H. 119 in North Clear Creek Canyon to the Floyd Hill interchange at I-70.
2. Highway relocation within Clear Creek Canyon (Alternatives 1, 2, and 3), would have a construction cost estimated to be in excess of $230 million.
3. Upgrading Golden Gate Canyon Road to federal and state highway standards would cost approximately the same as upgrading U.S. Highway 6 in Clear Creek Canyon. Given the choice of relocating U.S. Highway 6 in the existing corridor, this alternative has not been given further consideration.

4. Highway relocation outside of Clear Creek Canyon (Alternatives 4, 5, and 6), would have a construction cost estimated to range from $84 million to $112 million. However, good access to Gilpin County, along S.H. 119 is required to maintain the economic viability of the area. Access between Gilpin County and the Denver metropolitan area would be provided in the most cost effective way by highway relocation Alternatives 4, 5, and 6.
5. User costs for value of time and vehicle operating cost are expected to increase for all of the U.S. Highway 6 relocation alternatives. User costs for accidents are estimated to decrease for all of the roadway relocation alternatives due to improved roadway design standards. The net result of user cost analysis shows the highway relocation Alternatives 1, 2 and 3 would be expected to reduce annual user costs from $0.5 million to $1.9 million annually. Alternatives 4, 5, and 6 are estimated to increase user costs from $1.7 million to $2.1 million.
6. All of the roadway relocation alternatives should increase safety for traffic currently using U.S. Highway 6.
7. Construction of highway relocation Alternatives 1, 2, and 3 would increase travel times between Idaho Springs and Denver or Golden by 1 to 3 minutes. Travel times between Black Hawk and Denver or Golden are predicted to change by less than 1 minute. With Alternatives 4, 5, and 6, travel time between Denver and mountain locations are projected to be reduced 4 to 5 minutes. A 6 to 8 minute increase would be expected between Golden and mountain locations. Forecast changes in travel time are based on average traffic conditions.

3.2 BACKGROUND INFORMATION

3.2.1 Data Collection

Because the U.S. Highway 6 evaluation primarily concerns state highways, the primary source of traffic and roadway data was the CDOH. The following data were obtained from various groups within the CDOH:

1. Traffic volumes for 1987 (CDOH 1988b)
2. Accidents and Rates on State Highways, 1982 through 1986

3. Accident data by milepost for 1986 and 1987 for U.S. Highway 6, S.H. 58, I-70, S.H. 46
4. As-built plans for I-70 at Floyd Hill and Mount Vernon Canyon
5. As-built plans for U.S. Highway 6 in Clear Creek Canyon
6. Peak period traffic projections on I-70 from the I-70 west corridor study

Traffic volume data for Golden Gate Canyon Road were obtained from Jefferson County. Traffic volume data for 1987 (CDOH, 1988b) and accident rate data from 1986 (CDOH, 1987) are shown in Figure 3.1.

Field data collection included a field reconnaissance trip to determine the travel time and distances for various roadway sections in the project study area. The information was gathered during off-peak periods to get an average travel time to relate to annual average traffic conditions for development of travel time and operating costs. These data are shown in Figure 3.1.

Cost data used to develop construction cost estimates and maintenance costs were derived from the CDOH 1987 Cost Data published by the Cost Estimates Squad of the Staff Design Branch. These data have been evaluated and updated to prepare project construction costs in 1988 dollars.

3.2.2 Assumptions and Guidelines

To obtain annual cost data for a user cost analysis, average driving and traffic conditions were used as a basis for driving times within the corridor. Although driving times will vary, based on peak commuting or tourist periods, it is assumed that the comparative differences in driving times will be consistent.

It was a goal of the study to provide equal or better access to Gilpin and Clear Creek Counties with roadway relocation alternatives. This would minimize economic impacts on these areas that rely on commuter and tourist traffic to and from the Denver area. Roadway relocation alternatives were selected with the goal of minimizing user costs. All relocation alternatives provide access, equal to current conditions, to local roadways.

Design standards for new roadway construction will meet current federal and state standards for new highway construction for a 50 mph design speed. Existing U.S. Highway 6 in Clear Creek Canyon was constructed more than 35 years ago and was built to lower design standards than would be allowed today. It has narrower shoulders, sharper curves, and less guardrail than may be required on newer highways.

Safety is considered to be a prominent factor in the selection of alternatives. Although there are some passing lanes on U.S. Highway 6 westbound (uphill), there is only one lane eastbound (downhill). Passing opportunities are limited because of the many sharp curves. Improvements on I-70 would provide multiple lanes in each direction, allowing drivers the freedom to pass slower vehicles in a safe manner.

3.2.3 Affected Jurisdictions

The primary jurisdictions involved in the evaluation of U.S. Highway 6 are the CDOH and the Federal Highway Administration. All of the highways involved are state maintained highways that have been built with federal funds.

Jefferson, Clear Creek, and Gilpin Counties also have an interest in the project. U.S. Highway 6 contributes to the transportation needs and economic climate of all three counties. Black Hawk and Central City are tourist-oriented communities in the study area. U.S. Highway 6 is a route used by tourist and commuter traffic to and from these communities.

3.3 EVALUATION OF EXISTING ROADWAYS

3.3.1 Traffic and Accident Data

Traffic and accident data were analyzed to ascertain characteristics in the U.S. Highway 6 corridor and to identify a basis for user cost analysis. Traffic counts provided by the CDOH were analyzed to determine the origins and destinations of the traffic using U.S. Highway 6 in Clear Creek Canyon. The origin and destination analysis was simplified because there are virtually no access points along U.S. Highway 6 in Clear Creek Canyon.

For the purpose of this analysis, eight origin-destination pairs were established for traffic using U.S. Highway 6 in the canyon. They are as follows:

1. Denver and I-70 West
2. Denver and Black Hawk
3. Denver and Black Hawk-North
4. Denver and Floyd Hill Interchange
5. Golden and I-70 West
6. Golden and Black Hawk
7. Golden and Black Hawk-North
8. Golden and Floyd Hill Interchange

In the analysis, Denver is defined as the Sixth Avenue (U.S. 6)/I-70 interchange. (Traffic characteristics between this point and Denver City limits will be the same for all alternatives.) Golden is defined as the intersection of S.H. 58 and S.H. 93. The Black Hawk destination includes traffic using S.H. 279 west of Black Hawk. Black Hawk-North is the traffic travelling north of the intersection of S.H. 119 and S.H. 46. I-70 West is defined as traffic that uses I-70 west of the I-70/U.S. 6 interchange in Clear Creek Canyon. Only distribution of traffic using U.S. Highway 6 has been analyzed for this evaluation. Figure 3.8 shows the distribution of traffic using U.S. Highway 6 in Clear Creek Canyon (CDOH, 1988b).

Table 3.3 shows the existing and projected AADT (Annual Average Daily Traffic) and equivalent growth ADTE (Average Daily Traffic Equivalent) for each origin-destination pair. The AADT for the year 2007 is based on the CDOH 20-year traffic projection factor for U.S. Highway 6. This factor is based on historic traffic growth patterns for the highway. The equivalent growth ADTE is the equivalent traffic volume based on the equivalent uniform annual series for the AADT over the 30-year project design life at a discount rate of 8 percent (FHWA, 1981).

Because some of the improvement alternatives involve re-directing U.S. Highway 6 traffic to I-70, a capacity analysis of I-70 was done according to the 1985 Highway Capacity Manual (Transportation Research Board, 1985). I-70,

TABLE 3.3

Summary of Existing and Projected Traffic
No - Action Alternative

Origin-Destination	1987 Traffic (AADT)	2007 Traffic (AADT)(1) (20 Yrs)	Annual Equivalent Growth Factor	Equivalent Growth ADTE(2)
	U.S. 6 Traffic Through Clear Creek Canyon			
Denver - I-70 West	1,225	1,715	25	1,450
Denver - Black Hawk	698	977	14	830
Denver - Black Hawk North	275	385	6	330
Denver - Floyd Hill Interchange (U.S. 40)	102	143	2	120
Golden - I-70 West	1,544	2,162	31	1,830
Golden - Black Hawk	881	1,233	18	1,040
Golden - Black Hawk North	46	484	7	410
Golden - Floyd Hill Interchange (U.S. 40)	129	181	3	150
Totals	5,200	7,280	104	6,160

(1)Annual Average Daily Traffic.
(2)Average Daily Traffic Equivalent.

in the project area, was divided into the following three interchange segments:

1. U.S. 6 in Clear Creek Canyon to Floyd Hill Interchange
2. Floyd Hill Interchange to Genesee Interchange
3. Genesee Interchange to C-470/Rooney Road Interchange.

Results of the capacity analysis are shown in Table 3.4.

Accident data for U.S. Highway 6 were analyzed for two reasons. One reason was to identity deficiencies in the existing roadway. The second reason was to evaluate accident costs. The most recently published accident rates (CDOH 1986) on U.S. Highway 6 in Clear Creek Canyon were more than double the state averages for two-lane Federal Aid Highways for 1986. Table 3.5 shows comparisons of the various rates.

TABLE 3.4

Capacity Analysis of Interstate 70

Location	Capacity (C) (Vehicles/Hr.)(2)	Current DHV(4) (V) (Vehicles/Hr.)(2)	V/C	Current Level of Service (LOS)(1)(3)
Floyd Hill	2,540	1,350	0.53	B
Floyd Hill to Genessee	3,460	2,210	0.54	C
Mount Vernon Canyon	2,540	2,550	1.00	E to F

(1)Level of Service (LOS) Explanation:

- A Free Flow
- B Stable Flow
- C Stable Flow With Conflicts
- D Stable Flow, High Density, Restricted
- E Capacity, Unstable Flow at Low Speeds
- F Forced Flow, Breakdown of System, Stop and Go Condition

(2)All volumes are for one direction on I-70.
(3)Level of service calculated for direction with most adverse grade conditions.
(4)Design Hour Volumes

TABLE 3.5

U.S. Highway 6 Accident Rates - Clear Creek Canyon 1986

	U.S. Highway 6	Colorado Average Federal Aid Primary (Rural)
Total Accident Rate(1)	2.75	1.31
Injury Accident Rate(1)	1.42	0.51
Fatality Accident Rate(2)	9.16	2.39

(1)Accident rate per million vehicle miles.
(2)Accident rate per hundred million vehicle miles.

Accident data from 1986 and 1987 were plotted on a map of U.S. Highway 6 to determine accident patterns and safety deficiencies in the roadway. Although the rates for Clear Creek Canyon are high, a concentration of accidents at any particular location was not evident. Instead, accidents of various types are spread throughout the canyon. The most frequent types of accidents are overturned vehicles or fixed-object accidents and in more than half of all of the reported accidents, one or more vehicles left the roadway (CDOH, 1988a).

This could be attributed to the winding alignment and sharp curves within the canyon.

For use in the user cost analysis, accident rates for all of the major roadways in the study area were analyzed. Accident rates for 1982 through 1986 were averaged to predict how many accidents might occur on each roadway segment, based on the traffic volumes along that segment. For a no-build situation, numbers of accidents for each origin and destination pair were predicted, based on the equivalent growth ADTE over 30 years. These accident data are shown in Table 3.6.

3.3.2 CDOH Improvement Plans

No major improvements are anticipated in the next 5 years on U.S. Highway 6 and S.H. 119. However, minor safety improvements and bridge replacements may occur. It is anticipated that safety improvements are focused primarily on widening shoulders and installing guardrails.

TABLE 3.6

Projected Accidents by Type
No-Action Alternative

		No Build - U.S. 6 Annual Projected Accidents		
Origin-Destination	Equivalent Growth ADTE	Property Damage Only	Injury	Fatality
Denver - I-70 West	1,450	20	16	1
Denver - Black Hawk	830	12	11	1
Denver - Black Hawk North	330	5	5	0
Denver - Floyd Hill Interchange (U.S. 40)	120	2	2	0
Golden - I-70 West	1,830	22	18	1
Golden - Black Hawk	1,040	12	13	1
Golden - Black Hawk North	410	6	6	0
Golden - Floyd Hill Interchange (U.S. 40)	150	2	2	0
Totals	6,160	81	73	4

The construction cost for shoulder widening and bridge replacements for U.S. Highway 6 from S.H. 58 to I-70 has been estimated in this study to be $11.1 million. This cost includes widening shoulders to current standards for the entire length of U.S. Highway 6 in Clear Creek Canyon and replacing several structures. Widening of existing tunnels is not anticipated.

3.3.3 Maintenance Costs

Maintenance costs for the existing highway system were determined to compare to maintenance costs of highway relocation alternatives. The lane mileage of the existing highway system includes existing highways that fall within the improvement limits of all of the highway relocation alternatives. These areas are as follows:

1. U.S. Highway 6, S.H. 58 to I-70
2. S.H. 119, U.S. Highway 6 to end of reservoir
3. I-70, Sixth Avenue to U.S. Highway 6 (at base of Floyd Hill)

Minor maintenance of hot bituminous plant mix pavement is estimated to be $1000 per lane-mile per year. This unit cost is based on CDOH estimates for evaluation of economics for hot bituminous plant mix pavements. Two-inch, hot bituminous plant mix overlays are anticipated after 10, 20, and 30 years of life. Annual cost of maintenance of the existing roadways over 30 years is estimated to be $373,000.

3.3.4 User Costs

User costs for the existing highway system were estimated and used as a baseline for comparison to highway relocation alternatives. The user cost parameters include value of time, vehicle operating cost, and accident costs. Average annual user costs total $16.2 million for the existing highway system for the 30-year design life of the project, as detailed in Table 3.7.

TABLE 3.7

Projected Annual User Costs
No-Action Alternative

Origin-Destination	Equivalent Growth AADT	Annual Cost For Existing Condition: Mileage	Annual Cost For Existing Condition: Value of Time	Annual Accident Cost	Total Annual User Cost
Denver[1] - I-70 West[2]	1,450	$2,120,000	$980,000	$610,000	$3,710,000
Denver - Black Hawk	830	$1,450,000	$690,000	$520,000	$2,660,000
Denver - Black Hawk North[3]	330	$710,000	$390,000	$90,000	$1,140,000
Denver - Floyd Hill Interchange (U.S. 40)	120	$180,000	$90,000	$30,000	$300,000
Golden - I-70 West[2]	1,830	$2,230,000	$1,040,000	$650,000	$3,920,000
Golden - Black Hawk	1,040	$1,560,000	$750,000	$550,000	$2,860,000
Golden - Black Hawk North	410	$780,000	$380,000	$100,000	$1,360,000
Golden - Floyd HIll Interchange (U.S. 40)	150	$190,000	$90,000	$30,000	$310,000
Totals	6,160	$9,220,000	$4,360,000	$2,580,000	$16,160,000

(1)Denver is the I-70/Sixth Avenue Interchange for comparisons.
(2)I-70 West destination is Hidden Valley interchange for comparisons.
(3)Black Hawk North is the intersection of S.H. 119 and S.H. 46 (Golden Gate Canyon Road).

3.3.5 Travel Time and Distance

Travel time and distance predictions have been made for the no-action alternative and the six roadway relocation alternatives. To estimate average travel times, it has been assumed that roadway conditions are good in non-peak conditions. Average values have been used to determine incremental increases and decreases in travel time. The incremental differences are assumed to be consistent for all driving conditions. Table 3.8 shows the travel times projected for the various alternatives. Where U.S. Highway 6 is closed in Alternatives 4, 5, and 6, it is assumed that I-70 would be used as the alternative route.

3.4 ACCESS EVALUATION

3.4.1 Regional Access

U.S. 6 and S.H. 119 provide transportation access at two levels. On a regional basis, 66 percent of the traffic travelling to Black Hawk or Central City uses U.S. Highway 6. And, 71 percent of that traffic comes from Denver/Golden and 29 percent comes from I-70 west. Of the traffic travelling through Clear Creek Canyon, 58 percent travels to and from I-70 west, over half of which originates and ends in the Golden area.

In addition to the tourist traffic in Clear Creek Canyon, much of the use can be attributed to commuters. U.S. Highway 6 provides a direct link between Clear Creek and Gilpin Counties and major employment centers in Golden (such as the Adolph Coors Company) and in Denver.

3.4.2 Local Access

Local access in the canyon is limited. There are several gravel mining operations that either would be eliminated because of the construction of a dam, or maintained with access along the portion of U.S. Highway 6 left below the dam to provide access to the dam. No other property access was identified to exist along U.S. Highway 6 at the time of this study.

The only major identified access road impacted in the project area is Douglas Mountain Drive, which intersects S.H. 119 approximately one-half mile north of its intersection with U.S. Highway 6. This access point would be submerged if a dam were constructed at the Centennial site. Access would have to be maintained to Douglas Mountain Drive and could be maintained if U.S. Highway 6 and S.H. 119 were relocated to an alternative canyon alignment. If the existing U.S. Highway 6 and S.H. 119 alignments were abandoned, an access road would have to be constructed to Douglas Mountain Drive. Construction of an access road to the same standards as the existing Douglas Mountain Drive would have a direct cost of about $2,500,000.

TABLE 3.8

Summary of Travel Distances and Travel Times[4] for Roadway Relocation Alternatives

Origin - Destination	No Action		Alternative 1		Alternative 2		Alternative 3		Alternative 4		Alternative 5		Alternative 6	
	Travel Distance (Miles)	Travel Time (Minutes)	Travel Distance (Miles)	Travel Time (Minutes)	Travel Distance (Miles)	Travel Time (Minutes)	Travel Distance (Miles)	Travel Time (Minutes)	Travel Distance (Miles)	Travel Time (Minutes)	Travel Distance (Miles)	Travel Time (Minutes)	Travel Distance (Miles)	Travel Time (Minutes)
DENVER[1] - I-70 WEST[2]	19.0	26	21.8	29	20.9	29	19.9	28	18.1	21	18.1	21	18.1	21
DENVER - BLACK HAWK	22.8	32	22.3	32	22.3	32	22.3	32	23.4	29	22.1	27	22.3	29
DENVER - BLACK HAWK NORTH[3]	28.0	40	27.6	40	27.6	40	27.6	40	28.6	37	27.4	35	27.6	37
DENVER-FLOYD HILL INTERCHANGE(US 40)	19.8	28	18.1	25	22.0	30	23.5	32	14.5	17	14.5	17	14.5	17
GOLDEN - I-70 WEST[2]	15.9	22	18.6	25	17.7	24	16.7	23	22.1	28	22.1	28	22.1	28
GOLDEN - BLACK HAWK	19.6	28	19.2	28	19.2	28	19.2	28	27.4	36	26.1	34	26.5	36
GOLDEN - BLACK HAWK NORTH[3]	24.9	36	24.4	35	24.4	35	24.4	35	32.6	44	31.4	42	31.8	44
GOLDEN-FLOYD HILL INTERCHANGE(US 40)	16.7	23	14.9	20	18.9	25	20.4	28	18.7	25	18.7	25	18.7	25

(1)Denver destination is the I-70/Sixth Avenue interchange for comparison purposes.
(2)I-70 west destination is Hidden Valley interchange for comparisons.
(3)Black Hawk north destination is the intersection of S.H. 119 and A.H.46.
(4)Travel times are estimated for current average traffic conditions and in good weather.

3.5 ALTERNATIVES FOR HIGHWAY RELOCATION

3.5.1 Identification of Highway Relocation Alternatives

U.S. 6 traverses Clear Creek Canyon along the grade of Clear Creek at the bottom of the canyon. For the purpose of this study, it was assumed that the dam and reservoir would be constructed at the Centennial site. Under maximum reservoir pool conditions, U.S. Highway 6 would be submerged from the Centennial dam site, upstream to the U.S. Highway 6/I-70 interchange. S.H. 119 would be submerged from its intersection with U.S. Highway 6 to a point about two miles upstream. Figures 3.2 through 3.7 show the reservoir site as it relates to the roadway relocations.

Two basic highway relocation alternatives were considered at the outset of the evaluation. First, relocation of U.S. Highway 6 and S.H. 119 within Clear Creek and North Clear Creek Canyons was considered. Second, closure of the U.S. Highway 6 alignment was considered with a relocation of S.H. 119 tied to I-70. If the existing U.S. Highway 6 alignment were abandoned, then the designation of U.S. Highway 6 would have to be moved to I-70. New access to Gilpin County would then be provided via S.H. 119 or Golden Gate Canyon Road. Access for recreation and tourism between Golden and Central City would be maintained through Clear Creek Canyon by means of the existing road connected to a new county road around the reservoir.

Utilization of Golden Gate Canyon Road as a relocation alternative for U.S. Highway 6 was investigated. The steep grades and tight horizontal alignment of the existing roadway would not meet CDOH nor Federal Highway Administration criteria for a Federal Aid Primary highway. Costs of upgrading Golden Gate Canyon Road to federal and state standards would be comparable to those required to relocate U.S. Highway 6 within Clear Creek Canyon. For this reason, no further consideration was given to utilization of Golden Gate Canyon as a highway relocation alternative.

After reviewing the two basic road relocation alternatives, several variations were added and costs were calculated for the various combinations. The result was the development of six highway relocation alternatives. These alternatives and their associated construction costs are described in Section

3.5.3 and summarized in Table 3.9. The alternative alignments are shown in Figures 3.2 through 3.7.

3.5.2 Construction Cost Criteria

Construction cost estimates for each alternative were based on the CDOH 1987 Cost Data publication prepared by the Cost Estimating Squad of the Design Branch (CDOH 1987). Although the CDOH publication was used as a basis for construction costs, engineering judgement was exercised in determining roadway construction unit prices. The construction cost estimates shown are order-of-magnitude estimates and are not intended to be detailed construction estimates for the various projects.

TABLE 3.9

Cost Summary

Alternative (See List Below)	Construction Cost of Improvements	Annual Maintenance Cost
No Build	$ 11,200,000	$373,000
Alternative 1(1)	$232,000,000	$402,000
Alternative 2(1)	$264,000,000	$389,000
Alternative 3(1)	$259,000,000	$388,000
Alternative 1(2)	$218,000,000	$401,000
Alternative 2(2)	$249,000,000	$388,000
Alternative 3(2)	$244,000,000	$386,000
Alternative 4	$108,000,000	$386,000
Alternative 5	$112,000,000	$368,000
Alternative 6	$ 84,000,000	$390,000

(1)Largest Reservoir--230,000 af.
(2)Smallest Reservoir--110,000 af.

Construction cost estimates for all projects except for widening of I-70 were based on 1988 dollars. Because current volumes do not warrant widening of all of I-70, present value theory was used to determine those costs. To make this determination, the portion of I-70 from U.S. Highway 6 in Clear Creek Canyon to Rooney Road/C-470 was divided into the following three sections:

1. U.S. Highway 6 to Floyd Hill Interchange
2. Floyd Hill Interchange to Genesee Interchange
3. Genesee Interchange to Rooney Road/C-470 Interchange

Based on a capacity analysis of I-70, additional lanes will be required on the various segments at different times. Segment 1 will require additional lanes in 13 years, Segment 2 in 9 years, and Segment 3 immediately. Costs for each segment were estimated and converted to present value equivalents. Since U.S. Highway 6 traffic would utilize about 65 percent of the capacity available in the additional lanes for I-70, the cost of the widening attributed to the Clear Creek Project is 65 percent of the total of the present values for each segment of I-70.

