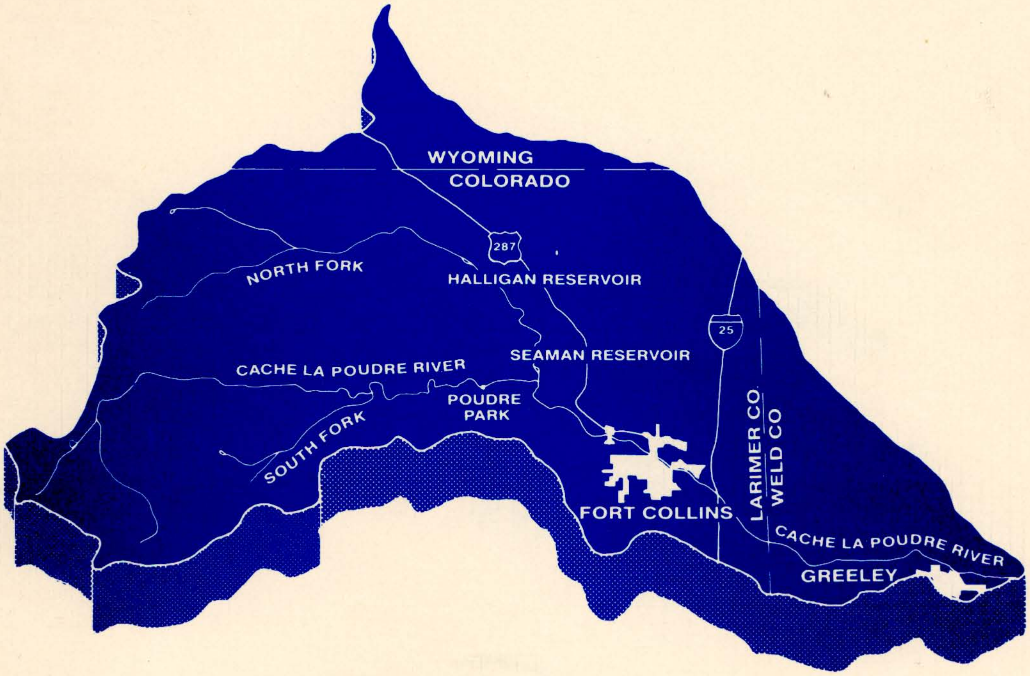
Cache la Poudre Basin Study

Final Report

Volume II



COLORADO WATER RESOURCES & POWER DEVELOPMENT AUTHORITY

1981

January 1987

HARZA ENGINEERING COMPANY CONSULTING ENGINEERS

January 30, 1987

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

Subject: Cache la Poudre Basin Study
Submittal of Volume II of the Final Report

Dear Mr. Kappus:

We are pleased to submit Volume II of a two-volume Final Report on the Cache la Poudre Basin Study consistent with our contract dated June 7, 1985. Volume II contains the findings from the Phase II portion of the Study dealing with plan formulation, evaluation, and selection. Volume I contains findings from Phase I of the Study which involved an appraisal of available water resources and future demands. A Summary Report on the entire study was issued in early January, 1987.

As described in Volume I, the Cache la Poudre Basin has sufficient water supply and storage facilities to satisfy water demand during a 1-in-10 year drought. However, water shortages will be experienced for more severe droughts. A 1-in-25 year drought, such as occurred in 1953 to 1956, will result in serious water shortages.

Municipalities and industry in the Basin are not presently subject to shortages because of policies which require acquisition of senior agricultural water rights as a prior condition for new urban development. To the extent that agricultural rights remain available for transfer, municipal and industrial water supplies should be adequate in the future.

Volume II describes the plan formulation and selection process. An extensive effort has been made to identify non-structural elements that could reduce the size and cost of structural measures needed to overcome water shortages. Shortages corresponding to a 1-in-25 year drought can be reduced by almost one-half with application of non-structural plan elements. Given the comparatively low cost of these measures, their importance cannot be over-emphasized.

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Two plans combining non-structural and structural elements have been recommended to the Authority as meriting further investigation. The preferred plan provides 274,000 acre-feet (af) of storage which, together with non-structural measures, could greatly reduce the effects of a 25-year drought. The plan includes construction of a 280-foot high roller-compacted concrete dam (Poudre) on the mainstem Cache la Poudre River just below the North Fork confluence, a 315-foot high rockfill dam (Glade) at an off-channel location about one mile north of Ted's Place, and a large pumped-storage hydroelectric facility. Twelve non-structural measures that involve conservation or better use of existing water resources are included in the plan. The direct cost of the structural elements of this plan, including the pumped-storage hydropower facility, is estimated to be $1.5 billion (January 1986 price level).

The alternative plan would provide about 156,000 af of storage in an initial stage which would provide an average annual yield of 29,000 af from native water and additional yields from Windy Gap and C-BT diversions. This plan includes construction of a 390-foot high concrete gravity dam on the mainstem at the Grey Mountain site, a large pumped-storage facility, and non-structural measures to conserve or better use available water resources. This plan could be expanded to 274,000 af of storage in the future. The direct cost of the structural elements of this plan, including hydroelectric power facilities, is estimated to be $1.3 billion.

Both plans include an 1800 megawatt pumped-storage hydroelectric project which could contribute significantly to payment of the water storage facilities if a market for this power develops in Colorado and adjacent states. Smaller pumped-storage facilities or staged construction of such facilities could be developed as market conditions dictate.

Both plans achieve an internal rate of return of approximately nine percent excluding inflation. Including inflation, these rates are on the order of 14 percent and are attractive in today's market place. However, to realize these rates of return, a market for this power must be identified.

Federal involvement in water project development has declined substantially. However, there may be future opportunities to facilitate financing of water projects with the joint development of pumped-storage hydropower in the Basin. A water project in the Basin may be financable through the sale of revenue bonds. Project implementation could be accomplished without pledging the local tax base.

We wish to express our appreciation for having had the opportunity to prepare the Basin Study. The scope and complexity of the assignment have made it a very interesting and challenging assignment for the Study Team.

We also wish to acknowledge the excellent support and guidance we have received from Blaine Dwyer P.E., your Project Manager, and from the Board. We look forward to any future opportunity to be of service to you.

Very truly yours,

R. J. Hunter, P.E.
Study Manager and
Vice President

FINAL REPORT

CACHE LA POUDRE BASIN WATER AND HYDROPOWER RESOURCES MANAGEMENT STUDY

VOLUME II

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January 1987

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Chapter 9

Potential Market for Additional Hydropower Development

9.0 POTENTIAL MARKET FOR ADDITIONAL HYDROPOWER DEVELOPMENT

9.1 INTRODUCTION

An assessment was made of the local and regional market for additional hydropower development in the Cache la Poudre Basin. According to the Plan of Study, this analysis was comprised of two components: 1) an evaluation of potential demand for hydropower produced in the Basin, and 2) an estimate of the market value of the power. In addition, a specific pumped-storage hydroelectric generation project has been proposed for the Basin. Given its unique marketing objectives, a brief discussion of this project is provided.

The demand analysis component is based primarily on secondary sources. Numerous reports, including those available from the Western Area Power Administration, were reviewed in seeking useful insights for this subtask. A number of recent studies have been completed which are applicable to this hydropower market analysis, including:

- "1985 Annual Data Summary Report", North American Electric Reliability Council, 1985.
- "Colorado Electric Supply Survey 1983-1993", Colorado Public Utilities Commission, April 2, 1984.
- "Task 1-5, Power Demand Forecast and Preliminary Market Assessment", St. Vrain Basin Reconnaissance Study, R. W. Beck and Associates/Dames & Moore, January, 1984.

The R. W. Beck report, which was prepared for a study sponsored by the Colorado Water Resources and Power Development Authority, has particular applicability to the Cache la Poudre Study. The geographic area of interest is quite similar, and the purposes of the hydropower analysis are comparable between the two studies. The Beck report also contains relatively current data (1983). Therefore, in order to avoid needlessly duplicating previous Authority-funded work, the St. Vrain report was utilized to the maximum extent feasible.

Where possible, primary data was used to verify or update the R. W. Beck report and other secondary sources. Preliminary conclusions or observations about the potential hydroelectric generation market were derived for both local and regional market areas.

Without knowing the timing and configuration of potential hydroelectric power projects in the Basin, it is not possible to prepare specific estimates of the market value of the power. Therefore, a range of values is provided based on several alternative methods. The resulting estimates rely heavily upon current relationships between electric power supply, demand, and costs.

9.2 POWER DEMAND PROJECTIONS

Because of the interconnection of transmission facilities among the various utilities in the region, it is common for electric power to be produced a great distance from where it will be consumed. This enables power production facilities to be sited where technical and economic conditions are most suitable.

However, there are disadvantages to transporting power over long distances. The primary drawback is transmission losses, which increase with the distance the power travels. Another drawback is the cost of using lines owned by other utilities. Wheeling charges and administrative expenses can be significant, and the availability of these lines can be limited. For these reasons, both local and regional markets have been evaluated with somewhat more detail placed on the local markets.

9.2.1 Local Market Areas

Geographically, the major utilities operating in and around the Basin are Public Service Company of Colorado, Platte River Power Authority, Tri-State Generation and Transmission Association, and Colorado Ute Electric Association.

9.2.1.1 Public Service Company of Colorado (PSC)

The PSC service territory covers a large part of the state with major load centers along the Front Range. The company experienced rapid load growth during the 1970's which leveled off during the early 1980s. The company's load increased by approximately seven percent annually during the 1970s with peak system demand of 1400 MW in 1970 and 2747 MW in 1980. By 1985, the load had grown to 3050 MW, or 2 percent annually from 1980.

Also during the 1970s, the peak load period in PSC's system shifted from winter to summer. In 1985, the summer peak was 3050 MW and the winter peak was 3020 MW. The company's latest available load forecasts indicate that this differential will gradually increase; by 1994 the summer peak is expected to exceed the winter peak by 12 percent.

The R. W. Beck report characterized the company's resources in 1983 as follows:

	Capacity (MW)
Baseload Capacity	2410
Intermediate Capacity	242
Peaking Capacity	429
Net Purchases	164
Total	3,245

Resources are comprised of generation capacity and net purchases. Total company owned capacity was 3081 MW with 2410 MW for baseload production and 671 MW for peak loads.

Company owned capacity in 1985 was approximately 3045 MW of which 2426 MW was baseload capacity and 619 MW was available for meeting intermediate and peak demands. This indicates that the company's generation resources have remained relatively stable between 1983 and 1985, although some retirements or deratings have occurred. Also, it should be noted that the company's owned capacity was equal to the peak load. Purchases comprise the company's only reserve.

A PSC study dated June 1983 was used by R. W. Beck in the St. Vrain Study for their evaluation of projected loads and resources. The study provided annual load projections to the year 2002 beginning with actual loads in 1982. Based on PSC's projected annual load growth rate of 2.1 percent between 1997 and 2002, Beck extended the company's load projections to the year 2020. The projections of both PSC and R. W. Beck are presented in Table 9.1, Line 1.

PSC provides updated loads and resources projections to the Colorado Public Utilities Commission (PUC) annually. The most recently available projections are also presented in Table 9.1. Lines 2 and 3 are based on projections made in 1984 and 1985, respectively. Line 4 is the company's actual 1985 peak demand taken from their 1985 Annual Report (Form 1) to the Federal Energy Regulatory Commission (FERC).

There are minimal differences among the three sets of projections. For example, the projections of peak demand in 1990 are all within 1.5 percent of each other, although PSC lowered its projections for 1990 in both the 1984 and 1985 studies. Overall, the projections are comparable.

The R. W. Beck study reported that PSC was planning (in 1983) generating capacity increases consisting of an additional 485 MW coal-fired unit at their Pawnee Station and a 75 MW uprating of the Fort St. Vrain nuclear plant. Both of these additions would be for baseload operations. The company also planned at that time to add another baseload, coal-fired facility sometime after 1992.

TABLE 9.1
Public Service Company of Colorado
System Annual Peak Electric Demand Projections
(Megawatts)

Line No.	Year of Forecast	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	2000	2005	2010	2015	2020
1	1983	2,809*			3,060					3,532					4,018	4,479	4,969	5,532	6,147	6,830
2	1984		2,770*	2,834	2,963	3,063	3,165	3,276	3,377	3,482	3,559	3,661	3,760							
3	1985			2,888*	2,980	3,071	3,160	3,274	3,379	3,473	3,560	3,647	3,734	3,828						
4	1985				3,050*															

*Actual

Source: Line 1 - "Power Demand Forecast and Preliminary Market Assessment," St. Vrain Basin Reconnaissance Study, R. W. Beck and Associates/Dames & Moore.
Line 2 - "Colorado Electric Supply Survey 1983-1993," Colorado Public Utilities Commission, April 2, 1984
Line 3 - "Colorado Electric Supply Survey 1984-1994," Colorado Public Utilities Commission, (Preliminary).
Line 4 - 1985 FERC Form 1, Public Service Company of Colorado, December 31, 1985.

Based on both the PSC and R. W. Beck projections of loads, resources, and power purchases, the R. W. Beck study concluded that the company would require approximately 3600 MW of resource additions between 1992 and 2020.

The 1985 PSC Loads and Resources Study identifies two planned capacity additions-- the additional Pawnee unit in 1991 and another 250 MW coal-fired unit in 1994. No mention is made of the 75 MW Fort St. Vrain uprating.[(1)] In general, these projections correspond with those in the 1983 study with resource additions moved back somewhat to correspond with the slightly lower load projections.

9.2.1.2 Platte River Power Authority (PRPA)

PRPA is a wholesale electric power supplier to four Colorado communities including Estes Park, Fort Collins, Longmont, and Loveland. The company's service territory is limited to the vicinity of these communities. System demand was 201 MW and 227 MW in 1982 and 1983, respectively. According to the R. W. Beck study, the relatively sharp increase in load from 1982 to 1983 was due primarily to prolonged cold weather rather than actual growth in connected loads. This conclusion is supported by the 217 MW peak demand which was experienced in 1984.

The following PRPA resources were reported in the R. W. Beck study for 1983:

[(1)]This unit is currently the center of considerable debate as to its usefulness to Colorado consumers. The Colorado Office of Consumer Counsel, which represents consumers in utility proceedings before the PUC, sought and obtained a multi-million dollar rebate from PSC because the company has been unable to generate any significant amounts of power from this unit even though they are earning a return on their investment in the unit.

	Capacity (MW)
WAPA Allocation (baseload)	235
Craig Station (baseload)	149
Rawhide Station (baseload)	250
Total	634

PRPA submitted projections of loads and resources to the PUC in 1985 which indicated that virtually no changes had taken place between 1983 and 1984 in the company's owned generating capacity or the level of WAPA allocations.

With reported capacity resources of 639 MW in 1984 and a firm system peak of 217 MW the same year, PRPA had reserve capacity of 194 percent. The bulk of this excess is being marketed to PSC at least until 1994.

Table 9.2 presents both the load projections provided in the R. W. Beck report (Line 1) and those submitted by PRPA to the PUC in 1984 and 1985 (Lines 2 and 3). The 1985 forecast indicates lower load growth than the 1983 and 1984 forecasts, especially in later years. The projected rates of load growth have been moderated somewhat with projected loads growing at less than 6 percent annually in the early 1990's in the 1985 projections compared to the 7 percent rate used in the 1983 and 1984 projections.

According to the R. W. Beck report, PRPA was considering construction of an additional unit at the Rawhide Station which would begin production in the mid- to late 1990's, providing enough additional power to meet the system's power needs into the early 2000's. PRPA's 1985 load and resource projections indicate no new capacity additions through 1994.

9.2.1.3 Tri-State Generation and Transmission (Tri-State)

Tri-State is wholesale supplier of electric power to Rural Electrification Association (REA) and public entities. As its name implies, Tri-State operates in three states: Colorado, Wyoming and Nebraska.

