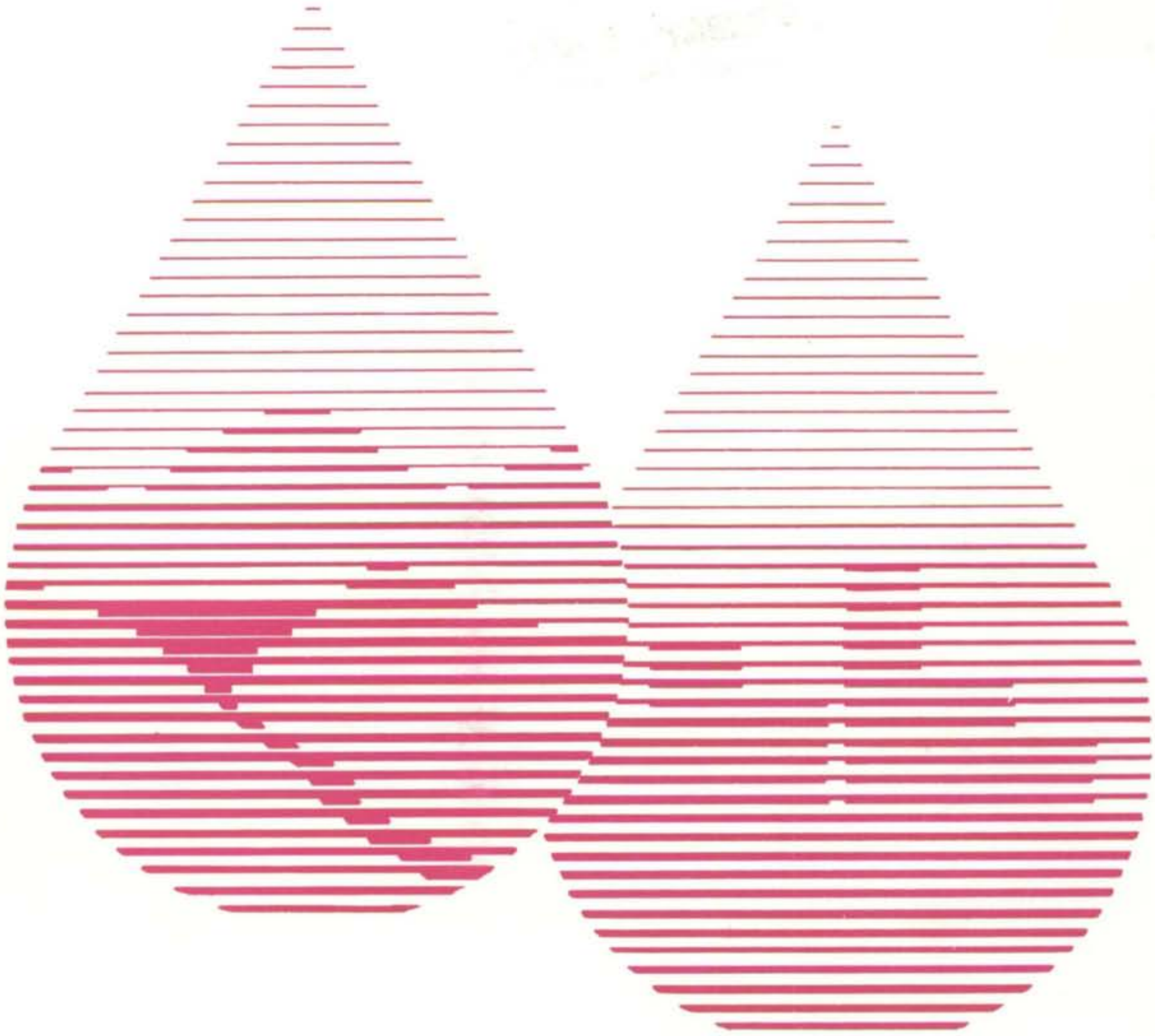
Clear Creek Project

Phase I - Feasibility Study

Summary Report



Colorado Water Resources & Power Development Authority 1981

November 1987

TUDOR ENGINEERING COMPANY

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November 16, 1987
File: 1160

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

Subject: Clear Creek Project
Submittal of Summary Report for Step 1 of the
Phase I - Feasibility Study

Dear Mr. Kappus:

We are pleased to submit this Summary Report for Step 1 of the Phase I - Feasibility Study for the Clear Creek project in accordance with our contract dated August 1, 1986.

Because this was a Phase I study, it was conducted at a prefeasibility level of evaluation. The purpose was to distinguish the major differences between alternative plans, provide an indication of viability for each alternative, and to determine if more refined studies are justified. This Phase I - Feasibility Study has been divided into two steps. The first step, the subject of this report, focuses on the selection of preferred water and power development plans. The second step of the Phase I Study would concentrate on refinement of key issues such as potential relocation of U.S. Highway 6, water right transfers, and transbasin imports.

The objective of the study was to make a preliminary evaluation of developing additional water supplies for Clear Creek basin water users. 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. The projects were then screened based on preliminary technical, economic, and environmental analyses.

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 this study by Western Environmental Analysts indicates that an impoundment on the main stem could support a cold water fishery and would likely improve water quality downstream from a new reservoir. This improvement in water quality is possible because metal concentrations are reduced by dilution and sedimentation in impounded waters.

Seven water supply scenarios were evaluated based on combinations of the following: capacities of existing diversion facilities, transbasin imports, water right transfers, and effluent exchanges. The studies indicate that, with 110,000 acre feet of storage, the potential safe yield from unappropriated native flows will range from 13,300 to 16,000 acre feet per year depending on the physical and legal diversion capacities of existing facilities. Native Clear Creek flows combined with potential imports from the Williams Fork Basin, utilizing Denver Water Department water rights and facilities, could provide safe yields ranging from 23,000 to 29,000 acre feet per year without taking into account the effect of other potential projects. In addition, the South Platte effluent exchange option combined with native flows has a potential safe yield of almost 35,000 acre feet per year.

Reservoir sites that will provide 100,000 acre feet of active storage are all in Clear Creek Canyon. There is, however, a site on Ralston Creek that would provide 63,000 acre feet of storage if an agreement could be reached with the Denver Water Board regarding the impact of the site on the existing Ralston Reservoir.

The unit cost for storage is high, especially when the cost of relocating U.S. Highway 6 is included for the Clear Creek canyon sites. The highway relocation cost is almost 40 percent of the total direct cost of each project in the Canyon. The unit cost for safe yield varies from less than $200 per acre-foot/year to more than $1000 per acre-foot/year depending on which water supply scenario is being considered, whether hydropower facilities are included, whether highway relocation costs may be reduced, and whether up-front funding is provided. In reviewing these costs, please keep the location of the project in mind. It is immediately upstream of the sponsors' existing diversion facilities and, therefore, the additional costs for conveying water from the storage facility to the treatment facilities would be minimal.

Combining major pumped-storage hydroelectric power facilities with the water supply projects could provide substantial benefits to both the water suppliers and the power suppliers. The study of pumped-storage economics currently being initiated by the Authority may provide very useful information for future Clear Creek studies.

We appreciated the opportunity to conduct this evaluation on the Clear Creek project. We would like to express appreciation for the assistance of the Clear Creek water users in the preparation of this basin-wide study. We also wish to acknowledge the excellent support and guidance we have received from you and your Project Manager, Blaine Dwyer. We look forward to working with you in the future as the project continues.

Sincerely,

TUDOR ENGINEERING COMPANY

John Williams, P.E.
Vice President

1160-4:4-2787

SUMMARY REPORT

CLEAR CREEK PROJECT

PHASE I - FEASIBILITY STUDY

Prepared for

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

Prepared by

Tudor Engineering Company
in Association with
Cheryl Signs Engineering
Woodward-Clyde Consultants
Western Environmental Analysts, Inc.

November 1987

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1.0 INTRODUCTION

This preliminary evaluation of developing additional water supplies in the Clear Creek basin was initiated by the Colorado Water Resources and Power Development Authority (Authority) at the request of the Clear Creek Water Users Alliance (Alliance). The purpose of this Summary Report is to present a concise overview of the methodologies and findings of the study. The Final Report for the study presents these topics in greater detail.

The Authority was created by the legislature in 1981 as a political subdivision of the State. The nine member Board of Directors represents the eight major drainage basins in the State, and the City and County of Denver. The Board is appointed by the Governor and confirmed by the Senate. As such, its purpose is to provide the State with a mechanism to fund water and hydroelectric projects by issuing revenue bonds. Since its inception, the Authority has focused on the planning, design, and financing of water resource projects.

The Alliance is a non-profit organization of individuals or legally recognized entities having the lawful right to the use of 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
Pleasant View Water & Sanitation District
Public Service Company of Colorado
Suburban Sand & Gravel, Inc.

The Clear Creek basin is located in central Colorado. It is bordered by the Continental Divide to the west and the confluence of Clear Creek and the South Platte River in Denver to the east. The mountainous upper basin supplies the major surface water runoff from annual snowmelt. The lower basin is a plains area where water is used by municipalities, industry, agriculture, and for recreation.

There are no major on-stream reservoirs in the Clear Creek basin to regulate and control the stream flows. Most of the unappropriated native flows occur during the spring runoff season. Unless new reservoir capacity is provided to store water in the basin, these native flows cannot be fully utilized by the existing water users.

1.1 AUTHORIZATION

The Clear Creek Phase I - Feasibility Study (Study) was authorized on April 4, 1986, by the Authority's Board of Directors in response to an application submitted by the Alliance. On August 1, 1986, the Authority entered into a contract with Tudor Engineering Company (Tudor) to provide lead consulting services for the study. Tudor subcontracted with three other firms to provide speciality services: Cheryl Signs Engineering (CSE) for hydrology, water supply, and water rights; Woodward-Clyde Consultants (WCC) for geology, geotechnical engineering, and ground water; and Western Environmental Analysts, Inc. (WEA) for water quality and environmental evaluations.

1.2 STUDY OBJECTIVE

The primary purpose of the Clear Creek Project is to increase and enhance the supply of Clear Creek water for municipal, industrial, and agricultural use. Other significant benefits from this project may include water quality enhancement, recreation, flood control, conventional hydropower, and pumped-storage hydropower.

The main objective of this study is to estimate the reservoir yields and associated preliminary costs for each alternative identified. Primary sources of water are the unappropriated native flows and flows made available by exchange. Other possible water sources that may enhance the reservoir yields include trans-basin diversions, transfer of existing water rights, and use of advanced water management practices.

This study includes a preliminary environmental overview of the alternative projects studied. It would be feasible to construct an impoundment that will significantly enhance the recreational, aesthetic, and economic value of the area. Enhancements by the project could include improvements in the water quality of Clear Creek. Clear Creek presently contains concentrations of heavy metals. Improvement of water quality is possible with a new reservoir because metal concentrations would be reduced by dilution and reservoir sedimentation.