3.5.3 Description of Highway Relocation Alternatives

Six specific highway relocation alternatives were developed from the two basic alternatives discussed in Section 3.5.1. Alternatives 1, 2, and 3 are based on relocating U.S. Highway 6 within Clear Creek Canyon. Alternatives 4, 5, and 6 require the relocation of U.S. Highway 6 to I-70. Descriptions of the alternatives are contained in the following paragraphs and the conceptual alignments are shown in Figures 3.2 through 3.7. Alternatives 1, 2, and 3 have different alignments for the high reservoir (230,000 af) and low reservoir (110,000 af) elevations. Alternatives 4, 5, and 6 are not dependent on reservoir elevation (see Figures 3.2 through 3.7).

3.5.3.1 Alternative 1

Alternative 1 is based on the relocation of U.S. Highway 6 and S.H. 119 within Clear Creek Canyon and North Clear Creek Canyon, respectively. The westerly portion of relocated U.S. Highway 6 would begin at the Floyd Hill interchange on I-70. The alignment would traverse the south wall of Clear Creek Canyon and meet S.H. 119 near the mouth of Horse Creek and the Junction of

Douglas Mountain Drive and S.H. 119. Two major structures (1500-feet and 2000-feet) would be constructed over the reservoir. This section of U.S. Highway 6 would consist of 2.2 miles of three-lane highway on 6-percent grade, and 1.0 mile of two-lane highway. The remaining roadway relocation would be around the north side of the reservoir and along the north wall of North Clear Creek Canyon and Clear Creek Canyon. It would start about 2.0 miles upstream of the existing U.S. Highway 6/S.H. 119 intersection and traverse along the canyon wall to the intersection of U.S. Highway 6 and S.H. 58 in Golden. It would consist of 5.0 miles of two-lane highway around the reservoir and 8.1 miles of three-lane highway on a 4-percent grade from the canyon floor to the top of the dam. Approximately 2.6 miles of bridges and 3700 linear feet of tunnel are required in this 13.1-mile stretch of highway. The total construction cost of Alternative No. 1 is estimated to be $232 million for the high reservoir and $218 million for the low reservoir.

3.5.3.2 Alternative 2

Alternative 2 would include the 13.1-mile stretch of highway relocation discussed for Alternative 1 along the north wall of North Clear Creek Canyon and Clear Creek Canyon. The westerly segment of relocated U.S. Highway 6, however, would connect S.H. 119, from about 3.4 miles upstream of the existing U.S. Highway 6/S.H. 119 intersection, to I-70 at the existing U.S. Highway 6/I-70 interchange in Clear Creek Canyon. The connection would require construction of a 4600-foot, two-lane tunnel. Also, the interchange of U.S. Highway 6 and I-70 would be upgraded to serve all movements in a fully directional interchange. I-70 would be relocated to provide a better alignment at the base of Floyd Hill and to accommodate the interchange. The construction cost of Alternative 2 is estimated to be $264 million for the high reservoir and $249 million for the low reservoir.

3.5.3.3 Alternative 3

As with Alternatives 1 and 2, Alternative 3 would use the 13.1-mile alignment along the north wall of North Clear Creek Canyon and Clear Creek Canyon. The connection of S.H. 119 and I-70 also would begin along S.H. 119 and 3.4 miles upstream of the existing S.H. 119/U.S.6 intersection. From there, a connection would be made to I-70 at the Hidden Valley interchange through a

5800-foot, two-lane tunnel. Only minor modifications would be required at the Hidden Valley interchange. The construction cost for Alternative 3 is estimated to be $259 million for the high reservoir and $244 million for the low reservoir.

3.5.3.4 Alternative 4

Alternatives 4, 5, and 6 all would involve the relocation of the U.S. Highway 6 designation from the Clear Creek Canyon alignment to I-70. With the relocation of U.S. Highway 6 to I-70, widening of I-70 would be required over a period of time. The portion of I-70 from the Genesee interchange to C-470/Rooney Road would be widened a lane in each direction immediately. In 9 years, traffic demands would require an additional lane in each direction from the Floyd Hill interchange to the Genesee interchange. In 13 years, traffic volumes would warrant widening of I-70 one lane in each direction from the U.S. Highway 6 interchange, at the base of Floyd Hill, to the Floyd Hill interchange. The traffic projections used for the timing of these improvements are based on CDOH expansion factors which reflect historical growth on U.S. Highway 6 and I-70.

Along with the I-70 improvements, Alternative 4 would include a 5800-foot two-lane tunnel connecting I-70 with S.H. 119. The tunnel alignment would begin at the I-70 Hidden Valley interchange and connect to S.H. 119, 3.4 miles upstream of the existing U.S. Highway 6/S.H. 119 intersection. To maintain access, a low-type design, gravel access road would connect S.H. 119 to Douglas Mountain Drive along the north wall of North Clear Creek Canyon. The Alternative 4 construction cost is estimated to be $108 million.

3.5.3.5 Alternative 5

Alternative 5 would include widening I-70 as described for Alternative 4. The I-70/S.H. 119 connection would be a 4600-foot, two-lane tunnel from the I-70/U.S. 6 interchange at the base of Floyd Hill to S.H. 119, 3.4 miles upstream of the existing U.S. Highway 6/S.H. 119 intersection. The I-70/U.S. 6 interchange would be upgraded as was described for Alternative 2. The construction cost for Alternative 5 is estimated to be $112 million.

3.5.3.6 Alternative 6

Alternative 6, would include widening of I-70, along with the addition of a surface connection between I-70 and S.H. 119. The alignment would begin on S.H. 119 approximately 2.3 miles upstream of the existing U.S. Highway 6/S.H. 119 intersection. The alignment would traverse the north wall of North Clear Creek Canyon to Douglas Mountain drive. It would then turn southwesterly and cross the reservoir over a 2000-foot bridge. The alignment would continue along the southerly wall of Clear Creek Canyon and connect with I-70 at the Floyd Hill interchange. This alignment would consist of 2.3 miles of two-lane road and 3.0 miles of three-lane roadway. Also, a major 2000-foot bridge and 3700 feet of smaller bridges are included in this alternative. The construction cost of Alternative 6 is estimated to be $84 million.

3.5.4 User Cost Comparisons

In determining the impacts of the highway relocation, the effect on the user must be quantified and compared for all of the highway relocation alternatives. Three basic user costs were identified and evaluated. These factors are travel time costs, vehicle operating costs, and accident costs.

Value of time estimates were based on the anticipated average travel time to traverse between specified origins and destinations, and included the number of persons per vehicle. The Denver Regional Council of Governments (DRCOG), the metropolitan planning organization, has developed hourly rates for various types of trips. A rate of $5.00 per hour per person is appropriate for AM and PM peak hour trips and $2.00 per hour per person for other times of day. This indicates that a higher value is placed on home-to-work travel. Because U.S. Highway 6 is used for recreation and commuter travel, an average value of $3.50 per hour per person was used to determine value of time. Vehicle occupancy was estimated using an average of 1.2 persons per vehicle, based on DRCOG statistics.

Vehicle operating costs, estimated to be $0.21 per mile, were based on Internal Revenue Service statistics for vehicle cost allowance.

Accident costs used for the U.S. Highway 6 evaluation were based on those published by the National Safety Council (American Association of State Highway and Transportation Officials, 1977). After adjustment to 1988 dollars, the rates used were: $329,000 per fatal accident, $16,000 per injury accident and $1300 per property damage accident.

To determine user costs for each highway relocation alternative, traffic projections were estimated for each improvement alternative.

For Alternatives 1 through 3, the traffic using improved U.S. Highway 6 was estimated to be the same as that for the existing roadway. To determine user costs on Alternatives 4-6, the equivalent growth annual average daily traffic was rerouted onto the various relocation alternatives. Differences between travel times and distances were determined. The differences in travel time and distances were converted to incremental savings or costs to the user. Accident rates for the new sections of highway were estimated using the 1986 statewide averages for the appropriate type of highway (CDOH 1986). U.S. Highway 6 is a Federal Aid Primary (rural) and S.H. 119 is considered a Federal Aid Secondary (rural). The differences in the various types of accidents were predicted based on the equivalent growth AADT. The differences were converted to costs or savings to the users.

The results of the user cost analysis are shown in Table 3.10. The table shows that all of the roadway relocation alternatives will result in a cost to the user in travel time and operating costs. For Alternatives 1, 2, and 3, travel time and distance would be increased for traffic using U.S. Highway 6 to travel between I-70 west and Denver/Golden. For Alternatives 4, 5, and 6 travel time and distance would be increased for travel between Golden and Black Hawk and I-70 west.

All of the roadway relocation alternatives will realize a savings in accident costs. For Alternatives 1, 2, and 3, the savings will be realized by improving the existing U.S. Highway 6 alignment. For Alternatives 4, 5, and 6, the savings result from relocating traffic to I-70, where the accident rates will be lower than they are now on existing U.S. Highway 6.

3.6 ABANDONMENT OF EXISTING ROADWAYS

The most cost effective of the six alternatives involve the relocation of U.S. Highway 6 to I-70. This would require following a procedure to abandon the existing U.S. Highway 6 and S.H. 119 alignments shown in Figures 3.2 through 3.7.

CDOH Procedural Directive No. 1306.1, Abandonment of Highway Routes and Portions Thereof, outlines the procedure that must be used to abandon the existing alignments. A summary of the required steps follows:

1. The District Engineer must discuss the abandonment with the Chief Engineer.
2. The Chief Engineer must agree that the roadway is no longer a necessary part of the state highway system.
3. Local officials must agree to accept the highway on the local system or agree that the route should be abandoned.
4. The District Engineer must determine damages, if any, to adjacent landowners.

TABLE 3.10

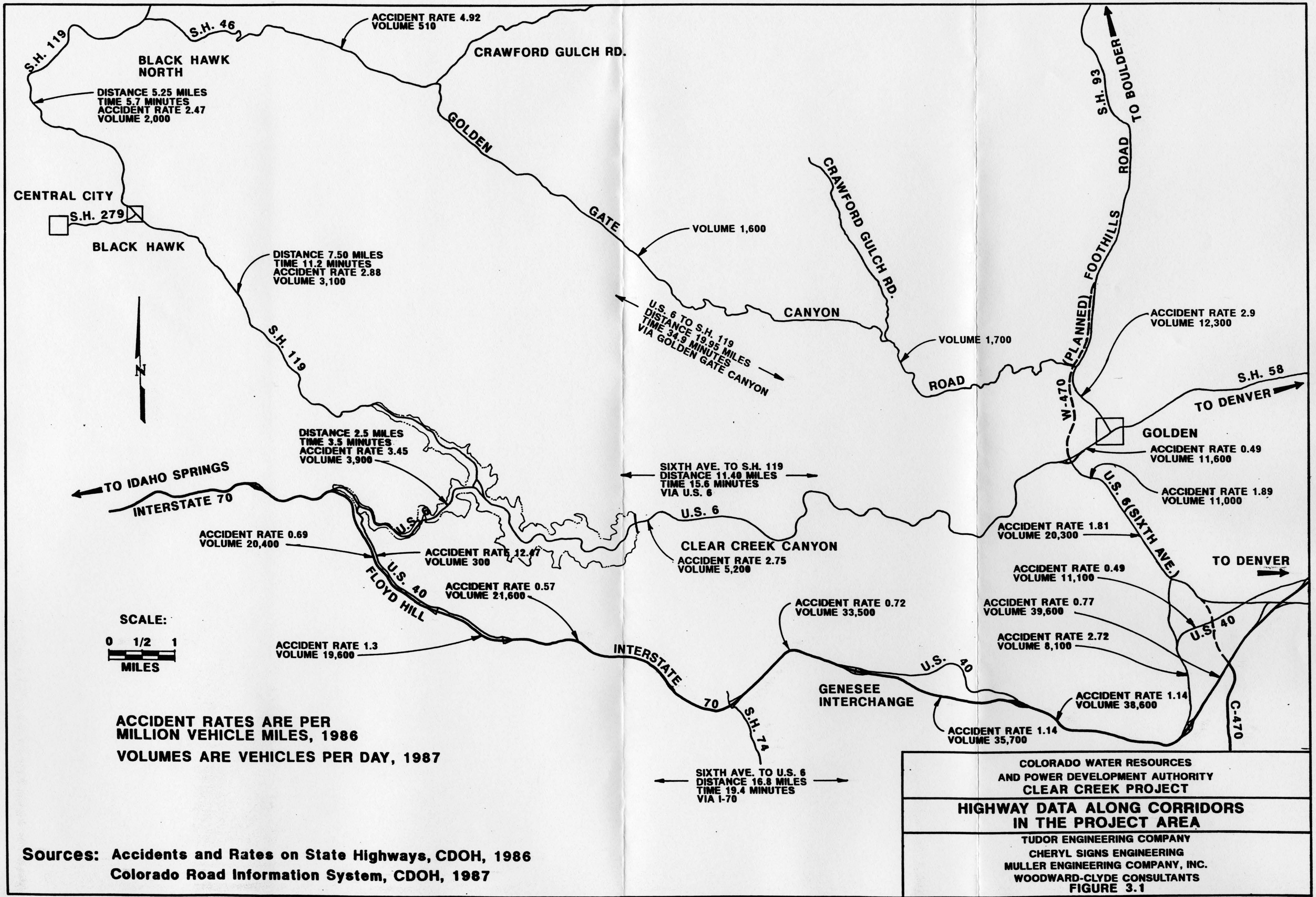
Costs and Savings to the User of Highway 6

Alternative (See List Below)	Annual Value of Time Savings (Cost)	Annual Operating Cost Savings (Cost)	Annual Safety Savings (Cost)	Total Annual Savings (Cost)
No Build	$0	$0	$518,000	$518,000
Alternative 1 (1)	($204,000)	($571,000)	$1,910,000	$1,135,000
Alternative 2 (1)	($159,000)	($417,000)	$1,880,000	$1,304,000
Alternative 3 (1)	($72,000)	($199,000)	$1,890,000	$1,619,000
Alternative 1 (2)	($204,000)	($571,000)	$1,910,000	$1,135,000
Alternative 2 (2)	($159,000)	($417,000)	$1,880,000	$1,304,000
Alternative 3 (2)	($72,000)	($199,000)	$1,890,000	$1,619,000
Alternative 4	($942,000)	($2,002,000)	$795,000	($2,149,000)
Alternative 5	($861,000)	($1,866,000)	$847,000	($1,880,000)
Alternative 6	($944,000)	($2,037,000)	$1,170,000	($1,811,500)

(1)Largest Reservoir--230,000 af.
(2)Smallest Reservoir--110,000 af.

5. The Chief Engineer must request the Division of Transportation Planning to secure Federal Highway Administration approval for changing a federal route.
6. The Chief Engineer must request the Division of Transportation Planning to prepare a resolution for approval of the Executive Director and submittal to the State Highway Commission.
7. The State Highway Commission must agree that the route is no longer a necessary part of the State Highway System.
8. The State Highway Commission must determine damages and pay appropriate amounts to affected landowners.

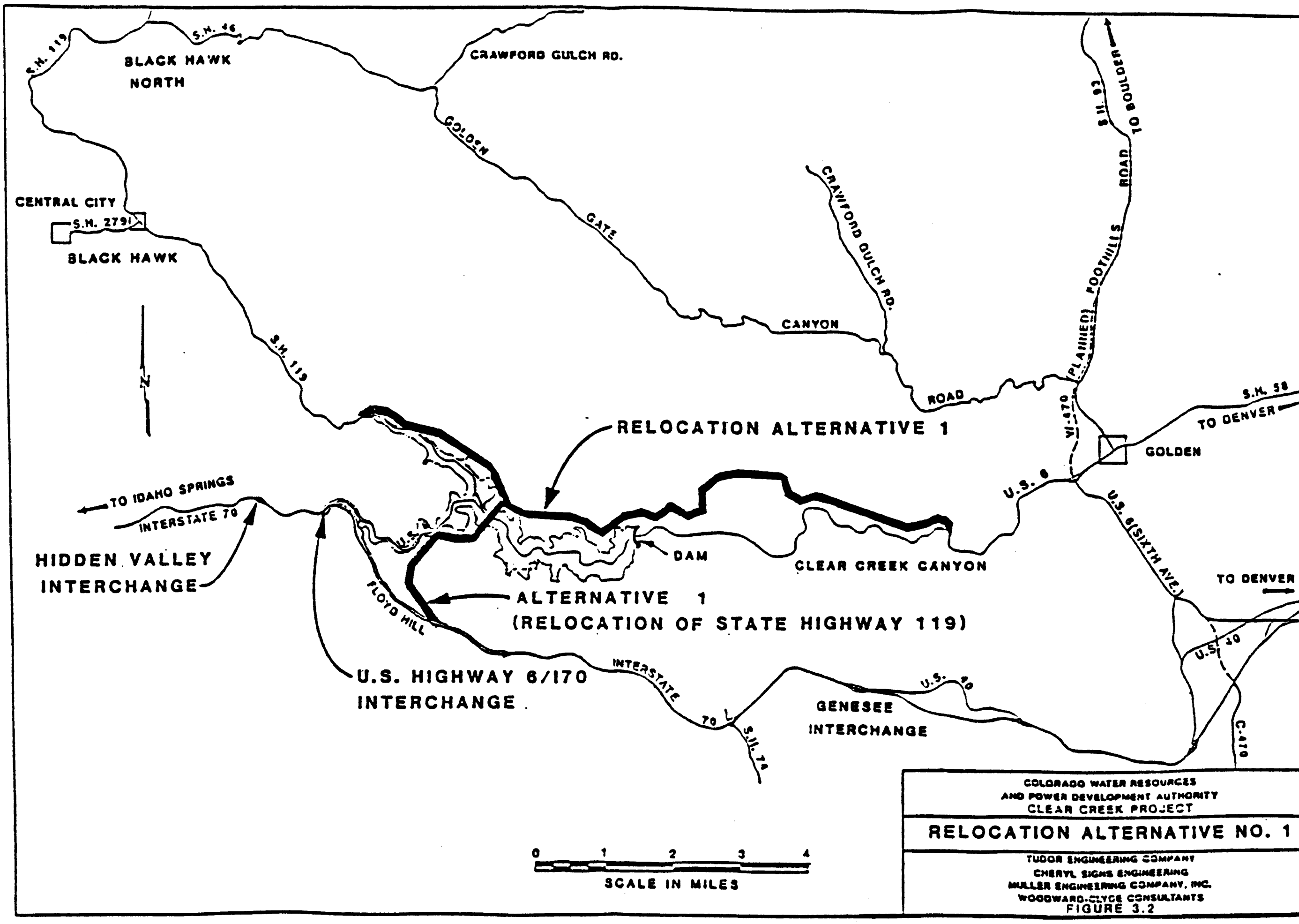
CDOH staff have indicated the need for a broader evaluation of the impact on the state highway system of eliminating U.S. Highway 6, the need for project justification, and the need for public discussion and input.