TABLE 9.2
Platte River Power Authority
System Annual Peak Electric Demand Projections
(Megawatts)

Line No.	Year of Forecast	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	2000	2005	2010	2015	2020
1	1983	201*			234					336					471	661	928	1,300	1,825	2,560
2	1984		227*	228	241	258	285	304	323	346	369	394	424							
3	1985			217*	227	241	269	284	302	320	339	359	380	403						

*Actual

Source: Line 1 - "Power Demand Forecast and Preliminary Market Assessment," St. Vrain Basin Reconnaissance Study, R. W. Beck and Associates/Dames & Moore.
Line 2 - "Colorado Electric Supply Survey 1983-1993," Colorado Public Utilities Commission, April 2, 1984.
Line 3 - "Colorado Electric Supply Survey 1984-1994," Colorado Public Utilities Commission, (Preliminary).

Because of loads for irrigation water pumping, Tri-State experiences a high summer peak. Many of its member cooperatives also distribute energy to serve oil and gas industry loads, particularly in Wyoming. Primarily because of these loads, the system has experienced rapid growth in the recent past. In the 1970s, system load grew at an annual rate of almost 10 percent, increasing from 393 MW in 1970 to 1009 MW in 1980. More recently, actual system peak demand was 1020 MW in 1982 and 930 MW in 1983.

The sharp decline in load between 1982 and 1983 demonstrates the potential volatility of the system's loads. In this case, a sharp reduction in irrigation demand was experienced due in part to the implementation of the federal government's Payment-in-Kind (PIK) Program which reduced the amount of irrigated land.

Although Tri-State operates very little of its own generating facilities, it does own or have claims on a substantial amount of electric capacity. The following generation resources, totaling 1733 MW, were cited in the R. W. Beck report:

	Capacity (MW)
WAPA Allocation:	
Missouri River Basin	266
Colorado River Storage Project	252
Craig Station	206
Laramie River Station	398
Republican River Station (peaking)	195
Burlington Station (peaking)	100
Purchases - Basin Electric	316
Total	1733

Tri-State has maintained all of these resources at the same levels, with no additions through 1985 based on the company's annual report to the PUC.

Tri-State load projections presented in the R. W. Beck report showed a gradual 1.3 percent annual increase between 1983 and 2020, with peak demand of 1113 MW in 1983 and 1826 MW in 2020. In the earlier years of the forecast, between 1985 and 1995, the growth rate was projected at 2.2 percent. System load projections of the Colorado portion of the Tri-State service area provided to the PUC in 1984 show an increase of 2 percent between 1983 and 1993. The R. W. Beck study reported that Tri-State had two planned additions to its generation resources--(1) a summer-winter capacity exchange with Colorado-Ute of 70 MW beginning in 1987 and (2) additional purchases from Basin Electric Cooperative of 174 MW during the 1983-2020 study period.

Based upon recent interviews with Tri-State personnel, these planned additions to capacity have been cancelled. Load growth projections compared to available capacity in the region have resulted in a postponement of any further increase in Tri-State generating capacity.

9.2.1.4 Colorado Ute Electric Association

The service area of Colorado Ute Electric Association (CUEA) is not contiguous to the Cache la Poudre River Basin, but its close proximity and important relationship to the other local utilities merit a brief description here.

CUEA is a generation and transmission cooperative and is the wholesale electric power supplier for 14 REA member cooperatives. The CUEA has significant winter peaks due in large part to ski area loads. During the 1970s, the system experienced a rapid increase in winter peak demand from 203 MW in 1970 to 489 MW in 1980; an annual average increase of over 9 percent. Peak load continued to climb in the 1980s with levels of 601 MW and 665 MW in 1982 and 1983, respectively. The owned capacity of CUEA in 1985 was approximately 970 MW at five coal-fired, baseload facilities.

9.2.2 Regional Market Area

The Rocky Mountain Power Area (RMPA) of the Western Systems Coordinating Council would be the regional market area for power produced in the Basin. This area includes a number of utilities. The larger utilities in the area are:

- Public Service Company of Colorado (PSC)
- Platte River Power Authority (PRPA)
- Tri-State Generation and Transmission (Tri-State)
- Colorado-Ute Electric Association
- Basin Electric Power Cooperative
- Black Hills Power & Light
- City of Colorado Springs
- Southern Colorado Power-Centel Corporation
- United States Bureau of Reclamation
  - Lower Missouri River Basin
  - Upper Colorado River Storage Project
- Western Area Power Administration
  - Loveland-Fort Collins Area Office
  - Salt Lake City Area Office

Approximately 70 percent of the regional load is from the three utilities evaluated in the local market area (PSC, PRPA, and Tri-State). The addition of Colorado-Ute Electric Association to this group brings this figure to over 80 percent.

Peak demand for RMPA was 5587 MW in 1983 and 5704 in 1984. Both of these peaks occurred during the winter. Load projections furnished to the North American Electric Reliability Council (NERC) by individual utilities

TABLE 9.3
Rocky Mountain Power Area
Loads and Resources Projections, 1985

	Line No.	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Peak Demand - Summer (MW)	1	6,190	6,446	6,751	6,991	7,216	7,447	7,596	7,842	8,086	8,335
Planned Resources - Summer (MW)	2	8,749	8,857	8,958	9,028	9,053	9,086	9,673	10,033	10,030	10,338
Reserve Margin - MW	3	2,559	2,411	2,207	2,037	1,837	1,639	2,077	2,191	1,944	2,003
Reserve Margin - Percent	4	41	37	33	29	25	18	27	28	24	24

(3) = (2) - (1)
(4) = (3)/(1)

Source: "1985 Electric Power Supply and Demand for 1985-1994," North American Electric Reliability Council, 1985.

in the RMPA are presented in Table 9.3. This information is published by NERC in their 1985 Annual Data Summary Report. Only summer peaks are shown because all of the load projections for each year beginning in 1985 are higher in the summer than the winter.

RMPA load growth is projected at slightly over 4 percent annually between 1984 and 1994. This is significantly lower than the 5.2 percent projected annual growth rate for 1982 to 1991 reported by Tudor in 1982. This moderation in projected growth rates corresponds with the diminished growth trend cited earlier in the local electric power market.

RMPA summer capacity for 1984 was 8807 MW of which approximately 60 percent was provided by coal-fired units. Another 24 percent was conventional hydroelectric capacity. Most of the remainder was provided by pumped-storage and dual-fuel peaking facilities. Based on a summer peak of 5608 MW, the region had a 57 percent reserve margin in 1984. The three utilities evaluated in the local market area accounted for less than 200 MW or only about 6 percent of the total RMPA reserve.

Planned resources for the RMPA are also included in the NERC report and are presented in Table 9.3. Planned resources, as defined by NERC, "...include total generating capacity which is existing, presently under construction, or in various stages of planning plus capacity purchases, less capacity sales." Regional generating capacity is projected to grow at a lower rate than loads. Between 1985 and 1994, planned resources are expected to increase at an annual rate of 1.9 percent. Approximately 75 percent of the increase in capacity will be from coal-fired generating facilities.

As shown in Table 9.3, summer capacity in the region by 1994 is projected to be 10,338 MW, providing a forecast reserve margin of 24 percent.

9.2.3 Summary of Power Demand Projections

Both the R. W. Beck and Tudor studies found that there will be little need for new electric power generating facilities -- either base load or peaking capacity -- in the area which might be served by a Basin project through the mid- to late-1990's. More recent data confirms these findings. In addition, the generally lower growth rates of power demand projections found in the recent data indicate that the current surplus in generating capacity may extend into the early 2000s. New generating facilities constructed in the Basin could not be in operation before about 1996.

R. W. Beck estimated that an additional 170 MW, 340 MW and 940 MW of peaking capacity will be necessary to meet the needs of Colorado utilities in 1995, 2000, and 2020, respectively. They also estimated a potential need for 400-650 MW of peaking capacity from utilities in New Mexico, Utah, and Arizona during 1995-2020. These appear to be reasonable levels of demand, although the timing is likely to be moved back somewhat due to generally lower projections of future peak demand.

Figure 9.1 illustrates the planned resources and projected peak loads in the Rocky Mountain region and among selected local utilities based on information available as of early 1986. By examining the capacity and peak demand relationships, several important conclusions can be drawn:

- Given current forecasts of power demand in the region alone, there will be no need for a large-scale power production facility, either for base load or peaking generation, between now and the year 2000.

- Almost all of the oversupply is due to an excess of base load capacity. A significant portion of this capacity has been pressed into service to handle peak demand and therefore there is sufficient capacity to serve both average and peak demand through the remainder of the century.

- As the excess supply is absorbed during this time period, it is possible that smaller scale peaking facilities will be needed as more of the base load plants are called upon to serve base rather than peak demand. However, the current proposals for modifying PSC's avoided cost rates will significantly lower payments for small facility peaking power. This in turn will have a negative impact on the economic viability of potential smaller peaking projects.

- As power demand increases into the next century, the current surplus of generation capacity will diminish. At some point early in the next century increased demand will necessitate the construction of new power production facilities. Initially there will be more of a need for peaking facilities as the base load plants which currently satisfy this portion of the demand are switched to base load operations.

- At the same time, the market value of power will increase as the time approaches when new facilities are needed (i.e., market value will begin to approach the level of avoided costs). Further pressure will be placed on power supplies as older plants are retired during the preceding time period.

There is no doubt that local and regional power demands will eventually necessitate the construction of new peaking facilities. Depending on economics and other factors, a pumped-storage project in the Basin might be one of these peaking facilities. The major unanswered questions are the exact timing of the needs and the economics of the available alternatives in the future. Competition from other hydroelectric projects (e.g., the Azure Pumped-Storage Project) or from thermal facilities which take the advantage of comparatively cheaper gas and oil than available in the recent past, could delay the need for a Basin project well into the next century. Regardless, planning will need to be initiated soon for new generation facilities given the long lead times to achieve on-line generation.

9.3 MARKET VALUE OF POWER

As noted earlier, without knowing the specific characteristics of a market for a Cache la Poudre Basin pumped-storage project, it is impossible to estimate with any degree of accuracy the potential market value of power produced at a future Basin facility. Power market studies would be performed in the feasibility phase of study. However, a range of estimates have been compiled which provide insight into the current value of power and energy in the region.

Forecasts of these values into the future would be counterproductive to this planning study for several reasons. First of all, the wide variation in current price estimates would be inherent in any projection, compounding the potential for error. Secondly, only real price changes, exclusive of inflation, are of interest in the economic analysis. A constant real price assumed for the future provides a conservative bias to the subsequent economic analysis which is desirable, given the level of uncertainty. Essentially, a constant market clearing price range for demand and energy charges was assumed.

Three separate approaches were used in developing estimates of the market value of power produced in the Basin. The first is an analysis of current market prices of power being sold within the region. The second is the development of rates based on the costs of building and operating future generating facilities in the region (avoided costs). The third relates to the charges associated with a combined cycle facility, which the pumped-storage project could presumably replace.

9.3.1 Current Market Prices

A number of sources were examined to determine what rates are currently being paid for electric power purchased in the region. These include previous studies performed by Browne, Bortz and Coddington and the annual reports of area utilities.

The cost of purchased power varies with the amount and availability of the power. A buyer will generally be willing to pay more for power when its delivery is guaranteed by contract. There are a number of sources of this so called "firm" power in the region. Many utilities in the area have significant reserves of capacity which they are currently marketing to other utilities on a long-term basis.

A number of utilities market excess reserves using short-term agreements.This occurs when the rates they can obtain for the power produced with this excess capacity exceed production costs. Consequently, this "dump" power is usually available on a sporadic basis and its price is a function of short run supply and demand factors. In general, the rates for this type of power are lower than for firm power; but this can vary depending on the availability of other sources of power and with unexpected variations in demand.

A few examples of 1985 purchases in the local area are presented below:

Purchasing Utility	Trans-action No.	Type of Power	Demand Charge ($/kW-mo)	Energy Charge ($/kW
Public Service Company of Colorado (PSC)	(1)	Dump	7.46	0.025
	(2)	Dump		0.125
	(3)	Firm	7.02	0.013
Tri-State Generation and Transmission (Tri-State)	(1)	Firm	1.65	0.0051
	(2)	Firm	15.34	0.0226
Tri-State Members	(1)	Firm	13.71	0.0198

It is clear from these selected examples that the rates vary widely throughout the region and also within an individual utility. There are many reasons for this. For instance, the second PSC purchase shown above was from a cogenerator selling peaking power to PSC at the avoided cost rates effective at that time. Under those rates, a qualifying facility could produce power only during peak hours and still receive the full avoided cost rates. As a result, the price per kWh was very high. Recently the Colorado PUC suspended these rates and is in the process of considering changes to PSC's avoided-cost tariffs. These proposed chances are discussed in detail below.

The two Tri-State purchases also vary substantially even though they are both long-term firm power purchases. The source of the lower priced power is the Western Area Power Administration (WAPA). Their effective 1985 rates are based on the costs of the Pick-Sloan Project. As pointed out earlier, WAPA is a major supplier of power in the region. Because of its extremely low rates, it can readily market all of its power production.

The other Tri-State power source is from recently constructed coal-fired base-loaded generating facilities operated by Basin Electric Power Cooperative. The high demand charge is a reflection of the high costs involved in building new generating facilities. The combination of the costs of these two power sources is reflected in the rate Tri-State charges its member distribution companies.

9.3.2 Avoided costs

This approach is based on a comparative analysis of the costs of constructing and operating facilities which could compete with a Basin project. The value of power produced by a Basin facility would be limited to the costs of power produced by these competing facilities. In simplest terms, a potential purchasing utility would favor purchasing power from a Basin facility as long as the costs of the power did not exceed the costs the utility would incur if it built its own facility or purchased power from another source.

9.3.2.1 Public Service Company of Colorado (PSC)

PSC has established rates it is willing to pay for power produced by cogenerators in accordance with the guidelines of the Federal Public Utilities Regulatory Policies Act (PURPA). The company is obligated to purchase this power from producers qualifying under the PURPA guidelines.

The existing rates were derived by estimating the costs of the next planned addition to PSC's generating facilities which is an additional coal-fired base-loaded unit at the Pawnee Station (Pawnee II). These projected costs are updated annually and both a capacity payment and an energy payment are determined.

The avoided cost rates PSC will pay to cogenerators for 1986 are:

Capacity Payment:	$19.38/kW-mo
Energy Payment:	$ .01603/kW

Reductions in the capacity payment are made if a power producer does not meet certain availability criteria.

The Colorado PUC has taken issue with the existing availability criteria because of the high per kWh payments which have been made to certain cogenerators whose facilities technically meet the specified availability standards, but whose operations are designed to provide peaking power only. Since the avoided costs are based on a base-load unit, it is considered inappropriate to apply the resulting avoided costs rates to a peaking unit. PSC also supports this position and has filed new rates with the PUC which it believes will correct this inequity.

The new rates offer two major differences. The first is that the capacity payment has been divided into two parts: an on-peak payment for power produced during the PSC system on-peak hours, and an off-peak payment for power produced during the system off-peak hours. The two payments add up to the basic capacity payment. For a large (over 25 MW), dispatchable facility brought on-line in 1986, the monthly capacity payments proposed by PSC and also those proposed by the PUC staff would be:

	PSC Proposal (\$/kW-mo)	PUC Proposal (\$/kW-mo)
On-peak	10.88	11.35
Off-peak	8.50	8.03
Total	19.38	19.38

A base load facility would be eligible for both on- and off-peak capacity payments and would thus be able to collect the full \$19.38. However, a facility operating only during the on-peak period -- such as a pumped-storage unit -- would only be eligible for the on-peak component of the capacity payment.

The second major change which has been recommended is in the availability criteria. This involves a per kWh limit on the capacity payment. In order to receive the full capacity payment under the proposed tariffs, a facility must produce a sufficient amount of energy during each period so that, when the capacity payment is spread over the total energy produced during the period, the result does not exceed a maximum amount.

The proposed payment capacity limits are:

	PSC. Proposal (\$/kWh)	PUC Proposal (\$/kWh)
On-peak	.038	.048
Off-peak	.029	.023

In both proposals, an 80 percent capacity factor is used to calculate the capacity payment limits. A generation facility operating at less than 80 percent capacity factor during a period would not receive the full capacity payment. Conversely, a facility operating at above 80 percent would receive the full capacity payment because, on a per kWh basis, the payment would be less than the limit.

The combined effect of these two proposed changes in PSC's avoided cost tariffs will be to significantly reduce payments by the company for peaking power produced at qualifying facilities. The maximum capacity payment for peaking power will be closer to $11/kW-mo rather than the full $19/kW-mo payment associated with the existing tariffs. This eliminates the possibility of large per kWh payments such as the one noted in the previous section.