1.3 STUDY PROCESS

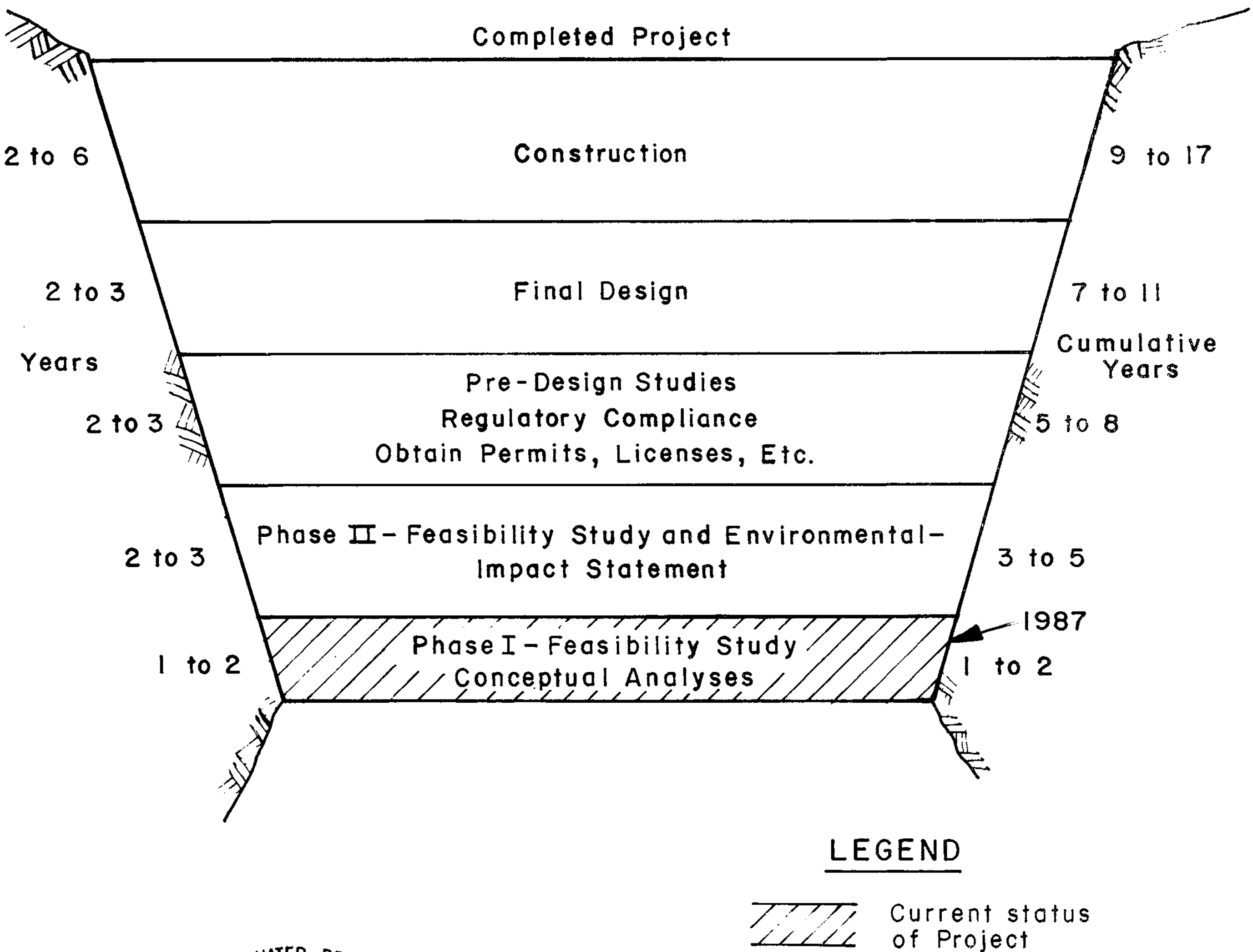
The study was carried out in accordance with "the Plan of Study" (POS) contained in the consultant's contract. The POS identifies 26 individual work tasks and groups them into five major activities. These major activities were data collection; population and water use projections; resource evaluations and water rights; project formulation; and project documentation. This Phase I (prefeasibility) study is the first step in a complex process leading to the construction of a water resources project. This process is illustrated in Figure 1.1.

This study was conducted at a prefeasibility level of evaluation. This means that it has been completed in sufficient detail to distinguish the major differences between alternatives, describe the viability of each alternative, and to determine if more refined studies are warranted. Existing reports prepared for a variety of water users were used in the preparation of this study. Additional sources of information for the preparation of this study are the Authority's recently completed feasibility studies of the Cache la Poudre Basin and the St. Vrain Basin.

The environmental analysis was conducted to identify concerns related with the development of the alternative projects, to determine environmental constraints and enhancements of the project, and to develop a general environmental ranking of the proposed projects. Environmental aspects addressed in this study include water quality, aquatic life, terrestrial wildlife, wetlands, aesthetics, cultural resources, and land use. Conclusions of this study are based upon available data sources, discussions with resource agency personnel, and judgment of the consulting team. Public comment will be elicited and detailed environmental studies will be conducted during subsequent phases of planning and design of the project.

This Phase I - Feasibility Study has been divided into two steps. The first step, the subject of this report, focuses on the selection of preferred water and power development plans. The second step, if conducted, would focus on the preferred plans and the key issues associated with their development. For example, the second step might examine potential markets for hydropower, recreational development possibilities, institutional aspects associated with increasing the yield of a potential Clear Creek reservoir, and relocation of existing facilities.

A detailed feasibility study would follow the second step of the prefeasibility study. It would be conducted at a level of detail suitable to support regulatory processes mandated under the National Environmental Policy Act (NEPA), to obtain permits and licenses, and to provide the financial information that would serve as the foundation for an investment decision. In addition, the feasibility study would include detailed geologic and geotechnical investigations. Final design for a selected project would follow the feasibility study.



COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY

CLEAR CREEK PROJECT

TIME REQUIRED TO IMPLEMENT A WATER RESOURCES PROJECT

TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
WOODWARD-CLYDE CONSULTANTS
WESTERN ENVIRONMENTAL ANALYSTS, INC.

DATE: MAY 1987 FIGURE 1.1

2.0 BASIN DESCRIPTION

2.1 INTRODUCTION

The Clear Creek basin is comprised of an upper and lower basin and has a total drainage area of 575 square miles. The mountainous upper basin, that part of the basin upstream from the mouth of Clear Creek Canyon, has a drainage area of approximately 398 square miles. The lower basin, which includes Ralston Creek, Leyden Creek, Lena Gulch, Little Dry Creek, and Van Bibber Creek, has a drainage area of approximately 177 square miles. Much of the lower basin is in the plains area, where the water from Clear Creek is used by agricultural users, municipalities, industry, and for recreation. A map of the Clear Creek basin is shown in Figure 2.1. Details of the lower basin are shown on Figure 2.2.

2.2 DATA COLLECTION

Data collected for this study included: topographic maps, aerial photos, geological maps, electric transmission line maps, and highway maps. Specific reports referenced in this study include the Metropolitan Denver Water Supply Systemwide Environmental Impact Statement (SEIS), Cache la Poudre Basin Study, St. Vrain Basin Reconnaissance Study, Colorado Department of Health reports on water quality and water quality standards, and the Clear Creek dam and reservoir studies conducted by Hydro Triad, Woodward-Clyde Consultants, and International Engineering Company. A detailed list of reference sources is given in the Appendix of the Final Report.

Previous studies and reports prepared for the Clear Creek basin and relevant to this project were also reviewed. Sources of documents reviewed include the Clear Creek Water Users Alliance, the U.S. Bureau of Reclamation, the Colorado Water Conservation Board, the State Engineer's Office, the Denver Water Department, and the U.S. Army Corps of Engineers. Various appendixes in the U.S. Army Corps of Engineers' SEIS were extremely useful for providing supplemental hydrological data. These data were used to summarize future water demands and to estimate the ground water potential of the study area.

2.3 INVENTORY OF EXISTING FACILITIES AND OPERATING PRACTICES

An inventory was conducted of the raw water supply systems and operating practices in the Clear Creek basin. There are no major water storage reservoirs or water supply diversion structures in the upper basin providing significant regulation of the Clear Creek flows. Water is supplied in the upper basin via transbasin diversion facilities, minor storage reservoirs, tributary wells, and minor diversion structures. Therefore, only water suppliers in the lower basin that currently use Clear Creek as a source of raw water were interviewed about their operating practices. A detailed list of their facilities and operational practices in the Clear Creek basin are given in the Final Report and its Appendix.

The transbasin diversion facilities importing water into the Clear Creek basin include Vidler Tunnel, Berthoud Pass Ditch, Gumlick Tunnel and the Eisenhower Tunnel (which diverts Straight Creek water for Highway Department and industrial use). Denver Water Board's (DWB) water which passes through the Gumlick Tunnel from the Williams Fork collection system is exported out of Clear Creek basin through Vasquez Tunnel to the Fraser River basin. These Williams Fork diversions then pass through the Moffat Tunnel and are conveyed by South Boulder Creek to Gross Reservoir. The South Boulder Diversion Conduit then conveys the water back into the Clear Creek basin at Ralston Reservoir before it is treated at the Moffat Treatment Plant.

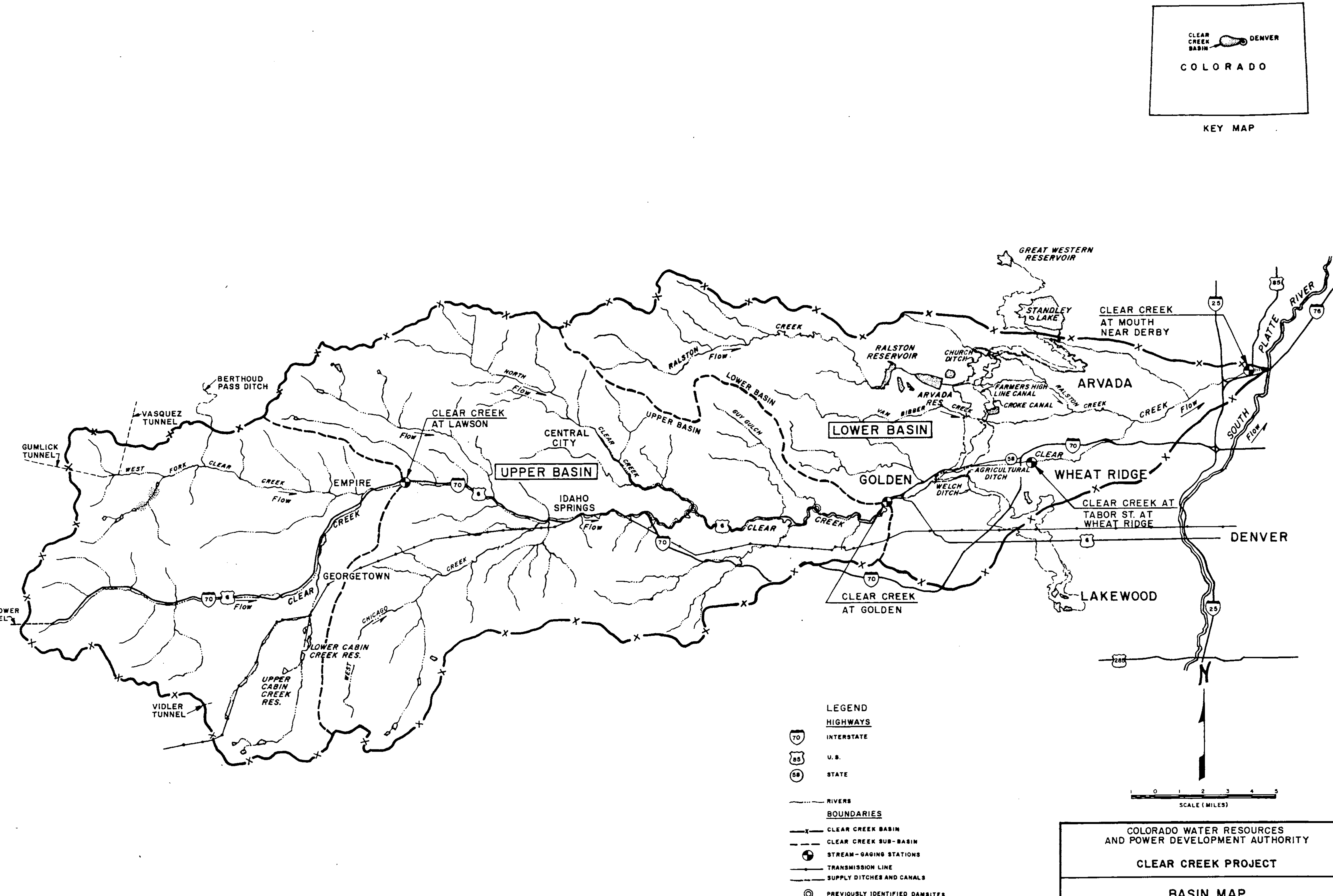
The water supply facilities in the lower basin include diversion structures, ditches, canals, storage reservoirs, and pump stations. These facilities serve more than 15 major agricultural water suppliers, industrial water users, and municipal water suppliers. The major diversion and conveyance facilities include Church Ditch; Farmers High Line Canal; Croke Canal; Agricultural Ditch; Wannamaker Ditch; Rocky Mountain Ditch; and the Clear Creek and Platte River Ditch. The major water supply facilities include Standley Lake, Great Western Reservoir, Arvada Reservoir, Maple Grove Reservoir, the Jefferson Storage system, and Ralston Reservoir, as shown in Figure 2.2.