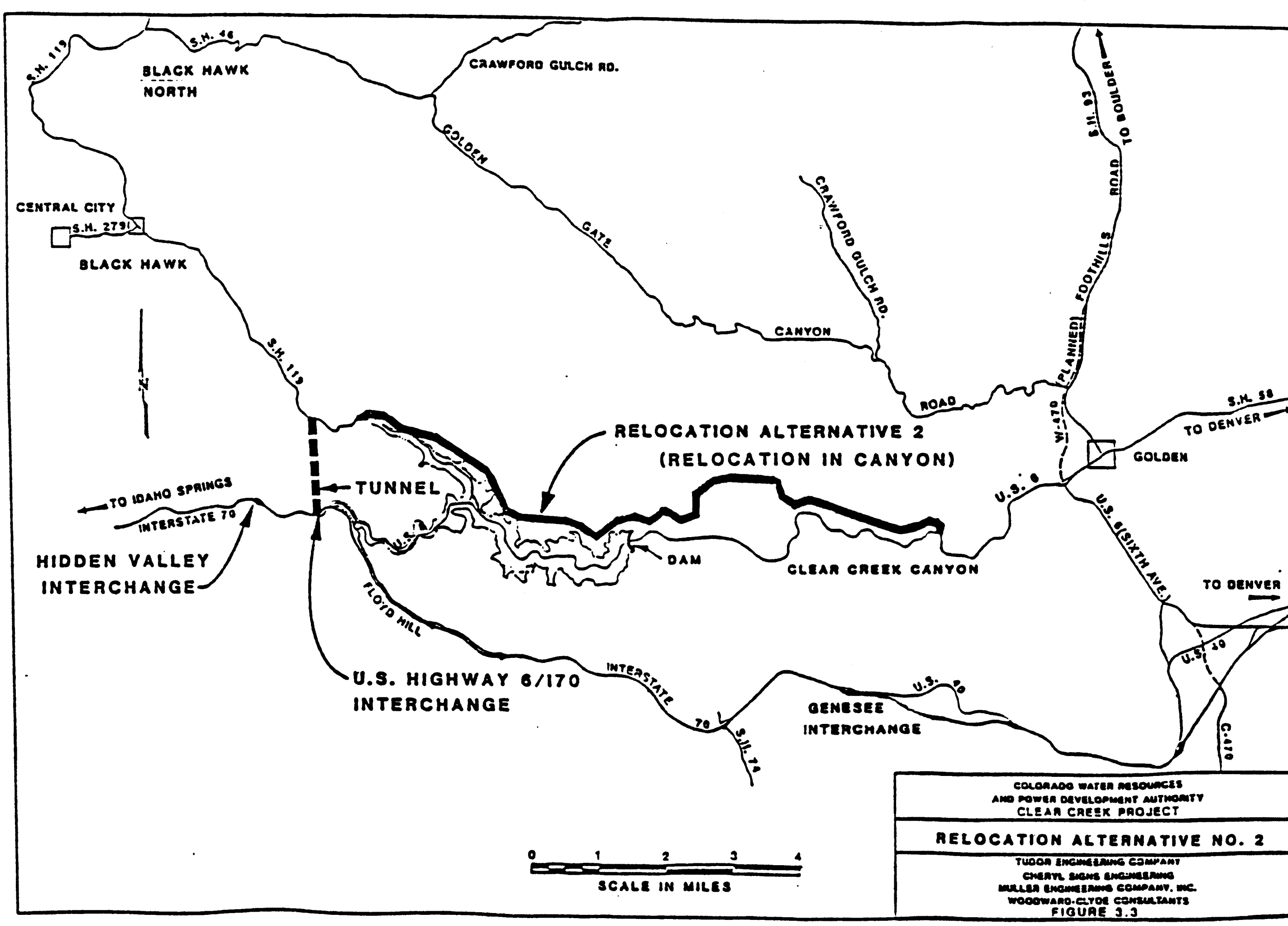


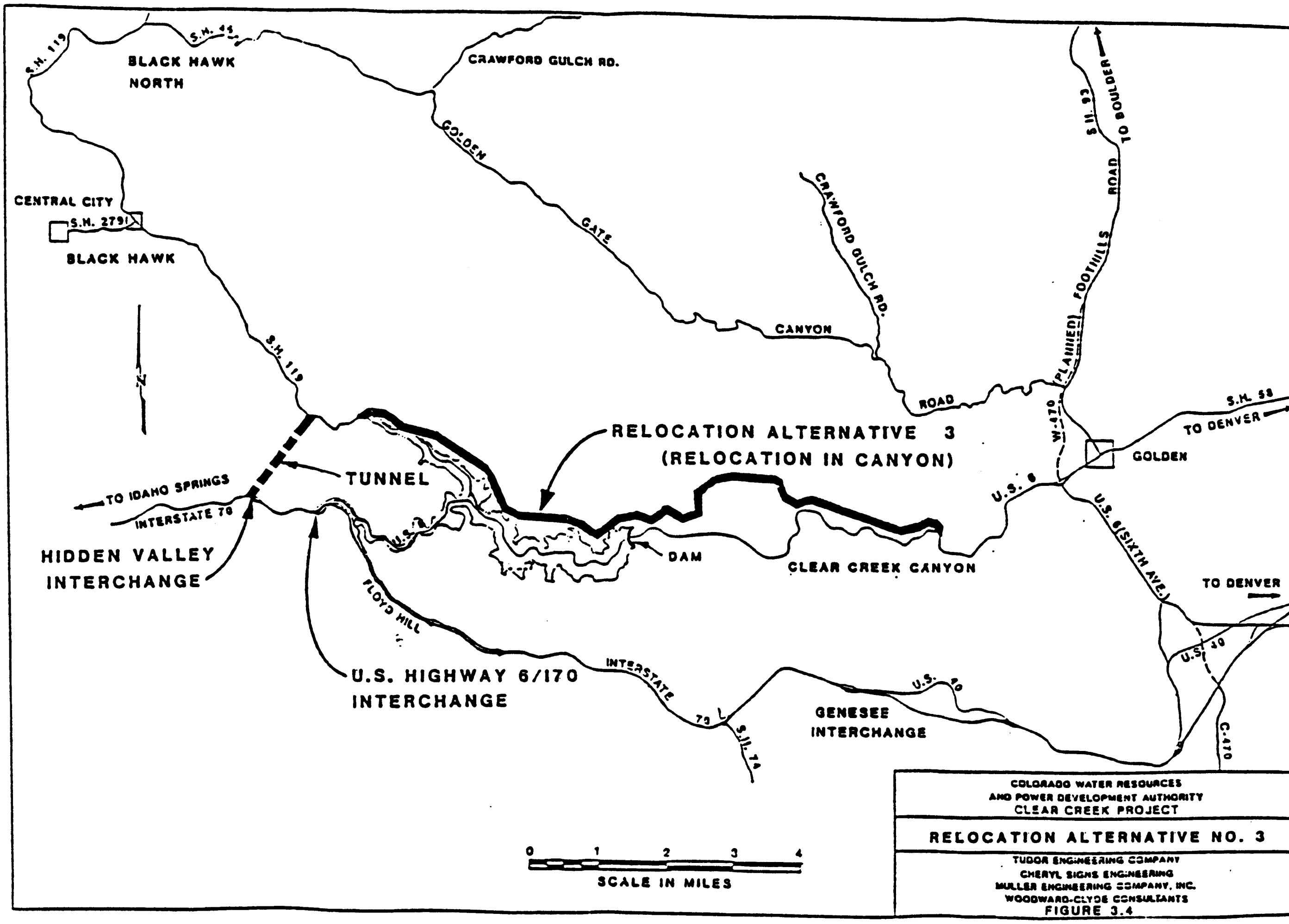
COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY
CLEAR CREEK PROJECT

HIGHWAY DATA ALONG CORRIDORS IN THE PROJECT AREA

TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
MULLER ENGINEERING COMPANY, INC.
WOODWARD-CLYDE CONSULTANTS
FIGURE 3.1


S.H. 119
S.H. 46
BLACK HAWK NORTH
CRAWFORD GULCH RD.
GOLDEN
GATE
CANYON
ROAD
CRAWFORD GULCH RD.
S.H. 93
TO BOULDER
FOOTHILLS
ROAD
(PLANNED)
W-470
CENTRAL CITY
S.H. 279
BLACK HAWK
S.H. 119
N
S.H. 58
TO DENVER
GOLDEN
RELOCATION ALTERNATIVE 1
TO IDAHO SPRINGS
INTERSTATE 70
U.S. 6
U.S. 6 (SIXTH AVE.)
HIDDEN VALLEY INTERCHANGE
DAM
CLEAR CREEK CANYON
TO DENVER
FLOYD HILL
ALTERNATIVE 1
(RELOCATION OF STATE HIGHWAY 119)
U.S. 40
U.S. HIGHWAY 6/170 INTERCHANGE
INTERSTATE 70
S.H. 74
GENESEE INTERCHANGE
U.S. 40
C.470
0 1 2 3 4
SCALE IN MILES
COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY
CLEAR CREEK PROJECT
RELOCATION ALTERNATIVE NO. 1
TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
MULLER ENGINEERING COMPANY, INC.
WOODWARD-CLYDE CONSULTANTS
FIGURE 3.2

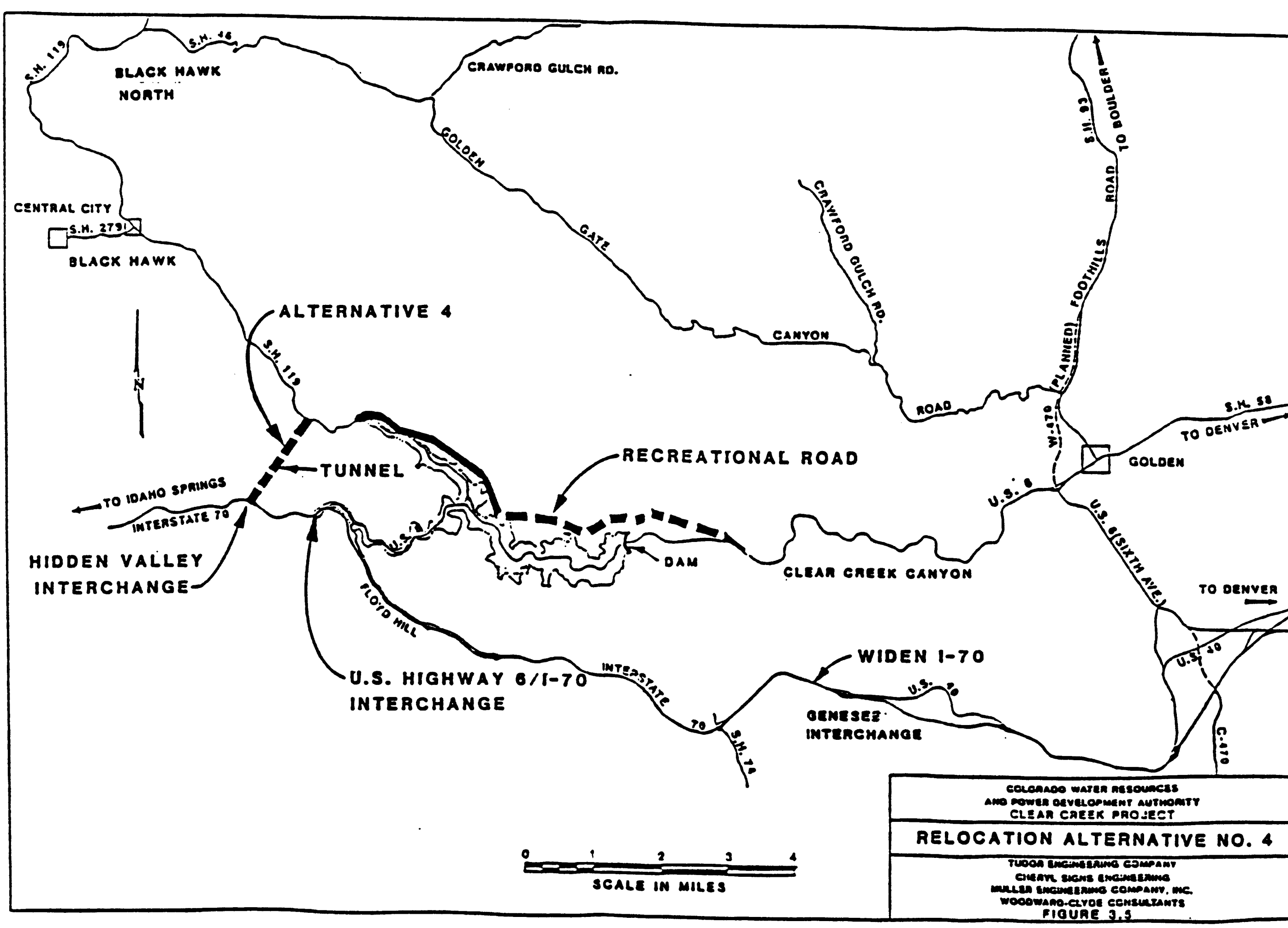

S.H. 119
S.H. 46
BLACK HAWK NORTH
CRAWFORD GULCH RD.
GOLDEN
GATE
CANYON
ROAD
CRAWFORD GULCH RD.
S.H. 93
TO BOULDER
FOOTHILLS
ROAD
(PLANNED)
W-470
CENTRAL CITY
S.H. 279
BLACK HAWK
S.H. 119
N
S.H. 58
TO DENVER
GOLDEN
RELOCATION ALTERNATIVE 2
(RELOCATION IN CANYON)
TUNNEL
TO IDAHO SPRINGS
INTERSTATE 70
U.S. 6
U.S. 6 (SIXTH AVE.)
HIDDEN VALLEY INTERCHANGE
DAM
CLEAR CREEK CANYON
TO DENVER
FLOYD HILL
U.S. 40
U.S. HIGHWAY 6/170 INTERCHANGE
INTERSTATE 70
S.H. 74
GENESEE INTERCHANGE
U.S. 40
C.470
0 1 2 3 4
SCALE IN MILES
COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY
CLEAR CREEK PROJECT
RELOCATION ALTERNATIVE NO. 2
TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
MULLER ENGINEERING COMPANY, INC.
WOODWARD-CLYDE CONSULTANTS
FIGURE 3.3



COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY
CLEAR CREEK PROJECT

RELOCATION ALTERNATIVE NO. 3

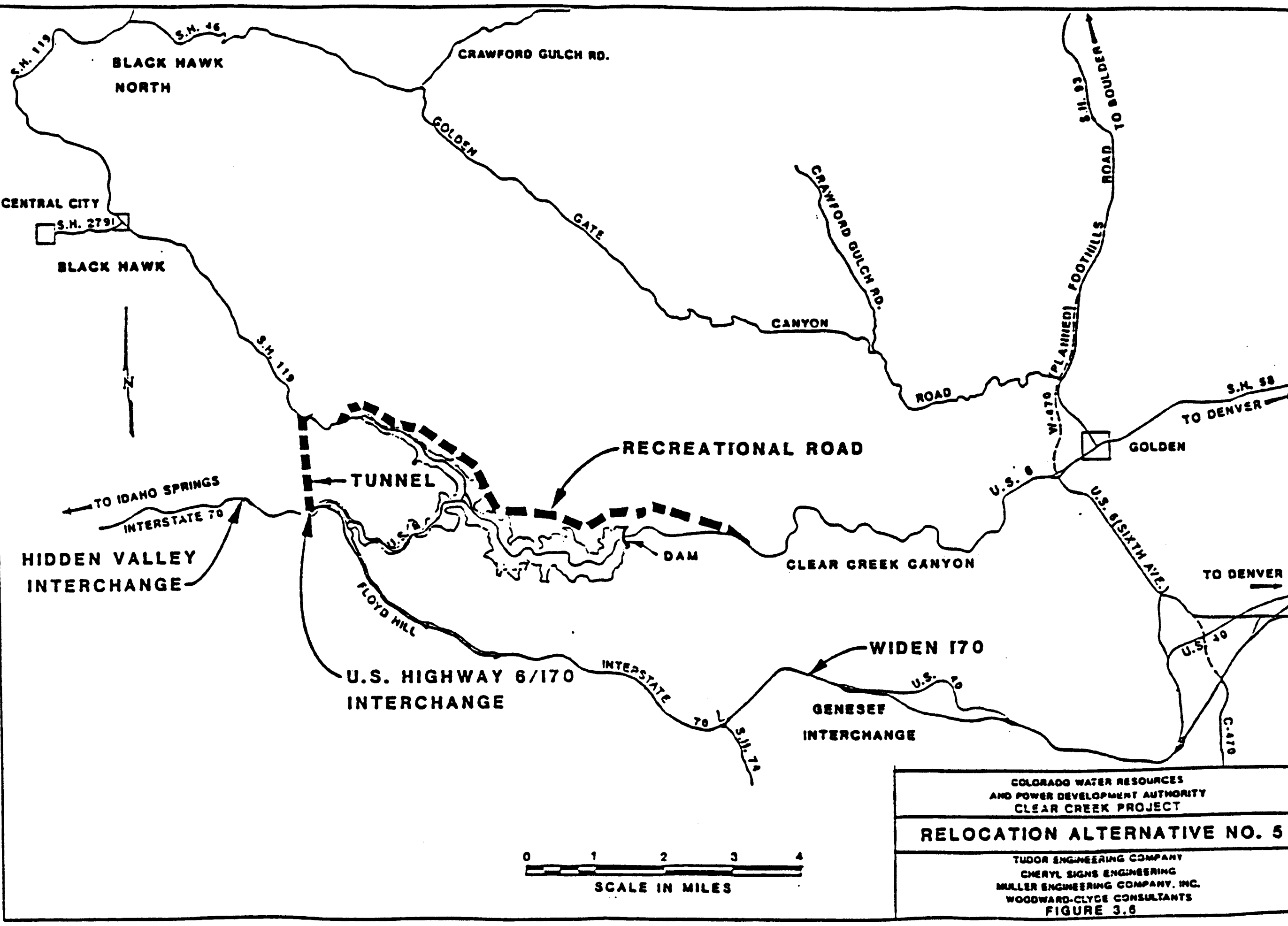
TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
MULLER ENGINEERING COMPANY, INC.
WOODWARD-CLYDE CONSULTANTS
FIGURE 3.4

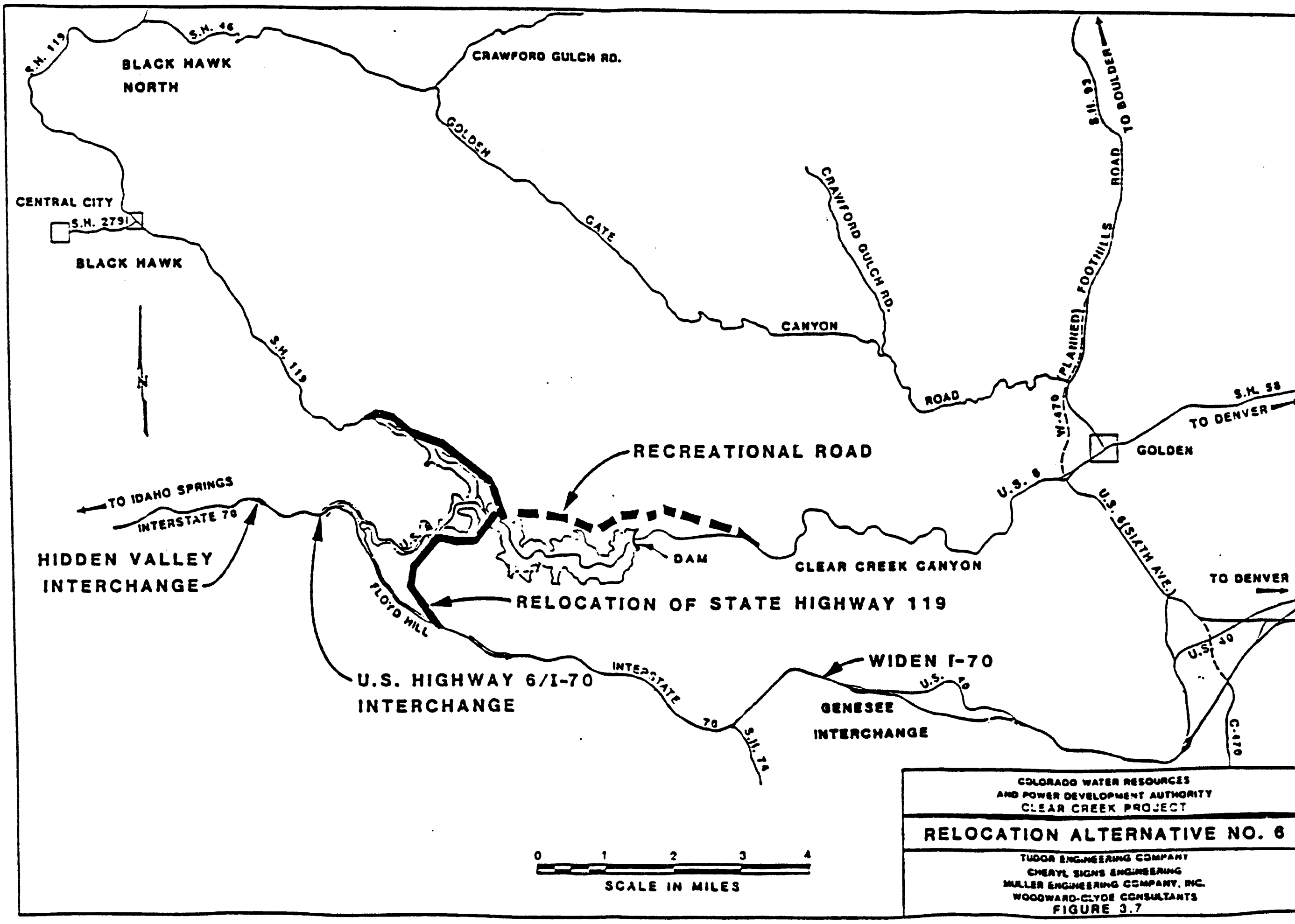


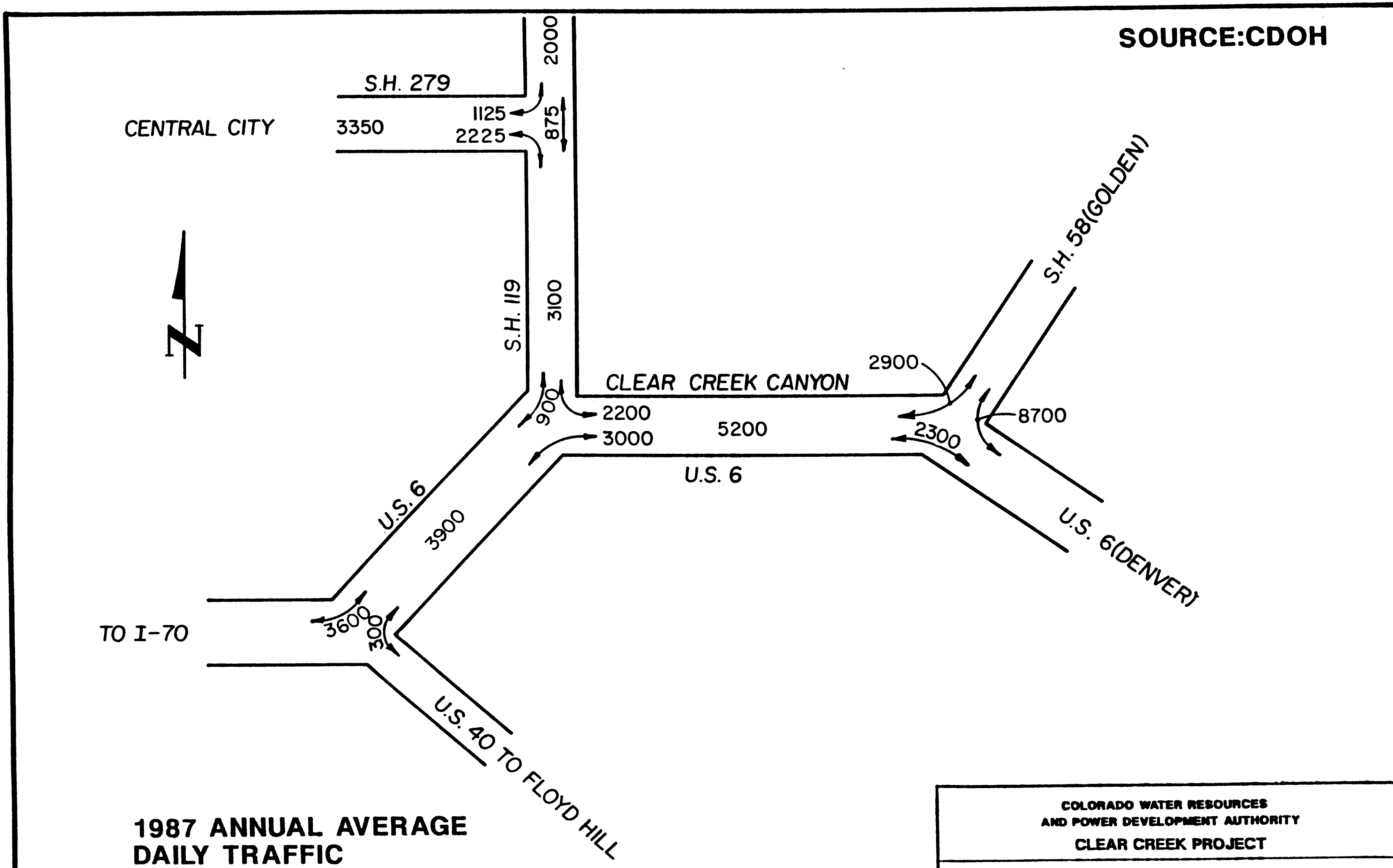
COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY
CLEAR CREEK PROJECT

RELOCATION ALTERNATIVE NO. 4

TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
MULLER ENGINEERING COMPANY, INC.
WOODWARD-CLYDE CONSULTANTS
FIGURE 3.5


S.H. 119
S.H. 46
BLACK HAWK NORTH
CRAWFORD GULCH RD.
GOLDEN
GATE
CANYON
ROAD
CRAWFORD GULCH RD.
S.H. 93
TO BOULDER
FOOTHILLS ROAD
(PLANNED)
W.470
CENTRAL CITY
S.H. 279
BLACK HAWK
S.H. 119
N
S.H. 58
TO DENVER
GOLDEN
RECREATIONAL ROAD
TUNNEL
TO IDAHO SPRINGS
INTERSTATE 70
U.S. 6
U.S. 6 (SIXTH AVE.)
HIDDEN VALLEY INTERCHANGE
DAM
CLEAR CREEK CANYON
TO DENVER
FLOYD HILL
U.S. 40
WIDEN I70
U.S. HIGHWAY 6/I70 INTERCHANGE
INTERSTATE 70
S.H. 74
U.S. 40
GENESEE INTERCHANGE
C.470
COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY
CLEAR CREEK PROJECT
RELOCATION ALTERNATIVE NO. 5
TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
MULLER ENGINEERING COMPANY, INC.
WOODWARD-CLYDE CONSULTANTS
FIGURE 3.6
0 1 2 3 4
SCALE IN MILES


S.H. 119
S.H. 46
BLACK HAWK NORTH
CRAWFORD GULCH RD.
GOLDEN
GATE
CANYON
ROAD
CRAWFORD GULCH RD.
S.H. 93
TO BOULDER
FOOTHILLS ROAD
(PLANNED)
W.470
CENTRAL CITY
S.H. 279
BLACK HAWK
S.H. 119
N
S.H. 58
TO DENVER
GOLDEN
RECREATIONAL ROAD
TO IDAHO SPRINGS
INTERSTATE 70
U.S. 6
U.S. 6 (SIXTH AVE.)
HIDDEN VALLEY INTERCHANGE
DAM
CLEAR CREEK CANYON
TO DENVER
FLOYD HILL
RELOCATION OF STATE HIGHWAY 119
U.S. 40
WIDEN I-70
U.S. HIGHWAY 6/I-70 INTERCHANGE
INTERSTATE 70
S.H. 74
U.S. 40
GENESEE INTERCHANGE
C.470
COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY
CLEAR CREEK PROJECT
RELOCATION ALTERNATIVE NO. 6
TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
MULLER ENGINEERING COMPANY, INC.
WOODWARD-CLYDE CONSULTANTS
FIGURE 3.7
0 1 2 3 4
SCALE IN MILES



COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CLEAR CREEK PROJECT

CENTENNIAL DAM
U.S. 6 TRAFFIC DISTRIBUTION

TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
MULLER ENGINEERING COMPANY, INC.
WOODWARD-CLYDE CONSULTANTS

FIGURE 3.8

Section 4

DAM LAYOUTS AND COSTS

4.0 DAM LAYOUTS AND COSTS

4.1 SUMMARY

4.1.1 Purpose

The studies documented in this chapter were performed to estimate construction costs for a range of dam heights at a representative reservoir site, within the Clear Creek Canyon, capable of storing at least 200,000 af of water. The Centennial damsite was chosen as the representative location for the dam and reservoir for purposes of the Clear Creek Project Phase I, Step 2 - Feasibility Study (Step 2 Study). Dam layouts and cost estimates were prepared for three dam heights and reservoir capacities at the Centennial site as noted in Table 4.1. The largest of the three dams would have a height of 540 ft with the potential for storing up to 230,000 af of water.