9.3.2.2 Earlier Study of Hydropower in the Basin

Preliminary values for power produced at a conventional hydro peaking facility of less than 100 MW capacity were developed in the Tudor Study (1983). The method used in deriving the values was to determine the avoided fixed and variable costs of a coal-fired cycling plant. It is believed that this type of thermal unit was the most likely alternative to a hydroelectric peaking facility.

Adjustments were made to reflect the differences in operating characteristics between thermal and hydro facilities. A levelizing factor was used to account for the future costs of escalation. The analysis was based on existing cost levels in 1982.

The following avoided costs were determined:

	Unescalated	Escalated
Capacity	$24.17/kW-mo	$22.92/kW-mo
Energy	$0.015/kWh	$0.028/kWh

A similar analysis was conducted in the study to determine the potential value for a run-of-river operation. Values for both firm and non-firm power were developed.

In each case, escalation factors were used to account for real increases (above inflation) in costs.

	Unescalated	Escalated
Non-firm (50% availability)	$0.025/kWh	$0.048/kWh
Firm (90% availability)	$0.070/kWh	$0.081/kWh

Determination of values for non-firm power were based on the thermal fuel(s) costs which would be incurred in producing power if the hydro power were not available. Because of the uncertainty of power availability from this type of facility, no credit was given for avoided capacity costs. Firm power values were based on the construction and operating costs associated with a large thermal base load unit using coal as a primary fuel source.

9.3.2.3 Combined Cycle Facility in the Midwest

As an alternative to the other approaches for estimating the avoided costs associated with a pumped-storage project, the demand and energy charges for a hypothetical combined-cycle, peaking facility in the Midwest were derived. Construction and operation costs for a large thermal peaking facility were based on the Technical Assessment Guide, published by the Electric Power Reserach Institute in May 1982. Costs, stated in 1986 dollars, include fixed inservice costs of debt service and repayment, fuel reserves, plus O&M expenses. This case study has applicability because: (1) the Cache pumped-storage project resources would quite likely be marketed outside the region in a large power demand area; and (2) if successfully marketed, the pumped-storage project would displace a facility such as this hypothetical combined cycle operation. In sum, demand and energy charges are:

Peaking Costs for Combined Cycle Facility

Demand Charge	Energy Charge
$5.79/kW-month	$0.411/kWh

9.3.3 Summary of Market Value of Power

The value of electric power, as with any commodity, is based on the interaction of supply and demand. Currently, the market area for Basin-produced power is experiencing a surplus of power which exerts strong downward pressure on purchased power rates. This is clearly demonstrated in the rates PSC purchased power for in 1985. PSC's payments for purchased power were substantially less than what the utility could produce the power for itself using new capacity.

Current market values and estimates of power are provided herein as a basis for future market values. This assumption is made because of the myriad of uncertainties and the specific nature of such transactions. As noted earlier, the level of demand for peaking resources in the region may approach 1,000 MW by 2020. Under certain market circumstances, competition facing hydroelectric projects could be from fossil fuel cycling plants.

During the past decade, cycling plants have been at a significant economic disadvantage due to historically high fuel costs, particularly for oil and natural gas. More recently fuel costs have diminished substantially making fossil plants more competitive with hydro facilities. In the long term, fossil fuel prices are expected to rise.

As demand increases in the area, however, existing reserves will be diminished. The value placed on the power from these new sources will be primarily a function of cost levels at the time and also the availability of alternatives. Current avoided cost rates will then become floor rather than ceiling prices.

With the above considerations in mind, the combined cycle facility costs in the Midwest are adopted as the demand and energy prices for the economic analysis. These are $5.79 per KW-month demand charge and 41.1 mills per Kwh energy charge. For conventional hydrogeneration or a small pumped-storage project, regional rates for avoided cost may be applicable, such as those for Public Service Company of Colorado.

9.4 A PROPOSED HYDROGENERATION PROJECT

The generic relationships of supply, demand and price of electric power have been addressed in previous sections of this chapter, but the actual need and price for hydroelectric generation in the Basin will be largely determined by specific project parameters. In fact, a specific large pumped-storage project has been proposed with a very specialized marketing strategy. The need for this project and the potential price associated with its output is based in part on its unique characteristics. Although still in the conceptual phase, a description of this project and its current status is relevant to this Basin planning study.

9.4.1 Background and Overview

Energy Resources Development Associates, Inc. (ERDA), a Fort Collins-based energy development company, has developed an operational and marketing concept for an Energy Storage and Transmission System (ESTS) which incorporates a 2,100 MW pumped-storage hydroelectric development in the Cache la Poudre Basin.

Under the ESTS concept, pumped-storage facilities (energy storage warehouses) will be constructed in the mountain ranges of the Continental Divide. These energy warehouses will be linked through transmission facilities to geographically diverse and strategically located participants' base load thermal power plants.

In the ESTS system, participants' base load thermal units (which normally shut down or reduce their output as demand in their service area decreases during off-peak demand periods) would first be used to meet electrical loads otherwise served by "higher-cost" generating sources accessible through the ESTS. Next, the electricity produced from all participating thermal units which exceeds that required for any loads economically accessible through the ESTS at any given hour could be stored in energy warehouses for future retrieval during peak demand periods.

ERDA proposes to enter into use rights agreements with selected electric utility companies that will:

- Allow participating utilities to store energy during off-peak demand periods and recall that energy during peak demand periods in lieu of building new generation; and
- Allow ERDA to use any unscheduled ESTS capacity or ESTS capacity available due to "schedule diversity" (both transmission and pump/generation schedules) to facilitate operation of a commodities market in electrical energy.

The right to store and withdraw energy on demand will enable utilities to meet new load demand requirements without new plant construction. The unscheduled portion of this storage capability, together with a dedicated transmission system, will provide ERDA with the means to establish and operate an electric energy "commodities market." The commodities market operation will provide the pricing mechanism to facilitate hourly energy interchange among utilities connected to the ESTS, which will result in the electrical generating plants with the lowest fuel costs meeting the hourly loads of all utilities participating in the hourly interchange market.

9.4.2 Preliminary Project Studies

ERDA has conducted market studies to assess the need for electrical energy services from the ESTS, and the market price for such services. Based on ERDA's review of national demand forecasts prepared by others, they assume there will be a 2.7 percent annual load growth through the year 2000. In order to meet that growth forecast, provide adequate reserves, and replace obsolete facilities, the nation's utilities must place on-line 130,000 MW of new generating capacity over and above facilities currently scheduled for construction between now and the year 2000. Under the most favorable circumstances, conservation and renewable resources could supply only 20 to 30 percent of the 130,000 MW required nationally to meet demand. Therefore, approximately 100,000 MW of new power generating plant are still required. ERDA proposes to develop its ESTS configuration to provide 5000 MW of that 100,000 MW national market, or approximately 5 percent.

ERDA will initially focus its ESTS participation offering to utilities in the upper mid-west, the Texas/Oklahoma areas, the Colorado/New Mexico areas, and the Pacific Southwest areas. Studies by the Department of Energy and data from the North American Electric Reliability Council indicate that perhaps as early as 1989 utilities in these regions might not have sufficient generating capacity and imports to meet forecasted loads with adequate reserves.

The magnitude of projected shortages varies from study to study. However, a reasonably conservative estimate would place 30 percent of the 100,000 MW new plant requirement in the initial targeted marketing region. This estimate is based upon present utility construction schedules. Any delays or cancellations of planned generating units will increase the deficiency and accelerate the timetable for these shortages to occur. The ERDA plan to capture 5000 MW of the regional market represents approximately a 20 percent regional market share.

ERDA has also developed an economic model of the ESTS in order to quantify the benefit of the ESTS versus conventional thermal plant alternatives. The ESTS Economic Model calculates and compares the annual costs of the ESTS with five different thermal alternatives:

Nuclear/Combustion Turbine Mix (Nuclear/CT)
Coal/Combustion Turbine Mix (Coal/CT)
Coal Plant Rehabilitation
Combined-Cycle
Combustion Turbine (CT)

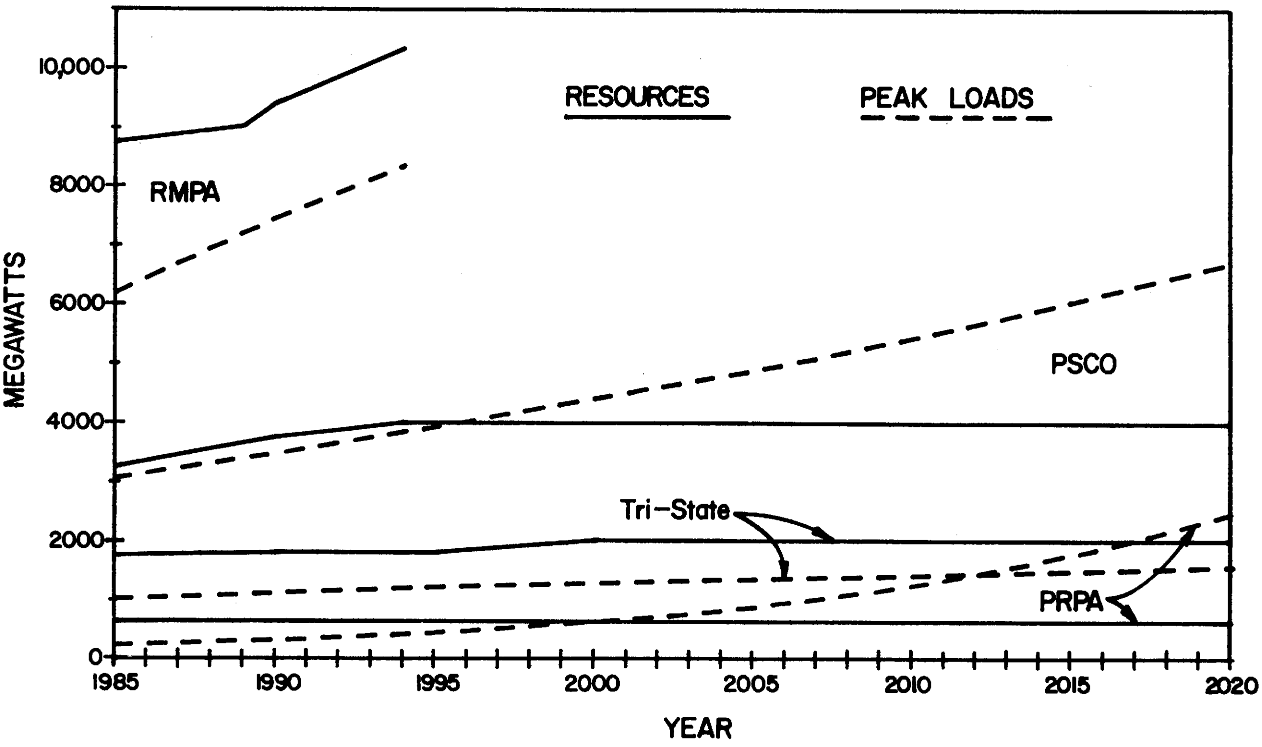
The two sources of economic value associated with the ESTS system are:

- Lower annual cost of the ESTS system compared with conventional thermal alternatives; and
- Revenues generated by participation in a wholesale market in electrical energy services.

The basic elements of annual cost calculated in the model for both the ESTS and the thermal alternatives are:

- Annualized Investment Cost;
- Annual Operation and Maintenance Cost; and
- Annual Fuel Cost.

The model calculates the annual cost savings of the 5000 MW ESTS versus the most likely alternative (combined cycle plants) to be $369 million, and the annual net revenues from participation in an electric energy wholesale market to be $669 million. The total economic advantage of the ESTS is therefore estimated to be $1,038 million per year. Further studies and evaluations of the ESTS concept will be conducted by ERDA or others.



Note: Demand projections are BBC estimates and extrapolations based on available projections. RMPA is Rocky Mountain Power Area. PSCO is Public Service Company of Colorado. Tri-State is Tri-State Generation and Transmission. PRPA is Platte River Power Authority.
Source: Colorado Public Utilities Commission and North American Electric Reliability Council, selected years.

COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY

PLANNED RESOURCES VS. PEAK LOADS

HARZA ENGINEERING COMPANY
Browne, Bortz & Coddington • M.W. Bittinger • Tom Pitts & Associates
Leonard Rice Consulting Water Engineers, Inc.

DATE DEC. 1987 FIGURE 9.1

Chapter 10

Non-Structural Plan Elements

10.0 NON-STRUCTURAL PLAN ELEMENTS

10.1 GENERAL

As described in Chapter 1, the purpose of this Study is to identify the best plan (or plans) for meeting the future water management needs of the Basin. Alternative plans, comprising both non-structural and structural plan elements were formulated as described in Chapter 11. Non-structural elements are those which do not involve major physical structures or facilities for water management. Generally, they can be implemented at low cost in comparison to structural elements such as dams and reservoirs. They include measures to enhance available water supplies and to reduce the demand for water. They also include institutional changes to improve the ways in which the water resource is managed. Extensive inputs on non-structural elements were obtained from Advisory Committee members.

A review was made of recent reports and studies in the region to identify potential non-structural plan elements for inclusion in the planning process. Thirty-two non-structural elements were identified. These elements were subjected to a screening analysis which resulted in selection of 12 elements for consideration in the plan formulation process.

A significant effort was devoted to the screening and evaluation of non-structural measures because of their relatively low cost in relation to structural elements such as storage dams and reservoirs. Although they usually are less costly to implement, the performance characteristics of non-structural measures in enhancing water supplies and reducing water demands often are difficult to quantify. This is especially true in the Poudre Basin because of the interrelationship between surface water and ground water resources, the high level of reuse that now occurs, and the comparatively high levels of water management that have been achieved through cooperation among water users within the Basin.

Each of the alternative plans described in Chapter 11 includes the set of non-structural plan elements selected with the screening and evaluation process presented in this chapter. In the plan formulation it was assumed that these non-structural elements would be implemented in combination with structural elements. Implementation of non-structural measures will require major cooperation among water users in the Basin and commitments to the basic objectives of enhancing water supplies by reducing the consumptive use of water.

10.2 IDENTIFICATION AND INITIAL SCREENING

10.2.1 Identification of Plan Elements

Non-structural plan elements were identified by review of several published sources, which included:

- St. Vrain Basin Reconnaissance Study prepared for the Authority in 1986.
- Informational Report on Conservation and Metering in Fort Collins prepared by the Water Utilities Department in 1980 and later updated.
- Corps of Engineers' Denver Metro EIS currently under preparation.
- Environmental Defense Fund's (EDF) Water for Denver, An Analysis of the Alternatives.
- U.S. Army Corps of Engineers studies including Evaluation of Drought Management Measures for Municipal and Industrial Water Supply, 1983; and The Evaluation of Water Conservation for Municipal and Industrial Water Supply: Illustrative Examples, 1981.

The 32 non-structural plan elements are listed in Table 10.1 and described in Section 10.3 which also indicates how the screening criteria were applied.

10.2.2 Screening of Plan Elements

The initial screening of plan elements was performed by comparing each element against a set of screening criteria. Non-structural plan elements were eliminated from further consideration in the plan formulation if:

- The element already has been implemented and/or was accounted for in making water demand forecasts;
- Adverse environmental effects, expected to be serious in nature, could occur with implementation of the element;
- Reductions in water consumption or increases in water supply are small in relation to expected costs and implementation requirements;
- There appears to be no clear advantage for the element in comparison to present methods of water system operation and management in the Basin; and
- Only minimal reductions in consumptive use are possible.

Screening results are summarized in Section 10.4, following description of each non-structural plan element.