An attempt was made to interview all of the major water suppliers in the basin. The discussions with the water users centered on water rights, existing water supply systems, criteria used in the safe yield analysis, development plans, viewpoints on the Clear Creek project, and critical institutional issues influencing the transfer of water rights to an upstream storage site.

Agricultural use in the Clear Creek basin has steadily declined as urbanization has utilized these lands as well as its water supply. The irrigated area was reported to be 120,000 acres in 1950 by the State Engineer. In 1980, the area was estimated to be 28,000 acres. The current average annual demand for agriculture in the basin is estimated to be 42,000 acre feet (af) per year, and the safe yield is estimated at 25,000 af per year.

The major municipal water suppliers and industrial water users currently receiving water from Clear Creek include Arvada, Broomfield, Consolidated Mutual, Adolph Coors Company, Crestview, Golden, Lakewood, Northglenn, North Table Mountain, Pleasant View, Public Service Company, Thornton, and Westminster.

The water suppliers that were interviewed generally responded that a large reservoir in the Clear Creek basin would provide benefits to their existing water supply systems. The reservoir would increase their safe yield, add flexibility to the operation of their raw water systems, and improve the quality of their raw water supply.



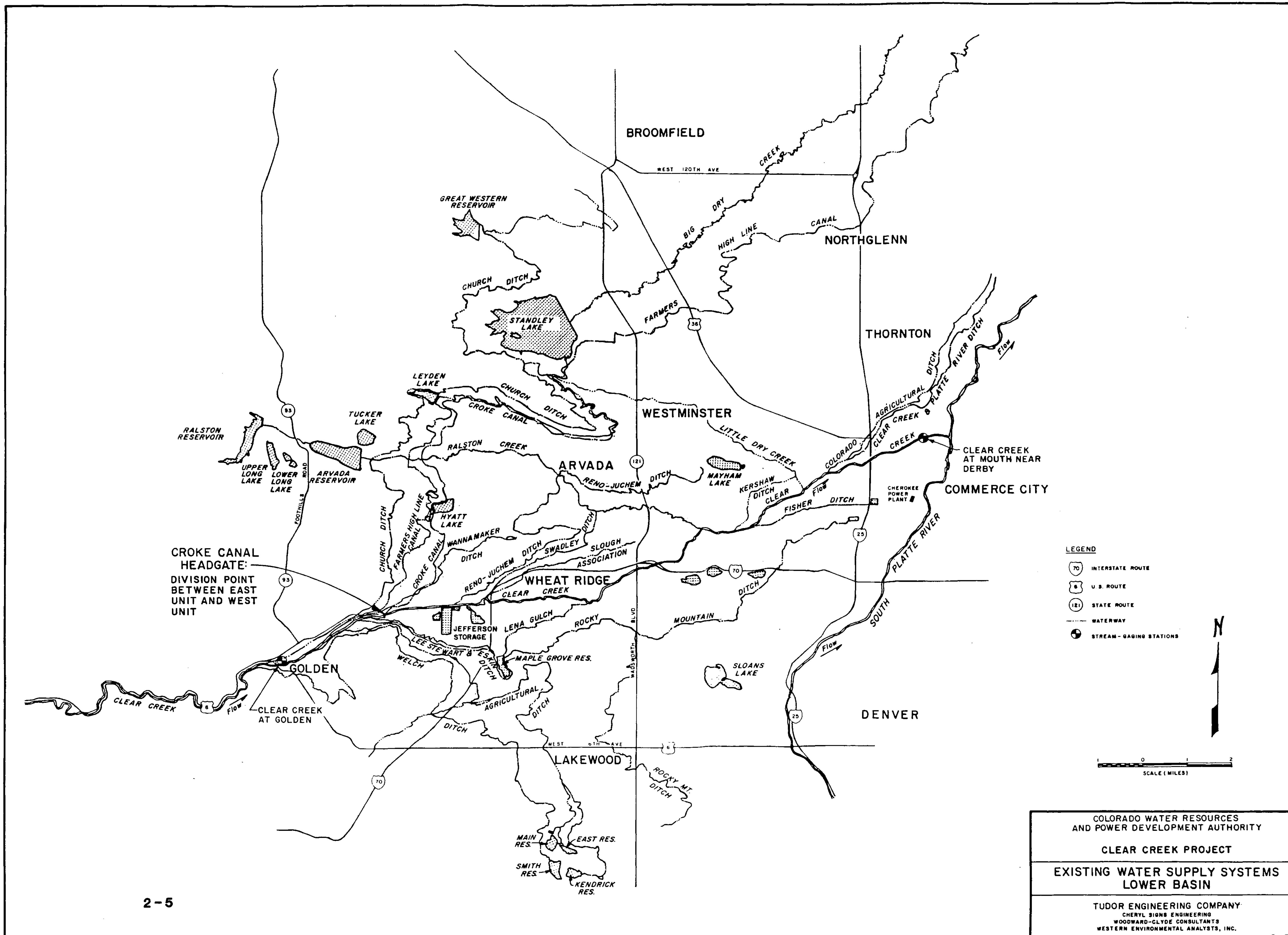
COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CLEAR CREEK PROJECT

BASIN MAP

TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
WOODWARD-CLYDE CONSULTANTS
WESTERN ENVIRONMENTAL ANALYSTS, INC.

DATE: AUGUST 1986 FIGURE 2.1



COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CLEAR CREEK PROJECT

EXISTING WATER SUPPLY SYSTEMS LOWER BASIN

TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
WOODWARD-CLYDE CONSULTANTS
WESTERN ENVIRONMENTAL ANALYSTS, INC.

DATE: OCTOBER 1986 FIGURE 2.2

3.0 HYDROLOGY AND WATER RIGHTS

3.1 INTRODUCTION

The hydrologic and water rights studies began with the compilation of hydrologic data and water rights information. Assessments were then made of native flow hydrology, potential imports from adjacent basins, institutional factors affecting water rights transfers discussed in Section 4, and conditional storage decrees.

3.2 COMPILATION OF HYDROLOGIC DATA AND WATER RIGHTS INFORMATION

The hydrologic information compiled for the study included streamflow, precipitation, transbasin imports, non-tributary flows, and diversion data. Data were collected for the Clear Creek basin and several adjacent basins, such as the South Platte River, Boulder Creek, Fraser River, and Williams Fork River.

The gaging station, Clear Creek at Golden, was the primary source of streamflow data for the study. This gaging station, at the mouth of Clear Creek Canyon, has continuous streamflow records for the years 1912 to 1985. The primary sources of precipitation data were the Edgewater and Lakewood stations. The combined record collected for these stations covers 1925 to 1982.

The water rights information compiled for the Clear Creek study included absolute and conditional decrees for both direct flow and storage rights. Also compiled was information on exchanges, changes of use, and augmentation plans decreed in the basin. A straight-line diagram of direct flow rights was prepared showing the appropriation and adjudication dates, flow rates, basin priorities, and headgate locations. The historical calls on Clear Creek from the South Platte were collected for the years 1947 through 1985.

3.3 NATIVE FLOW HYDROLOGY

The annual native flows for the Clear Creek at Golden gaging station were derived by subtracting the estimated transbasin imports and non-tributary flows into the basin, and by adding the historical ditch diversions upstream of the gaging station.

The estimated mean annual native flow is 166,000 af per year for the years 1912 to 1985. For the period from 1912 to 1930, the mean annual native flow was 190,000 af per year, and for 1931 to 1985, 158,000 af per year. For the purposes of this study, only the period from 1931 through 1985 was selected as the representative long-term hydrological period because of questions regarding the reliability of the streamflow data for 1912 to 1930.

3.4 POTENTIAL IMPORTS FROM ADJACENT BASINS

A preliminary evaluation of the potential imports was made for each of the following adjacent basins: Bear Creek, North Fork of the South Platte River, South Platte River, Blue River, Williams Fork River, Fraser River, and South Boulder Creek. The evaluation factors included the utilization of existing conveyance facilities, potential basin yield, cost to enlarge or rehabilitate conveyance facilities, water rights and policy issues, and environmental concerns.

The only adjacent basin selected for further consideration was the Williams Fork basin. In addition to technical, economic, and environmental issues, utilization of Williams Fork water would have significant legal and institutional issues associated with it. For example, an agreement would be required with the DWB for use of either the existing Williams Fork collection system or for the proposed gravity system extension. However, several members of the Alliance are signatories to the Metropolitan Water Development Agreement and the Williams Fork extension is included in that agreement.

Because the evaluation of the Williams Fork hydrology was based on information contained in the SEIS, the storable flows were estimated for the three hydrological conditions used in the SEIS: average, wet, and dry. The water supply that may be available to the Clear Creek Project from the existing Williams Fork system was estimated to be 8700 af per year for the average condition. For the expanded Williams Fork gravity collection system, it was estimated that 19,700 af per year may be available under average conditions.

Additional supplies may be available for the existing Williams Fork collection system because there are occasions when the DWB does not divert its fully decreed amount of water because of restrictions in its delivery system and because of its current water demand patterns. In this preliminary evaluation, minimum streamflow requirements and historic calls for Williams Fork water from downstream water users were taken into account. However, this evaluation did not attempt to evaluate the effect of Denver's recent agreements with the Colorado River Water Conservation District, the Northern Colorado Water Conservancy District, and the Public Service Company.

The effect of the potential development of Two Forks Reservoir on the yield from the Williams Fork Basin was not evaluated because the information needed to perform this analysis was not available. Therefore, the figures presented above should be considered as the upper limits of the amount of water that may be available from the Williams Fork Basin. An evaluation of the effect of developing Two Forks Reservoir may be a key component of Step 2 of this Phase I Study, if it is conducted.

3.5 SOUTH PLATTE EFFLUENT EXCHANGE

Under Colorado water law, water imported from another basin may be used to extinction by the supplier that imports the water. Presently, a large portion of the wastewater effluent associated with west slope imports is being returned to the South Platte and is not, therefore, being used to extinction. If appropriate agreements could be reached with the importers, it may be possible to use the waste water effluent to meet downstream calls on the South Platte River and to exchange this supply for native Clear Creek flows. These native flows would otherwise be used to meet the downstream calls. This exchange would allow the storage of additional Clear Creek native flows and would, therefore, increase the reservoir yield of the Clear Creek project.