Dam costs were developed to be utilized in conjunction with the reservoir operation studies to evaluate project economics. The results of these studies are summarized in the cost curves presented in Figures 4.1 and 4.2 which relate construction costs to a range of dam heights (Figure 4.1) and to a range of reservoir volumes (Figure 4.2). The engineering studies conducted to produce these designs and cost estimates included: selection of a typical damsite; site-specific geologic and geotechnic investigations; dam layouts; and preparation of cost estimates and construction schedules.

4.1.2 Background

The Clear Creek Project Phase I, Step 1 - Feasibility Study (Step 1 Study) identified 16 potential reservoir storage sites on the mainstem of Clear Creek and its major tributaries. These sites include 11 for water supply storage and 5 upper reservoirs for pumped storage. The 11 sites for water supply storage include 4 canyon damsites and 7 off-stream storage sites. Conceptual layouts were made for all 16 sites and cost estimates were prepared to determine the relative storage costs. The results of these studies are given in the Step 1 Study (Authority, 1987).

TABLE 4.1

Centennial Dam
Cost Summary(5)

Reservoir Volume(1) (acre-feet)	Dam Height(2) (feet)	Dam Volume(3) (yd^3)	Construction Cost of Dam(4) ($ million)
110,000	420	650,000	142,000,000
165,000	480	950,000	166,400,000
230,000	540	1,200,000	211,200,000

(1)Total reservoir volume including permanent recreation pool of 30,000 af.
(2)Dam height above streambed.
(3)Dam volume for a concrete-arch dam.
(4)Construction cost includes a 25 percent contingency and 15 percent for engineering and administrative costs.
(5)Cost relationships for dams ranging in height from 420 feet to 540 feet were based on cost estimates for these three dams. Figures 4.1 and 4.2 show these cost relationships in graphical form.

Based on the results of the Step 1 Studies, it was concluded that a reservoir of at least 100,000 af capacity would be needed to produce a firm water supply yield that was both sufficient in quantity as well as potentially cost effective for the project sponsors. It was further concluded that a storage capacity of 200,000 af or more may provide additional firm yield at an even lower unit cost ($/af/yr) due to economies of scale. During Step 1 Studies it was determined that the only reservoir sites with capacities in excess of 100,000 af were located in Clear Creek Canyon. Therefore, dam and reservoir investigations for the Step 2 Study only considered sites located in Clear Creek Canyon between the canyon mouth at Golden and the confluence of North Clear Creek. This 10-mile reach of Clear Creek Canyon was investigated to identify a representative dam and reservoir site adequate to store a volume from 100,000 af to at least 200,000 af.

The Centennial damsite was selected in these Step 2 Studies as a representative canyon damsite within this river reach. This site was used because of its adequate reservoir storage capacity, favorable damsite topography, and damsite geology.

4.1.3 Centennial Damsite

The Centennial damsite is located in Clear Creek Canyon approximately 3 miles downstream of the confluence with North Clear Creek and 8 miles from the mouth of the canyon at Golden. This damsite is 1 mile upstream of Tunnel No. 3. A layout of typical project features at the Centennial damsite is shown in Figure 4.3.

The Centennial reservoir could store up to 230,000 af of water. Under maximum flood conditions, the reservoir would extend upstream along Clear Creek to the Interstate 70, U.S. Highway 6 interchange, and up North Clear Creek for approximately 1.5 miles.

The Centennial damsite is located in a steep canyon topography and the terrain is conducive to the construction of a concrete-arch dam. Field reconnaissance indicates that a dam at this site would be founded on massive gneisses and granites, which generally provide an excellent foundation for concrete-arch dams.

4.1.4 Scope of Work

The scope of work documented in this chapter includes four principal tasks: selection of a typical damsite; site-specific geologic and geotechnical investigations; dam layouts; and preparation of cost estimates and construction schedules. These tasks were performed to refine the work of the Step 1 Study by producing a range of dam construction costs at a specific canyon damsite.

1. Selection of Representative Damsite for Step 2 Study - The dam siting of the Step 1 Study was reviewed to select a representative damsite that could store up to 200,000 af. The four canyon damsites identified in the Step 1 Study were investigated during the Step 2 Study but were not used as the representative canyon damsite because of potential topographic or geologic constraints that could limit those sites to less than the 200,000 af reservoir capacity being considered in these Step 2 Studies
2. Damsite Geology - The scope of the geologic and geotechnical investigation included screening potential canyon damsites to determine the most geologically suitable site, and site-specific studies of the selected site. Site-specific geologic investigations concentrated on determining the suitability of the Centennial damsite to support a major concrete dam. These investigations included determining rock types and jointing trends

and estimations of foundation weathering. The potential for reservoir seepage at the Black Hawk Fault was also addressed

3. Dam Layouts - Arch dam layouts were prepared for three dam heights at the Centennial damsite. These layouts provide the basis for construction cost estimates for reservoirs ranging from 110,000 to 230,000 af. This range of storages was selected to provide a wide range of reservoir capacity for use in the operation studies. Features considered for the dam layout include: river diversion; foundation excavation and treatment; arch dam geometry; spillway; outlet works; and power plant sizing
4. Cost Estimates - Cost estimates were prepared to provide a range of dam construction costs for reservoir capacities from 100,000 to 230,000 af. Quantities and costs were estimated for three dam heights to produce a relation between dam height and construction cost and also between reservoir capacity and construction cost. Details of cost estimating procedures are given in Section 4.5

4.2 DESIGN CRITERIA

4.2.1 Dam Heights Considered

Three dam heights were used to determine the relationship between dam height and construction costs. The three dam heights and reservoir capacities investigated are shown in Table 4.2 below. Dam height is measured from the existing streambed elevation of 6690 Mean Sea Level (MSL).

4.2.2 Dams

Layouts were prepared for each dam height based upon design requirements defined in the Design of Arch Dams (U.S. Bureau of Reclamation, 1977). All dams were laid out as double-curvature thin-arch dams. An arch dam was selected for the purposes of these preliminary designs because of the suitable canyon shape and foundation conditions for the arch, the ability of this design to incorporate the spillway and outlet works as part of the dam structure, and the local availability of borrow for concrete dam construction. Concrete quantity estimates of dam volumes were based upon planimetered areas from dam layout drawings. The minimum excavation depth used for the layouts was 20 feet at the abutments and 30 feet in the stream channel.

TABLE 4.2

Summary of Dams and Reservoirs Studied

Dam Crest Elevation (MSL)	Dam Height (ft)	Reservoir Storage (af)
7110	420	110,000
7170	480	165,000
7230	540	230,000

4.2.3 Spillway

The spillway was sized to pass the probable maximum flood (PMF) without overtopping the dam. The spillway would be an ungated central overflow type with a flip bucket type energy dissipator. No freeboard was considered between the PMF maximum water surface elevation and the dam crest. Freeboard above the PMF maximum water surface elevation was assumed to be provided by the dam parapet.

4.2.4 Outlet Works

A large capacity outlet works would be needed to minimize the frequency of spillway use and permit controlled releases from the dam. The outlet works would be sized for a hydraulic capacity of 5000 cfs; this capacity outlet works could pass a 25-year return period flood without requiring use of the spillway. A multiple ported intake structure would be provided on the upstream face of the dam. Reservoir intake gates, located at several reservoir levels, would allow for selective level withdrawal releases from the reservoir.

4.2.5 River Diversion

The construction diversion system assumed for this study would protect the construction site against a 25-year flood. The diversion system would consist of a diversion tunnel constructed at the dam abutment and a diversion dam to divert river flow to the tunnel.

4.2.6 Power Plant

A conventional power plant could be located at the base of the dam. The power plant would be operated as a run-of-river facility and would have a capacity of approximately 12 megawatts. The power generating facilities would share a common intake structure with the outlet works.

4.2.7 Minimum Reservoir Pool

A recreation pool of 30,000 af has been assumed for the reservoir operation. This 30,000 af pool allows for 10,000 af of sediment storage.

4.3 GEOLOGY

4.3.1 Dam and Reservoir Geological Requirements (Site Identification)

The site identified as a representative dam and reservoir in the Clear Creek Canyon can provide the reservoir storage volumes required for the study. This damsite appears suitable for the construction of a major dam. The criteria used to identify the damsite include canyon shape, abutment weathering, bedrock jointing frequency, and the direction of bedrock jointing in relation to the geometry of the dam.

No subsurface geotechnical investigations were conducted as part of this study. Site identification was based upon existing geologic maps and literature, review of aerial photos at a scale of 1:62,500, an aerial reconnaissance of prospective damsites, and brief field inspections which found that the abutments of the selected damsite are exposed and provide a good indication of the damsite geology. Preliminary geological reconnaissance indicates that the site will be suitable for the construction of a major storage facility.

4.3.2 Foundation Assumptions

Layouts for the dams assume that the abutments will be shaped to distribute loadings from the dam and to remove weathered bedrock. The minimum excavation depth assumed for layouts and quantity estimating was 20 feet. Areas of the foundation requiring foundation shaping were estimated to have rock cuts up to 100 feet deep as shown in Figure 4.4.

For the quantity estimates, foundation treatment was assumed to consist of consolidation grouting of the entire dam foundation, a deep curtain grout line, abutments adits, and a drainage gallery.

4.3.3 Damsite Geology

The Centennial damsite and reservoir site are underlain predominately by crystalline rocks, typically banded gneisses, with some granites and pegmatite dikes and veins. A reconnaissance level geologic map was prepared in the field and is shown in Figure 4.5.

The left abutment (north abutment) of the Centennial damsite is characterized by relatively smooth colluvial-covered grassy slopes interspersed with ribs of more resistant rock. The colluvium that covers much of the left abutment is estimated to range up to 30 feet in thickness. The depth of weathering at the left abutment undoubtedly is varied but likely extends 10 feet into the rock, and may extend considerably more. The exposed bedrock typically is fresh to slightly weathered, hard and durable. No free water was observed either running across or emanating from the left abutment on the site inspection of June 28, 1988.

The rock in the left abutment appears suitable for founding the dam type being considered. Colluvial materials on the left abutment will need to be removed beneath the dam foundation. The depth of excavation into rock will likely be controlled by the depth of weathering of the pegmatite veins. For cost estimating purposes at this level of study, blanket grouting is assumed to be required beneath the dam foundation, and a grout curtain will be required to reduce seepage losses.

The river bed area is strewn with granitic/gneissic boulders, in what is likely to be a discontinuous or incomplete layer. It is expected that in places, the creek flows directly on bedrock at the proposed damsite. On the right side of the valley bottom, bedrock is exposed in a rock wall. Based on observations of the two abutments, the gneiss in the valley bottom should support the foundation of the dam type being considered.

The right abutment (south abutment) of the Centennial damsite is composed of a massive block of mainly gneiss, with minor granite. The right abutment rises steeply from the creek bottom for several hundred feet before beginning to flatten. There appear to be fewer minor joint sets in the bedrock in the right abutment than in the left, although detailed studies likely will show a similar number.

Nearly all exposed bedrock observed on the right abutment is hard and fresh to slightly weathered. There is a noticeable absence of pegmatite veins compared with the left abutment, and the rock mass appears to be much more homogeneous. A minor seep of water was noted on June 28, 1988 from the colluvial deposit upstream of the right abutment. In sharp contrast with the grassy left abutment, much of the right abutment appears to be suitable to support a concrete-arch dam. Excavation depths will be less than for the left abutment but grouting considerations should be similar.

4.3.4 Reservoir Geology

Virtually any reservoir of the sizes being contemplated in the canyon would overlie a fault zone. In the case of the Centennial site, the reservoir overlies the Black Hawk Fault. This is a vertical fault trending in a south 30-degree each direction, crossing the creek bed approximately one-half mile upstream of the dam axis. Near the bridge crossing the creek, the fault zone appears to be up to several hundred feet wide. The rocks are highly shattered and are oxidized or weathered to a rusty-orange color. The material appears similar to that being extracted from a quarry several miles downstream where gravels created by the Windy Gap fault are being mined. The Black Hawk Fault is not considered potentially active by the Colorado Geological Survey (Kirkham and Rogers, 1981). According to Kirkham and Rogers, the Black Hawk Fault has not exhibited movement in the last 24 million years.

The potential exists for the migration of some reservoir waters southeastward along the fault for approximately 1.5 miles into Beaver Brook. However, faults of the age of the Black Hawk Fault, at least 70 million years, can be silicified and relatively tight; consequently, significant seepage losses along the fault are not anticipated.

A second area of potential reservoir seepage involves a mapped Tertiary gravel deposit above an elevation of approximately 7150 feet on the right side. It is possible that at high water levels water could seep into the gravels. If bedrock does not underlie this gravel deposit to an elevation greater than the maximum reservoir level, then water could seep out of the reservoir and into the Beaver Brook drainage. It is judged that the probability of seepage losses by this pathway is not significant.

4.3.5 Potential Borrow Areas

Numerous locations exist within the reservoir site that could be used as borrow sources for shot rock for aggregate. Sand and gravel sources may exist in the valley bottom, specifically along North Clear Creek, but the volume and quality of the material is not known. Neither test pit excavation in the valley bottom nor testing of potential shot rock and alluvial borrow material was performed.

4.4 ENGINEERING AND DESIGN

4.4.1 Dam

Three dam heights for the Centennial damsite were laid out to estimate relative costs of storage. Dam heights above streambed ranged from 420 feet to 540 feet. A summary of statistics for the dams studied are given in Tables 4.4, 4.5, and 4.6. Arch dam layouts were prepared with the assistance of special consultant Milton Kramer.

Features considered for the three layouts are similar and, for purposes of this report, the layout drawing is shown for a typical dam. For purposes of illustration, the layout drawing for dam height 480 feet is included in Figure 4.4.

The dam radius ranges from 900 feet for the lowest dam considered to 1000 feet for the highest dam considered. Base width of the dam at the maximum section will range from 60 feet for the lowest dam to 80 feet for the highest dam. The dam crest width was laid out as a minimum and will not permit a public road crossing on the dam crest.

4.4.2 Flood Hydrology

4.4.2.1 PMF Analysis

The PMF for a reservoir at the Centennial damsite is estimated to have a peak discharge of 320,000 cfs. Estimates of PMF peak discharge are based upon Hydrometeorological Report No. 55 (National Oceanic and Atmospheric Administration, 1984) and studies conducted by Tudor Engineering Company for the U.S. Bureau of Reclamation (Tudor Engineering Company, 1982). The 72-hour probable maximum precipitation (PMP) for the Clear Creek catchment is 24 inches. The runoff from this PMP was estimated to derive the PMF hydrograph. The capacity of the proposed reservoir is small in comparison to the estimated volume of the PMF (370,000 af), so the flood peak would pass through the reservoir with only slight attenuation. Preliminary flood routing indicates that a spillway with a 500-foot long crest would pass the full PMF with approximately 30 feet of surcharge above the spillway crest.

4.4.2.2 Flood Frequency Analysis

A flood frequency analysis was prepared to determine sizing requirements for the outlet works and construction diversion facilities. The distribution of flood peaks is mixed. Most annual maximums are the result of snowmelt in June. Others are the result of runoff from rain in August and September. When the peak occurs in early July, it is usually the result of runoff from rain combined with late snowmelt.

The largest known discharge at Golden is 8700 cfs (U.S. Geologic Survey, 1988). This flood occurred on August 1, 1888, at a location approximately 6 miles downstream from the present gaging station. Return periods for various floods are given on Table 4.3.

TABLE 4.3

Flood Frequency Analysis(1)

Return Period Years	Peak Discharge, cfs
2	1,550
10	3,350
25	5,000
100	8,300

(1)For Clear Creek within the Clear Creek Canyon.

4.4.3 Spillway

A 500-foot long spillway would be incorporated into the crest of the dam. The spillway crest would be ungated with a high flip bucket chute designed to direct flow away from the toe of the dam as shown in Figure 4.4. The spillway would operate on an infrequent basis to reduce the occurrence of downstream spray and erosion. A stilling pool would be provided to dissipate energy from the impact of spillway flow on the stream channel. Normal flood releases could be made through the outlet works facilities.

Flood routings were conducted with the reservoir level at the spillway crest at the beginning of the flood. Routing of the PMF through the reservoir results in no significant reduction in the PMF flood peak. The maximum surcharge required to pass the PMF inflow of 320,000 cfs is approximately 30 feet.

4.4.4 Outlet Works

The outlet works are designed to be incorporated into the dam structure and consist of an intake structure, steel outlet pipes embedded within the dam, and a reinforced concrete control house. A multiple ported intake structure would be located on the upstream face of the dam to permit selective level reservoir withdrawals. Gates would be located on the upstream face of the dam for the emergency shut off of the outlet works. Downstream regulating gates would be located in the powerhouse at the toe of the dam. The hydraulic capacity of the outlet works was sized to provide 5000 cfs to pass a 25-year flood without operating the spillway. This hydraulic capacity is sufficient to meet the State Engineer's reservoir evacuation requirements.

4.4.5 Construction Diversion Facilities

The river diversion system would consist of an upstream diversion dam and an 18-foot diameter tunnel in the right abutment of the dam. The tunnel would be 1300 feet long and would not be lined. The upstream cofferdam would be approximately 40 feet high. Diversion facilities were sized to pass a 25-year flood of 5000 cfs without flooding the damsite area. Upon completion of dam construction, the upstream end of the diversion tunnel would be plugged with concrete.

TABLE 4.4

Centennial Damsite Summary Sheet
Reservoir Capacity of 110,000 af
Dam Height at 420 Feet

Reservoir:	
Maximum Water Surface Elevation (PMF Condition)	7110 ft
Maximum Operating Water Surface Elevation	7080 ft
Minimum Operating Water Surface Elevation	6920 ft
Total Storage at Maximum (and Minimum) Operating Water Surface Elevation	110,000 af (30,000 af)
Surface Area at Maximum (and Minimum) Operating Water Surface Elevation	740 acres (280 acres)
Dam:	
Type	Arch Dam
Maximum Height Above Streambed	420 ft
Crest Elevation	7110 ft
Crest Length	1460 ft
Crest Thickness	18 ft
Base Thickness	58 ft
Dam Volume	650,000 yd^3
River Bed Elevation	6690 ft
Spillway:	
Crest Elevation	7080 ft
Crest Length	500 ft
Capacity	320,000 cfs
Outlet Works:	
Type	Selective Level Withdrawal
Conveyance	Steel Liner
Control Gates	Jet-Flow Gates
Capacity	5000 cfs
Power Plant(1):	
Installed Capacity(2)	12 MW (approximately)
Number and Type of Units	2-6 MW Francis
Diversion During Construction:	18-Foot I.D. Tunnel
Maximum Design Capacity	5000 cfs

---

(1)Only the civil works for the power plant are included in Step 2 Studies.

(2)Installed capacity of 12 MW power plant based upon preliminary studies conducted as part of the Step 1 Feasibility Study (Authority, 1987).

TABLE 4.5

Centennial Damsite Summary Sheet
Reservoir Capacity of 165,000 af
Dam Height at 480 Feet

Reservoir:	
Maximum Water Surface Elevation (PMF Condition)	7170 ft
Maximum Operating Water Surface Elevation	7140 ft
Minimum Operating Water Surface Elevation	6920 ft
Total Storage at Maximum (and Minimum) Operating Water Surface Elevation	165,000 af (30,000 af)
Surface Area at Maximum (and Minimum) Operating Water Surface Elevation	960 acres (280 acres)
Dam:	
Type	Arch Dam
Maximum Height Above Streambed	480 ft
Crest Elevation	7170 ft
Crest Length	1620 ft
Crest Thickness	21 ft
Base Thickness	66 ft
Dam Volume	950,000 yd^3
River Bed Elevation	6690 ft
Spillway:	
Crest Elevation	7140 ft
Crest Length	500 ft
Capacity	320,000 cfs
Outlet Works:	
Type	Selective Level Withdrawal
Conveyance	Steel Liner
Control Gates	Jet-Flow Gates
Capacity	5000 cfs
Power Plant(1):	
Installed Capacity(2)	12 MW (approximately)
Number and Type of Units	2-6 MW Francis
Diversion During Construction:	18-Foot I.D. Tunnel
Maximum Design Capacity	5000 cfs

(1)Only the civil works for the power plant are included in Step 2 Studies.

(2)Installed capacity of 12 MW power plant based upon preliminary studies conducted as part of the Step 1 Feasibility Study (Authority, 1987).