TABLE 10.1

Inventory and Screening of Non-structural Options

Potential Non-Structural Element	CWPRDA St. Vrain Study	EDF Water for Denver	Fort Collins Conservation Study	Corps of Engineers Denver Metro EIS	Selected Corps of Engineers Studies	Comments	Consider In Plan Formulation (Task 8)	Consider for Emergencies
Water Supply Management								
Phreatophyte Control/Vegetation Management	•			•		Adverse environmental effects; limited effectiveness.		
Ditch Lining	•				•	Relatively small benefits in comparison to expected costs; additional data is needed to quantify results.	•	
Conjunctive Use of Groundwater and Surface Water	•			•	•	Hign potential for alleviating shortages; possible water quality concerns.	•	
Dredge Existing Reservoirs	•			•		Small benefits in comparison to expected costs.		
Hydrologic Instrumentation	•					Required for more-effective and real-time water management.	•	
Reuse of Municipal Waste Water	•		•	•	•	Already implemented through current practices and accounted for in water supply and demand analyses.		
Transfer of Storage Decrees	•					Would be part of reservoir consolidation to reduce evaporation loss and replace storage lost due to restrctions.	•	
Transfer of Points of Diversion	•					Already implemented but additional opportunities may exist.	•	
Modification of Reservoir Filling Sequences	•					Already implemented.		

TABLE 10.1 (Continued)

Inventory and Screening of Non-structural Options

Potential Non-Structural Element	CWPRDA St. Vrain Study	EDF Water for Denver	Fort Collins Conservation Study	Corps of Engineers Denver Metro EIS	Selected Corps of Engineers Studies	Comments	Consider In Plan Formulation (Task 8)	Consider for Emergencies
Reduce Municipal Distribution System Leakage			●	●	●	Relatively small benefits; system leakage is not excessive.		
Evaporation Suppression					●	Adverse environmental effects.		
Weather Modification	●			●		Sufficient information not expected for several years; possible adverse environmental effects; present information indicates that it is not viable with existing methods.		
Deficit Irrigation Practices	●					Reduce storage requirements; needs to be considered in reservoir sizing.	●	●
Water Demand Management								
Water Conservation Kits/Public Information	●	●	●	●	●	Public information is part of conservation strategy; kits are of limited effectiveness.	●	
Increasing Block Rates/Summer Surcharge	●	●	●	●	●	Requires metering/education; strong public opposition possible.		
Low Demand Plumbing Fixtures	●	●		●	●	Already implemented; built into demand forecasts.		
Universal Metering	●	●	●	●	●	Incorporated in demand forecasts; except part of Fort Collins which could become metered.	●	

TABLE 10.1 (Continued)

Inventory and Screening of Non-structural Options

Potential Non-Structural Element	CWPRDA St. Vrain Study	EDF Water for Denver	Fort Collins Conservation Study	Corps of Engineers Denver Metro EIS	Selected Corps of Engineers Studies	Comments	Consider In Plan Formulation (Task 8)	Consider for Emergencies
Outdoor Watering Restrictions	●	●	●	●	●	Accepted practice during water-short periods.	●	●
Water Use Rationing	●	●			●	Mild rationing is ineffective. Severe rationing could result in major land-scape damage.		●
Landscaping Restrictions for New Homes	●	●		●	●	Demand reduction might be significant.	●	
Prohibitions on New Connections						Major implications for local economy.		●
Ban on Outdoor Use					●	Adverse effects on urban vegetation.		●
Commercial/Industrial Conservation				●	●	Accounted for in other non-structural measures and/or considered in demand forecasts.		
Pressure Reduction			●		●	Limited savings; public opposition		●
Landscape Irrigation System Improvements			●			High cost measure; not considered further in Denver EIS.		
Irrigation Efficiency Improvements	●				●	High cost to improve on-farm efficiency.		
Institutional Measures								
Drought Insurance	●					"Defacto" programs now in place with existing leasing, but formalization may be beneficial.	●	

TABLE 10.1 (Continued)

Inventory and Screening of Non-structural Options

Potential Non-Structural Element	CWPRDA St. Vrain Study	EDF Water for Denver	Fort Collins Conservation Study	Corps of Engineers Denver Metro EIS	Selected Corps of Engineers Studies	Comments	Consider In Plan Formulation (Task 8)	Consider for Emergencies
Basinwide Cooperative Management Organization	●					Could be required to implement various non-structural measures, particularly planned conjunctive use.	●	
River Basin Authority with Regulatory Power	●					No clear advantage over present operations.		
Restructured Water Rights	●					Requires changing State laws.		
Improved Water Management Through Market Process	●					No clear advantage over present operations.		
Water Court Enforcement of Water Use Efficiency Goals	●					Requires changing State laws.		

10.3 DESCRIPTION OF NON-STRUCTURAL PLAN ELEMENTS

The following sections describe the 32 non-structural plan elements considered for inclusion in the plan formulation process in the Cache la Poudre Basin Study. More detailed descriptions are provided in the Task 7 Summary Report. The text indicates expected performance of each element and the reasons why an element was selected for inclusion in the plan formulation or was dismissed from further consideration.

10.3.1 Water Supply Management Elements

10.3.1.1 Phreatophyte Control

There are about 20,000 acres of land in the study area occupied by wetlands, including low-lying areas, lands adjacent to ditches and reservoirs, and lands adjacent to drainages. Applying an average annual consumptive use of 1.65 af per acre per year results in a total consumptive use of 33,000 af per year. Conceivably, a portion of this consumptive use could be saved if phreatophyte control measures were implemented.

A large part of the involved acreage contains cottonwood and willow trees and other vegetation that has significant aesthetic value in addition to its importance to certain species of wildlife. Because of the benefits associated with these lands, it is prudent to consider that not more than 10 to 15 percent of the estimated 33,000 af could be saved without adverse effect on aesthetics and wildlife. Therefore, up to 5000 af per year might be made available for other uses if phreatophyte control measures were implemented. The 10 to 15 percent figure was confirmed to some extent by examination of 1970 land use mapping (CSU, 1973) which indicated phreatophyte areas of 4000 acres around existing reservoirs, corresponding to about 6000 af/yr of consumptive use at 1.65 feet per year.

In general, it was concluded that phreatophyte control may not be a particularly viable measure. Water savings of about 5000 af per year may be possible with adverse environmental effects limited to areas where phreatophytes have prospered because of man's activities. Documentation for phreatophyte control costs is not readily available. An agency may be needed to implement phreatophyte control. Historically, individuals undertaking phreatophyte control measures have had difficulty, under current water law, in diverting the additional water made available by these measures. Primarily because of environmental and legal considerations, phreatophyte control was not considered further in the Study.

10.3.1.2 Ditch Lining

Detailed information on losses from ditches in the Basin is not available. In Task 3, a ditch loss of 20 percent was used in calibrating the RIBSIM model for historical conditions in the Basin (Harza, 1986). This loss was assumed to be comprised of five percent consumptive loss to evaporation and phreatophytes and 95 percent seepage into ground water and return flow to downstream ditches. The seepage and return flow component (95% of the 20% loss or 19% of the total diversion) is believed to be available for beneficial use in the same ditch system at a later time or in another ditch system.This occurs because seepage helps to replenish ground water supplies. The five percent evaporation and phreatophyte loss (one percent of the total diversion) is not available for consumptive use by crops. Some portion of this latter loss might be made available for consumptive use by lining of irrigation ditches; however, the primary effect of ditch lining would be to reduce seepage losses that currently replenish ground water supplies. Historically, total diversions of water have averaged about 400,000 af per year; therefore, ditch lining conceivably could reduce consumptive use by about 3000 af per year (one percent of 400,000 af less 1000 af of evaporation losses that also would occur from lined ditches).

Although the potential for enhancing water supply apparently is small, control of ditch seepage is believed to be a topic that warrants further study. The considerable reuse of water in the Basin is generally looked upon as a measure of high efficiency. The Basin reportedly is using its supply at least twice before it enters the South Platte River and perhaps as much as three times if reuse within ditch systems is considered. However, this situation can also be an indication of an opportunity to improve efficiency, because a high irrigation water reuse factor may imply either excessive water applications to crops or excessive losses in water conveyance and storage facilities. It should be noted that reducing ditch losses will increase the Basin water supply only if adequate storage capacity is provided to capture and control the water that is saved.

A study on the impact of current irrigation operations on water use efficiency, leaching of nutrients from the soil, and pollution of ground water and waters leaving the Basin, while beyond the scope of the present Study, merits attention at some future time. Although further study is needed before firm recommendations can be made, it is considered to be prudent to include ditch lining in formulating a plan for water resource management.

Order-of-magnitude ccsts for ditch lining in the Basin were derived from some published information of a study of the annual costs of unlined and lined ditches serving a 17,000-acre irrigated area in southeastern Idaho (Yoo and Busch, 1985). Annual costs for lined canals included amortization of the investment cost for lining. The difference in annual costs between lined and unlined ditches, over the 17,000-acre service area, was estimated to be $22 per acre. This per-acre cost was applied to one-third of the irrigated acreage in the Basin on the assumption that ditches (main canals and laterals) overlying alluvial aquifers would be responsible for most of the seepage losses. By inspection, it appears that one-third of the irrigated area might overlie alluvial aquifers. The annual cost of $1.3 million (60,000 acres x $22/acre) would translate to a capital cost of about

$15 million. Because the annual savings in consumptive use are small and are difficult to quantify, savings (benefits) attributable to this measure were not included in shortage reduction estimates described in Chapter 11. Costs for ditch lining also were not included in the economic analysis.

10.3.1.3 Conjunctive Use of Ground Water and Surface Water

Conjunctive use of surface water and ground water in a basin or region generally involves using the aquifer (or aquifers) as long-term storage facilities available to supplement fluctuating surface water supplies. The primary requirements for continued conjunctive use are the availability of recharge water and a means to replenish withdrawals from the aquifers(s).

A fairly high level of conjunctive use management now exists in the study area. Individual irrigators having both surface and ground water, practice conjunctive use by pumping ground water when surface supplies are short or unavailable.

Two scenarios of planned conjunctive use of surface water and ground water have been identified. One involves using existing wells but changing current operating procedures while the other involves maximizing the use of aquifer storage capacity by constructing new wells. Under either scenario, the beneficiary or operator of the planned conjunctive use operation probably would need to be a broad-based organization to develop and administer the operation.

The two scenarios represent a minimum and maximum level of commitment to a planned conjunctive use operation. Intermediate levels are possible and may be more likely than either extreme. As discussed below, conjunctive use appears to be a promising water management option for the Basin.

Scenario 1

Under conjunctive use Scenario 1, existing wells or selected wells would be pumped to a greater extent than normal during a water short period. This additional pumpage would be used for irrigation. Surface water belonging to the well owners would then be supplied to water users needing drought protection. This might be accomplished through a system where the well owners would contract with an organization to rent a portion of the well owners' surface water. Water users needing drought protection then would contract with the organization for water deliveries in shortage years. To gain well owner participation, the water users would pay a "standby fee" each year and would pay for the cost of additional pumping by the well owners. To assure that aquifers are recharged as fast as possible during periods of plentiful surface water supply, spreading basins for artificial recharge would be constructed below the major irrigation ditches at places where they cross the aquifers. Increased pumpage under Scenario 1 may be from 20,000 to 35,000 af in a dry year.

Scenario 2

Scenario 2 involves construction of new wells to support the planned conjunctive use operation and was included as the conjunctive use element in the plan formulation. The new wells would overcome the problems associated with using existing wells. These problems include low hydraulic capacity of the wells due to age and other factors and less than optimum well location and spacing.

To achieve the goals of Scenario 2, the aquifers of the Basin also would have to be brought under some sort of central organization. This organization would be responsible for all financial technical, operational, and administrative aspects of the conjunctive use operation. Piecemeal or divided control could not be expected to obtain and administer necessary financing, and arrangements with purchasers, nor could it develop and carry out unified pumping programs to maximize the resource. The organization probably would own and operate the wells and the distribution systems from these wells which would be needed to irrigate lands currently irrigated all or in part by the existing wells. Under Scenario 2, dry-year pumpage might be increased by 70,000 to 100,000 af. Normal year pumpage, with properly placed higher efficiency wells and better control over operation, might be increased by 10,000 to 15,000 af per year.

Recharge of the aquifers after heavy pumpage would ideally be from existing surface water storage facilities providing water that is relatively sediment-free. Recharge would be performed in water surplus periods after surface water storage rights have been satisfied. Flood-irrigation of fields following the normal irrigation season may be a viable recharge method. A more reliable method would involve construction of specially prepared recharge basins at strategic locations.

Cost Estimate - Scenario 2

To achieve the above-noted objectives for Scenario 2 it is estimated that approximately 420 wells would be needed. (There are 1600 wells operating in the study area at the present time.) It is believed that field checking and testing could identify about 200 existing wells that would be usable thus reducing the number of new wells to about 220. The estimates for the total number of wells and their costs are presented in Tables 10.2 and 10.3 based on the following assumptions:

1. Pumpage capability under Scenario 2 will be twice current pumpage.
2. Peak seven-day pumpage requirements will equal 10 percent of annual pumpage.
3. Wells under the Larimer County System in the Spring Creek and Lone Tree Creek aquifers will average 2 cfs, and all others will average 3 cfs.
4. It is estimated that the system would operate for 10 weeks to produce 150,000 af in one year.

5. Alluvial aquifers beneath the Cache la Poudre River have not been included. This would minimize and delay impacts on river flows until after the irrigation season.

Water Quality Concerns

In 1974, the USGS sampled a number of wells in the Boxelder aquifer and a report was prepared (Hurr and Schneider, 1977). Chemical analysis of the samples shows that the concentrations of certain elements, primarily selenium, and total dissolved solids exceed recommended limits in some areas of the Boxelder Aquifer (see Figure 3.3).

There is not sufficient data available to ascertain the effect that this contaminated ground water is having on surface supplies in the Basin or in the South Platte River Basin downstream from Greeley. However, high concentrations of selenium as indicated in the USGS report are potentially dangerous and merit further investigation. With the information available, it is estimated that more than 200 irrigation wells, representing about 15 percent of the ground water supply, could be affected. Selenium in excessive amounts is toxic to both humans and wildlife. The recommended upper limit for domestic use is only 10 micrograms per liter or .01 mg/l.

Wells in the Boxelder Aquifer north of Wellington showed selenium concentrations within acceptable limits. These wells were tested only once in May 1974. In wells south of Wellington that were tested over a period of months, appreciable variations in selenium concentrations were recorded. A similar situation may exist north of Wellington.

When the irrigation wells in the Basin are being used in conjunction with surface water supplies, dilution may not be sufficient, particularly during dry years. Therefore, a dangerous situation with respect to selenium could exist either in the immediate area or downstream where accumulation may be occurring.

TABLE 10.2
Estimated Number of Wells - Conjunctive Use Scenario 2

	Peak Pumpage (af/week)	Well Capacity (cfs)	No. of Wells
Boxelder Aquifer			
North Poudre System	2800	3	67
Larimer County System	1500	3	37
Spring Creek Aquifer			
Larimer County System	2900	2	106
Larimer and Weld System	3300	3	80
Lone Tree Aquifer			
Larimer County System	1900	2	70
Larimer and Weld System	2500	3	60
Total No. of Wells			420[1]

[1]Note: Up to 200 wells that are existing in the Basin may be utilized in the conjunctive plan.

TABLE 10.3
Cost Estimate - Conjunctive Use Scenario 2

	Unit Cost ($)	Quantity	Cost ($)
Install and Test Well[1]	20,000	220 wells	4,400,000
Power Lines and Irrigation System[2]	20,000	220 wells	4,400,000
Subtotal			8,800,000
Recharge Basins[3]		560 acres	3,900,000
Construction Cost			12,700,000
Investment Cost			14,200,000

[1]16-inch diameter casing, with screen and gravel pack. Assumes 1350 gpm pump at 100 ft total design head.

[2]Includes connections to existing electrical distribution system and pipelines to supply water for existing irrigation systems.

[3]Based on a recharge rate of 3 ft/day in carefully prepared recharge basins which were estimated to cost $7000 per acre to construct.

For these reasons, it is recommended that additional studies be carried out to determine the seriousness of the selenium problem. The presence of selenium may affect the feasibility of conjunctive use management of ground water and surface water supplies described previously in this section.

Excessive salinity in irrigation water can affect plant growth thereby depressing crop yields. Generally, water with total dissolved solids (TDS) concentrations less than 500 mg/l is considered not to be a problem with respect to salinity. Problems may be expected if irrigation water has TDS concentrations between 500 to 2000 mg/l, depending on the types of crops being grown. The crop types being grown in the study area generally are tolerant to irrigation water in this salinity range. Many wells in the Boxelder Aquifer show concentrations between 1500 and 3000 mg/l.