3.6 INSTITUTIONAL FACTORS AFFECTING WATER RIGHTS TRANSFERS

Existing water rights transferred to the proposed reservoir sites would facilitate a more efficient use of Clear Creek water. This study identified water rights amenable to an upstream transfer. The easiest water rights to transfer upstream would be those having a small reliance on return flows. Other factors considered in transferring these rights included the necessity for change-of-use decrees as well as hydrologic limitations.

The water rights upstream of and including Croke Canal and Rocky Mountain Ditch are considered good candidates for upstream transfer. Proceeding downstream, the Reno-Juchem may be transferrable, but the ditches in the Slough association would be more difficult to transfer. Those downstream of the Slough Association headgate on the Clear Creek are not feasible for transfer to an upstream reservoir site because of their reliance on return flows.

3.7 CLEAR CREEK PROJECT CONDITIONAL STORAGE APPLICATIONS

There have been three conditional storage applications submitted by the Alliance or its members for reservoirs in the upper Clear Creek basin. None of the appropriations contain filling rates for the reservoirs. This means that the water can be diverted from Clear Creek at the flow rate that is physically available and in priority. These three reservoir sites are identified in this study as the Bridge, Confluence, and the Guy Gulch sites. The application for the Confluence Reservoir site is the only one of the three that has received a conditional decree. These sites are shown on Figure 6.1.

3.8 SOUTH PLATTE CONDITIONAL STORAGE DECREES

There are several conditional storage decrees in the South Platte basin that are senior to the Clear Creek project conditional storage applications. Development of these South Platte conditional decrees would decrease the amount of water available to the Clear Creek Project. However, the probability of their development is difficult to predict. It is likely that those serving only agricultural uses will continue to experience difficulty, because of the present inability of agriculture to support the high cost of new water supply projects.

Construction of the Narrows project on the South Platte River near Fort Morgan would have the most significant effect on the Clear Creek Reservoir. Narrows is the most senior downstream, conditionally decreed reservoir. It is decreed for 718,147 af, which is 2.8 times as large as Dillon Reservoir. Although some of the conditional decrees owned by the DWB are senior to the Narrows decree, they are upstream on the South Platte or on its tributaries.

Therefore, their effects on Clear Creek will not be as great as those experienced from the Narrows decree. Developing the Narrows decree would significantly reduce the storable flow available to the more junior water right of a potential Clear Creek Reservoir.

4.0 HYDROLOGIC MODELING

4.1 INTRODUCTION

The purpose of the basin modeling effort was to estimate the storable flows available for the Clear Creek Project junior decrees and to evaluate the effects of various water management scenarios. The water management scenarios were evaluated by performing reservoir operation studies to determine the safe yield for each scenario. The hydrologic model developed by CSE in 1983 was updated and expanded for these applications.

4.2 DESCRIPTION OF MODEL

The CSE model operates on a daily basis from April through October (summer) and on a monthly basis from November through March (winter). The summer diversions required a daily analysis because of large daily fluctuations in flow and because diversion could be made by all of the active water right holders. The winter period was modeled on a monthly basis because of more constant flows and because the Croke Canal filling Standley Lake essentially diverts the entire flow. In addition to the water rights diversions from the stream, the model also incorporates conditional decrees. The water available for diversion is grouped into five categories: flow through the gaging station on Clear Creek near Golden, irrigation return from lawns to the stream, precipitation runoff, waste water treatment plant effluent, and return flows from the ditch diversions. The model utilizes 13 segments divided according to the major ditch headgates in the lower Clear Creek basin.

The Clear Creek flows from the Golden gaging station were adjusted for the historical Welch and Church Ditches' and City of Golden's diversions, Henderson Mine flows, and Jones Pass imports. The model then adjusts the flow through the Golden gaging station to account for releases from Agricultural Ditch's Mountain Reservoirs.

4.3 CALIBRATION

To calibrate the model, Clear Creek diversions from 1950 through 1980 were added to the flows through the Derby gaging station, and this combined value was then compared with the values generated by the model. The model's prediction of the April through October supply averaged 98 percent of the actual supply.

4.4 MODELING PERIOD

In planning water resource projects, it is customary to select a period to be used in the hydrologic modeling from the historical streamflow records. This modeling period should be statistically equivalent to the long-term period of record, should include the driest period of record and, when the operation studies are performed, the reservoir should spill before and after the dry period.

Several different modeling periods were considered and the 1947 through 1974 period was selected. This period includes the driest period of record, the 1952 to 1956 drought. The mean annual flow for the modeling period is 99.9 percent of the long-term value and the standard deviation is 99 percent of the long-term value.

4.5 STORABLE FLOWS

Storable flows from Clear Creek were estimated for several conditions: Clear Creek junior decree [1/] for existing facility capacities, Clear Creek junior decree for future facility capacities, transfer of all feasible water rights, and transfer of selected Alliance water rights. Existing and future facility capacities were examined because some of the existing facilities are being rehabilitated to their historic capacities. This rehabilitation has the potential of reducing the flow available to the Clear Creek junior decree. The existing facilities are shown on Figure 2.2. The water rights selected as being feasible for upstream transfer in the last two cases were those located above and including the Croke Canal.

Storable flows were also estimated from the Williams Fork collection system in its existing and proposed gravity expansion conditions. In addition, storable flows were estimated for a scenario in which the waste water effluent derived from transbasin imports is used to satisfy the South Platte calls to Clear Creek. This is possible because, under Colorado water law, the water suppliers who import water from another basin are allowed to

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[1/] The Clear Creek junior decree refers to the conditional decrees held by the Alliance or members that would be available to the Clear Creek Project.

use those imports to exhaustion. In some cases, the waste water effluent associated with these imports is not presently being used by the importer. The average annual storable flows during the years 1947 to 1974 for these different conditions are provided in Table 4.1.

TABLE 4.1

Average Annual Storable Flows

Condition	Storable Flows (af per year)
Clear Creek Junior Decree Existing Facilities Capacities	23,359
Clear Creek Junior Decree Future Facilities Capacities	19,617
Transfer of all Feasible Water Rights	138,925 [1/]
Transfer of Selected Alliance Water Rights	41,072 [1/]
Williams Fork-Existing Collection System	31,944 [1/]
Williams Fork-Gravity Collection Expansion	38,965 [1/]
South Platte Effluent Exchange	45,657 [1/]

4.6 RESERVOIR OPERATION STUDIES

Reservoir operation studies were prepared to estimate the storage versus yield relationship for the storable flow conditions defined above. The Bridge Reservoir site was selected for these studies because it was considered representative of the other proposed reservoir sites and because potential storage capacity is large enough to evaluate all of the storable flow conditions. In addition, this reservoir could serve as the lower reservoir in a potential pumped storage project for several alternative upper reservoirs.

1/ Includes the Alliance's most senior decree associated with the potential reservoir with existing facilities capacities.

4.6.1 Definition of Safe Yield

Safe yield was defined as the constant annual demand that could be provided without reducing the storage in the reservoir below a predetermined minimum operating level at any time in the 1947 to 1974 modeling period. It was determined that the most severe drought in the study period for a potential Clear Creek Project was 1952 through 1956, for junior decree alternatives with existing capacities less than 110,000 af. For capacities larger than 110,000 af, the critical period shifted to the late 1960's.

4.6.2 Operating Criteria

The minimum operating level for main stem reservoirs was set at 10,000 af to account for a conservation pool and for sedimentation. Due to the smaller size of the off-stream reservoirs, the minimum operating level was set at 5000 af. The maximum normal operating water level of each reservoir was set at the spillway crest elevation. Spillways are sized to pass the full probable maximum flood (PMF) 1/ without overtopping the dam, in accordance with the State Engineer's dam safety requirements.

4.6.3 Results

The results of the reservoir operation studies are summarized in Table 4.2. Reservoir yield versus storage are provided for several different storable flow conditions and reservoir capacities. For the junior decree condition with existing capacities, the estimated safe yield ranges from 5,500 af per year for a 40,000 af reservoir to 16,000 af per year for 120,000 af reservoir. For a combination of junior decree with existing capacities and Williams Fork imports with the existing collection system, the yearly safe yield ranges from 10,200 af for a 40,000 af reservoir to 23,000 af for a 120,000 af reservoir. For the South Platte effluent exchange option, the yearly safe yield ranges from 18,000 af for the 40,000 af reservoir to 35,000 af for the 120,000 af reservoir.

1/ The Probable Maximum Flood (PMF) is the estimated flood that would result if all the factors that contribute to a flood were to reach the most critical combination of values that could occur simultaneously. The PMF is an estimate of the boundary between possible and impossible floods.

TABLE 4.2

Safe Yields - Bridge Reservoir
(af per year)

Condition	Reservoir Capacity 40,000 af	80,000 af	120,000 af
Junior Decree with Existing Capacities	5,500	12,000	16,000
Junior Decree with Future Capacities	5,500	10,000	13,300
Transfer of all Feasible Water Rights (Basin Management) 1/	9,000	17,500	26,000
Transfer of Selected Alliance Water Rights 1/	6,500	14,000	18,800
Williams Fork Imports with Existing Collection System 1/ 2/	10,200	18,000	23,000
Williams Fork Imports with Gravity Collection Expansion 1/ 2/	11,000	22,500	29,200
South Platte Effluent 1/ Exchange	18,000	28,000	35,000

1/ Includes the Clear Creek Alliance's most senior decree associated with the potential reservoir with existing facilities capacities.

2/ Effect of Two Forks Reservoir not included. See Section 3.4.

5.0 OTHER WATER SUPPLY CONCERNS

5.1 INTRODUCTION

Other water supply concerns addressed in this section of the study include: demand projections; water quality aspects; potential ground water development; the impact of technological advances; the potential of leasing agricultural water, and additional factors which may affect future water supply projects in the Clear Creek basin.

5.2 DEMAND PROJECTIONS

Future water demands were forecasted for the water users and suppliers who now use Clear Creek as a water supply. Forecasts were estimated for municipal, industrial, and agricultural users for the year 2035. Forecasts for municipal water suppliers were based on the information provided in the SEIS and from interviews with water suppliers. Forecasts for industrial users were based on estimates prepared primarily by the two major industrial water users in the basin: Adolph Coors Company and Public Service Company of Colorado. Each of these entities have their own water supply systems whereas numerous other industrial users make use of municipal water supply systems. Forecasts for agriculture were based on an estimated agricultural acreage of 3000 acres in the year 2035. The water demand forecasted for the year 2035 ranges from 168,000 af per year to 215,000 af per year. This range in forecasts resulted from different assumptions for population, households, and employment in the area.

Forecasted demands compared to current safe yields are provided in Table 5.1. The difference between the future water demand and current safe yield is larger than the estimated project yield from the Clear Creek junior decree regardless of the project alternative.

TABLE 5.1

Water Demands For The Year 2035
Versus Current Safe Yields
(af per year)

Projection [1/]	Future Water Demand	Current Safe Yield	Difference
Low	167,900	150,100	17,800
Medium	175,500	150,100	25,400
High	181,600	150,100	31,500
Basin Water Suppliers	215,440	150,100	65,340

5.3 WATER QUALITY

The Clear Creek watershed was one of the most intensively mined drainages within Colorado during the last century. The mines and associated tailings deposits yield high concentrations of metals that are detrimental to aquatic life. Also, the stream shows marked degradation resulting from disturbance of large portions of the stream bed during the course of placer mining activities that coincided with the precious metal mining boom. Thus a large portion of the surface waters of the Clear Creek drainage have suffered severe water quality degradation both from the point of view of aesthetics and of aquatic life.