TABLE 4.6

Centennial Damsite Summary Sheet
Reservoir Capacity of 230,000 af
Dam Height at 540 Feet

Reservoir:	
Maximum Water Surface Elevation (PMF Condition)	7230 ft
Maximum Operating Water Surface Elevation	7200 ft
Minimum Operating Water Surface Elevation	6920 ft
Total Storage at Maximum (and Minimum) Operating Water Surface Elevation	230,000 af (30,000 af)
Surface Area at Maximum (and Minimum) Operating Water Surface Elevation	1200 acres (280 acres)
Dam:	
Type	Arch Dam
Maximum Height Above Streambed	540 ft
Crest Elevation	7230 ft
Crest Length	1845 ft
Crest Thickness	24 ft
Base Thickness	80 ft
Dam Volume	1,200,000 yd^3
River Bed Elevation	6690 ft
Spillway:	
Crest Elevation	7200 ft
Crest Length	500 ft
Capacity	320,000 cfs
Outlet Works:	
Type	Selective Level Withdrawal
Conveyance	Steel Liner
Control Gates	Jet-Flow Gates
Capacity	5000 cfs
Power Plant(1):	
Installed Capacity(2)	12 MW (approximately)
Number and Type of Units	2-6 MW Francis
Diversion During Construction:	18-Foot I.D. Tunnel
Maximum Design Capacity	5000 cfs

(1)Only the civil works for the power plant are included in Step 2 Studies.

(2)Installed capacity of 12 MW power plant based upon preliminary studies conducted as part of the Step 1 Feasibility Study (Authority, 1987).

4.5 CONSTRUCTION COSTS AND SCHEDULE

4.5.1 General

Construction cost estimates were prepared for three dam heights. Construction costs were based on quantity estimates of the major construction items such as diversion of the river, excavation, foundation treatment, concrete placement costs, and appurtenant facilities such as the spillway, outlet works, and the power plant. In all, 29 items were used to prepare the cost estimates.

4.5.2 Construction Costs

The costs for concrete are based upon estimates of aggregate production, forming, and placement of costs. Concrete placement costs are based on the use of one cableway located on the left and right abutments. The cost of concrete batching plants and access roads to both abutments were considered as part of the contract mobilization costs. Each of the abutment access road works will be approximately 3400 feet in length. The costs of cement, concrete cooling, foundation grouting, and reinforcement were estimated as separate construction items. All prices are August 1988 figures.

A detailed list of major construction items was prepared for each dam height. The most significant items comprising the construction are the costs of excavation, concrete, and cement. Quantity estimates of these items were determined by preparing preliminary dam designs and computing quantities from these drawings. The unit costs were estimated from experience on similar construction projects. The three major items comprise approximately 60 percent of the dam construction costs. Table 4.7 shows a cost estimate for the dam having a 165,000 af reservoir and a dam height of 480 feet. The corresponding construction schedule for these items is shown on Figure 4.6.

Figure 4.1 shows the relationship between total construction cost for the dam and the dam height above existing streambed. These costs include a 25 percent contingency and a 15 percent allowance for engineering and administration. The estimated cost for interest during construction and project financing are included later in this report as part of the financial analysis of the project. Figure 4.2 shows the relationship between the total construction cost of the dam versus reservoir volume. Construction costs range from $142 million for the 110,000 af reservoir to $211 million for the 230,000 af reservoir.

4.5.3 Construction Schedule

Construction of the dam is estimated to require almost five years as shown on Figure 4.6. The first year of construction would include the contractor's move-in and mobilization and construction of the diversion tunnel and diversion facilities. Access roads would be built from the existing highway to the left and right abutments of the dam.

The major activity during the second year would be the excavation for the dam. This would include excavating for the powerhouse, tailrace, and the abutment adits.

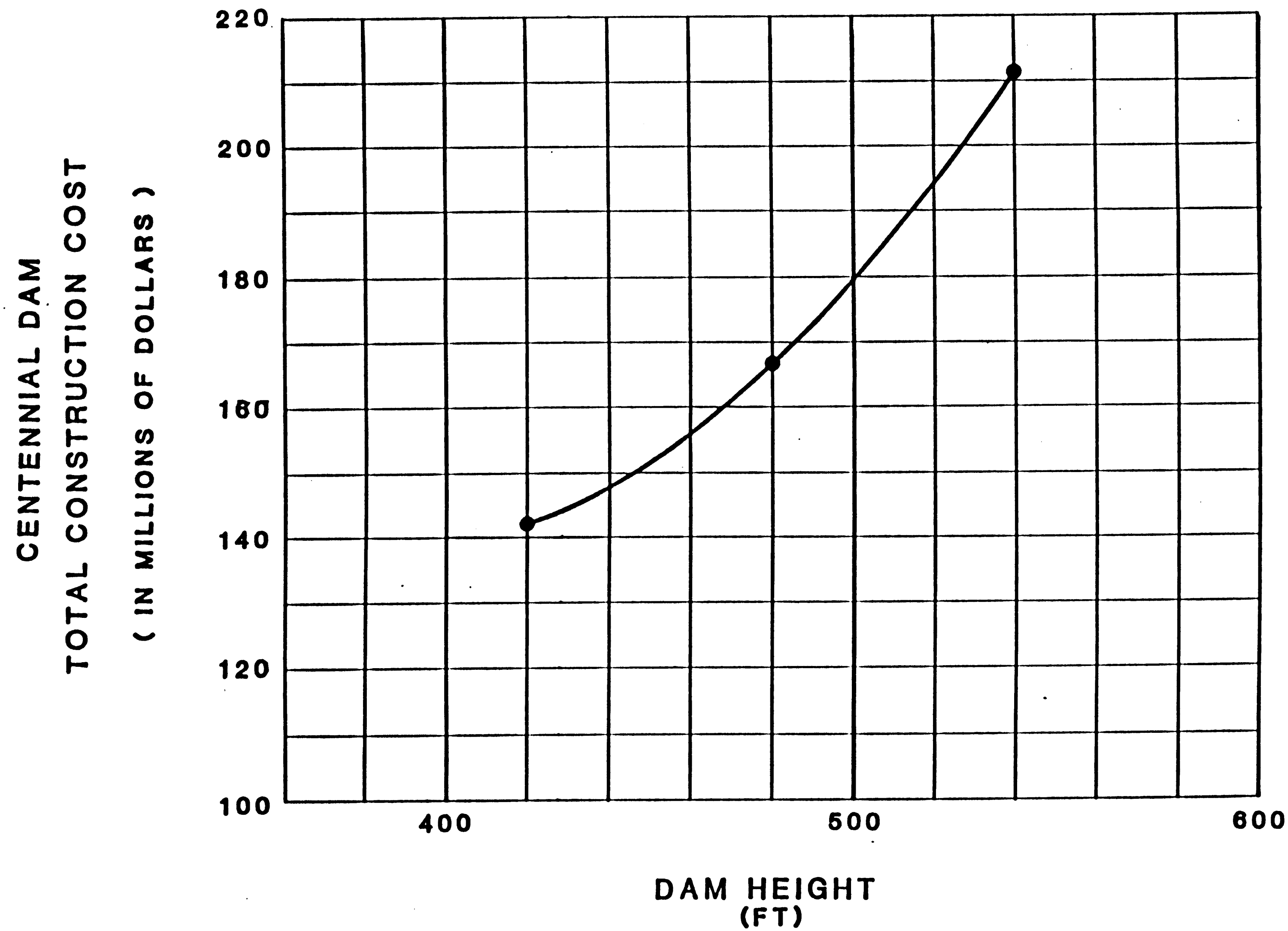
The third and fourth years would include foundation grouting, concrete placement for the dam, powerhouse and tailrace construction, plunge pool concrete, penstock steel, miscellaneous metals, piping, fittings, and the installation of mechanical and electrical equipment.

The fifth year would include topping out the dam concrete, completing the curtain grouting, drilling the drainage holes, installing the intake gates and trashracks, and placing the diversion tunnel plug.

TABLE 4.7

Centennial Dam-Example Cost Estimate For:
Total Construction Cost
Dam Height 480 Feet
Reservoir Volume 165,000 af

	Quantity	Unit Cost (Dollars)	Total Cost (Dollars)
Mobilization and Demobilization	L.S.		6,500,000
Access Roads and Bridges	L.S.		4,680,000
Diversion Tunnel	1300 L.F.	1750.00	2,275,000
Diversion Tunnel Intake	L.S.		300,000
Diversion Tunnel Cofferdams	L.S.		100,000
Care of Water During Construction	L.S.		350,000
Dam Rock Excavation	340,000 yd^3	30.00	10,200,000
Powerhouse and Tailrace Rock Excavation	7500 yd^3	30.00	225,000
Abutment Adits	400 L.F.	600.00	240,000
Consolidation Grouting	16,000 L.F.	20.00	320,000
Curtain Grouting	70,000 L.F.	26.00	1,820,000
Drain Holes	48,000 L.F.	15.00	720,000
Dam Concrete	800,000 yd^3	60.00	48,000,000
Powerhouse and Tailrace Concrete	7500 yd^3 (est.)	300.00	2,250,000
Spillway Plunge Pool Concrete	6000 yd^3 (est.)	150.00	900,000
Diversion Tunnel Plug Concrete	500 yd^3 (est.)	300.00	150,000
Portland Cement	150,400 Ton	80.00	12,032,000
Reinforcing Steel	3,000,000 Lbs.	0.50	1,500,000
Cooling Concrete	675,000 L.F.	2.80	1,890,000
Grouting Cooling Pipe	680,000 L.F.	0.10	68,000
Penstock Steel	1,400,000 Lbs.	2.70	3,780,000
Penstock Intake Structure	L.S.		300,000
Waterstop	L.S.		600,000
Miscellaneous Metals	650,000 Lbs.	2.50	1,625,000
Piping, Fittings, and Valves	375,000 Lbs.	7.00	2,625,000
Mechanical	L.S.		2,575,000
Electrical	L.S.		4,750,000
Intake Gates, Hoist, and Trashracks	L.S.		2,285,000
Draft Tube Gates and Guides	L.S.		325,000
Powerhouse Architectural	L.S.		1,400,000
Miscellaneous Items	L.S.		1,000,000
Subtotal Direct Costs			115,785,000
Contingency (25 Percent)			28,946,250
Direct Cost			144,731,250
Engineering and Administration (15 Percent)			21,709,688
Total Construction Cost			166,440,938



NOTE:

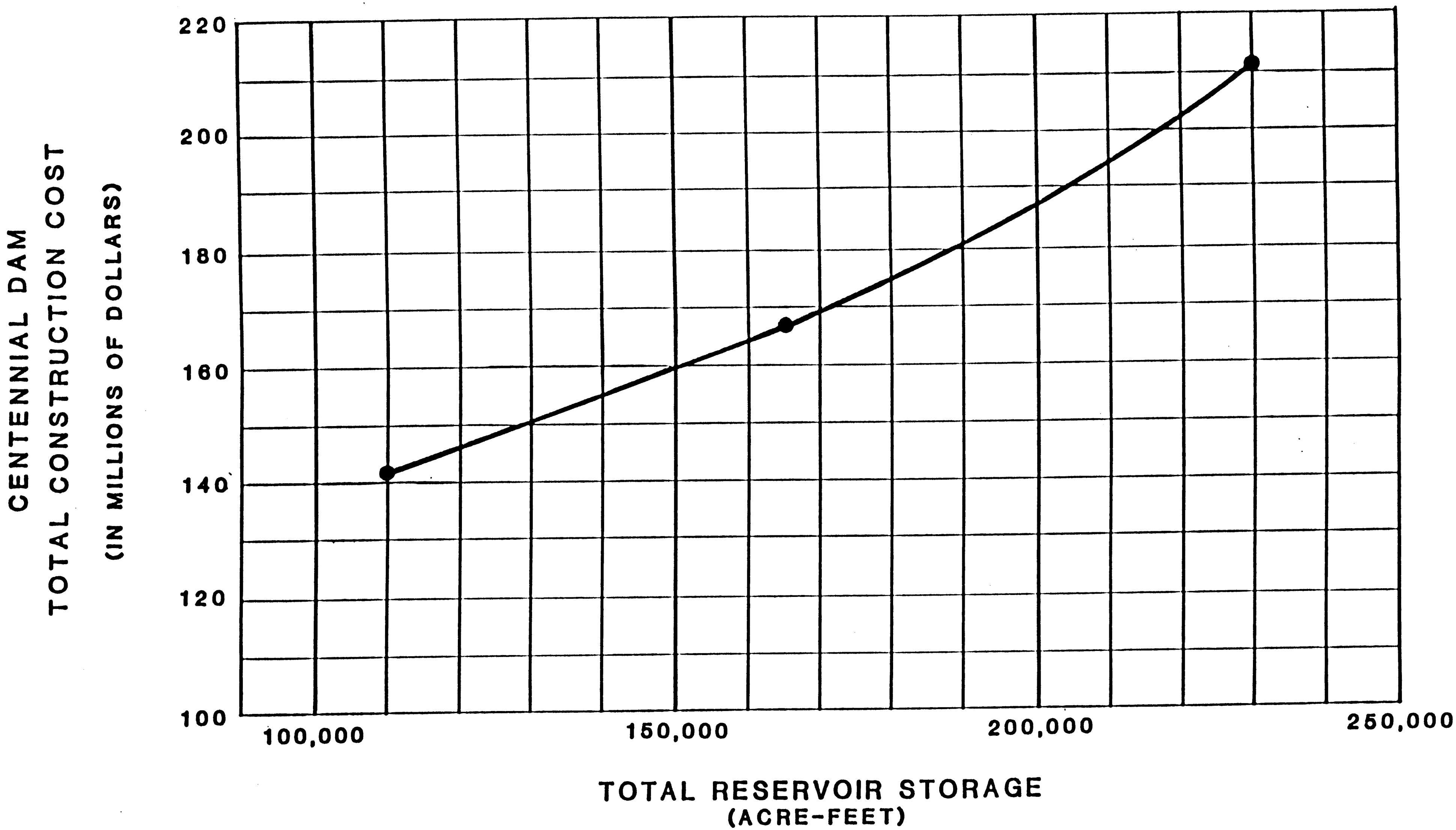
● COST ESTIMATES WERE PREPARED FOR DAM HEIGHTS 420 FT, 480 FT, AND 540 FT

COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY
CLEAR CREEK PROJECT

DAM HEIGHT VS CONSTRUCTION COST FOR CENTENNIAL DAM

TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
MULLER ENGINEERING COMPANY, INC.
WOODWARD-CLYDE CONSULTANTS

DATE: SEPTEMBER 1988 FIGURE 4.1



NOTE:

● COST ESTIMATES WERE PREPARED FOR RESERVOIR STORAGES 110,000 AF, 165,000 AF, AND 230,000 AF

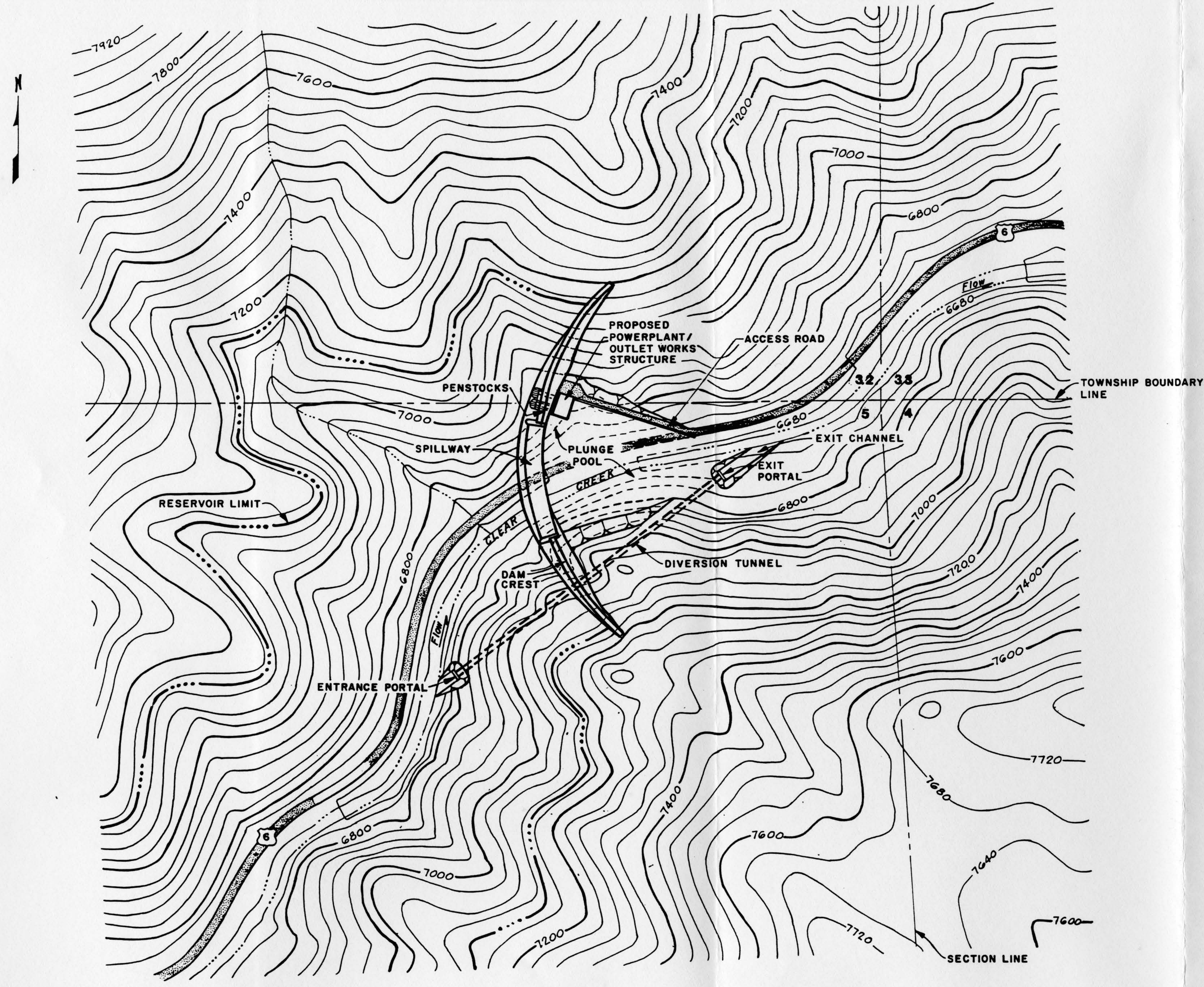
COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CLEAR CREEK PROJECT

RESERVOIR VOLUME VS CONSTRUCTION COST FOR CENTENNIAL DAM

TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
MULLER ENGINEERING COMPANY, INC.
WOODWARD-CLYDE CONSULTANTS

DATE: AUGUST 1988 FIGURE 4.2



NOTES:

1. TOPOGRAPHY IS BASED UPON PHOTOGRAPHIC ENLARGEMENT OF 1" = 2000' USGS QUADRANGLE, EVERGREEN, COLORADO, 1979
2. DAM LAYOUT AND RESERVOIR LIMITS ARE SHOWN FOR A 165,000 ACRE FOOT RESERVOIR.
3. NORTH ABUTMENT IS LOCATED IN T. 3 S. R. 71 W. SOUTH ABUTMENT IS LOCATED IN T. 4 S. R. 71 W.