Legal Considerations

As part of the recharge operation under either scenario, it may be desirable to transfer some surface water storage rights to ground water storage. Certain of the Cache la Poudre plains reservoirs are unable to store their decreed amount because of sedimentation. Dredging of silted reservoirs was considered (Section 10.3.1.4), but was found to be an expensive option. Legal transfers to alternate places of storage, such as aquifers, may be a good solution to maintain the storage rights.

Other legal considerations must be involved in implementing a planned conjunctive use operation. Even under Scenario 1, the increased pumping envisioned with planned conjunctive use may not be coverable under existing approved Plans for Augmentation, such as that of the Cache la Poudre Water Users Association. This plan sets no upper limit on individual well pumping nor a total for the plan, so it is possible Scenario 1 could be implemented within it. However, those who have reason to believe that Scenario 1 would injure their water rights if implemented, or the State Engineer, could bring the question into water court for a decision. With higher pumpage possible under Scenario 2, the legal considerations associated with its implementation are expected to be more constraining.

If a new Plan for Augmentation would be required to cover the additional pumping under either scenario, a major portion of the additional pumping should be located sufficiently far from the River so that the major impact of the pumping on streamflow comes after the irrigation season. Thus, the additional pumping should be located as much as practicable above the Larimer and Weld Canal in the Boxelder Creek valley fill and above the Greeley No. 2 Canal in the Spring Creek and Lone Tree Creek valley fill aquifers.

10.3.1.4 Dredge Existing Reservoirs

Several reservoirs supplied by the North Fork of the Cache la Poudre via the North Poudre Ditch have lost much of their capacity due to sediment deposition. Among these are Clark Reservoir, Indian Creek Reservoir, North Poudre No. 3, and the Boxelder reservoirs. These reservoirs alone account for a decreed storage totalling in excess of 10,000 af. It is believed that their gradual loss of capacity is having an adverse effect on the system. Certain other reservoirs in the plains may be experiencing similar problems.

Among the possible solutions is the removal of accumulated sediment to regain lost storage capacity. Another possibility to regain storage capacity is transfer of storage rights to another reservoir or to ground water. While the volumes of sediment involved are important in terms of lost storage, they are small in terms of the effort that would be required to remove the sediment.

Estimates for removal of accumulated sediment in Cherry Creek Reservoir in the suburban Denver area were prepared recently by the Corps of Engineers (COE, 1985). Cherry Creek Reservoir is a large flood control structure with significant fishery and recreational resources. The study considered two sediment removal options -- (1) hydraulic dredging and (2) drainage of the reservoir and removal by conventional means. Hydraulic dredging was not recommended in the COE study. Cost estimates developed by the COE are presented in Table 10.4.

The data in Table 10.4 indicate a range of sediment removal costs from $3.30 to $14 per cubic yard (cy) of sediment removed for dredging and $5 to $9 per cy for lake drainage and removal using earth-moving equipment. This corresponds to a cost range of $5400 to $22,600 per af of sediment removed (or storage volume regained). A key factor in estimating sediment removal cost is the potential for selling dredged material to help offset hauling costs.

Environmental impacts would be dependent on the sediment removal method and disposal procedures selected. The operation would need to be managed to avoid adverse effects. Lake draining might have eventual beneficial effects associated with improved water quality and recreational opportunities; however, habitat and species would be lost during reservoir draining and drying.

TABLE 10.4

Sediment Removal Costs Developed by COE for Cherry Creek Reservoir

	Removal Volume (cy)	Haul Volume (cy)	Removal Frequency (years)	Total Cost[2] ($)
Hydraulic Dredging				
High Estimate	2,000,000	3,550,000[1]	10	28,000,000
Low Estimate	1,800,000	0	10	6,000,000
Lake Drainage/Conventional				
High Estimate[3]	2,000,000	1,000,000	10	18,000,000
Low Estimate	2,000,000	1,000,000	10	10,000,000

(1) Includes effects of bulking.
(2) Includes cost of disposal.
(3) Assumes draglines required.

Dredging of existing reservoirs was not considered in the plan formulation because of high cost. The cost range noted above exceeds the cost of the various structural options discussed in Chapter 10.

10.3.1.5 Hydrologic Instrumentation

The installation of hydrologic data collection facilities in the Basin could help to increase the high levels of water management that now exist. These facilities would consist primarily of data collection platforms (DCP) consisting of snow/weather stations and streamgaging stations similar to those installed recently by the NCWCD in the Fraser River Basin upstream from the Windy Gap Project.

The primary purpose of these stations would be to provide more data to water managers about snowpack depths and snow moisture content. This information then would be used to develop water management strategies prior to the start of the irrigation season. Farmers would be informed about expected water supplies early enough to make decisions on their cropping patterns for the season. Municipalities could determine whether drought emergency measures might be needed and provide early warning to residents and commercial/industrial concerns. A drought period leasing program, wherein municipalities lease water from farmers who would forego or limit their diversions for irrigation, would be enhanced with the greater availability of information regarding expected water supplies.

An instrumentation program involving 15 DCP's would cost about $210,000 to implement based on recent costs experienced by the NCWCD for snowpack telemetry and streamgaging stations installed in the Fraser River Basin.

The element was selected for inclusion in the plan formulation because of its benefits to water management and low cost.

10.3.1.6 Reuse of Municipal Wastewater

No significant increases in water use efficiencies appear to be achievable in the area of wastewater reuse. The City of Fort Collins has two wastewater treatment plants, one of which discharges into the river and the other into Fossil Creek Reservoir. Effluent from both plants is reused for agricultural purposes. A higher level of reuse might be achievable if wastewater from the Fort Collins Wastewater Treatment Plant No. 2 could be made available for diversion at an upstream location, above the Larimer and Weld Canal, for example. This might require a pump-back arrangement. However, a new storage facility would provide the operational flexibility needed to enhance the reuse of Fort Collins wastewater. With storage, ditch systems upstream from Fort Collins Wastewater Treatment Plant No. 2 could "reuse" Fort Collins wastewater through exchange agreements with downstream systems.

The City of Greeley also operates two wastewater treatment plants. One discharges into the Cache la Poudre River at the east limits of the city. The second plant is located 8 miles east of Greeley and discharges into Lone Tree Creek. In both cases, reuse occurs outside of the Basin because of irrigation diversions from both the Poudre River and the South Platte River.

Wastewater reuse was not considered in the plan formulation except from the standpoint of identifying an opportunity to pump-back or exchange return flows at Greeley that are legally entitled to the Basin.

10.3.1.7 Transfer of Storage Decrees

Storage decrees associated with existing reservoirs in the Basin could be transferred to a new storage facility. Transfers would be made to accomplish one or more of the following objectives:

- Reduce the total reservoir evaporation losses in the Basin by consolidating a portion of the existing reservoir storage in a new reservoir that has a lower ratio of surface area to storage volume;

- Replace that storage now unavailable due to restrictions on storage by the State Engineer because of dam safety concerns; and

- Provide more flexibility and efficiency in water supply systems operations in the Basin.

A new storage facility that includes provision for consolidation of some existing storage capacity would improve system operations because of reduced maintenance costs for existing reservoirs, reduced seepage losses with elimination of certain reservoir inlet channels, improved water delivery capabilities, and greater opportunity to effect exchanges among water users.

The State Engineer's "Roster of Dams" lists slightly more than 100 dams in the lower Poudre Basin. This document gives the approximate reservoir volume and surface area for each reservoir when full. A total of 375,000 af of storage capacity and 16,000 acres of surface area have been indicated for the plains reservoirs. These values are not precise. The amount of storage lost to sedimentation is not known and in most instances reservoir basins have not been surveyed, so gage height versus volume relationships are not known.

In addition to the Roster of Dams, the Dam Safety Branch of the State Engineer maintains a list entitled "Current Restrictions". This list records dams for which reservoir gage height restrictions are in effect due to some inadequacy of the dam or its appurtenant structures. The September 1985 list included 17 plains reservoir dams with a total loss of storage of approximately 14,000 af due to gage height restrictions. These dams are possible candidates for consolidation into new upstream facilities.

Annual evaporation loss from the plains reservoirs is estimated to be about 15,000 af using very approximate methods. This loss could be reduced by using reservoirs that store more water with less exposed water surface;

in other words, deeper reservoirs. Excluding Horsetooth Reservoir which stores almost half of the 375,000 af indicated in the Roster of Dams, the average depth of the plains reservoirs is about 15 feet. This average depth results from dividing total storage by total surface area.

If all reservoirs with an average depth of 10 feet or less were selected for consolidation into a new and much deeper facility, 46 reservoirs (almost half of the plains reservoirs) comprising 15,000 af of storage capacity would be involved. Their total surface area when full is 2700 acres. A new upstream facility would require only 10 to 20 percent of this area to store the same amount of water.

Evaporation from the 46 reservoirs would be about 2500 af per year. In a new facility with much less surface area, the loss would be about 300 af to 600 af per year and the resulting saving about 2000 af per year.

Transferring storage decrees totalling 15,000 af to a new facility would cost about $14 million, based on a unit cost of new storage capacity of $900 per af.

The transfer of storage decrees to a new reservoir may be desirable but would be dependent on water user objectives and subject to legal concerns. This measure should be considered in subsequent investigations of additional storage in the Basin, if these are undertaken. Yield and cost were not quantified for the current Study.

10.3.1.8 Transfer of Points of Diversion

The existing points of diversion are fixed along the river by headgate location and water rights decrees. The Water Commissioner and water users in the Basin cooperate to maximize the availability of water for diversion. With these cooperative arrangements, a junior right holder can make direct diversions from the river while compensating a senior right holder with water released from the junior appropriator's storage facilities. This diversion and exchange arrangement enables the junior appropriator to irrigate lands located topographically above his storage facilities, protects the senior appropriator by providing an equivalent supply, and reduces conveyance losses that would occur between the river headgate facilities of appropriators involved in the exchange.

A similar situation exists under existing Plans for Augmentation which cover the pumping of water from alluvial aquifers. As described in Section 3.4.3, legislation passed in 1969 (Water Right Determination and Administration Act of 1969) requires that each large capacity well be included in an approved Plan for Augmentation. About three-fourths of the wells in the Basin are covered under five organizational augmentation plans. The 1969 Act brought wells diverting ground water tributary to surface streams into the same priority system as surface water diversions.

Additional transfers of points of diversion may be undertaken in the future particularly to implement a conjunctive use operation; therefore, this element was included in the plan formulation although yield and cost were not quantified.

10.3.1.9 Modification of Reservoir Filling Sequence

The current procedures of the Water Commissioner for filling reservoirs are designed to make the most efficient use of available storage. Reservoirs are routinely filled out-of-priority under cooperative understandings among the water users of the Basin. Currently, the upper basin reservoirs are filled first and emptied last while the plains reservoirs are filled last and emptied first. The Water Commissioner tries to maintain water as high up in the Basin as possible. The filling and emptying sequence has been refined over time and is believed to be at or near the optimum.

This element was not considered further because it already has been implemented.

10.3.1.10 Reduce Municipal Distribution System Leakage

The water distribution systems of Fort Collins, Greeley, and the water districts are in good condition and losses due to leakage are believed to be within normally accepted limits.

Benefits from implementing leakage reduction measures would be very small and this element was not considered in the plan formulation process.

10.3.1.11 Evaporation Suppression

This measure is similar to phreatophyte control in that a relatively large apparent gain in Basin water supply could be achieved. Evaporation from the plains reservoirs is estimated to average 15,000 af/yr. Methods of evaporation suppression include: covering the reservoir; windbreaks; selective withdrawal systems; and application of monomolecular films or other agents.

Suppression of evaporation from existing reservoirs is not considered to be a viable means of enhancing water supply in the Basin because none of the methods listed above have been proven to be effective.

10.3.1.12 Weather Modification

Reliable information is not available on the potential for increasing watershed yields by weather modification using cloud seeding. The USBR developed a proposal in 1983 to undertake a demonstration project in selected West Slope areas of Colorado to evaluate cloud seeding. If this project is funded in the near future it will be at least 10 years before any findings on the effectiveness of cloud seeding can be available. If cloud seeding shows promise on the West Slope, the Basin could benefit because of the various trans-basin diversions, including C-BT and Windy Gap, now supplying water. The effectiveness of cloud seeding on the East Slope, including the Basin itself, would need to be studied following completion of the USBR study.

This element was not considered further in the plan formulation because data on potential yield and costs are not yet available.

10.3.1.13 Deficit Irrigation Practices

Deficit irrigation refers to planned shortages in the amount of water provided to meet crop consumptive use during drought conditions. There is evidence that incremental increases in crop yield become relatively small as the actual amount of water provided approaches 100 percent of theoretical consumptive use. Experimental data developed by Danielson, et. al. (1977) suggests that providing about 85 percent of theoretical optimum consumptive use is reasonable under drought conditions. The cost of this measure was estimated to be $300 per af based on the economic value of water indicated in Chapter 7.

This element is included in plan formulation because reservoirs may be sized to meet less than the full consumptive use needs of crops. This determination would be made in the feasibility phase.

10.3.2 Water Demand Management Elements

10.3.2.1 Water Conservation Kits and Public Information

Programs to distribute indoor water conservation kits and literature on water conservation have been widely considered by water utilities. Fort Collins has studied a program to purchase and distribute water flow reduction kits. The water saving devices would include toilet dams, shower flow restrictors, and faucet control devices. The flow reduction kits would be delivered to each home by the water utility with supporting installation information.

Recent studies have developed differing estimates of reductions in water diversions from implementing an indoor conservation program: Fort Collins (1-3% savings); St. Vrain Basin Study (9%); and Metropolitan Denver EIS (1%). Because existing high water using fixtures will be gradually replaced by low use fixtures as homes are remodeled or existing fixtures wear out, the corresponding decreases in water diversions are already reflected in the water demand forecasts presented in Chapter 6. While a program to distribute indoor water conservation kits could speed up conversion from high use fixtures, the effect on water demand would be minimal because of limited effects on consumptive use. It must also be noted, however, that wasteful use of municipal water tends to stress water treatment and wastewater treatment plants unnecessarily. Wasteful use also unnecessarily concentrates water lower in the Basin, where in the case of Fort Collins it is still reusable but more subject to loss from the Basin and in the case of Greeley, it is completely lost from the Basin. These concerns apply to many of the demand management measures.

Public information is a necessary component of any progressive water demand reduction program. Both Fort Collins and Greeley have implemented public information programs. The direct effect of these programs on water demand savings is difficult to quantify. The objectives of public information on water use might be threefold: (1) enhance the implementation of a program such as indoor conservation devices or outdoor water restrictions; (2) improve the public acceptance of more severe or emergency restrictions; and (3) induce long-term changes in individual behavior to encourage water saving practices. Use of public education to achieve objectives (1) and (2) is assumed in the analysis of those particular conservation measures. The water savings achieved directly by public information (objective 3) are very difficult to quantify.

The water demand forecasts presented in Chapter 6 do reflect any changes in water use patterns attributable to past programs. While no specific yield is estimated for future expansion of public education efforts, public information should be an integral component of any conservation strategy and part of a long-range water management plan.

10.3.2.2 Increasing Block Rate Pricing

Water rates traditionally are set based on a cost of service rationale. That is, rates are designed so that each customer class pays in relation to what it costs the utility to supply it with water. Decreasing block rate structures are often employed to reflect these operating cost relationships. Increasing block rate structures break with the concept of cost of service in order to discourage "excess" water use. Under this structure, the charge per 1000 gallons becomes greater as water use increases.

For purposes of example, Fort Collins and Greeley might reduce their flat monthly charges but increase their charges per 1000 gallons to $1.00 for use beyond 20,000 gallons per month. High water users in summer months would see an increase from $0.74 to $1.00 for the last 1000 gallons used. In economic terms, this is an increase in "marginal price."

Empirical studies of price responsiveness indicate that for every one percent increase in marginal price, a 0.2 to 0.4 percent decrease in water demand might be expected. Because the example would increase customers' marginal price for water by $0.26 from a base of $0.74 (35 percent increase), water demand for these customers might decrease by 7 to 14 percent.