The purpose of the study's water quality investigation was to summarize the data available in the upper Clear Creek basin and to use these data to make a preliminary assessment of the water quality in and downstream of the potential reservoirs. The investigation documents the existing water quality problems and how these problems might relate to impounding Clear Creek at the alternative project sites. The fishery potential of an impoundment and the

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[1/] Based on water demand forecasts for the municipal use presented in Appendix 2 of the SEIS for Series 1, 2, and 3 projections for population, households, and employment prepared by DRCOG. Low refers to Series 1, medium to Series 2, and high to Series 3. The estimates are concurrently being reevaluated. Suppliers' figure is the aggregate of the individual projections provided by the water suppliers interviewed as part of the study.

water quality conditions required to support a full diversity of aquatic life were also considered. A preliminary assessment was then made of the downstream improvements in water quality benefits attributable to an impoundment.

The composite water chemistry data base shows Clear Creek as having a very low concentration of suspended solids and a moderately low specific conductance as indicated by major ionic solid characteristics. These characteristics are within or near the expected range for native mountain waters in Colorado. Regarding the heavy metals of cadmium, lead, copper, and zinc, however, the data base shows that the concentrations within the main stem, major tributaries and many individual minor tributaries substantially exceed chronic exposure limits for aquatic life. The concentrations are the most extreme for copper and zinc.

Based on current information, the preliminary analysis indicates that an impoundment on the main stem of Clear Creek or an impoundment receiving substantial amounts of water from it would support a cold water fishery and full diversity of aquatic life. This would be possible because of the strong tendency of metal concentrations to decrease in impounded waters because of sedimentation and flocculation. Metals in solution become flocculated from prolonged contact with organic matter in reservoirs. In addition, an impoundment reduces the most extreme concentrations by dilution. These factors result in an improved quality of the water within the reservoir as well as downstream from the reservoir.

5.4 GROUND WATER

Development of non-tributary ground water under municipal boundaries is not considered to be a viable, near-term alternative for water suppliers who currently receive water from Clear Creek. Based on the costs currently being experienced by municipalities in the basin for developing ground water within their boundaries, the ground water development cost may be several times higher than the preliminary estimates provided in the SEIS for municipalities in the Clear Creek study area. The quality of some of the non-tributary ground water is poor, and the water will probably require treatment.

5.5 TECHNOLOGICAL ADVANCES

Recent technological advances may affect the cost and benefits of the Clear Creek Project. They include advances in operation of water supply systems, improvements in design and construction methodologies, improved efficiency of hydroelectric powerplant equipment and operation, and increased emphasis on water conservation. These advances are difficult to quantify in terms of increased reservoir yields or construction costs, but it is important to recognize their positive effects.

Several technological advances could reduce future increases in water use and demands of the Clear Creek basin. These advances are Supervisory Control and Data Acquisition (SCADA) systems, satellite instrumentation systems, drought leasing, computerized scheduling for irrigation projects, household water saving devices, and advanced irrigation systems.

SCADA systems and satellite instrumentation systems could have the greatest impact on water use and demand in Colorado, as well as in the Clear Creek basin. SCADA systems could improve the overall operating efficiency of the water supply systems, and satellite instrumentation systems, used in conjunction with drought leasing arrangements, could improve delivery efficiencies and reduce demands during drought periods. The Satellite Monitoring System funded by the Authority and operated by the State Engineer's office is providing real-time data for flows and diversions to improve water management in the State and to monitor the State's compact commitments. This technology is rapidly progressing and will be an even more valuable tool in the future.

5.6 POTENTIAL FOR LEASING AGRICULTURAL WATER

The water available for lease from the agriculture sector during a drought period would be somewhat less than the current safe yield of 25,000 af per year. The actual quantity is difficult to estimate because a portion of the safe yield assigned to the agricultural sector is used for nontraditional agricultural uses such as irrigating parks and other open spaces. In addition, there are uncertainties related to future agriculture demand and there may be difficulties in negotiating agreements with individual farmers.

There are a variety of leasing arrangments that could be developed between M&I suppliers and agricultural water users. One leasing arrangement is commonly referred to as "drought insurance." This is a concept whereby the lessor (municipal or industrial water supplier) has access to agricultural water rights under specific conditions or from purchased water rights which are leased back to farmers during normal to wet years. Other conventional leasing arrangemnts could also be used. These arrangements usually give the lessor the first right of refusal to purchase the water at the offered price, should the agricultural owner decide to sell. With improved snow-pack monitoring and associated run-off models, it is now possible to predict irrigation season low flow occurrences resulting in better water management under drought conditions.

5.7 ADDITIONAL FACTORS THAT WILL INFLUENCE DEVELOPMENT

There are several additional water supply factors that will influence the planning and feasibility of the project. These factors include: the changing market for power i.e., the value of pumped storage hydropower [1/], diminished federal role in providing financial support for water projects, the impact of environmental mitigation in conformance with the NEPA process (more specifically, the issues concerning federally listed endangered species of the Platte River Basin in central Nebraska), and the development of recreational opportunities at and downstream of a major reservoir close to the Denver metro area.

An attempt has been made to address these factors at these initial stages of project planning; however, these factors will have a changing role as the project progresses from this initial project planning to a definite project plan and final design.

[1/] For pumped-storage hydroelectric power generation, two reservoirs are needed, located a short distance apart but separated in elevation. Water is released from the upper reservoir to generate electricity during the work day and early evening when electrical power demand is at its peak. When electrical demand is low, at night and weekends, water is pumped back to the upper reservoir from the lower reservoir to replenish the water supply. Pumped-storage hydropower is financially attractive in many instances because the peak-demand energy is much more valuable than the off-peak energy. The shorter the distance between reservoirs in relation to the elevation difference, the greater the potential financial return.

6.0 ALTERNATIVE STORAGE SITES AND FORMULATION OF ALTERNATIVE PROJECTS

6.1 INTRODUCTION

Eleven alternative storage sites were identified: four main stem sites in Clear Creek Canyon, one site on North Clear Creek, and six sites located on smaller tributaries. In addition, five upper reservoirs were identified which could be used in potential pumped-storage developments. The alternative storage sites are shown on Figure 6.1.

After the potential storage sites were identified, 12 alternative projects were formulated to develop all or most of the potential firm yield from the storable native flows in the basin. In addition, ten pumped storage projects were also identified that could be combined with water supply storage to form multipurpose pumped-storage projects.

6.2 ENVIRONMENTAL OVERVIEW

An environmental overview was conducted for the 16 potential reservoir sites. For this overview, five categories of broadly defined environmental resources were evaluated: terrestrial wildlife, wetlands, aesthetics, cultural, water quality, and land use.

Potential environmental impacts were ranked for each site. This ranking was based upon relative degree of predicted impact: low, moderate, and high. These predictions were based on a preliminary data search, on discussions with various agency personnel, and professional judgment. No threatened or endangered species were identified in the study area.

If the Clear Creek project includes hydroelectric power as part of the original construction, a license from the Federal Energy Regulatory Commission (FERC) would be required before the start of construction. If hydroelectric power is not included as part of the original construction, the Corps of Engineers would possibly be the lead agency for permitting purposes because of the required 404 dredge and fill permit. The U.S. Fish and Wildlife Service, in compliance with Section 7 of the Endangered Species Act, would be involved because of potential impact on endangered species in the South Platte River basin. The construction of a major project would most likely require a full EIS in compliance with the NEPA.

6.3 GEOTECHNICAL ASSESSMENT

A general overview was prepared of the geology of the Clear Creek basin. This was a prefeasibility level assessment based on published geological information and on-site investigation of surficial geology at several of the damsites.

The Clear Creek drainage basin is comprised of two distinct areas: the mountains and the plains. The geology of the mountains is characterized by Precambrian rocks. The geology of the plains consists of relatively flat sedimentary beds in the eastern part which dip up steeply against the edge of the mountain front in the western part forming hogbacks. The rocks of the plains are generally sandstone, siltstone, and shale with some limestone.

There are several faults in the Precambrian rock of the mountains. These include Black Hawk, Junction Ranch, Floyd Hill, Windy Saddle, Golden, and several unnamed faults. Except for Floyd Hill, none of the faults are considered active by the Colorado Geological Survey. The Floyd Hill fault does not come in contact with any proposed damsite or reservoir area.

Several preliminary conclusions were drawn regarding engineering geology for the purposes of this study. The foundation conditions for most of the dam sites in the mountains will probably be suitable for concrete dams. At most of these sites, the construction materials for earth and rockfill dams may be limited. The geological conditions should also be suitable for excavating tunnels with tunnel boring machines and for excavating underground cavities for underground power plants.

Earthquake loading will need to be considered for the design of all major structures. It does not appear, however, that the area is located in a highly seismic area and none of the identified dams or reservoirs are located on active faults as defined by the Colorado Geological Survey. Additional site-specific studies would be required during the feasibility stage to further assess the geotechnical features of each site.

6.4 ALTERNATIVE PROJECTS

Preliminary layouts were prepared for each of the twelve alternative projects. The design criteria included conservation and sediment storage allocations resulting in minimum reservoir storage criteria, freeboard requirements, spillway requirements to pass the probable maximum flood (PMF), outlet work sizing, and sizing of construction diversion facilities. Four different dam types were considered in the layouts: concrete arch, roller-compacted concrete, earth fill, and concrete faced rockfill.

The characteristics of alternative projects are summarized in Table 6.1. This list includes dam type, dam height, maximum water surface elevation, active reservoir storage, and costs. A project description and layout drawing were prepared for each project and are included in the final report. A typical dam layout drawing is shown in Figure 6.2.

6.5 PRELIMINARY COST ESTIMATES

The preliminary cost estimates were based on quantity take-offs and current unit prices for the major items included in the project features. These items included the major structural components of each alternative as well as land acquisition, road relocation, and an allowance for miscellaneous minor items that were not accounted for individually. A 25 percent contingency and a 15 percent allowance for engineering and administrative costs were added, in that order, to obtain the Total Construction Cost. The Total Construction Cost is listed for each alternative on Table 6.1. The 25 percent contingency amount accounts for costs associated with: unforeseen geotechnical conditions, design refinements, environmental mitigations, construction delays, water right acquisition costs, and other factors that cannot be quantified during these early stages of project planning. As the project progresses to final design and more information is available concerning the project, the amount set aside for contingencies would be reduced.

The Total Capital Cost is obtained by adding interest during construction to the Total Construction Cost. To obtain the Total Investment Cost, allowances for the debt service reserve fund and financing expenses were added to the Total Capital Cost. Interest during construction was computed based using an 8 percent interest rate with a linear drawdown of funds over a five-year construction period. The debt service reserve fund was assumed to equal one year of debt service. Financing expenses were assumed to equal 3 percent of the total investment cost for projects less than 40 million dollars and 1.5 percent of the total investment cost for projects greater than 40 million dollars.

Annual costs were obtained by amortizing the Total Investment Cost. If the scenario being evaluated included up-front funding (as explained in Section 7.3), the Total Capital Cost was reduced by this amount and the Total Investment Cost was recomputed prior to the amortization. The amortization was based on thirty year financing at an 8 percent interest rate. Annual operation and maintenance (O&M) expenses were estimated to be 0.2 percent of the Total Construction Cost for projects without pumped storage hydropower. For projects with pumped storage hydropower, the annual O&M was estimated to be $1 million per year.