LEGEND

- WATERWAY
- ROADWAY
- 6 EXISTING U.S. ROUTE
- 32 TOWNSHIP
- 7680 CONTOURS AT 40 FOOT INTERVALS

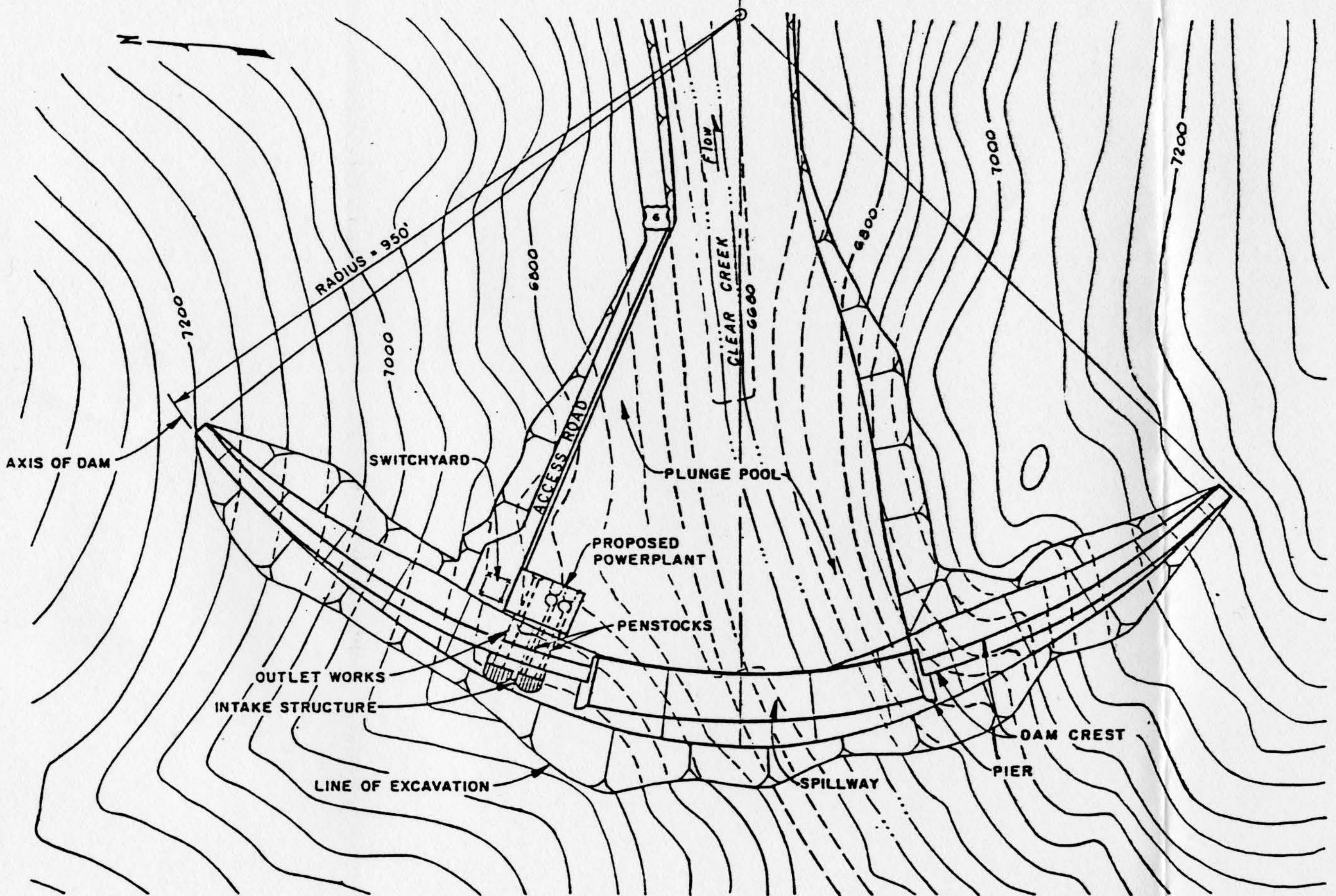
200 0 200 400 600
SCALE IN FEET

COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY
CLEAR CREEK PROJECT

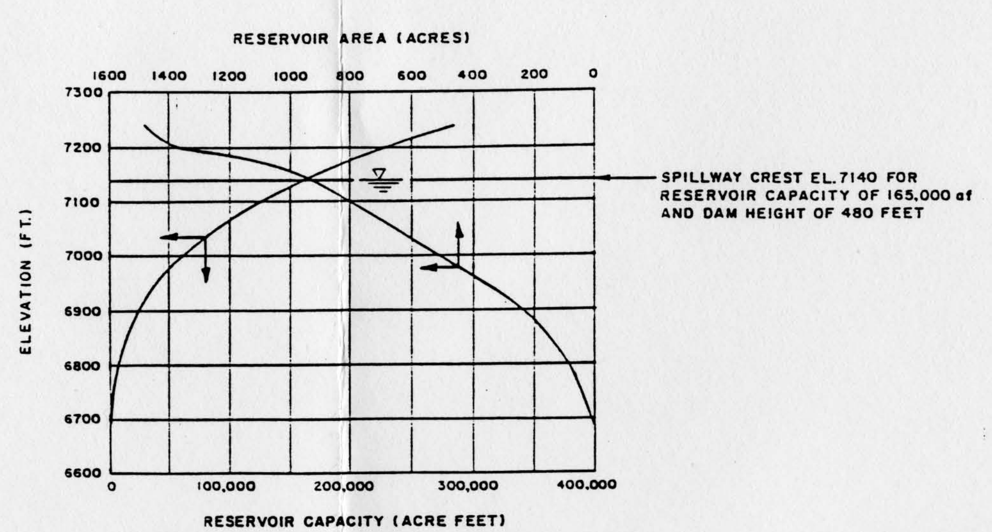
CENTENNIAL DAMSITE
TYPICAL PROJECT PLAN

TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
MULLER ENGINEERING COMPANY, INC.
WOODWARD-CLYDE CONSULTANTS

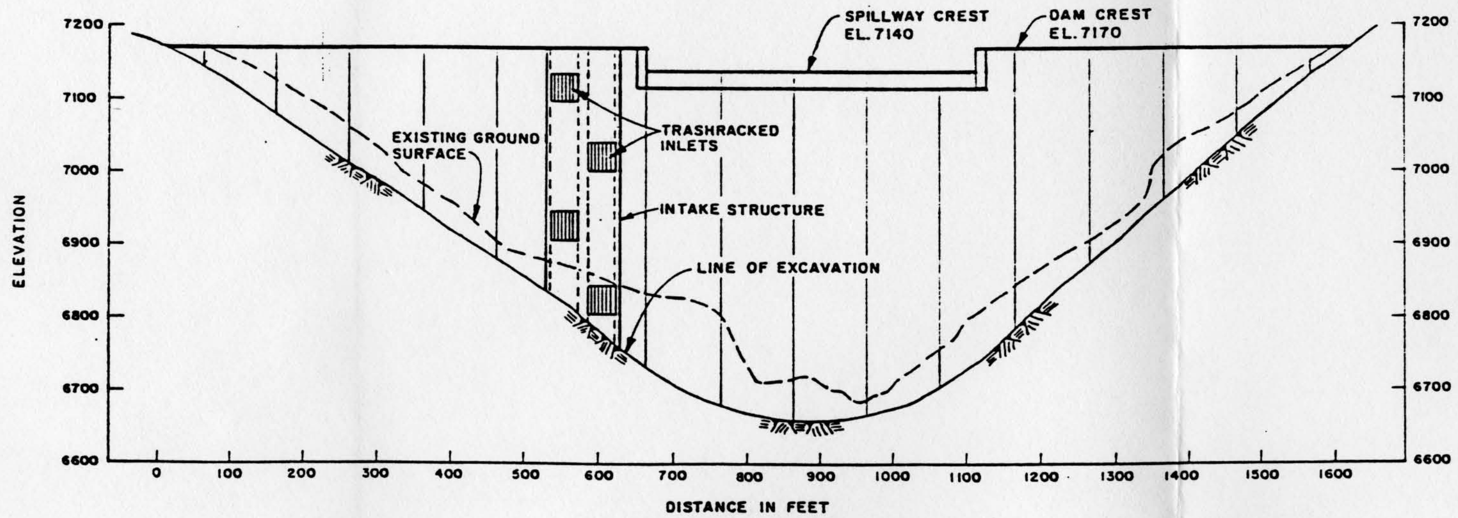
DATE: JUNE 1989 FIGURE 4.3



PLAN

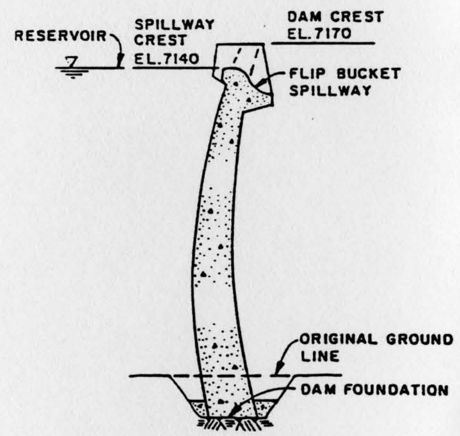


RESERVOIR ELEVATION vs STORAGE



PROFILE ALONG AXIS OF DAM

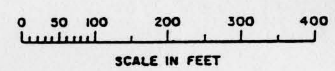
LOOKING DOWNSTREAM



DAM SECTION AT SPILLWAY

NOTE:

LAYOUT SHOWN IS ONE OF THREE CONCEPTUAL DESIGNS. THIS LAYOUT SHOWS A 480 FOOT HIGH DAM WITH 165,000 af RESERVOIR CAPACITY. THE OTHER CONCEPTUAL DESIGNS WERE PREPARED FOR A 420 FOOT HIGH DAM WITH 110,000 af RESERVOIR CAPACITY AND A 540 FOOT HIGH DAM WITH 230,000 af RESERVOIR CAPACITY.



COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CLEAR CREEK PROJECT

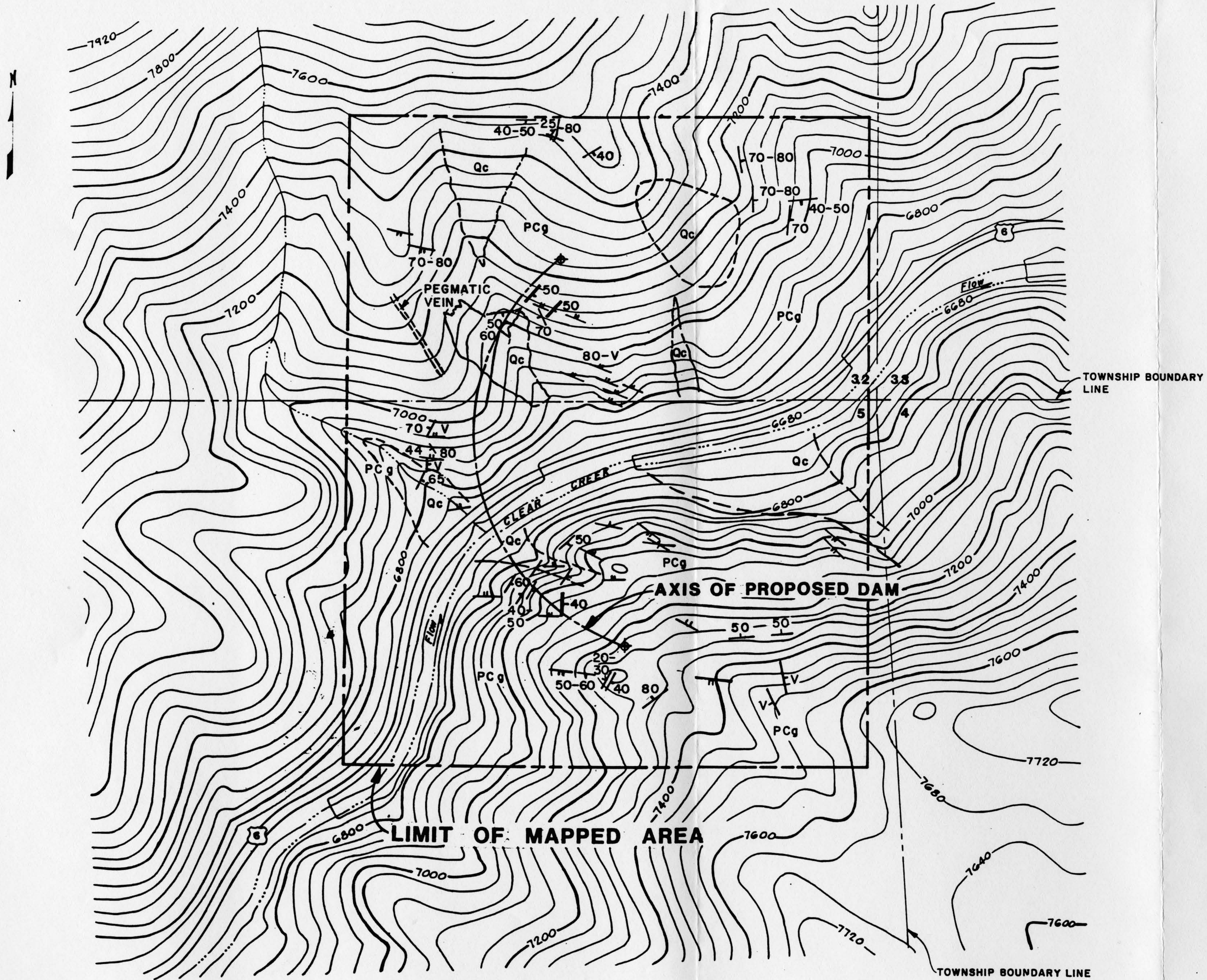
CENTENNIAL DAM

TYPICAL PLAN, PROFILE & SECTION

TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
MULLER ENGINEERING COMPANY, INC.
WOODWARD-CLYDE CONSULTANTS

DATE: MARCH 1989

FIGURE 4.4



NOTE:
FIELD WORK CONDUCTED ON JUNE 28, 29 1988

LEGEND:

- FOLIATION
- 60 JOINT WITH DIP ANGLE WHERE MEASURED
- MAJOR JOINT
- CONTACT BETWEEN GEOLOGIC UNITS, DASHED WHERE APPROXIMATE
- Qc COLLUVIUM
- PCg PRECAMBRIAN GNEISS
- SECTION BOUNDARY

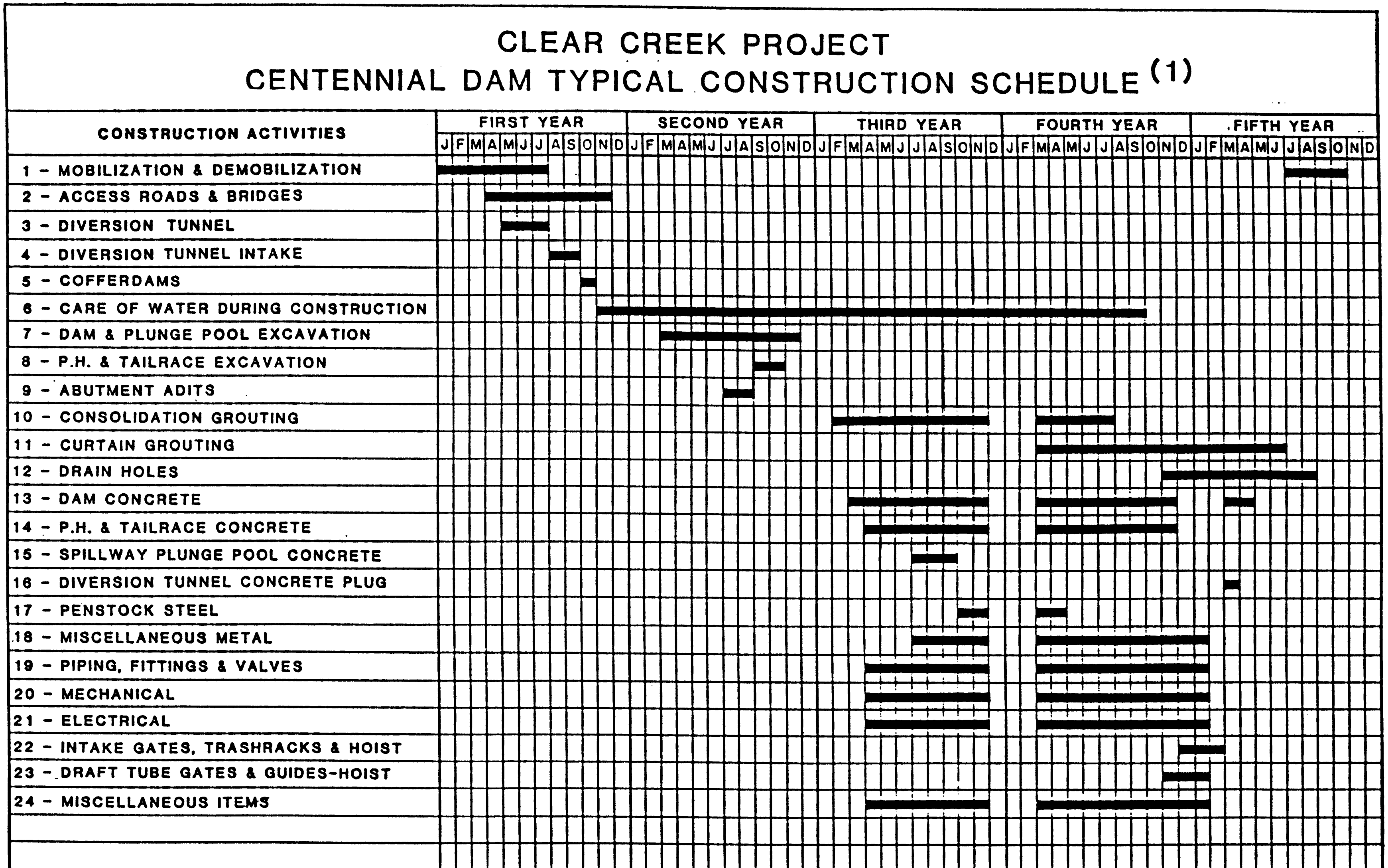
200 0 200 400 600
SCALE IN FEET

COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY
CLEAR CREEK PROJECT

CENTENNIAL DAMSITE
RECONNAISSANCE LEVEL
GEOLOGIC MAP

TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
MULLER ENGINEERING COMPANY, INC.
WOODWARD-CLYDE CONSULTANTS

DATE: JUNE 1989 FIGURE 4.5



(1) DAM CREST ELEVATION 7170

COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY
CLEAR CREEK PROJECT

CENTENNIAL DAM
TYPICAL CONSTRUCTION
SCHEDULE

TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
WOODWARD-CLYDE CONSULTANTS
LEONARD RICE CONSULTING WATER ENGINEERS, INC.
MULLER ENGINEERING COMPANY, INC.

DATE: MAY 1989 FIGURE 4.6

Section 5

ECONOMIC AND FINANCIAL EVALUATION

5.0 ECONOMIC AND FINANCIAL EVALUATION

5.1 GENERAL

5.1.1 Purpose

The proposed Clear Creek Project would provide substantial benefits resulting from the storage of water. This section presents an economic and financial evaluation of the project.

5.1.2 Alternatives

For the purposes of this report, a representative damsite on Clear Creek was considered with dam heights ranging from 420 to 540 feet. Six alternatives for the relocation of U.S. Highway 6 and four water supply scenarios were evaluated. These components are described below. Costs and schedules are addressed under subsequent headings.

5.1.2.1 Dam Heights

Physical data for three heights of dam are presented on Table 5.1. These three dam heights were used to develop representative data for costs and for firm yield of water supply studied for a range of project sizes at the representative site. The dam heights studied were 420, 480, and 540 feet with reservoir sizes of 110,000 af, 165,000 af, and 320,000 af, respectively. The dam layouts and cost estimates are addressed in Chapter 4.

TABLE 5.1

Physical Data for a Range of Dam Sizes

		Total Storage Capacity		
		110,000 af	165,000 af	230,000 af
1.	Dam Height (ft)	420	480	540
2.	Dam Crest Elevation (ft)	7,110	7,170	7,230
3.	Minimum Recreation Pool (acres)	290	290	290
4.	Minimum Recreation Pool (af)	30,000	30,000	30,000
5.	Maximum Required Water Supply Storage (af)	80,000	135,000	200,000

5.1.2.2 Road Relocation

The alternatives for road relocation are addressed in Chapter 3. Six highway relocation alternatives were considered for this economic evaluation. These alternatives include three alternative relocations in Clear Creek Canyon and three locations outside of Clear Creek Canyon. Conceptual designs for the three alternatives in Clear Creek Canyon were developed for both the lowest dam height of 420 feet, and for the highest dam height of 540 feet. These alternatives are designated 1L, 2L, 3L, and 1H, 2H, 3H, respectively. The three alternatives outside of Clear Creek Canyon are designated 4, 5, and 6.

5.1.2.3 Water Supply

The four water supply scenarios selected for financial analysis are summarized in Table 5.2. These scenarios were selected from the seven scenarios presented in Chapter 2 and include (AS) Alliance sources, (ASX) Alliance plus SPX, (BAM) basin management, and (BC) basin combined. All four scenarios include the provision of a minimum recreation pool of 30,000 af, or about 290 acres. The maximum reservoir size suggested for each scenario in Table 5.2 is the reservoir storage required to maximize the firm yield for water supply. This reservoir size is called the "maximum required reservoir capacity" in this report.

5.1.3 Summary

5.1.3.1 Description of Analysis

The economic and financial evaluation consisted of the determination of investment costs, annual costs, and unit costs of firm yield for a range of reservoir sizes, six alternatives for highway relocation, and four water supply scenarios. The costs associated with highway relocation were considered both separately, and also combined into the total project costs. The incremental cost of firm yield for the total project was determined and the sensitivity of project costs to interest rates was investigated.

Potential benefits associated with the project were identified. These benefits include water supply, recreation, improved water quality, reduced road costs, hydropower, flood control, and other benefits, and cost savings to both the Alliance and the regional economy.

TABLE 5.2

Firm Yield for a Range of Reservoir Sizes
(af/year)

Water Supply Scenario	Total Storage Capacity 110,000 af	165,000 af	Maximum Required
AS-Alliance Sources	19,400	24,600	26,000(1)
ASX-Alliance Plus SPX	27,300	36,900	38,700(2)
BAM-Basin Management	21,200	31,500	43,200(3)
BC-Basin Combined	37,600	53,900	61,000(4)

(1)Maximum required capacity = 180,000 af.
(2)Maximum required capacity = 175,000 af.
(3)Maximum required capacity = 230,000 af.
(4)Maximum required capacity = 189,000 af.

5.1.3.2 Results

The following results are summarized from the economic and financial evaluation.

1. For each of the four water supply scenarios, the maximum yield and minimum unit cost of firm yield both occur at the "maximum required reservoir capacity." Cost and size parameters for these four projects are presented in Table 5.3.
2. Three of the four water supply scenarios have unit costs below \$1,000/af/year. These scenarios are Alliance plus SPX (ASX), basin management (BAM), and basin combined (BC).
3. The fourth water supply scenario, Alliance sources (AS), should be dropped from further consideration because the minimum unit costs exceed \$1,200/af/year.
4. The most cost-efficient highway relocation alternative is Alternative No. 6.
5. The best reservoir size for each of the water supply scenarios is the size that produces both maximum yield and minimum unit cost of firm yield. This is the "maximum required reservoir capacity" for each scenario as shown in Table 5.3. Unit cost of firm yield is the annual cost of an acre-foot of firm yield, comprised of the annual debt service plus the annual operation and maintenance cost, divided by the project firm yield.

TABLE 5.3

Project Costs
Representative Project - Four Water Supply Scenarios

Scenario	Firm Yield(1) (af)	Unit Cost(2) ($/af/yr)	Annual Cost(3) ($1000)	Construction Cost ($1000)	Capital Cost ($1000)	Investment Cost ($1000)	Reservoir Storage(4) (af)	Dam Height (ft)
AS	26,000	1,262	33,000	274,000	338,000	377,000	180,000	494
ASX	38,700	935	36,000	309,000	375,000	419,000	175,000	489
BAM	43,200	843	37,000	311,000	385,000	429,000	230,000	540
BC	61,000	631	39,000	330,000	400,000	447,000	189,000	502

(1)Maximum firm yield which can be developed for each scenario.
(2)Includes annual debt service plus operation and maintenance per acre-foot of firm yield.
(3)Includes annual debt service plus operation and maintenance.
(4)Storage required to develop maximum firm yield; figure includes 30,000 af for recreation pool.

6. The project has potential benefits in addition to water supply. These benefits may accrue to either the Alliance or to the regional economy, and include recreation, improved water quality, reduced road costs, hydropower, and flood control.

5.1.4 Evaluation Criteria

The criteria and assumptions used for this analysis are described below. The investment cost, or total required investment to construct the project, is addressed first, followed by the annual cost of paying for this investment. Project revenues are addressed following the discussion of project costs.

5.1.4.1 Investment Costs

The investment cost is the total cost of constructing the project and includes the costs of engineering, interest during construction, reserve funds, and financing costs in addition to direct construction costs. Investment costs are determined by beginning with the design engineer's estimate of "total direct cost" of the project. The total direct cost is the sum of line items from the cost estimate plus a 25 percent allowance for contingencies. Total direct costs plus a 15 percent allowance for engineering and administration equals the "total construction cost." Capital cost is the sum of the total construction cost plus "interest during construction" (IDC). The investment cost is the sum of the capital cost, reserve fund requirements, and the financing cost.

The construction costs associated with the project include the costs of land, dam construction, hydropower, recreation facilities, and highway relocation. The hydropower costs in this analysis include only the facilities necessary to provide the future inclusion of hydropower and are not the total cost of the hydropower. Provisions for hydropower will be included only if further analysis verifies previous findings indicating that hydropower will produce revenues greater than costs over the life of the project. All construction costs are presented in 1988 price levels.

The cost of IDC for each year is equal to 8 percent of the costs incurred during that year plus 8 percent of costs incurred in previous years. IDC is included in each year's annual cost for this calculation.

The reserve fund is equal to one year's debt service. This debt service is for 30 years at 8 percent interest and is based on the total investment cost. The financing cost is 1.5 percent of the total investment cost.

The construction period for the dam would be about 5 years. Construction for highway relocation would occur during years two through five of the dam construction period for highway relocation Alternatives 1H, 2H, 3H, 3L, and 4. Construction for highway relocation would occur during years three through five of the dam construction period for Alternatives 1L, 2L, 5, and 6.

In addition to the capital costs associated with construction, expenditures would be required for water rights and downstream storage for those two water supply scenarios that include a South Platte effluent exchange. The amount of the water rights required for the two alternatives is presented in Table 5.4 and the cost is presented in Table 5.5.