About two-thirds cf outdoor water applications at the household level have been found to be consumptively used. Households would likely become more efficient in the face of price increases and disproportionately cutback on excess applications on lawns. For estimation purposes, it is assumed that 50 percent of the cutbacks in outdoor demand would be reductions in consumptive use, and two-thirds of the total household cutbacks would be in outdoor demand. Hence only one-third of any demand reduction brought about by pricing programs would reflect savings in consumptive use.

The annual savings in consumptive use due to increasing block rate pricing is estimated to be 3500 af in the year 2020 under Series 3 and 4400 af for the same year and growth scenario if Fort Collins implements a metering program.

The implementation cost for this element would be small. In order to reduce their water bills some customers would incur costs of conversion to low water use landscaping or indoor retrofit. Public resistance to this program is likely to be substantial at the outset. To some extent, public education could reduce this resistance. This non-structural element was not considered in the plan formulation because it was believed unlikely that the cities and water districts of the Basin would convert from contemporary pricing policies.

10.3.2.3 Low Demand Plumbing Fixtures

Changes in plumbing codes to require low water use fixtures in new construction is often considered as a water conservation measure in water resources planning studies. Several basin municipalities have already revised plumbing codes to require low water use fixtures. For example, Fort Collins Ordinance 29 passed in 1978 requires installation of three and one half gallons per flush (or less) toilets, three gpm shower heads and two gpm lavatory faucets. While these regulations explicitly prohibit installation of inefficient fixtures, in fact, old high water use fixtures are no longer available for purchase.

Because of these trends, the water demand forecasts provided in Chapter 6 reflect decreasing indoor water use for existing homes in the basin.

10.3.2.4 Universal Metering

Greeley is implementing a plan to gradually meter all customers. The effects of this program in reducing future water demands are reflected in the water demand forecasts. Fort Collins has not yet implemented a universal metering program. The Fort Collins Water and Wastewater Utility has developed a metering plan, which in Spring 1986 was before the Fort Collins City Council. Provisions of the plan include:

- All new homes are to be metered at time of construction.
- All unmetered residential homes, which now have a meter yoke, would have a meter installed.
- All other unmetered homes would be required to have a meter installed upon sale of the home.

Eighty percent of customers would be metered within 10 years. Virtually all homes would be metered by 2020.

Fort Collins estimates that metering would induce customers to reduce water use by an average of 129 gallons per household day. Outdoor water demand would be primarily affected. Multiplying by the number of unmetered customers under Series 3 economic conditions in the year 2020, metering would reduce Fort Collins demand by 8600 af per year, of which about 4300 af is estimated to be consumptive use.

Fort Collins estimated meter installation costs to average $100 per unit. This includes materials, labor, and city inspection costs. Costs are lowest for new homes and homes with meter yokes already installed. Costs are highest for existing homes, which would require installation of meters outside the dwelling. Under Series 3, 59,000 dwelling units would be metered by the year 2020. The cost to install these meters would be $5.9 million over the implementation period.

Benefits of metering extend beyond reduction of net consumptive use. For example, metering would reduce the amount of water treatment plant capacity needed to meet peak day demands. Operation and maintenance costs related to water treatment and delivery would be reduced. Fort Collins places a value of $300 per meter on these benefits. Revenues to the water utility could become more variable and uncertain and extra contingency funds might be required.

One environmental impact is related to the possible degradation of lawn quality in Fort Collins. There might also be several social and economic disadvantages of metering. Unmetered customers currently benefit from the additional water they now use. By making customers cut back on water, they lose these benefits. In order to conserve water, customers might have to more carefully monitor water use and in some cases, tolerate less attractive lawns. Dollar costs of installing low water use landscaping are not included in the estimates of implementation costs. There would be temporary inconvenience from installation of meters and interruption of water service. A general resistance to metering is also possible.

Metering in Fort Collins was included in the plan formulation because of low cost in relation to the amount of consumptive use savings.

10.3.2.5 Outdoor Watering Restrictions

Raymond Anderson's study of the 1977 Fort Collins watering restrictions concludes that the program reduced overall demand in the July 15-August 23 period by 20 percent. Based upon these findings, a 15 percent reduction in annual demand might be expected. About two thirds of watering applied to a typical Fort Collins lawn has been found to be consumptively used.

Because water restrictions would induce more efficient watering practices, significant reductions in excess (not consumptively used) water applications might be expected. For purposes of this analysis, only 50 percent of the reduction in outdoor watering would represent consumptive use. Annual savings in consumptive use might be 12,000 in 2020 under Series 3.

Implementation costs are expected to be minimal. As noted in the Fort Collins studies, water restrictions can have an undesirable aesthetic effect on landscaping and endanger homeowners investments in lawns and plantings. Restrictions would also decrease water revenues from metered customers possibly stressing water department financing. Unless implemented only during a shortage or drought, these water restrictions would be unpopular.

Because the potential consumptive use savings are large (12,000 af/yr during a water-short period) and because costs are low, this measure was included in the plan formulation. Outdoor restrictions also are applicable during emergency conditions.

10.3.2.6 Water Use Rationing

Municipalities could ration water use to a percentage of normal demand. For metered customers, allowable water use for each month could be based on the customer's use for that period in the previous year. If water demand exceeded that level, the customer would pay a penalty price for any excess water use. Penalties for excess use could range up to complete cutoffs in water deliveries for certain customers in times of severe shortages.

Water use rationing might vary from mild penalty pricing for excess use to outright prohibition of uses beyond minimum indoor water needs. Mild restrictions would likely reduce some excess water applications to lawns. Since most of this excess water would be returned to the surface or ground water systems, there would be little effect on consumptive use. Severe rationing could eliminate <u>all</u> outdoor watering, resulting in reductions in consumptive use in 2020 of 54,000 af under Series 3. Rationing in water-short periods would reduce diversions and help to maintain water higher in the Basin. It also could reduce peak demand stresses on municipal water treatment distribution systems.

The direct implementation costs of this program would be small and computer programs could be adapted to target excess water users.

Because mild rationing programs might have little impact on consumptive use and severe rationing could result in major damage to area landscaping, this conservation program is considered applicable only for emergency use during severe shortages.

10.3.2.7 Landscaping Restrictions on New Homes

Municipalities could enact ordinances regulating lawn area. This program could be structured in a manner similar to the landscaping restrictions adopted by the City of Aurora. Aurora's restrictions focus on lawn installation for new homes. Restrictions apply to soil preparation, grass types, and lawn area. Lawn size limitations vary from 2,600 feet of sod for a 4,000 square foot lot (65 percent of lot area) to 4,400 square feet of sod for a 13,000 square foot lot (34 percent). Persons installing a lawn must apply for a lawn permit; once the lawn is installed it is inspected to ensure compliance.

A lawn restriction program would affect outdoor water use of single family homes to be constructed within the planning period. Based upon estimates developed in the Denver Metro EIS, a preliminary estimate of yield for a lawn restriction program might be about 80 gallons per household per day. This corresponds to about one-quarter of the average outdoor water demand projected for new single family units in Greeley and Fort Collins. Yield in the first year of implementation would be small because few dwellings would have been subject to the restrictions. By 2020, however, the program would affect 94,000 new dwelling units under Series 3.

Municipal water diversions might be reduced by 8,400 acre feet by 2020 and consumptive use might be reduced by 5600 af.

Based upon the findings of the Denver Metro EIS, the direct cost of enforcing the program might be about $100 per home. Annual enforcement costs might average about $100,000 to $300,000 in the Basin. Substitute landscaping typically is more expensive for a homeowner to install than bluegrass turf. Denver Metro EIS research found that installing rock or low water use vegetation instead of a certain area of turf would imply an extra cost of over $1000 per home.

Implementation of this measure would reduce M&I diversions and consumptive use each year because of reduced lawn size and watering. Although public opposition may be strong, this measure was included in the plan formulation.

10.3.2.8 Prohibitions on New Connections

In times of severe water shortages, municipalities could pass ordinances prohibiting any extension of water service to new customers. For the year 2020 under Series 3 conditions, 3400 af of consumptive use could be saved in the fifth year of a ban on new connections.

Although the direct costs of implementing this conservation program are minimal, indirect costs would be substantial. A ban on growth would have major implications for the local economy. Workers and businesses related to the construction industry would face severe economic dislocation. Secondary impacts would be expected throughout the economy.

Little public support for such a measure could be expected under most circumstances. For example, a survey of Denver area residents prepared for the Metro Denver EIS assessed the impact on quality of life of a ban on new water taps. Over one-half of the respondents indicated that tap restrictions would negatively affect their quality of life. For these reasons, this measure was not considered in the plan formulation.

10.3.2.9 Ban on Outdoor Water Use

In periods of severe shortage, municipalities could pass ordinances to ban all outdoor water use. Fines would be levied for non-conforming households.

About one-half of future municipal and industrial water diversions are projected to be utilized for outdoor watering. In 1985, a ban on outdoor use would have saved about 30,000 af. In 2020, a ban on outdoor use would reduce water diversions by 80,000 af under Series 3. Not all of the water applied is consumptively used; some water returns for downstream diverters or ground water uses. Based upon previous research in Fort Collins, two-thirds of the water applied to lawns is expected to be consumptively used. Savings in net consumptive use might be 54,000 af in 2020 under Series 3.

The direct cost of passing and enforcing an ordinance banning outdoor water use would be small. However, most of the water needs of municipal vegetation comes from outdoor watering. Therefore, a ban on outdoor water use would severely stress this vegetation. Temporary impacts would include aesthetically undesirable lawns and the inability to wash cars or fill swimming pools. Permanent damage could be expected, particularly to bluegrass lawns. For these reasons, this measure was not considered in the plan formulation.

10.3.2.10 Commercial/Industrial Conservation

Two of the conservation programs discussed for residential water users -- water conservation kits and low flow plumbing fixtures--could also be applied to commercial and industrial users. These commercial/industrial conservation programs suffer from the same flaws indicated in the analyses of these specific items. Other demand reduction programs discussed in this section are assumed to reflect commercial and industrial as well as residential water savings. Demand forecasts presented in Chapter 6 reflect the commercial and industrial water conservation programs of several large water users in the Basin. Additional opportunities among large individual users may be possible, especially during emergencies. This measure was not considered specifically in the plan formulation.

10.3.2.11 Pressure Reduction

A pressure reduction conservation program might be implemented by reducing water pressure throughout municipal water systems or by installing pressure reduction valves in individual homes. As reported in the Denver Metro EIS, pressure reduction might be expected to reduce water use in the shower and in sinks. Because of the nature of these uses, little reduction in consumptive use could be expected.

The direct costs of implementing a pressure reduction program would be small.

Certain household appliances and irrigation systems rely on a minimum water pressure to operate. Adverse public reactions might be expected.Because of the very limited savings in consumptive use and potential public resistance, pressure reduction was not considered further in the plan formulation.

10.3.2.12 Landscape Irrigation System Improvements

Improvements in the landscape watering practices of homes and businesses could reduce outdoor water applications in the Basin. Possible improvements include installation of drip irrigation systems for gardens and shrubbery and conversion to automated irrigation systems controlled by timers or moisture sensors.

However, because increased landscape irrigation efficiency would do little to reduce M&I consumptive use of water, it would have little effect on potential water shortages in the Basin.

Installation of sophisticated landscape irrigation systems is relatively expensive. The Denver Metro EIS screens out consideration of this conservation measure on the basis of cost. This measure was not considered in the plan formulation for this Study.

10.3.2.13 Irrigation System Efficiency Improvements

Three components of system efficiency have been analyzed: (1) river diversion efficiency; (2) conveyance efficiency; and (3) on-farm efficiency. In all three cases, existing efficiency levels have been found to be good. This is due in large part to the high degree of cooperation that exists between water administrators and water users. This is not to say that improvements cannot still be made. However, considering the present levels of efficiency, any future incremental changes will be relatively small with one exception, diversions from the river.

Slightly more than 90 percent of the water available in the river is diverted for beneficial use. The remainder, which amounts to an average of about 37,000 af per year, passes through the Basin and discharges into the South Platte River because there is not sufficient storage capacity in the Basin to capture it.

Conveyance efficiency pertains to the river and to the system of ditches and reservoirs between the river and farm headgates. An efficiency of 80 percent has been determined for these facilities. This is an average for the entire lower basin. The resulting 20 percent so-called loss is not in fact a loss to the system. As described in Section 10.3.1.2, it is estimated that 95 percent of this amount goes to return flows, which reappear in downstream ditches, or to ground water. The actual loss to phreatophytes and evaporation is estimated to be approximately one percent of the total amount diverted.

It is concluded that, taking the Basin as a whole, conveyance efficiency is very good. It is suggested, however, that consideration be given in the future to specific areas within the Basin where ditch lining may be beneficial.

Overall Basin farm efficiency is close to 70 percent. Davis and Sorensen (1969) note that irrigated farm efficiencies in the United States range from 60 to 75 percent with the higher values being obtained by sprinkler irrigation and/or very high level management. Efficiency could probably be increased a few percentage points with the installation of sprinkler systems. Some installations already exist in the Basin. The cost ($700-$900 per acre for center pivot) is relatively high however, and the economic and financial feasibility of such an undertaking would have to be analyzed on a farm by farm basis. Where economic feasibility could be achieved, tax incentives might be considered to facilitate financial arrangements.

This measure has not been considered specifically in the plan formulation. Conversion to sprinkler systems would not be financially feasible for most farmers unless the economic picture for agriculture improves dramatically.

10.3.3 Institutional Plan Elements

Institutional elements as presented herein pertain to both supply- and demand-related conservation measures.

10.3.3.1 Drought Insurance

Drought insurance refers to a concept wherein a municipality or industry would have access to certain agricultural water during periods of drought or other water emergency conditions. The municipality would accumulate funds in a special account during wet or average years to pay out to participating agricultural users in critical years. The advantages of such an arrangement are that alternative high cost storage facilities would be deferred or eliminated, and no modification of Colorado water law would be necessary.

It is apparent that the municipality could only consider agricultural users with rights of sufficient seniority to insure the availability of a defined minimum quantity of water under a pre-determined drought condition.

The amounts paid to agricultural users would presumably be based on net profit lost on acreage corresponding to the water that had been sold. If, for example, an average water application amount of 20 inches were assumed, then, for each 1000 af needed by the municipality, 600 acres would be taken out of production.

At the present time in the Basin, municipalities are acquiring agricultural water rights which they are leasing back to farmers. These rights can be relied on during droughts and to provide additional water supplies to meet growing water demands in the future. The current buy/lease-back arrangement represents a "defacto" form of drought insurance as described above.

Continued use of these procedures to provide drought protection in the M&I sector, perhaps under more formalized procedures, appears to have merit. Drought insurance appears to be an excellent method of protecting the highest value use of water during dry years while maintaining agriculture during normal water years.

10.3.3.2 Basinwide Cooperative Water Management Organization

A high level of cooperation among water users in the Basin now exists; however, establishing a more formalized process for cooperation may be desirable.

One concept, identified in the St. Vrain Basin Study, involves forming an organization that would buy agricultural water rights and would lease water to agricultural and M & I users in the Basin. The organization probably would be similar to a mutual ditch company. Shares in the company would be awarded in proportion to the water rights conveyed to it by current water users, giving weight to both the magnitude of the rights involved and their seniority. However, in order to achieve efficiency gains, water would be leased on a cash basis to the highest bidders and not allocated in proportion to shares owned, as is the case with mutual ditch companies. This provision would ensure the flexibility necessary to achieve efficient water use. The economic gains from increased efficiency would be distributed in proportion to shares owned, in the form of cash dividends. In this way, owners of vested water rights would be assured of economic returns at least as great, and often considerably greater, than those which they receive under current institutional arrangements.

A second type of basinwide organization not involving the purchasing of water rights, might be considered. Implementation of a conjunctive use operation in the Basin probably will require the formation of a broad-based organization with the capability to contract with well owners who also own stock in irrigation companies (i.e., have surface water rights). Under this contract, well owners would rent a portion of their surface water to the organization during water short years and pump more water to meet their own needs. The organization would administer the conjunctive use operation to assure that all participants receive equitable treatment. The organization also might administer a more formal drought insurance program and coordinate the overall management of water resources in the Basin through cooperative agreements among water users.

No matter what organizational and management structure is selected, a basinwide organization should be considered for future implementation. This will help to insure that the current high levels of cooperation among water users will continue in the future.