6.6 PUMPED-STORAGE POTENTIAL

In the preliminary evaluation of the pumped storage potential of the Clear Creek basin, ten multipurpose projects were identified. These multipurpose projects are listed in Table 6.2. This list includes summaries of upper reservoir data, lower reservoir data, pumped storage characteristics, and project costs.

The storage requirements for the upper reservoirs were based on an operating cycle for full-load generation of 10 hours per weekday, 5 days per week, and pumping 10 hours per weekday, and 20 hours per weekend.

Several large multipurpose pumped storage projects were identified, including the upper Elk Creek-Bridge Project (750 MW) and the Elk Creek-Tunnel No. 1 project (640 MW), as shown on Figure 6.3.

TABLE 6.1
Characteristics of Alternative Projects

Site	Dam Type	Dam Height (Ft.)	Normal Max. Water Surface Elevation (Ft.)	Active Storage (af)	Firm Yield 1/	Length of Water Conductor (Ft.) 2/	Total Construction Cost ($1000)	Total Capital Cost ($1000) 3/	Total Investment Cost 4/ ($1000)	Comments
On-Stream										
Tunnel No. 1	Conc. Arch	560	6,425	110,000	16,500	-	224,300	273,700	305,400	Site has additional storage potential.
Bridge	Conc. Arch	535	6,690	110,000	16,500	-	277,240	338,300	377,490	Site has additional storage potential.
Tunnel No. 3	Conc. Arch	565	7,050	110,000	16,500	-	286,290	349,350	389,820	Site has additional storage potential.
Confluence	RCC Gravity	360	7,200	35,000	7,000	-	191,650	233,860	260,950	Max. water surface elevation limited to 7,200 to avoid flooding I-70.
North Clear Creek	Conc. Faced Rockfill	445	7,415	60,000	9,000	-	353,320	431,140	481,090	Max. water surface elevation limited by diversion from main stem.
Off-Stream										
Guy Gulch	RCC Gravity	500	7,200	30,000	6,000	28,500	258,420	315,340	351,870	Max. water surface elevation limited by diversion from main stem.
Tucker Gulch	RCC Gravity	460	7,080	50,000	8,000	39,000	208,710	254,680	284,190	Max. water surface elevation limited by diversion from main stem.
Soda Creek	RCC Gravity	400	8,200	30,000	6,000	38,500	167,700	204,640	228,340	Max. water surface elevation limited by diversion from main stem.
Fall River	RCC Gravity	455	8,215	40,000	9,000	27,000	187,640	228,960	255,490	Existing land use constraints exist.
Pine Ridge	Rockfill	285	6,310	20,000	5,000	27,000	225,660	275,360	307,260	Reservoir size limited by height and width of hogback.
Upper Ralston	Rockfill	360	6,345	60,000	9,000	31,000	263,490	321,530	358,780	Reservoir size limited by height and width of hogback.
On-Stream/Off-Stream										
Confluence-Tucker Gulch	Combination of Above			85,000	13,000	30,000	424,080	517,480	577,440	

1/ Firm yield from native flows only.

2/ Pertains only to off-stream and on-stream/off-stream projects.

3/ Total Capital Cost equals Total Construction Cost plus interest during construction.

4/ Total Investment Cost represents Total Capital Cost plus a debt service reserve fund and financing expenses. See Section 6.5.

TABLE 6.2

Multipurpose Pumped Storage Projects

Upper Reservoir					Lower Reservoir				Pump Storage Characteristics		
Site	Dam Type	Dam Height (Ft.)	Reservoir Operating Range (Ft.)	Active Storage (AF)	Site	Dam Type	Dam Height (Ft.)	Maximum Operating W.S. El. (Ft.)	Average Gross Head (Ft.)	Installed Capacity 1/ (MW)	L/H Ratio
Horse Creek	RCC	320	8240 to 8120	6,200	North Clear Creek	Conc. Faced Rockfill	445	7,415	765	200	7:4
Horse Creek	RCC	320	8240 to 8120	6,200	Confluence	RCC	360	7,200	980	260	7:1
Upper Elk Creek	RCC	250	8200 to 8100	12,000	Tunnel No. 3	Concrete Arch	565	7,050	1,100	580	11:3
Upper Elk Creek 2/	RCC	250	8200 to 8100	12,000	Bridge	Concrete Arch	535	6,690	1,460	750	8:4
Elk Creek	RCC	250	7680 to 7600	12,000	Bridge	Concrete Arch	535	6,690	950	500	9:6
Elk Creek	RCC	250	7680 to 7600	12,000	Tunnel No. 1	Concrete Arch	560	6,425	1,215	640	9:7
Guy Gulch Left Hand	RCC	275	7260 to 7200	3,000	Tunnel No. 1	Concrete Arch	560	6,425	815	110	14:2
Upper Elk Creek	RCC	250	8200 to 8100	12,000	Guy Gulch	RCC	500	7,200	950	500	11:8
Elk Creek	RCC	250	7680 to 7600	12,000	Guy Gulch	RCC	500	7,200	440	230	4:7
Belcher Hill	RCC	310	7350 to 7270	12,000	Upper Ralston	Rockfill	360	6,345	965	500	5:1

1/ Capacities were rounded to nearest 10 MW.

2/ This project will require a tailwater in the upper reach of Bridge Reservoir.

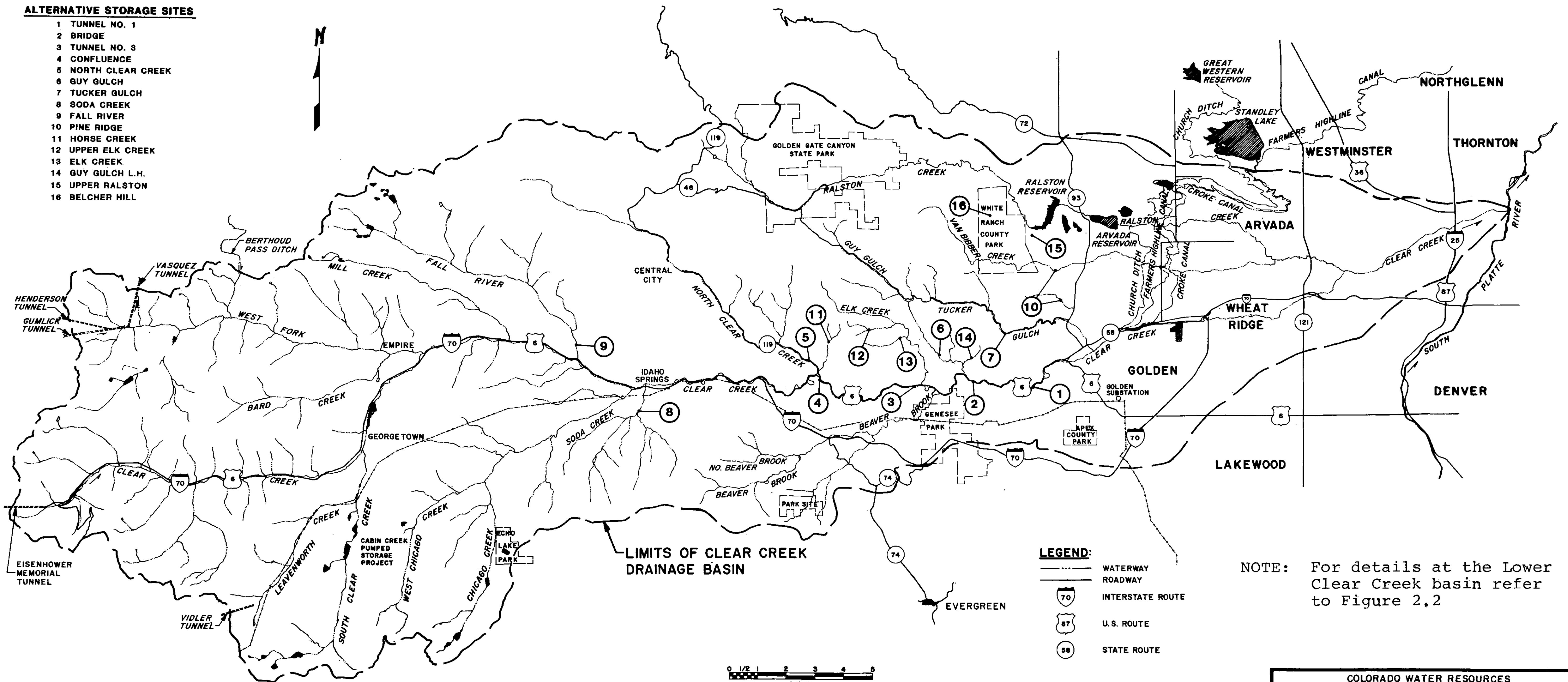
6.7 RELOCATIONS REQUIRED

If a large dam is constructed in Clear Creek Canyon, U.S. Highway 6 would have to be relocated or abandoned. The relocated highway would be up to 600 feet above the existing canyon floor and would require deep excavation cuts in the steep canyon walls, several tunnels, and several bridges.

Two preliminary cost estimates were prepared for relocating U.S. Highway 6. For the first estimate, probable Federal Highway Administration requirements were used. The design speed would be 45 mph throughout the replacement, and four lanes would be provided on the two mile grade up to the dam (one traffic lane each direction, one passing lane, and one braking lane). A two lane road was assumed for the six miles of road around the reservoir perimeter. The estimated construction cost for this relocation without contingencies, interest during construction, engineering, and administrative costs is $75,000,000.

A second estimate was prepared for a relocation with design criteria similar to existing road conditions. Assumptions for this cost estimate include: design speed of 45 mph with reduced speeds of 35 mph at curves, and three lanes provided on the grade up to the dam (one traffic lane in each direction, and one braking lane). The road around the reservoir rim was assumed to be two lanes as in the first estimate. The estimated construction cost for this option is $57,000,000 before contingencies, engineering, and administrative costs.

These estimates include allowances for such major items as excavation, bridges, tunnels, and pavement. Unit costs used for the estimates were based on actual costs for other similar Colorado projects and were reviewed by personnel from the Colorado Department of Highways.



COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

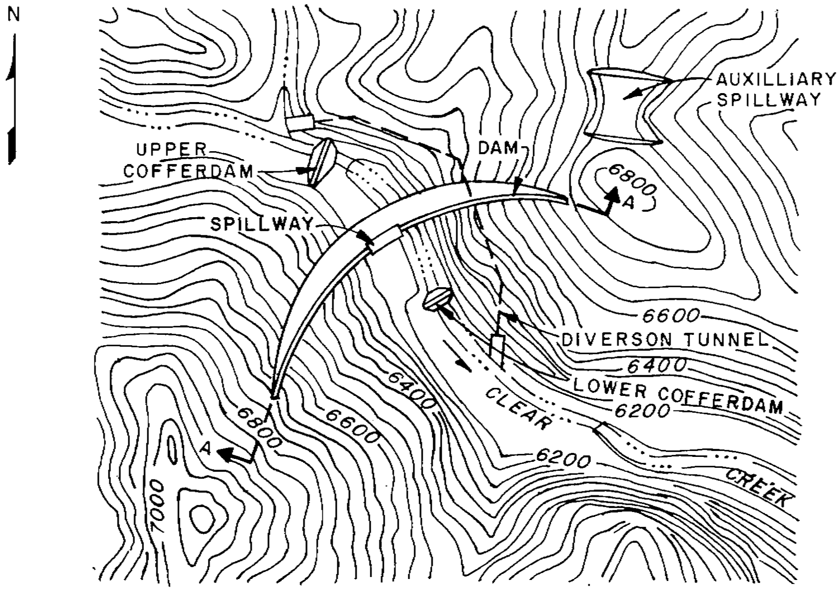
CLEAR CREEK PROJECT

ALTERNATIVE STORAGE SITES

TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
WOODWARD-CLYDE CONSULTANTS
WESTERN ENVIRONMENTAL ANALYSTS, INC.