TABLE 5.4

Water Rights Required for South Platte Effluent Exchange (af/year)

	Reservoir Capacity (af)		
Water Supply Scenario	110,000	165,000	Maximum(1)
ASX-Alliance Plus SPX	7,900	12,300	12,350
BC-Basin Combined	13,300	17,800	16,200

(1)See Table 5.2

TABLE 5.5

Cost of Water Rights and Storage for South Platte Exchange[(1)] ($1000)

Water Supply Scenario	Reservoir Capacity (af) 110,000	165,000	Maximum[(2)]
AS-Alliance Sources	0	0	0
ASX-Alliance plus SPX	23,700	36,900	37,000
BAM-Basin Management	0	0	0
BC-Basin Combined	39,900	53,400	48,600

(1)Based on $3,000/af and amounts shown in Table 5.4.
(2)See Table 5.2.

5.1.4.2 Annual Costs

The annual costs of each alternative would be the cost of debt service on the bonds plus the cost of operation and maintenance (O&M). This cost would be partially offset by interest earned on the reserve fund. The debt service was assumed as repayment of bonds with an interest rate of 8 percent and a 30-year repayment period. The reserve fund was assumed to be equal to one year's debt service. The reserve fund earns 8 percent annual interest. The annual cost of O&M for each alternative was estimated as $2,000,000 in 1988 dollars.

5.1.4.3 Revenues

Revenues associated with the project would result from the sale of water. Additional revenues could accrue to the Alliance from the sale of electricity. These revenues have not been determined.

5.2 ECONOMICS

5.2.1 Cost of Firm Yield

Investment costs and annual costs of firm yield for a range of reservoir sizes were calculated for each of the four water supply scenarios in combination with each of the six highway relocation alternatives. The annual costs include debt service and O&M, less interest on reserve funds. All costs are in 1988 dollars.

Project investment costs for a range of possible reservoir sizes are shown in Table 5.6 for each of the four water supply scenarios in combination with each one of the six highway relocation alternatives. Project investment costs with highway relocation Alternatives 1, 2, and 3 range from a low of $506 million with the smallest reservoir to a maximum of $692 million with the largest reservoir. With highway relocation Alternatives 4, 5, and 6, project investment costs range from a low of $328 million with the smallest reservoir to a high of $485 million with the largest reservoir.

TABLE 5.6
Cost Summary

Road Relocation Alternative	Water Supply Scenario	Investment Costs ($1000) Reservoir Volume (af) 110,000	165,000	Maximum(1)	Unit Costs of Firm Yield ($/af/yr) Reservoir Volume (af) 110,000	165,000	Maximum(1)
1	AS	506,338	-	579,672	2,236	-	1,899
1	ASX	535,083	-	620,921	1,675	-	1,363
1	BAM	506,338	-	631,699	2,046	-	1,241
1	BC	554,732	-	649,573	1,259	-	914
2	AS	548,293	-	622,844	2,413	-	2,035
2	ASX	577,038	-	664,093	1,801	-	1,454
2	BAM	548,293	-	674,871	2,208	-	1,323
2	BC	596,687	-	692,746	1,350	-	961
3	AS	546,299	-	617,599	2,404	-	2,018
3	ASX	575,045	-	661,141	1,795	-	1,451
3	BAM	546,299	-	671,919	2,200	-	1,317
3	BC	594,693	-	689,794	1,346	-	957
4	AS	363,717	399,617	413,364	1,635	1,409	1,376
4	ASX	392,463	444,373	454,613	1,240	1,038	1,012
4	BAM	363,717	399,617	465,391	1,496	1,100	927
4	BC	412,111	464,385	483,266	949	741	680
5	AS	365,490	401,390	415,136	1,643	1,415	1,382
5	ASX	394,235	446,146	456,386	1,253	1,042	1,015
5	BAM	365,490	401,390	467,164	1,503	1,105	930
5	BC	413,884	466,158	485,039	953	744	683
6	AS	327,784	363,384	377,130	1,483	1,288	1,262
6	ASX	356,229	408,140	418,380	1,140	958	935
6	BAM	327,784	363,384	429,159	1,357	1,006	843
6	BC	375,879	428,153	446,616	870	686	631

(1)Maximum required volume to obtain maximum firm yield: AS=180,000 af, ASX=175,000 af, BAM=230,000 af, BC=189,000 af.

Based on these investment costs in Table 5.6, the unit cost of firm yield for each project combination is shown in the same table. These unit costs versus reservoir capacity are also shown on Figure 5.1. Unit cost of firm yield is the annual cost of an acre-foot of firm yield, comprised of the annual debt service plus the annual operation and maintenance cost, divided by the project firm yield. Unit costs for projects including highway relocation Alternatives 1, 2, and 3 range from a low of $903/af/year to a high of $2400/af/year. With highway Alternatives 3, 4, and 5, unit costs range from a low of $630/af/year to a high of $1640/af/year. The minimum unit cost of $630/af/year is for a project with a 189,000 af reservoir in combination with highway relocation Alternative 6 and water supply scenario BC (the basin combined scenario). The project would have a firm yield of 61,000 af/yr and an investment cost of $447 million. From Table 5.6, it can be seen clearly that the projects having the minimum unit cost of firm yield are those which: (1) provide the largest amounts of firm yield, and (2) those which use the largest usable reservoir capacity which is required for a given water supply scenario.

The cost of highway relocation is a significant part of the investment cost and the unit cost of firm yield for each of the project combinations shown in Table 5.6. Investment cost just for highway relocation varies from a minimum of $108 million for relocation Alternative 6 to a maximum of $354 million for Alternative 2. This translates into a range of unit costs for firm yield ranging from $180/af/yr to $1500/af/yr. Highway relocation Alternatives 1, 2, and 3 can add from $450/af/yr to $1500/af/yr to the unit cost of firm yield while the range for Alternatives 4, 5, and 6 is from $180/af/yr to $720/af/yr.

The investment and unit costs for the project exclusive of highway relocation costs. These costs range from $487/af to $1028/af.

5.2.2 Marginal Cost of Firm Yield

The incremental amounts of yield decrease continually up to the maximum usable size of reservoir for water supply scenarios AS, ASX, and BC. The incremental yield of water supply scenario B increases slightly as the reservoir capacity increases from 165,000 af to 230,000 af.

For all alternatives, the marginal annual cost for an acre-foot of water decreases when the reservoir size is increased from 110,000 af to 165,000 af. The marginal unit cost increases for reservoir capacities greater than 165,000 af for water supply scenarios AS, ASX, and BAM. The marginal unit cost for water supply scenario BC decreases continually up to the maximum required reservoir storage of 189,000 af.

5.2.3 Sensitivity Analysis

The sensitivity of the cost of water to the interest rate was investigated briefly. For a project with a 189,000 af reservoir, highway relocation Alternative No. 6, and water supply scenario BC, basin combined, the unit cost of water with an 8 percent interest rate was calculated as $631/af/yr. Increasing the interest rate to 10 percent would increase this cost to $804/af/yr. This project is very sensitive to interest rates because the initial costs are very high. The change in interest rate presented above would result in an increase of about $20 million in interest during construction.

5.2.4 Potential Benefits

The proposed Clear Creek Project would be a multipurpose project with benefits to both the project proponents and the regional economy. These benefits are addressed below.

5.2.4.1 Water Supply

The principal benefit from the Clear Creek Project would be water supply to the project proponents. As previously indicated, the project could provide from 19,400 to 61,000 af of municipal and industrial water supply annually, depending on the final project configuration and water supply scenario.

The water supply benefits to the Alliance will be realized by the construction of the Clear Creek Project with essentially zero additional conveyance or other infrastructure costs to Alliance members. The existence of conveyance facilities adequate to deliver the project water represent a substantial cost savings when compared to projects at other locations.

In addition to the primary function of water supply to the project proponents, the project would also have potential water supply benefits to other Clear Creek water users. The project could be used to provide temporary storage for others, particularly in the early years of operation. This storage could be valuable for temporary use by others while additional water supplies are developed. This storage could also provide temporary storage for others to use during rehabilitation of existing storage facilities.

5.2.4.2 Recreation

Recreation benefits resulting from the project will include use of the reservoir, Clear Creek, and surrounding areas for a variety of purposes. This benefit will not result in any revenue to the Alliance, but will produce benefits to the local and regional economy. These recreation uses would be significant because of the proximity of the proposed project to the Denver metropolitan area.

Water related recreation associated with the project would include flat water recreation in the reservoir; reservoir fishing; and stream fishing downstream from the reservoir. A minimum recreation pool of about 300 acres would be provided for the representative project presented in this report. Flat water recreation would include boating and swimming in the reservoir. The reservoir would increase the habitat available for fisheries and would provide a substantial new recreational fishery. Stream fishing downstream from the reservoir could be enhanced by the regulation of volumes released, and by control of the temperature and oxygen content of releases. The improvement of water quality from heavy metals settling in the reservoir would also improve the fishery. Regulation of reservoir releases might also enhance the suitability of the downstream channel for boating and rafting.

The representative project would include an upper park around the reservoir and a linear park between the dam and Golden. These parks would include facilities for day use and possibly for overnight camping.

Recreation from this project would provide revenue to the state from state park fees. This would be a direct benefit to the state. In addition to the fees, benefits would also accrue to the regional economy. These benefits could be relatively direct in nature, such as revenues for concessionaires at the park, or could be of an indirect nature from the incidental use of services by people traveling to and from the park.

5.2.4.3 Improved Water Quality

A benefit from the proposed project would be the improvement of water quality downstream of the dam, resulting from sedimentation of heavy metals due to deposition in Clear Creek Reservoir. This benefit would not provide revenue to the Alliance, but would result in decreased treatment costs for downstream water users. Additionally, the placement of the reservoir would eliminate temporary shutoffs that have occurred historically as the result of point sources of pollution. This benefit would accrue to all downstream water users. Improvement of water quality would also be beneficial to downstream fishery resources.

5.2.4.4 Reduced Road Costs

The relocated highway would be constructed to higher safety standards and should result in an overall reduction in accidents. This would be a substantial benefit to the local and regional economies from the reduction of both material damage and injuries or deaths.

The highway relocation alternatives outside of Clear Creek Canyon would result in an overall reduction in the miles of federal highway in Colorado. It might be possible to use this mileage elsewhere in the County or State for purposes of federal highway funding. It might also be possible to obtain federal funds for part of the cost of the highway relocation.

5.2.4.5 Hydropower

As previously mentioned, hydropower would be included only if revenues from the sale of power exceed the costs of hydropower. This benefit would be revenue to the Alliance. The development of hydropower would also offset the production of electric power from fossil fuels at some other location, reducing the use of non-renewable resources and replacing a generating source that produces atmospheric pollution with clean, non-polluting hydroelectric power.

5.2.4.6 Flood Control

If the reservoir volume were to exceed the volume required for water supply and the minimum recreation pool, a flood control benefit would exist. This benefit has not been quantified. The sizes of reservoir that appear to be attractive based on this evaluation of the representative project appear to be substantially smaller than the maximum size of the reservoir that can be constructed at the site. As much as 65,000 af could be made available as a flood control pool.

5.2.4.7 Other Benefits

The project would also result in other benefits and cost savings. The reservoir area would be logged during construction of the dam, and this sale of timber could also be a cost savings to the Alliance as well as a regional economic benefit. A quarry would be developed in the reservoir area during construction for the provision of aggregates for dam and highway construction. This quarry could also provide rock for other uses.

Numerous jobs would be created during project construction. The local economy would benefit directly not only from the creation of these jobs, but also from the infusion of the income from these jobs into the local economy in the form of consumer spending.

5.3 FINANCIAL EVALUATION

5.3.1 Construction Schedule

As previously mentioned, all project features would be constructed over a 5-year period. Five years would be required to build the dam and associated facilities. Construction of the highway would proceed during dam construction and have approximately the same completion date as the dam construction. Four years would be required for highway relocation Alternatives 1H, 2H, 3H, 2L, and 3L. Three years would be required for highway relocation Alternatives 1L, 4, 5, and 6.

5.3.2 Investment Cost

The calculation of capital costs is shown in Table 5.7 through Table 5.10 for four representative projects. The representative project for each water supply scenario includes one project for each of the four water supply scenarios, a reservoir with the maximum required capacity, and highway relocation Alternative 6. The capital cost calculation is shown for each water supply scenario, including contingencies, engineering, and administration, and interest during construction. A graph showing the relationship between investment costs and reservoir volume is shown in Figure 5.2.

TABLE 5.7

**Capital Cost Determination for Alliance Sources (AS)
Water Supply Scenario
All Costs in $1000**

Year	Highway Reloc.(1)	Dam Constr.(2)	Recreation Facilities	Water Rights For Effluent Exchange	Total Constr.	Highway I.D.C.	Dam I.D.C.	Capital Cost
1	0	24,484	0	0	24,484	0	2,129	26,613
2	0	24,427	0	0	24,427	0	4,438	28,865
3	12,800	50,083	0	0	62,883	1,113	9,179	73,175
4	31,000	69,765	0	0	100,765	3,905	16,044	120,714
5	40,200	10,368	11,000	0	61,568	7,741	19,297	88,606
	84,000	179,127	11,000	0	274,127	12,759	51,088	337,974

(1)Highway Relocation Alternative No. 6.
(2)Dam Crest Elevation=7184 ft, Storage=180,000 af, Firm Yield=26,000 af/yr.

TABLE 5.8

**Capital Cost Determination for Alliance Plus SPX (ASX)
Water Supply Scenario
All Costs in $1000**

Year	Highway Reloc.(1)	Dam Constr.(2)	Recreation Facilities	Water Rights For Effluent Exchange	Total Constr.	Highway I.D.C.	Dam I.D.C.	Capital Cost
1	0	24,099	0	0	24,099	0	2,096	26,194
2	0	24,088	0	0	24,088	0	4,372	28,460
3	12,800	49,388	0	0	62,188	1,113	9,047	72,348
4	31,000	68,797	0	0	99,797	3,905	15,816	119,519
5	40,200	10,224	11,000	37,000	98,424	7,741	22,255	128,419
	84,000	176,596	11,000	37,000	308,596	12,759	53,586	374,941

(1)Highway Relocation Alternative No. 6.
(2)Dam Crest Elevation=7179 ft, Storage=175,000 af, Firm Yield=38,700 af/yr.

TABLE 5.9

Capital Cost Determination for Basin Management (BAM)
Water Supply Scenario
All Costs in $1000

Year	Highway Reloc.(1)	Dam Constr.(2)	Recreation Facilities	Water Rights For Effluent Exchange	Total Constr.	Highway I.D.C.	Dam I.D.C.	Capital Cost
1	0	29,667	0	0	29,667	0	2,580	32,247
2	0	29,355	0	0	29,355	0	5,357	34,712
3	12,800	60,189	0	0	72,989	1,113	11,056	85,158
4	31,000	83,842	0	0	114,842	3,905	19,308	138,056
5	40,200	12,460	11,000	0	63,660	7,741	23,027	94,428
	84,000	215,513	11,000	0	310,513	12,759	61,328	384,601

(1)Highway Relocation Alternative No. 6.
(2)Dam Crest Elevation=7230 ft, Storage=230,000 af, Firm Yield=43,200 af/yr.

TABLE 5.10

Capital Cost Determination for Basin Combined (BC)
Water Supply Scenario
All Costs in $1000

Year	Highway Reloc.(1)	Dam Constr.(2)	Recreation Facilities	Water Rights For Effluent Exchange	Total Constr.	Highway I.D.C.	Dam I.D.C.	Capital Cost
1	0	25,516	0	0	25,516	0	2,219	27,734
2	0	25,428	0	0	25,428	0	4,623	30,051
3	12,800	52,137	0	0	64,937	1,113	9,559	75,609
4	31,000	72,627	0	0	103,627	3,905	16,705	124,237
5	40,200	10,793	11,000	48,600	110,593	7,741	24,279	142,613
	84,000	186,502	11,000	48,600	330,102	12,759	57,384	400,245

(1)Highway Relocation Alternative No. 6.
(2)Dam Crest Elevation=7170 ft, Storage=189,000 af, Firm Yield=61,000 af/yr.

The representative project for water supply scenario Alliance sources (AS) would have a dam 494 feet high and a 180,000 af reservoir. The investment cost for this project would be $377 million. The investment cost is the sum of the capital cost, the reserve fund, and a financing cost.

The representative project for water supply scenario Alliance plus SPX (ASX) would have a dam 489 feet high and a 175,000 af reservoir. The investment cost for this project would be $418 million. It should be noted that the investment cost for this alternative is greater than the investment cost for the representative project for water supply scenario AS, although the dam and reservoir are smaller. This is due to the cost of water rights and upstream storage for the South Platte Effluent Exchange.

The representative project for water supply scenario basin management (BAM) would have a dam 540 feet high and a 230,000 af reservoir. The investment cost for this project would be $429 million.

The representative project for water supply scenario basin combined (BC) would have a dam 502 feet high and a 189,000 af reservoir. The investment cost for the project would be $451 million. Again, this cost includes the cost of water rights and upstream storage for the South Platte Effluent Exchange.

5.3.3 Annual Costs

The annual cost is debt service plus operation and maintenance (O&M) minus interest earned on the reserve fund. As an example, a cost summary for the BC scenario is shown in Table 5.11.

5.3.3.1 Debt Service

As previously stated, the debt service was based on repayment of the total investment in equal annual installments over a 30-year period at 8 percent annual interest. For the representative projects for water supply scenario AS, ASX, BAM, and BC the annual debt service would be $33,500,000, $37,200,000, $39,700,000, and $38,100,000, respectively.

TABLE 5.11

Cost Summary for Basin Combined (BC) Water Supply Scenario

Item	Cost ($1000)
Land	2,779
Highway Relocation(1)	58,435
Dam Construction(2)	126,961
Recreation Facilities	7,652
Water Rights (Effluent Exchange)	33,809
Subtotal	229,636
Contingency (25%)	57,409
Total Direct Cost	287,045
Engineering & Administration (15%)	43,057
Total Construction Cost	330,102
Interest During Construction	70,143
Capital Cost	400,245
Reserve Fund (One Year Debt Service)	39,672
Financing Cost (1.5% of Investment Cost)	6,699
Investment Cost	446,616
Annual Cost	**($1000)**
Debt Service (30 Years at 8%)	39,672
Operation and Maintenance	2,000
Interest on Reserve (8%)	3,174
Total Annual Cost	38,498
Firm Yield	61,000 af/yr
Annual Cost Per Acre-Foot Firm Yield	631 $/af

(1)Highway Relocation Alternative No. 6
(2)Dam Crest Elevation=7192 ft, Storage=189,000 af

5.3.3.2 Operation and Maintenance

The cost of O&M was assumed to be $2,000,000 for the first year of operation for all alternatives. This cost would increase at a rate roughly equal to the general inflation rate.

5.3.3.3 Interest on Reserve Funds

The investment cost includes a reserve fund equal to one year's debt service. This reserve fund was assumed to earn 8 percent annual interest.

5.3.3.4 Total Annual Cost

The total annual cost is the cost of debt service plus the cost of O&M minus the interest earned on the reserve fund. The annual unit cost of firm yield is the annual cost divided by the firm yield; this information is summarized below.

The major component of the annual cost is debt service. Because this cost does not escalate, the annual cost would remain essentially constant for the first 30 years of project operation. After 30 years the bonds would be retired and the cost of the project would be the cost of O&M.

The annual unit cost of firm yield is debt service plus O&M minus interest on the reserve fund. The reserve fund would be used to pay the last year's debt service, occurring in year 30 of project operation. After year 30, the cost of the Project would be the cost of O&M.

Annual cash flow was determined for the ASX, BAM, and BC water supply scenarios. For these scenarios, the first year unit cost of firm yield would range from $631/af/year to $935/af/year. The cost would range from $727/af/year to $11,086/af/year in year 29 of project operation. Following retirement of the bonds, the annual unit cost of firm yield would be less than $150/af/year and could be less than $100/af/year, depending on the final project configuration and water supply scenario. Cash flow for the Basin Combined (BC) Water Supply Scenario is shown in Table 5.12.