10.3.3.3 River Basin Authority With Regulatory Powers

Colorado statutes permit establishing river basin authorities that are empowered to set and enforce standards for achieving efficient water use, as well as to tax and to construct and operate water management facilities. No river basin authorities have yet been established under this statute, but it is clearly a device which could provide by regulatory means the same increases in water use efficiency and management as could be achieved with a cooperative organization. There do not appear at this time to be clear advantages in changing the present systems of water management in the Basin.

10.3.3.4 Restructured Water Rights

This measure, identified in the St. Vrain Basin Study, involves amending State of Colorado water laws to achieve greater efficiency in water use. Plan elements involving changes in State law were not considered for the current Study. Changing water laws appropriately would be the subject of a much broader study covering water issues on a Statewide basis.

10.3.3.5 Improved Water Management Through Market Processes

Water currently is traded quite actively in the Basin and the existing market tends to allocate water to its highest and most valuable use during drought periods. As conceived for the St. Vrain Basin Study, this measure involves forming a private corporation to buy existing agricultural water rights and to lease water to agricultural, municipal, and industrial users. This could achieve more efficient water use within and between sectors and between time periods. The economic gains from more efficient water use would accrue in part to the sellers of water rights and in part to the investors. Such a proposal is presently under consideration by a major investor in the St. Vrain Basin. Given the high-level of cooperation among water users in the Cache la Poudre Basin, forming a corporation does not appear to offer significant advantages over present operations in the Basin.

10.3.3.6 Water Court Enforcement of Water Use Efficiency Goals

The existing water court system could also be used to achieve more efficient water use. Legislative action would be required to direct that beneficial use be more stringently interpreted to exclude waste. Existing statutes can be interpreted to do so, but the loose interpretation presently given to those statutes suggests that additional legislation may be required to effect change. Since changing State law probably would be required, this element would be more appropriately considered in a much broader study than one covering a single basin.

10.4 EVALUATION OF NON-STRUCTURAL ELEMENTS

10.4.1 Screening

The 12 non-structural plan elements passing the initial screening are:

Category	Non-Structural Plan Element
• Water Supply Management	• Ditch lining • Conjunctive use • Hydrologic instrumentation • Transfer of storage decrees • Transfer of points of diversion • Deficit irrigation practices
• Water Demand Management	• Public information programs • Universal metering • Outdoor water use restrictions • Landscaping restrictions (new homes)
• Institutional Measures	• Drought insurance • Basinwide organization

Certain plan elements listed in Table 10.1 are expected to be valuable during emergency situations such as an extremely prolonged water short period or a water system failure. These include water use rationing, outdoor water use bans, and similar measures. Plans for their implementation should be included in emergency plans by various water users and administrators.

Each element was then evaluated based on these factors: long-term performance (firm yield of water made available each year); short-term performance during droughts; implementation cost; acceptability to the public; dependability; adverse environmental effects; other beneficial effects; possible mitigation measures required.

Results of the evaluation are summarized in Table 10.5. While each of the elements should be considered for implementation under a basinwide plan, there are four which have significant effects on the water supply situation in the Basin -- conjunctive use, universal metering, outdoor watering restrictions, and landscaping restrictions for new homes. The effects of implementing these measures in terms of additional supply or reduced demand have been considered in the plan formulation process. Other measures listed in Table 10.5 either have small or no effect on supply or demand; however, their implementation also should be considered because of benefits related primarily to better management of water resources in the Basin. As shown below, the combined effect of non-structural measures in the year 2020 under Series 3 conditions would be substantial. As shown below, the amount of water supply reduction attributable to non-structural measures ranges from about 22,000 af on an annual basis to 107,000 af during a single year of prolonged drought when conjunctive use is relied on heavily to overcome water shortages:

Yields from Non-Structural Elements Passing the Initial Screening and Having Quantified Yields

Element	Annual Yield (af)	Drought Yield[1] (af)
Conjunctive Use	12,000	85,000
Universal Metering	4,300	4,300
Outdoor Water Use Restrictions	-	12,000
Landscaping Restrictions	5,600	5,600
	21,900	106,900

(1) In a single year of a prolonged drought.
(2) In Fort Collins. Metering in Greeley is reflected in the demand forecasts.

TABLE 10.5
Evaluation of Non-Structural Plan Elements
Passing the Initial Screening
(September 1986)

Evaluation Factor	Supply Management Elements: Ditch Lining	Conjunctive Use	Hydrologic Instrumentation	Transfer of Storage Decrees	Transfer of Points of Diversion	Deficit Irrigation Practices	Demand Management Elements: Public Information	Universal Metering	Outdoor Watering Restrictions	Landscaping Restrictions (New Homes)	Institutional Elements: Drought Insurance	Basinwide Organization
Long-Term Performance (Water yield each year)	3000 af (1)	10,000 to 15,000 af	(1)	2000 af (4)	(1)	-	(1)	4300 af (2)	12000 af (2)	5600 af (2)	-	-
Short-Term Performance (One time yield during drought)	(3)	70,000 to 100,000 af	(1)	(3)	(1)	(6)	(1)	(3)	(3)	(3)	-	-
Implementation Cost												
Capital ($Million)	15.0	14.2	0.2	(5)	-	-	-	-	Minimal	-	-	-
Annual ($Million/yr)	1.3	1.3	0.04	-	-	-	0.1	0.6	-	0.3 (8)	0.18	0.17
Cost ($) per af of Yield	-	130	-	-	-	-	-	140	-	50	-	-
Acceptability to Public	Moderate	Moderate to High	High	Moderate	Moderate	Moderate	High	Moderate	Low	Low	Moderate	Moderate to High
Dependability	High	High	(7)	Moderate	(7)	(7)	(7)	Moderate	Moderate	High	(7)	(7)
Possible Adverse Environmental Effects (Terrestrial and aquatic wildlife)		* Reduced water quality	* Disruptions during DCP construction * Small areas of lost habitat * Visual impacts	* Lost aquatic habitat in plains reservoirs								
Other Effects of Implementation				* Former reservoir lands available for other land uses		* Possible reduced yields and income		* Possible decline in lawn appearance	* Possible decline in lawn appearance			
Potential Mitigation Measures		* Water quality management program	* Use visually appealing designs * Avoid wilderness areas	* Improve habitat at other reservoirs				* Encourage landscape conversion with incentives	* Encourage landscape conversion with incentives			

(1) Difficult to quantify.
(2) For Series 3, year 2020 demand level.
(3) Annual savings could be stored and used to help overcome drought shortages. A new storage facility would be needed.
(4) New storage facility required to transfer storage decrees.
(5) New reservoir needed for this element.
(6) Should be considered in final sizing of reservoirs.
(7) Not applicable; yields from these measures are difficult to quantify.
(8) Excludes $94 million in added cost to new homes by year 2020 under Series 3.

10.4.2 Cost of Non-structural Elements

Table 10.6 presents a summary of the estimated costs (in 1986 dollars) for implementing the various non-structural plan elements. Total investment cost is estimated to be about $31 million and total annual cost is estimated to be about $4 million.

TABLE 10.6
Costs of Non-Structural Measures

	Total Investment Cost[g] ($ Million)	Annual Cost[g] ($ Million)
Ditch lining[a]	15.0	1.30
Conjunctive use	16.0	1.40
Hydrologic instrumentation	0.2	0.04
Transfer of storage decrees	(b)	(b)
Transfer of points of diversion	(c)	(c)
Deficit irrigation practices	(d)	(d)
Public information program	-	0.10
Universal metering[e]	(h)	0.17
Outdoor watering restrictions	-	-
Landscaping restrictions[f]	-	0.30
Drought insurance	-	0.18
Basinwide organization	-	0.17
Total	31.2	3.66

(a) Order-of-magnitude estimate only.
(b) New reservoir needed to implement this element.
(c) Likely part of conjunctive use operation.
(d) To be considered during feasibility phase in evaluating the effects of not alleviating drought period shortages.
(e) In the area of Fort Collins not metered at present or to be metered in future under present plans. In-place Greeley metering program assumed to be complete by year 2020.
(f) New homes only. Costs do not include additional costs to buyers of new homes.
(g) Costs represent January 1986 price levels.
(h) By 2020, 59,000 meters would be installed at a cost of $100 per meter (giving a total installed cost of $5.9 million). The annual cost is based on installing 1690 meters per year and excludes meter reading and maintenance costs.

Chapter 11

Plan Formulation

11.0 PLAN FORMULATION

11.1 INTRODUCTION

Combined plans were formulated employing combinations of non-structural and various structural plan elements to alleviate projected water shortages and meet other Study objectives. Non-structural plan elements were described in Chapter 10. This chapter describes the plan formulation process and the structural elements associated with each plan.

11.2 OBJECTIVES OF A COMPREHENSIVE WATER RESOURCES MANAGEMENT PLAN

The objectives of implementing a comprehensive water resources management plan for the Basin are to:

- Augment existing water supplies and redistribute existing supplies as appropriate to alleviate potential future shortages of water;
- Develop the hydroelectric resources of the Basin;
- Enhance water-based recreational opportunities;
- Protect water quality;
- Enhance fish and wildlife resources; and
- Provide flood control.

Ideally, a comprehensive water management plan would satisfy all of the objectives with minimal adverse effects. Presumably such a plan would be acceptable to all interest groups. In practice, however, it is not possible to develop a plan that satisfies all objectives equally and tradeoffs and mitigative measures are required. For example, augmenting existing supplies may require construction of a dam and reservoir that would inundate existing stream and wildlife habitat in the reservoir area. This action would reduce the length of stream available for stream-based recreation (angling, kayaking, hiking, etc.). However, flat-water recreation opportunities (angling, boating, hiking, etc.) would be created at the reservoir. Also, the reservoir might be operated to enhance existing stream-based recreation opportunities below the dam, thus providing a net recreational benefit for the area.

11.3 PLAN FORMULATION PROCESS

The plans that have been formulated include both non-structural and structural elements. Identification, screening, and selection of non-structural elements has been described in Chapter 10. Twelve of these elements were selected for inclusion in each of the combined plans.

Formulation of structural components of the alternative plans followed a similar process of identification, screening, and selection. This process began with a map study to identify suitable sites for storage, diversion, and power facilities. Identification and screening of individual sites proceeded concurrently and the possible combinations of structural plan elements were brought into consideration. Out of this process evolved five basic structural plans which were then subjected to more detailed evaluation. These plans include varying amounts of mainstem storage, North Fork storage, off-channel storage, and two pumped-storage hydropower arrangements. As evaluation advanced, staged development variations of two of the five plans were included for consideration, bringing the total number of plans under consideration to seven.

Structural plan formulation was guided by several considerations including the objectives cited in Section 11.2 and by a number of basic factors and criteria that are summarized in the following subsections.

11.3.1 Water Shortages and Alleviation Measures

Plan formulation was based on Series 3-year 2020 water shortages for a 25-year drought event. Water resources available to the Basin are adequate to meet normal year agricultural and M&I demands into the future provided that no new lands are brought under irrigation. At this time, it appears likely that additional water resources in the Basin would be developed to provide supplemental water to existing irrigated lands. Basin water resources are not adequate to alleviate agricultural water shortages during a 25-year drought if new lands brought under irrigation. Planning for a 50-year drought was not considered because the estimated shortages for this type of event, under 1985 conditions in the Basin, are about equal to the 25-year drought. This situation may result because of the 50-year drought definition adopted for the Basin Study. It has been assumed that the municipalities will continue to acquire water rights that will provide firm supplies for M&I use during droughts in excess of a 25-year return period.

Results of the water shortage analysis are summarized in Table 11.1 for 1985 conditions and for Series 2 and Series 3 economic conditions and are based on RIBSIM results described in Chapter 7. Series 2 refers to a moderate economic growth scenario and Series 3 refers to a strong economic growth scenario. Shortages expected to be experienced under 1-in-25 year drought conditions do not vary substantially.

TABLE 11.1
Water Shortages Under Various Drought Conditions

Return Period of Drought (yrs)	Drought Duration (yrs)	Cumulative Drought Shortage (af)		
		1985	Series 2-Year 2020	Series 3-Year 2020
1-in-10	2	7,000	8,000	353,000 (1)
1-in-25	4	447,000	439,000	449,000 (2)
1-in-50	6	493,000	ND	ND

(1) Includes 65,000 acres of new irrigated land.
(2) Excludes new lands. Selected target for plan formulation.
ND - Not determined. Analysis for 1985 conditions indicated that shortages during a 50-year drought are not much more severe than during a 25-year drought.

Alleviation of the 449,000 af water shortage corresponding to a 1-in-25 year drought of four years duration under Series 3 conditions can almost be achieved by the application of both non-structural and structural elements. Table 11.2 shows the distribution of shortages that would occur in the 1953-56 drought (identified as a 1-in-25-year drought) under Series 3 conditions in the year 2020. Non-structural measures could reduce the total shortage from 449,000 af to 251,000 af, a 44 percent reduction. As described in Section 10.4, non-structural measures with quantified yields can provide about 22,000 af per year during a drought, exclusive of conjunctive use operations. Structural measures could further reduce the shortage to a total of 79,000 af over a three year period (Table 11.3). Water made available by the structural measures includes 25,000 af per year from storable flows and 24,000 af per year from additional Windy Gap and C-BT diversions into the Basin (see Section 11.5).

TABLE 11.2
Effect of Non-Structural Measures on Reducing
25-Year Drought Shortages (Series 3, Year 2020)
(acre-feet)

Drought Year	Total Water Shortage	Non-Structural Savings	Conjunctive Use Water Pumpage	Remaining Total Shortage(4)
1	11,000	11,000(1)	(2)	0
2	224,000	22,000	97,000(3)	105,000
3	121,000	22,000	12,000	87,000
4	93,000	22,000	12,000	59,000
Total	449,000	77,000	121,000	251,000

(1) An estimated savings of 11,000 af can be effected by ditch lining, metering, and minor restrictions.
(2) Not needed in first year of drought.
(3) Includes pumpage of 85,000 af to reduce worst-year drought shortage.
(4) Structural measures would be needed to overcome these shortages.
Note: Shortages were determined by RIBSIM in Task 5. They do not include new lands.

TABLE 11.3
Application of Structural Measures

Year	Remaining Total Shortage(1) (af)	Upper Basin Storable Flow(2) (af)	Additional Windy Gap and C-BT (af)	Remaining Total Shortage (af)
1	0	0	0	0
2	105,000	50,000	24,000	31,000
3	87,000	25,000	24,000	38,000
4	59,000	25,000	24,000	10,000
	251,000	100,000	72,000	79,000

(1) See Table 11.2.
(2) For firm yield of 25,000 af/yr. Other yields from storage were considered.

11.3.2 Potential Sites for Water Storage

Potential damsites for water supply storage were identified during Task 7. The ten damsites are shown on Figure 11.1 and include: five sites on the mainstem Cache la Poudre River below Poudre Park; one site on the South Fork; three sites on the North Fork, including two existing damsites; and one off-channel site in the hogback east of Poudre Canyon.

Potential storage projects were combined in various ways during the plan formulation process, which also included consideration of pumped-storage facilities operating in combination with water supply facilities.

The mainstem sites are Portal (at the Canyon Mouth about four miles below the mainstem-North Fork confluence), Grey Mountain (about two miles below the confluence at a site identified by the USBR), Poudre (just below the confluence), Trailhead (about 0.7 miles upstream from confluence), and Footbridge (about 2.6 miles upstream from the confluence).

The South Fork site is called Rockwell and is located about 11 miles upstream from the mainstem. The City of Fort Collins has a conditional storage right of 4900 af at this site and has been considering development at this site for many years. This site appears suitable for a small to intermediate-sized storage project. For the Basin Study, the Rockwell site was evaluated for a total storage of 17,000 af, involving an 180-ft high concrete gravity dam. Development of the Rockwell site to this storage capacity was found to be considerably more expensive on a cost per unit storage basis than the other sites. It may be that for a smaller storage volume (5000 to 10,000 af) the Rockwell site would be more attractive. This amount of storage is far less than that required to regulate a large portion of the native storable flows and/or additional Windy Gap and C-BT imports to the Basin. For these reasons, Rockwell was not considered in the plan formulation.