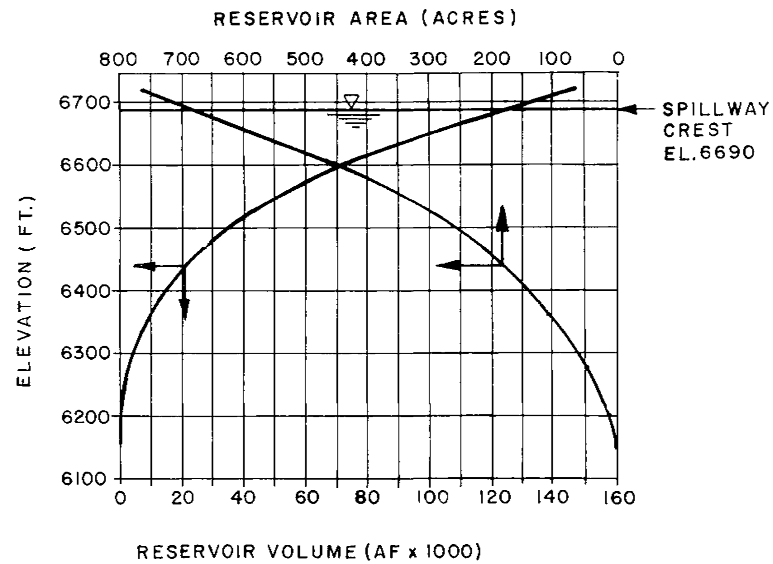
DATE: APRIL 1987

FIGURE 6.1

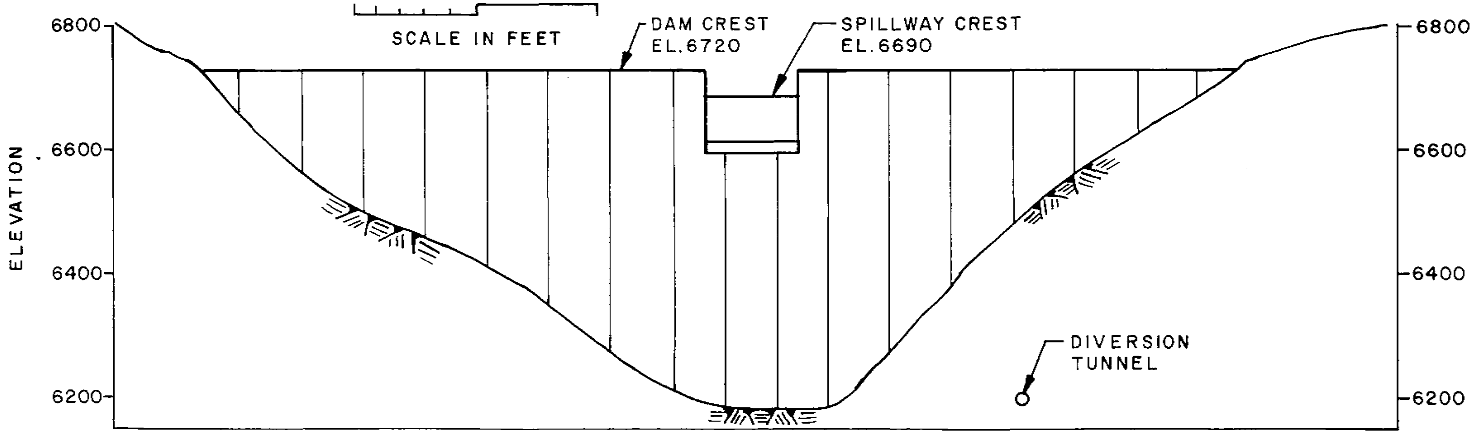


SITE PLAN

0 500 1000
SCALE IN FEET



RESERVOIR ELEVATION vs STORAGE



PROFILE A-A

ALONG AXIS OF DAM

0 200 400
SCALE IN FEET.

COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CLEAR CREEK PROJECT

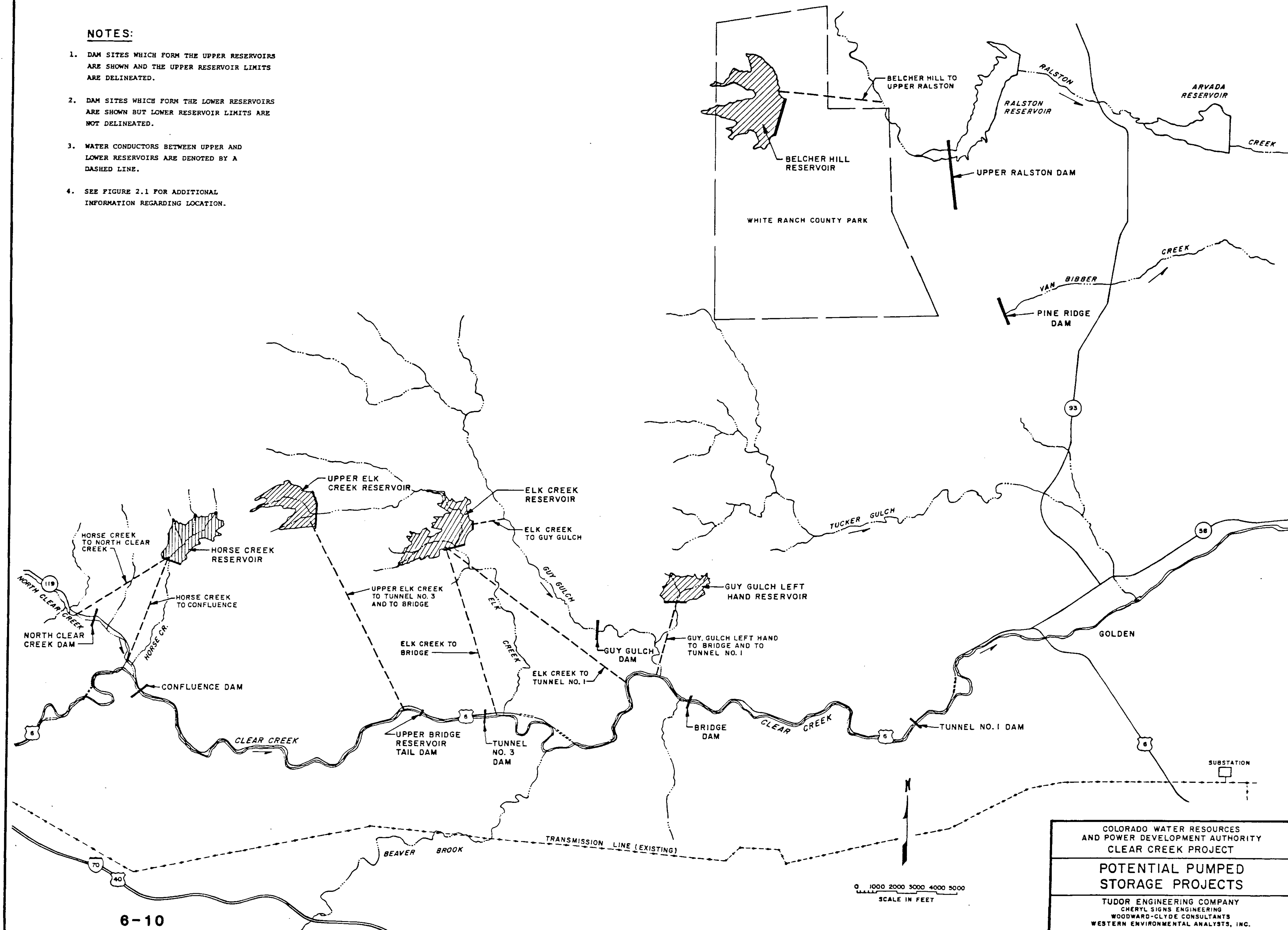
BRIDGE SITE PLAN AND PROFILE

TUDOR ENGINEERING COMPANY
WOODWARD-CLYDE CONSULTANTS
WESTERN ENVIRONMENTAL ANALYSTS, INC.

DATE: FEBRUARY 1987 FIGURE 6.2

NOTES:

1. DAM SITES WHICH FORM THE UPPER RESERVOIRS ARE SHOWN AND THE UPPER RESERVOIR LIMITS ARE DELINEATED.
2. DAM SITES WHICH FORM THE LOWER RESERVOIRS ARE SHOWN BUT LOWER RESERVOIR LIMITS ARE NOT DELINEATED.
3. WATER CONDUCTORS BETWEEN UPPER AND LOWER RESERVOIRS ARE DENOTED BY A DASHED LINE.
4. SEE FIGURE 2.1 FOR ADDITIONAL INFORMATION REGARDING LOCATION.



COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY
CLEAR CREEK PROJECT

POTENTIAL PUMPED STORAGE PROJECTS

TUDOR ENGINEERING COMPANY
CHERYL SIGNS ENGINEERING
WOODWARD-CLYDE CONSULTANTS
WESTERN ENVIRONMENTAL ANALYSTS, INC.

DATE: APRIL 1987 FIGURE 6.3

7.0 PRELIMINARY SCREENING

7.1 INTRODUCTION

The preliminary screening was conducted in three steps. First, in the initial screening, several sites were eliminated from further consideration based upon technical, economic, and environmental judgments; second, a preliminary cost ranking was prepared for the projects surviving the initial screening; and third, the results of that preliminary ranking combined with other factors were used to select projects for further study.

7.2 INITIAL SCREENING

The initial screening was based on the following key factors: the active storage available, safe yield potential, cost of active storage, cost of safe yield, potential environmental impact, and hydroelectric potential. In the initial screening the following projects were eliminated: North Clear Creek, Guy Gulch, Soda Creek, Fall River, and Pine Ridge, as shown on Figure 6.1. A summary of the initial screening is provided in Table 7.1.

7.3 PRELIMINARY COST RANKINGS

Phase I Feasibility studies conducted by the Authority generally use a cost estimating procedure (see Section 6.5) that may be considered a preliminary financial analysis. The project sponsor, the Clear Creek Water Users Alliance has indicated that there would be up-front funding from the municipal and industrial water users if the project were to be constructed. In the case of the municipal users, the up-front payment may come largely from tap fees collected before and immediately following project construction. Given the large lead time on this project, (it is estimated that the project would not be constructed until after the year 2000) it may be possible for the sponsors to accumulate substantial funds for up-front contributions. Industrial water users have already begun to accumulate funds for future water supply systems in some cases.

Detailed financial studies and evaluations of projected population growth and tap sales have not been conducted because this is a preliminary study and its primary purpose is to compare alternatives on an equal basis. The study is not intended to make a final evaluation of financial feasibility. It is worthwhile, however, to demonstrate the effect that up-front funding has on the total annual cost for the projects.