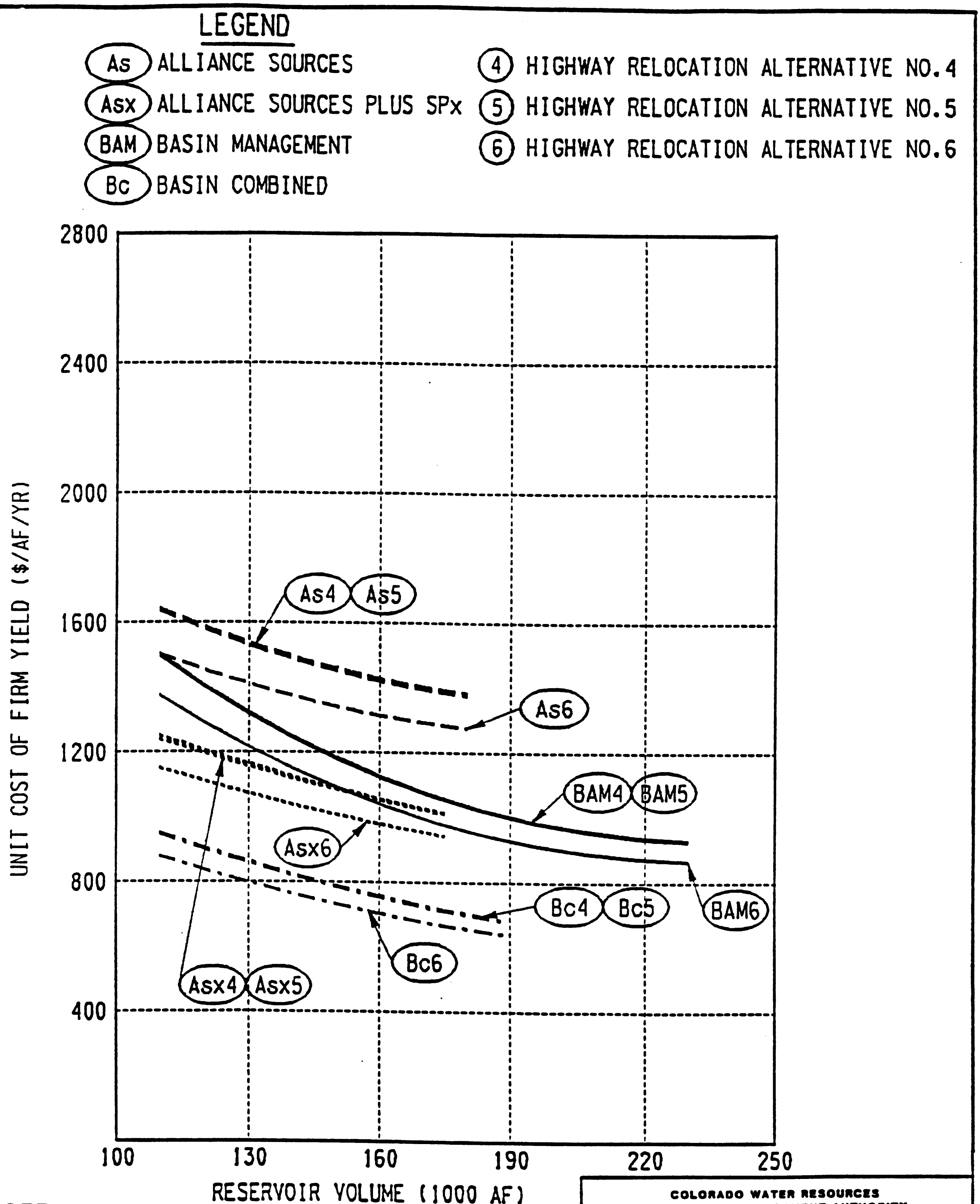
Water Supply Scenario	Debt Service ($1000)	O&M ($1000)	Interest On Reserve ($1000)	Annual Cost ($1000)	Unit Cost of Firm Yield ($/af/yr)
AS	33,500	2,000	2,680	32,820	1,262
ASX	37,164	2,000	2,973	36,191	935
BAM	38,121	2,000	3,050	37,071	843
BC	39,672	2,000	3,174	38,498	631

TABLE 5.12

Cash Flow for Basin Combined (BC) Water Supply Scenario

Year	Annual Investment Cost[(1)] ($1000)	Debt Service[(1)] ($1000)	O&M[(2)] ($1000)	Interest On Reserve[(3)] ($1000)	Annual Cost[(4)] ($1000)	Annual Unit Cost of Firm Yield[(5)] ($/af/yr)
1	27,734	-	-	-	-	-
2	30,051	-	-	-	-	-
3	75,609	-	-	-	-	-
4	124,237	-	-	-	-	-
5	188,985	-	-	-	-	-
6	-	39,672	2,000	3,174	38,498	631
7	-	39,672	2,100	3,174	38,598	633
8	-	39,672	2,205	3,174	38,703	634
9	-	39,672	2,315	3,174	38,813	636
10	-	39,672	2,431	3,174	38,929	638
11	-	39,672	2,553	3,174	39,051	640
12	-	39,672	2,680	3,174	39,178	642
13	-	39,672	2,814	3,174	39,312	644
14	-	39,672	2,955	3,174	39,453	647
15	-	39,672	3,103	3,174	39,601	649
16	-	39,672	3,258	3,174	39,756	652
17	-	39,672	3,421	3,174	39,919	654
18	-	39,672	3,592	3,174	40,090	657
19	-	39,672	3,771	3,174	40,270	660
20	-	39,672	3,960	3,174	40,458	663
21	-	39,672	4,158	3,174	40,656	666
22	-	39,672	4,366	3,174	40,864	670
23	-	39,672	4,584	3,174	41,082	673
24	-	39,672	4,813	3,174	41,311	677
25	-	39,672	5,054	3,174	41,552	681
26	-	39,672	5,307	3,174	41,805	685
27	-	39,672	5,572	3,174	42,070	690
28	-	39,672	5,851	3,174	42,349	694
29	-	39,672	6,143	3,174	42,641	699
30	-	39,672	6,450	3,174	42,948	704
31	-	39,672	6,773	3,174	43,271	709
32	-	39,672	7,111	3,174	43,610	715
33	-	39,672	7,467	3,174	43,965	721
34	-	39,672	7,840	3,174	44,338	727
35	-	39,672	8,232	3,174	5,059	83

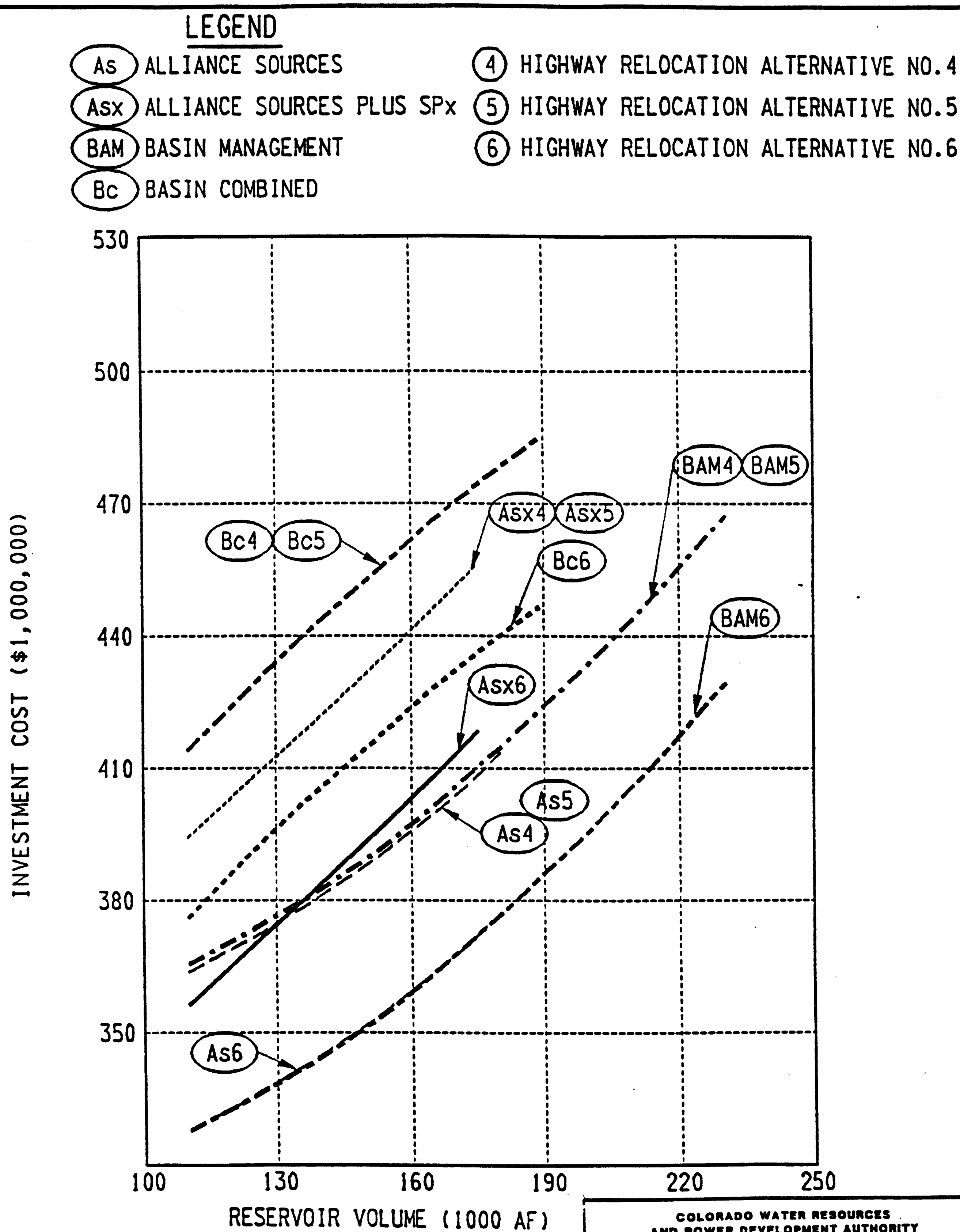
(1)Highway Relocation Alternative No. 6, Storage=189,000 af, Firm Yield=61,000 af/year. See Table 5.10 for capital cost determination.
(2)Escalates at 5 percent annually.
(3)8 percent annual interest on reserve fund.
(4)Debt service for year 35 from reserve fund.
(5)Firm Yield=61,000 af/year.



NOTE:

UNIT COST OF FIRM YIELD IS DETERMINED BY ADDING THE ANNUAL DEBT SERVICE TO THE ANNUAL COST OF OPERATION AND MAINTENANCE, THEN DIVIDING BY THE PROJECT FIRM YIELD.

COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY CLEAR CREEK PROJECT
UNIT COSTS OF WATER
TUDOR ENGINEERING COMPANY CHERYL SIGNS ENGINEERING WOODWARD-CLYDE CONSULTANTS LEONARD RICE CONSULTING WATER ENGINEERS, INC. MULLER ENGINEERING COMPANY, INC.
DATE: JUNE 1989 FIGURE 5.1



COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CLEAR CREEK PROJECT

PROJECT INVESTMENT COSTS

TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
WOODWARD-CLYDE CONSULTANTS
LEONARD RICE CONSULTING WATER ENGINEERS, INC.
MULLER ENGINEERING COMPANY, INC.

DATE: JUNE 1989 FIGURE 5.2

Section 6

REFERENCES

6.0 REFERENCES

American Association of State Highway and Transportation Officials, 1977. A Manual on User Benefit Analysis of Highway and Bus Transit Improvements. Washington, D.C.

Authority (Colorado Water Resources & Power Development Authority), "Clear Creek Project, Phase I - Feasibility Study." November, 1987.

CDOH (Colorado Department of Highways), 1982. Accidents and Rates on State Highways 1982. Staff Traffic and Safety Projects Branch, Denver, Colorado.

CDOH, 1983. Accidents and Rates on State Highways 1983. Staff Traffic and Safety Projects Branch, Denver, Colorado.

CDOH, 1984. Accidents and Rates on State Highways 1984. Staff Traffic and Safety Projects Branch, Denver, Colorado.

CDOH, 1985. Accidents and Rates on State Highways 1985. Staff Traffic and Safety Projects Branch, Denver, Colorado.

CDOH, 1986. Accidents and Rates on State Highways 1986. Staff Traffic and Safety Projects Branch, Denver, Colorado.

CDOH, January 1, 1988. 1987 Cost Data. Cost Estimates Squad of the Staff Design Branch. Denver, Colorado.

CDOH, 1988a. Summary of Traffic Accident Experience 1/1/86 Through 12/31/87. Staff Traffic and Safety Projects Branch. Denver, Colorado.

CDOH, 1988b. Colorado Road Information System. State Highway Portion, Division of Transportation Development, Program Support Branch. Denver, Colorado.

Federal Highway Administration, 1981. "Design of Encroachments of Flood Plains Using Risk Analysis." Hydraulic Engineering Circular, #17, Washington, D.C.

JRP (Colorado Joint Review Process), November 18, 1988, "Water Project Approval in Colorado," prepared by Steve Norris, Program Director.

National Oceanic and Atmospheric Administration, "Hydrometeorological Report No. 55." 1984.

Transportation Research Board, 1985. Highway Capacity Manual. Special Report 209. Washington, D.C.

Tudor Engineering Company, "Report on Assessment of Low-Head Hydroelectric Sites in the Western States." March, 1982.

U.S. Bureau of Reclamation, Design of Arch Dams. 1977.

U.S. Geological Survey. Kirkham and Rogers. 1981.

U.S. Geological Survey, "Water Supply Papers."

Section 7

GLOSSARY

7.0 GLOSSARY

abutment - the foundation support at the end of a dam, arch, or bridge.

acre - a measure of area; equivalent to 43,560 square feet.

acre-foot - the volume of water equal to the quantity required to cover an acre of land to a depth of 1 foot, or 43,560 cubic feet.

active storage - reservoir capacity used to store and regulate streamflow to meet established reservoir operating requirements.

aggregate - a mixture of sand and gravel graded to be suitable for use in producing concrete.

augmentation - enlarging or increasing the quantity of an item, as increasing the flow of a stream or river.

bedrock - any solid rock exposed at the surface of the earth or overlain by unconsolidated material.

call - a situation in water right administration where junior water rights are not allowed to divert streamflow in order to satisfy more senior water rights.

capital cost - the amount of money paid for project construction and interest during construction.

conditional decree - a decree of the court awarding a priority date to an appropriation of water that reserves eventual water use for a facility planned, but not yet operational.

conduit - a channel for conveying water or fluid.

construction cost - the amount paid for building project facilities plus appropriate contingencies, as well as engineering, legal, and administrative expenses.

consumptive use - the amount of water consumed during use of the water and no longer available to the stream system. For irrigation, consumptive use is water used by crops in transpiration and building of plant tissue.

contingency factor - an additional amount added to cost estimates in recognition of unknown factors that could result in higher actual costs.

conveyance - the act of transporting (e.g., water is conveyed in a pipeline, canal, or tunnel).

costs (economic) - the stream of value required to produce the desired product. In water resources projects this is often the construction cost required to develop the resource, and the engineering and administration, and operation, maintenance, and replacement costs required to continue the project in service.

crest - the top line or peak of a dam or hill.

Cretaceous Period - the third and latest of the periods included in the Mesozoic Era. Approximately from 65 to 135 million years ago.

crystalline - of or pertaining to the nature of a crystal, having regular molecular structure.

cubic feet per second - the volume of water measured in cubic feet that passes a specific point in one second; equals 724 af per year of 449 gpm.

cultural resource - a building, site, district, structure, or object significant in history, architecture, archaeology, culture or science.

dead storage - the volume in a reservoir below the lowest controllable level, thus not susceptible to gravity release.

debt service - principal and interest payments necessary to retire the debt incurred in financing a project.

decree - an official document issued by the Court defining the priority, amount, use, and location of a water right or plan of augmentation. When issued, the decree serves as a mandate to the State Engineer to administer the water rights involved.

direct diversion - the diversion of water from a natural flowing stream.

discharge, or rate of flow - the volume of water passing a particular point in a unit of time. Units of discharge commonly used include cubic feet per second (cfs) and gallons per minute (gpm).

ditch (or canal) - a trench cut into the surface of the ground to transport water from a stream to a point of use away from the stream.

diversion - (1) the act of taking of water from a stream or other body of water into a canal, pipe, or other conduit. (2) A man-made structure for taking water from a stream or other body of water.

divert - to remove water from its natural course or location, or to control water in its natural course or location, by means of a ditch, canal, flume, reservoir, bypass, pipeline, conduit, well, pump, or other structure or device.

drainage area - the drainage area of a stream at a specified location is that area, measured in a horizontal plane, which is enclosed by a drainage divide. It is expressed in acres, square miles, or other units of area.

drawdown - the decrease in elevation of a lake, reservoir, or aquifer due to a release or discharge from the lake or reservoir or by pumping from the aquifer.

endangered species - life forms found on the U.S. Department of the Interior's list and published in the Federal Register. Their presence on the list implies their continued existence as a species is questionable.

energy - the capacity for performing work. The electrical energy term generally used is kilowatt-hours and represents power (kilowatts) operating for some time period (hours).

energy costs - the variable costs associated with production of electrical energy, representing the cost of fuel and most operation, maintenance, and replacement expenses.

environment - all the conditions, circumstances, and influences surrounding and affecting the development of an organism or group of organisms.

environmental analysis - an analysis of alternative actions and their predictable short- and long-term environmental effects.

exchange - a formal or informal agreement between owners of water rights to allow flexibility in the use of water. An example would be releasing reservoir storage water to a calling ditch, rather than decreasing the upstream diversion. There are many methods which have been devised by water users to exchange water rights.

existing reservoir - a reservoir that was created by the construction of an embankment.

fault - a fracture or fracture zone along which there has been displacement of the sides relative to one another parallel to the fracture.

firm water supply (or yield) - an assured minimum supply of water (or yield) under the most adverse water year supply conditions. The firm yield for this project is defined as the maximum annual supply that can be delivered to a river demand each year of the period from 1947 through 1974.

flood - (1) an overflow or inundation that comes from a river or other body of water and causes or threatens damage. (2) Any relatively high streamflow overtopping the natural or artificial banks in any reach of a stream. (3) A relatively high flow as measured by either gage height or discharge quantity.

freeboard - represents the vertical distance between the maximum elevation reached in routing of the spillway design flood and the top of the dam.

gage - (1) an instrument used to measure magnitude or position; gages may be used to measure the elevation of a water surface, the velocity of flowing water, the pressure of water, the amount of intensity of precipitation, the depth of snowfall, etc. (2) The act or operation of registering or measuring magnitude or position. (3) The operation, including both field and office work, of measuring the discharge of a stream of water in a waterway.

geological - of, or pertaining to the science which deals with the earth, the rocks of which it is composed, and the changes which it has undergone.

gneiss - a coarse-grained rock in which bands rich in granular minerals alternate with bands in which schistose minerals predominate.

grout curtain - a water barrier in a dam foundation formed by inserting chemicals or cement through drilled holes.

hydroelectric - the production of electricity by use of water power.

hydroelectric plant of hydropower plant - an electric power plant in which the turbine-generators are driven by falling water.

hydrology - the science dealing with water on the land, its properties, laws, and geographic distribution.

igneous - rocks formed by solidification from a molten or partially molten state.

impervious material - fine-grained materials, such as clays, that strongly impede the seepage of water.

inflow design flood - the size of flood that a dam, spillway, and reservoir are designed to accommodate without overtopping the dam.

inundate - to flood or cover with water.

investment cost - the total cost of constructing the project and includes the costs of engineering, interest during construction, reserve funds, and financing costs in addition to direct construction costs.

irrigable land - arable land for which a water supply is available.

irrigation - the application of water to crops, lawns, and gardens by artificial means to supplement natural precipitation. Water can be applied by spreading over the ground, by sprinkling, or dripping.

joint - fracture in rock, generally vertical or transverse to bedding, along which no appreciable movement has occurred.

kilowatt (kW) - one thousand watts.

kilowatt-hour (kWh) - the amount of electric energy involved with a one kilowatt demand over a period of one hour. It is equivalent to 3,413 Btu of heat energy.

megawatt (MW) - one thousand kilowatts.

megawatt-hour (MWh) - one thousand kilowatt-hours.

mitigate - to lessen the severity.

outcrops - exposure of geologic formations on the land surface.

outlet works - a gated or valved conduit at a dam and reservoir used to regulate the storage.

overburden - material of any nature, consolidated or unconsolidated, that overlies a rock unit of interest.

Paleozoic - one of the eras of geologic time. Approximately from 225 to 570 million years ago.

Pennsylvanian - the sixth of seven periods in the Paleozoic Era. Approximately from 280 to 320 million years ago.

permeability - the measure of the relative ease with which a porous medium can transmit a liquid under a potential gradient.

permeable material - that which allows water to pass through easily.

Permian - the last of seven periods in the Paleozoic Era. Approximately from 225 to 280 million years ago.

Pleistocene - The earlier of the two epochs in the Quarternary Period. Approximately from 0.1 to 2 million years ago.

power (electric) - the rate of generation or use of electric energy, usually measured in kilowatts.

Precambrian - all rocks formed before the Cambrian Period. Approximately from 570 million years ago to the formation of the earth.

probable maximum flood (PMF) - the estimated flood that would result if all factors that contribute to a flood were to reach the most critical combination of values that could occur simultaneously.

recreation pool - a minimum reservoir storage capacity to be maintained for recreation. These studies assume a minimum reservoir storage for recreation of 30,000 af.

reservoir - a pond, lake, or basin, either natural or artificial, used for the storage, regulation, and control of water.

reuse - subsequent use of imported water, by the importer, for the same purpose as the original use. An example would be the treatment of sewage water to result in potable water to be recycled into the raw water system.

revenue bond - project funding, repayment for which is strictly dependent on the income from the project to meet the interest and principal payments.

Richter scale - the range of numerical values of earthquake magnitude.

sediment storage - the volume of a reservoir set aside to store incoming sediments that are deposited in the reservoir over the useful life of the project.

sedimentation - the process of subsidence and deposition of suspended matter carried by water, sewage or other liquids, by gravity. It is usually accomplished by reducing the velocity of the liquid below the point where it can transport the suspended material.

seepage - the process by which surface water flows into and through the ground or through a dam.

seismic - pertaining to an earthquake or earth vibration.

seismicity - the phenomenon of earth movements of seismic activity.

shear zone - a zone in which shearing has occurred on a large scale so that the rock is crushed and brecciated.

spillway - overflow channel of a dam.

storable flow - the portion of river inflow to a reservoir legally available for storage in the reservoir after considering all senior water rights and diversions both upstream and downstream.

storable decree - a decree of the court allowing the storage of water, usually in a reservoir.

storage right - a type of water right that allows storing streamflow in a reservoir for subsequent beneficial use.

surcharge - reservoir storage designed to accommodate a sudden increase in the flow of water into a reservoir.

terrace - a relatively flat, horizontal, or gently inclined surface, sometimes long and narrow, which is bounded by a steeper ascending slope on one side and by a steeper descending slope on the opposite side.

Tertiary - the earlier of two geologic periods within the Cenozoic Era. Approximately from 2 to 65 million years ago.

topographic - of, relating to, or concerned with the configuration of the earth's surface, including its relief and the position of its natural and man-made features.

transfer - the process of moving a water right originally decreed to one ditch, to another ditch by court decree. A transferred water right generally retains its priority in the stream system and may or may not retain its right to divert its entire decreed amount.

transmountain - the crossing or extending over or through a mountain.

water level - the height of water in a reservoir, well, or aquifer.

water right - a legal right to use the water of a natural stream or the water beneath the surface for a specific beneficial purpose such as irrigation, municipal, or industrial use, which is subject to other rights in the system.

watershed - the whole region or area contributing to the water supply of a river of lake.

water supplies - water controlled and regulated in quantity and quality, by man-made features, to meet the water demands of a specific area.

water yield - the quantity of water expressed either as a continuous rate of flow (i.e., cubic feet per second) or as a volume per unit of time (i.e., acre-feet per year), which can be collected for a given use or uses from surface or ground water sources in a watershed. The yield may vary with the use proposed, with the plan of development, and also with economic considerations. (2) Total runoff. (3) The streamflow in a given interval of time derived from a unit area of watershed. It is determined by dividing the observed streamflow at a given location by the drainage area above that location and is usually expressed in cubic feet per second per square mile.

watt - the rate of energy transfer equivalent to one ampere under a pressure of one volt at unity power factor.

weathering - the group of processes, such as the chemical action of air and rain water and of plants and bacteria and the mechanical action of changes of temperature, whereby rocks on exposure to the weather change in character, decay, and finally crumble into soil.

yield - amount of water that a system can reliably supply.

Section 8

ACRONYMS AND ABBREVIATIONS

8.0 ACRONYMS AND ABBREVIATIONS

af	acre-feet
Alliance	Clear Creek Water Users Alliance
Authority	Colorado Water Resources and Power Development Authority
BLM	Bureau of Land Management
CDOH	Colorado Department of Highways
CDOW	Colorado Division of Wildlife
cfs	cubic feet per second
COE	U.S. Army Corps of Engineers
El.	Elevation
ft	Feet
FERC	Federal Energy Regulatory Commission
GWh	gigawatt hours, equivalent to 1000 MWh
kV	kilovolt
kW	kilowatts, equivalent to 1000 watts
kWh	kilowatt-hour
M&I	Municipal and Industrial
MSL	mean sea level
MW	megawatts, equivalent to 1,000,000 watts (capacity term)
MWh	megawatt hours (energy term)
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
OM&R	Operation, Maintenance, and Replacement
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
POS	Plan of Study
sq. mi.	square miles
USBR	United States Bureau of Reclamation
USGS	United States Geological Survey
yr	year