Therefore, Table 7.2 provides the annual costs per af of yield with and without up-front funding, and for four different scenarios: No. 1, based on all costs; No. 2, without road relocation costs; No. 3, with major hydro benefits; and No. 4, without road relocation costs and with major hydro benefits. For the costs with up-front funding, it was assumed that the sponsors would provide a cash contribution equal to the Interest During Construction (IDC). This is approximately 22 percent of the Total Construction Cost as calculated with an 8 percent interest rate, a 5-year construction period, and a uniform withdrawal of funds. Operation and Maintenance costs are included in the Total Annual Cost figures. Table 7.2 indicates that, with up-front funding equal to the interest during construction, the yield costs would range from $100 per af/yr to more than $1000 per af/yr.

It is important to note the location of this project when reviewing its estimated costs. Other water supply options for the Clear Creek Basin include substantial conveyance facilities and costs to get the water to the end user. The alternatives that have been evaluated in this study are located immediately upstream of the existing diversion facilities and would, therefore, greatly reduce these conveyance costs.

Two safe yield figures are shown on Table 7.2 for each storage site. The upper figure is for the junior decree with existing capacities and Williams Fork imports with its existing collection system. As discussed in Section 3.4, the effect of other potential projects on Williams Fork imports, such as the Two Forks Project, have not been quantified. The lower figure is for the South Platte Effluent Exchange option. These two options represent medium and upper level values in the range of safe yield options that were evaluated. Their inclusion in the table is not meant to imply that they are the most likely options.

7.4 SELECTION OF PROJECTS

The Confluence and Confluence-Tucker Gulch Projects were eliminated based upon the preliminary rankings shown on Table 7.2 and the potentially higher environmental impact of a dam at the Confluence site. The Tucker Gulch Project was eliminated based solely on costs. The four remaining projects are: Bridge, Upper Ralston, Tunnel No. 1, and Tunnel No. 3. Refinements to the preliminary analyses conducted for these four remaining projects are needed before it is decided which projects are recommended for the Phase II Feasibility Study. None of these projects appear to have a clear environmental advantage over the others.

Items that should be addressed during the next step of this prefeasibility study include: further evaluation of the potential for transbasin imports and effluent exchange, refinement of reservoir yield estimates, additional study of the U.S. Highway 6 relocation with assessment of possible abandonment, and evaluation of the multipurpose pumped-storage project using information from the Authority's proposed pumped-storage economics study. The second step of this Phase I Feasibility Study will provide the information so that the four remaining projects can be compared and a rational decision made on project selection and on proceeding with the Phase II Feasibility Study.

TABLE 7.1

Initial Screening

	Storage Constraints	Safe-Yield Limitations	Storage Costs	Safe-Yield Costs	Potential Environmental Impact: Overview	Potential Environmental Impact: Threat. & Endangered Species	Hydro Potential for Pumped-Storage	Comments
On-Stream								
Tunnel No. 1	None	Moderate	Moderate	Moderate	Low-High	None	Large	
Bridge	None	Moderate	Moderate	High	Moderate-High	None	Large	
Tunnel No. 3	None	Moderate	Moderate	High	High	None	Large	
Confluence	I-70	High	High	High	High	None	Moderate	
North Clear Creek 1/	None	High	High	Very High	High	None	Moderate	Eliminate: Very high costs for storage and yield.
Off-Stream								
Guy Gulch 1/	None	High	Very High	Very High	Moderate	None	Moderate	Eliminate: Very high costs for storage and yield.
Tucker Gulch	Topo	Moderate	High	High	Low-Moderate	None	Large	
Soda Creek 1/	Topo	High	High	Very High	Low-Moderate	None	Small	Eliminate: Very high costs for storage and yield.
Fall River 1/	Topo	High	High	Very High	High	None	Small	Eliminate: Very high costs for storage and yield.
Pine Ridge 1/	Topo	High	Very High	Very High	Moderate	None	Moderate	Eliminate: Very high costs for storage and yield.
Upper Ralston	Topo	Low	High	High	Moderate-High	None	Large	
On-Stream/Off-Stream								
Confluence-Tucker Gulch	I-70 & Topo	High	High	High	High	None	Large	

1/ Sites that were eliminated from further consideration.

TABLE 7.2
Preliminary Cost Rankings

With All Costs Financed 1/

Scenario #1: Based on all Costs

Storage Site	Safe Yield 2/ (af/yr)	Yield Costs ($/af/yr)
1. Tunnel No. 1	23,000	1190
	35,000	780
2. Bridge	23,000	1480
	35,000	970
3. Tunnel No. 3	23,000	1530
	35,000	1000
4. Tucker Gulch	13,300	1930
	21,300	1200
5. Upper Ralston	16,000	2020
	25,300	1280
6. Confluence	10,900	2160
	18,400	1280
7. Confluence-Tucker Gulch	20,500	2540
	28,200	1850

Scenario #2: Without Road Relocation Costs

Storage Site	Safe Yield 2/ (af/yr)	Yield Costs ($/af/yr)
1. Tunnel No. 1	23,000	720
	35,000	470
2. Confluence	10,900	880
	18,400	520
3. Bridge	23,000	910
	35,000	600
4. Tunnel No. 3	23,000	940
	35,000	620
5. Confluence-Tucker Gulch	20,500	1720
	28,200	1250
6. Tucker-Gulch	13,300	1780
	21,300	1110
7. Upper-Ralston	16,000	1980
	25,300	1250

Scenario #3: With Major Hydro 3/

Storage Site	Safe Yield 2/ (af/yr)	Yield Costs ($/af/yr)
1. Bridge	23,000	810
	35,000	530
2. Upper Ralston	16,000	1000
	25,300	640
3. Tunnel No. 1	23,000	1190
	35,000	780
4. Tunnel No. 3	23,000	1410
	35,000	930
5. Tucker Gulch	13,300	1930
	21,300	1200
6. Confluence-Tucker Gulch	20,500	2540
	28,200	1850
7. Confluence	10,900	3340
	18,400	1980

Scenario #4: Without Road Relocation Costs and with Major Hydro 3/

Storage Site	Safe Yield 2/ (af/yr)	Yield Costs ($/af/yr)
1. Bridge	23,000	240
	35,000	160
2. Tunnel No. 1	23,000	720
	35,000	470
3. Tunnel No. 3	23,000	830
	35,000	540
4. Upper Ralston	16,000	960
	25,300	610
5. Confluence-Tucker Gulch	20,500	1720
	28,200	1250
6. Tucker Gulch	13,300	1780
	21,300	1110
7. Confluence	10,900	2070
	18,400	1230

With Up-Front Funding Equal to Interest During Construction 1/

Scenario #1: Based on all Costs

Storage Site	Safe Yield 2/ (af/yr)	Yield Costs ($/af/yr)
1. Tunnel No. 1	23,000	990
	35,000	650
2. Bridge	23,000	1220
	35,000	800
3. Tunnel No. 3	23,000	1260
	35,000	830
4. Tucker Gulch	13,300	1580
	21,300	990
5. Upper Ralston	16,000	1670
	25,300	1050
6. Confluence	10,900	1780
	18,400	1050
7. Confluence-Tucker Gulch	20,500	2090
	28,200	1520

Scenario #2: Without Road Relocation Costs

Storage Site	Safe Yield 2/ (af/yr)	Yield Costs ($/af/yr)
1. Tunnel No. 1	23,000	590
	35,000	390
2. Confluence	10,900	720
	18,400	430
3. Bridge	23,000	750
	35,000	490
4. Tunnel No. 3	23,000	770
	35,000	510
5. Confluence-Tucker Gulch	20,500	1420
	28,200	1030
6. Tucker-Gulch	13,300	1460
	21,300	910
7. Upper-Ralston	16,000	1620
	25,300	1030

Scenario #3: With Major Hydro 3/

Storage Site	Safe Yield 2/ (af/yr)	Yield Costs ($/af/yr)
1. Bridge	23,000	150
	35,000	100
2. Upper Ralston	16,000	320
	25,300	210
3. Tunnel No. 1	23,000	530
	35,000	350
4. Tunnel No. 3	23,000	760
	35,000	500
5. Tucker Gulch	13,300	1580
	21,300	990
6. Confluence-Tucker Gulch	20,500	2090
	28,200	1520
7. Confluence	10,900	2370
	18,400	1400

Scenario #4: Without Road Relocation Costs and with Major Hydro 3/

Storage Site	Safe Yield 2/ (af/yr)	Yield Costs ($/af/yr)
1. Bridge	23,000	4/
	35,000	4/
2. Tunnel No. 1	23,000	150
	35,000	100
3. Tunnel No. 3	23,000	280
	35,000	190
4. Upper Ralston	16,000	300
	25,300	190
5. Confluence-Tucker Gulch	20,500	1420
	28,200	1030
6. Tucker Gulch	13,300	1460
	21,300	910
7. Confluence	10,900	1330
	18,400	790

1/ See Section 12.3 for an explanation of the two cost rankings. See Section 8.3 for cost estimating methodology.

2/ The upper figure is for the junior decree with existing capacities and Williams Fork imports with its existing collection system. The lower figure is for the South Platte Effluent Exchange option. These two values represent the medium and upper safe yields, respectively, that may be supplied by the projects. Their inclusion in this table is not meant to imply that they are the most likely options. See Section 4 for additional discussion of these options.

3/ Based on the value of $1000 per kW for pumped storage.

4/ Hydro would pay for entire project at $875/kW.

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

The major findings of the study are based on the storable flow estimates, reservoir operation studies, preliminary cost estimates, and the preliminary project screening.

Using a modeling period of 1947 to 1974, the yearly storable flows for the Clear Creek junior decree are estimated to range from 23,000 af for present facility capacities to 19,600 af for future facility capacities.

Based on the reservoir operation studies, nearly 110,000 af of active storage are required to obtain substantial yields in the Clear Creek basin. With this storage requirement, the estimated annual safe yield from unappropriated native flows will be approximately 16,000 af. Transbasin imports, water right transfers, or effluent exchanges will be required if it is desired to increase the safe yield of the project and to have a more cost effective storage facility. Each of these potential measures have significant institutional and legal issues that would have to be resolved before they are implemented.

Imports from the Williams Fork combined with the native flows could provide safe yields ranging from 23,000 to 29,000 af per year. In addition, the South Platte effluent exchange combined with native flows has a potential safe yield of almost 35,000 af per year.

There are several storage sites in Clear Creek Canyon that could provide active storage of 110,000 af. There is also one possible off-stream storage on Ralston Creek that provides an active storage of 63,000 af.

The unit cost for storage is high, especially when the cost of relocating U.S. Highway 6 is included for the Clear Creek canyon sites. The highway relocation cost is almost 40 percent of the total direct construction cost of each project in the canyon.

The joint benefits could be substantial for developing a major pumped-storage project in conjunction with water supply storage. Joint development could provide lower-cost power and water than if each project were developed separately.

8.2 RECOMMENDATIONS

Based on the study findings, the following recommendations are made:

- A more detailed assessment should be made as part of Step 2 evaluations of the institutional aspects associated with enhancing Clear Creek project yields. This assessment should cover imports from Williams Fork basin, water right transfers, and effluent exchange options.

- The possibility of abandoning U.S. Highway 6 should be thoroughly explored, both with the Colorado Highway Department and with the Federal Highway Administration. The relocated highway would be a major cost to the project and would not offer significant advantages over I-70 in either grade or travel times.

- Several pumped storage projects have been identified which include upper reservoirs north of the Clear Creek Canyon and above Ralston Creek. Future basin investigations for water supply storage should include determination of the optimum capacity of a pumped storage facility based upon regional energy needs and the effect of the plant capacities on the cost of water supply.