North Fork sites include New Seaman, involving a new dam just downstream from the existing Seaman Dam, New Halligan Dam just downstream from the existing Halligan Dam, and Calloway Hill Dam located about 13 miles upstream from the existing Seaman Dam. Cost estimates prepared in Task 7 indicated that storage at New Seaman and New Halligan would be competitive with other sites. A dam at Calloway Hill was found to be more expensive than equivalent storage at New Halligan. This site, therefore, was not considered in the plan formulation. Comparative cost studies showed that building New Seaman Dam would be less expensive than raising the existing dam, primarily because of an increase in storage achievable at the New Seaman site. Comparative cost studies for the Halligan indicated that building a new dam would be less expensive than raising the existing Halligan Dam.

Off-channel storage could be provided at Hook and Moore Glade (Glade damsite) about one mile north of Ted's Place. A reservoir at Glade would be filled by diversion of water from the mainstem and/or North Fork of the Cache la Poudre River. The Glade site offers the largest storage potential of all sites under consideration.

Layout and cost studies for the potential storage projects were prepared in Task 7. Preliminary estimates of costs of storage and yield of water from storable flows were prepared to demonstrate a range of possible developments for a water storage project. When pumped-storage was considered in combination with the various storage elements, allocations of reservoir storage for water supply and hydroelectric power functions were made. This resulted in storage volume and corresponding yield reductions for several of the larger reservoirs, particularly Portal and Grey Mountain. The costs of yield provided in Table 11.4 are based on estimated annual costs based on tax-free revenue bond financing (see Section 11.4). Bonding costs were added to the investment costs determined in Task 7 in order to estimate the annual cost of each storage element in Table 11.4. The costs shown in Table 11.4 are comparative estimates and refinements were made in Task 8 when various structural plan elements were combined, together with non-structural elements, to formulate alternative water resource management plans. The costs do, however, indicate the range of potential costs for water storage in the Basin, excluding hydropower development components.

11.3.3 Considerations for Plan Formulation

The plan formulation process for the Cache la Poudre Basin Study considered the following factors:

- Non-structural measures generally are more cost-effective than structural measures and their implementation should be encouraged at the local level. In the plan formulation, non-structural measures have been applied first, followed by structural measures.

- Water shortages are not predicted to be significant in the M&I sector for a 25-year drought under even the most optimistic economic scenario for future growth in the Basin. Municipalities in the Basin have policies of acquiring agricultural water rights prior to urban development and most of the future urban development will occur on lands that currently are irrigated. However, the City of Thornton has taken actions to acquire water rights in the Basin. Available water resources in the Basin, therefore, may come to have regional significance.

TABLE 11.4
Comparison of Water Management Plan Elements
(Excluding Pumped-Storage and Environmental Mitigation Considerations)

Sites	NWS Elev. (ft)	Storage at NWS El. (af)	Annual Yield (1) (af)	Investment Cost ($ Million)	Cost of Yield (5) ($/af)
Mainstem					
Portal	5630	310,000	32,000	312	910
	5583	217,000	28,000	233	780
Grey Mountain	5630	204,000	27,000	153	520
	5583	131,000	22,000	115	480
Poudre	5630	143,000	23,000	137	560
	5583	92,000	15,000	82	510
	5540	55,100	8,000	61	720
Trailhead (2)	5595	24,200	--	55	--
Footbridge (2)	5579	200	--	20	--
South Fork					
Rockwell (6)	8000	17,000	5,100	64	1,200
North Fork					
New Seaman (3)	5700	157,900	14,300	138	810
	5600	54,200	7,400	59	670
	5540	24,900	3,200	37	970
Halligan (3)	6448	62,900	6,700	33	530
	6415	35,300	5,100	24	510
Calloway Hill (6)	6260	63,000	7,100	94	1,270
	6200	36,000	4,500	58	1,240
Off-Channel					
Glade No. 1 (4)	5590	303,000	32,400	516	1,500
	5480	107,800	20,200	320	1,490
Glade No. 2 (4)	5590	208,000	27,500	540	1,850
	5480	57,100	10,600	307	2,730

(1) Under constant monthly demand, Series 2-Year 2020 storable flows.
(2) These are diversion projects, no unit cost for yield is given.
(3) Storage and yield are incremental over existing reservoir.
(4) Investment costs include costs of diversion from the mainstem and North Fork.
(5) Estimated annual cost ($/yr) divided by yield (af/yr); see Task 8 Summary Report (Harza, 1986). Indicator of relative attractiveness.
(6) Not considered in the plan formulation because of high cost in relation to other elements.

Note: Costs for Portal Dam are from the Task 7 Summary Report. They later were adjusted for conventional concrete construction rather than roller-compacted concrete (RCC).

- Water shortages in the agricultural sector would be significant for a 25-year drought event if it occurred now (450,000 af during the 4 years of 25-year drought). Similar shortages of agricultural water in a 25-year drought are predicted to occur in the future. Economic losses to the regional economy could be as high as $180 million (in 1986 dollars) if the 1950's drought were repeated.

- The opportunity to implement a major pumped-storage hydroelectric facility exists in the Basin and portions of the revenues produced by the facility could be used to help pay for the development of water supplies to benefit the Basin.

- Storage is needed in the Basin for additional Windy Gap and C-BT deliveries. The NCWCD has indicated that 124,000 af of storage capacity will be needed.

- To obtain a yield of 25,000 af from storable flows, 150,000 af of storage capacity will be needed.

11.3.4 General Criteria

A number of general criteria were adopted for sizing the structural elements and to define basic operating characteristics. The criteria are described herein.

11.3.4.1 Preliminary Design Floods

Flood frequencies and Probable Maximum Floods (PMFs) have been computed at prefeasibility level for each of the water management facilities. They have been used to develop preliminary sizes for spillways and construction diversion facilities.

Estimated peak flows for 10, 25, 50, and 100-year frequencies were adopted from a report by the Corps of Engineers (COE, 1981), on flood hazards and dam safety in the Cache la Poudre Basin, or were computed using USGS regional curves. The results are contained in Table 11.5.

PMFs were computed using the general storm Probable Maximum Precipitation (PMP) from "Hydrometeorological Report No. 55" (HMR 55) (NOAA, 1984) and unitgraphs employing the dimensionless graph method. The results are presented in Table 11.6. A 48-hour storm duration was selected for the PMP, except in the case of the off-channel site at Glade.

TABLE 11.5
Flood Frequency

Project Sites	Drainage Area (sq. mi.)	Flood Frequency, Peak Flows (cfs) 10-Yr	25-Yr	50-Yr	100-Yr
Mainstem:					
Portal	1,055	7,000	9,500	13,500	17,400
Grey Mountain	1,054	7,000	9,500	13,500	17,400
Poudre	1,052	7,000	9,500	13,500	17,400
Trailhead	483	5,800	9,500	14,000	20,000
Footbridge	478	5,800	9,500	14,000	20,000
South Fork:					
Rockwell	86	1,500	2,600	3,500	5,000
North Fork:					
New Seaman	567	2,500	4,700	8,000	12,000
New Halligan	355	1,980	3,700	6,290	9,260
Calloway Hill	367	1,980	3,700	6,290	9,260
Off-Channel:					
Glade	15	2,600	4,600	5,500	9,000

TABLE 11.6
Probable Maximum Floods

	Basin Avg. PMP (inches)	Base Flow (cfs)	Creager C	Peak PMF Inflow (cfs)	Total Volume(3) (af)
Mainstem:					
Portal	19.2	2,000	83	327,000	707,000
Grey Mountain	19.2	2,000	83	327,000	707,000
Poudre	19.2	2,000	83	327,000	707,000
Trailhead	20.3	2,000	57	158,000	343,000
Footbridge	20.3	2,000	57	158,000	343,000
South Fork:					
Rockwell	(2)	700	57	65,000	64,000
North Fork:					
New Seaman	22.8	300	74	222,000	476,000
Halligan	(2)	240	74	179,000	305,000
Calloway Hill	(2)	240	74	179,000	305,000
Off-Channel:					
Glade	28.2(1)	50	214	82,800	21,500

(1) For 12 Hours.
(2) Determined PMF by transposition; therefore PMP not determined.
(3) Above base flow

11.3.4.2 Storage-Yield Relationships

Storage-yield analyses were prepared for individual reservoirs on the mainstem, South Fork, and North Fork using a reservoir operations program. For reservoirs on the mainstem below the North Fork confluence, it was found that storage-yield relationships were essentially the same (i.e., the effect of evaporation from different reservoir surface areas was not too pronounced). Figure 11.2 presents the storage-yield relationship for a reservoir on the mainstem regulating both mainstem and North Fork storable flows. Yield estimates were based on storable flows determined for Series 3-year 2020 conditions, as presented in Chapter 7. For preliminary planning, it was assumed that the yield from storable flows would be a 100 percent firm supply (i.e., the indicated yield would be provided each year of the 30-year study period). During Task 7, three demand scenarios were examined in the yield analysis -- a constant monthly demand (typical of M&I use); an agricultural consumptive use pattern wherein water would be supplied to match the consumptive use demands of the crops being grown in the Study Area; and a shortage alleviation pattern wherein water would be supplied to correspond with periods of shortage. The average annual firm yield of water did not vary substantially among the three demand scenarios.

Storage-yield relationships also were estimated for storable flows at Rockwell, New Halligan, and New Seaman, based on reservoir operation studies. Yield from storage at Glade reservoir would be dependent on the efficiency of diversion facilities supplying the off-channel facilities. With gravity diversion and adequate conveyance capacity, the yield from Glade Reservoir would be about equivalent to that shown on Figure 11.2, provided that both forks of the river are controlled.

11.3.4.3 General Criteria for Structural Elements

Preliminary project feature layouts were developed for each structural element. These include only major structures, that is dams, spillways, outlet works, river diversion facilities, power facilities, access roads, road relocations, and water conveyance facilities. Layouts were not prepared for potential environment mitigation or enhancement measures.

Several different dam types were considered depending on the damsite. Conventional concrete gravity dams and roller compacted concrete (RCC) gravity dams were considered for canyon sites on the mainstem and the North Fork. RCC construction involves concrete placement using earthmoving type methods and is less expensive than conventional concrete placement methods. However, there is no experience at present with RCC construction for dams much in excess of 300-ft high. For planning it was considered prudent to assume that concrete dams in excess of 350 ft would be build using conventional concrete placement methods and that lower concrete dams would be of RCC construction.

Glade dam likely would be a rockfill structure, based on a preliminary cost comparison with RCC construction. Rockfill was not considered for canyon sites based on a cost comparison at the Poudre damsite.

It may be possible to construct arch dams at certain of the canyon sites. The Grey Mountain site, for example, appears to be well-suited for an arch dam. During the feasibility study, if it is undertaken, analyses will be made to determine the optimum dam type and configuration for a particular site. Dam types are identified in each plan to provide the reader with an indication of the basis for construction cost estimates.

Spillways for all dams would have ungated crests and be designed to pass the PMF without overtopping the dam. Spillway crests have been set five feet above maximum normal water surface elevations except at Trailhead and Footbridge dams where crest elevations have been set at maximum normal water surface elevations. In addition, spillway crest elevations have been set so that river levels will not rise above El. 5640 at Poudre Park when a spillway is passing the 1-in-200-year flood peak.

The low-level outlets associated with each potential dam have been designed to comply with the requirements of the State Engineer. These requirements are:

1. Low-level outlets must be able to draw down a full reservoir five feet in 5 days.
2. With 10 ft of head, low-level outlets must be capable of discharging the mean annual peak flow plus downstream calls in excess of that amount.

The low-level outlets have been positioned above a theoretical 100-year sediment level. The outlets in general would be equipped with high pressure sluice gates for larger discharges and a perforated sleeve valve for lesser discharges.

Facilities for diversion during construction have been sized for the 1-in-25-year flood, as identified in Table 11.4.

Certain plans involve tunnels for conveying water to storage or to hydroelectric power facilities. It was assumed that these would be concrete-lined pressure tunnels with maximum flows velocities of 15 ft per second, or less.

It was assumed that the powerhouse associated with a pumped-storage project would be an underground facility with access by tunnel. The selection of underground facilities was based primarily on aesthetic considerations. The type and location of powerhouse would be selected after comparative studies of different options during the feasibility phase.

Reservoir construction would require the relocation of major highways (Route 14, Route 287) and various utilities. Routing studies would be performed during a feasibility-level to select optimum alignments for the relocations.

11.4 COST ESTIMATING PROCEDURES

Cost estimates include direct construction cost, land acquisitions, relocations, and contingencies (covering additional costs due to unforeseen site conditions, approximations, and mitigation), engineering, interest during construction, and other indirect costs. Estimates of direct construction cost are based on price levels prevailing in Colorado in January 1986. Cost data and cost curves were used in estimating the direct construction cost of individual elements in each plan. These data and curves were developed by Harza on prior engineering studies.

In developing the estimated construction cost of each plan, consideration was given to availability of materials, difficulty of construction, geologic and geotechnical considerations, accessibility, acquisition of land, relocations, construction period, and technological limitations. The information on which the preliminary estimates were based was limited to that readily available from reports, studies, and preliminary field reconnaissance.

Construction costs were converted to total capital requirements by adding interest during construction and financing costs.

The estimated total capital requirements of each plan includes the following:

- All direct construction costs associated with the plan including land acquisition, mitigation, relocations, access roads, and related costs.
- A contingency allowance, taken at 25 percent of the total of direct construction costs for water storage facilities and 30 percent for pumped-storage facilities. (Different allowances were used because of more uncertainties regarding pumped-storage cost estimates).
- Engineering and owner administration costs, including the costs of permitting and licensing, feasibility studies, design, contract documents, and construction management, generally taken as 15 percent of the summation of direct construction costs plus contingency.

- Interest during construction is based on the estimated construction period and assumed cash flow from the beginning to end of construction, and the interest rate used for determining all project financing costs. The summation of interest during construction and the previously listed construction cost components and indirect costs is termed Total Investment Cost.
- Bond reserve fund and estimated costs associated with marketing a bond issue to finance project construction which when added to the Total Investment Cost gives the Total Capital Requirement to implement the plan.

Annual costs were estimated assuming tax-free bond financing with interest rates and bond term selected by the Authority. Annual costs were computed for a nominal annual interest rate of 8 percent including inflation. A 30-year bond term is assumed. Annual costs include estimates of amortization of capital, operation, maintenance, and interim replacement of major parts or equipment (O,M&R), administration and general expenses, insurance, and credit for interest earned on reserves. The economic analysis described in Chapter 12 was based on a real interest rate (nominal rate less inflation) and considered only construction, O,M & R, and other related costs. Bond costs were not included in the economic analysis.

For planning at this preliminary level, land costs were assumed to be $1000 per acre without regard to ownership. Under each plan, there are varying amounts of federally owned and privately owned lands that would need to be acquired for reservoirs.

Each plan also includes relocations of one or two major highways (Colorado Route 14 along the mainstem Cache la Poudre and Colorado 287 which would be affected by off-channel storage at Glade). For planning, the cost of relocating Route 14 was assumed to be $1.5 million per mile and the cost of relocating Route 287 was assumed to be $1.0 million per mile. These estimates are based on engineering judgement.

Cost estimates provided later in this chapter do not include specific estimates for mitigation and enhancement measures. Transmission facility costs also are not included. Mitigation costs would be determined in the feasibility phase when specific requirements are identified. The liberal 25 to 30 percent contingency allowance in all cost estimates should be adequate to cover mitigation costs. Under the ESTS concept, significant annual benefits would be derived from operation of a commodities market in electrical energy. It was assumed that these benefits would offset the cost of transmission line construction needed to connect a pumped-storage project in the Poudre Basin with load centers.

11.5 COMBINED PLANS

Five alternative combined plans were developed together with staging variations for two of these plans. Each plan includes a common group of non-structural elements whose basic function is to minimize the cost of structural elements by more efficient use of the present water supply. To provide a firm basis for evaluation, comparison, and ultimately selection of a preferred plan, the alternative plans were formulated to present a broad range of possibilities.

The five alternative combined plans are:

Plan A: Portal Reservoir - Trailhead Reservoir - Greyrock Mountain Pumped-Storage (P-S) Project (Figure 11.3)

Plan B: Grey Mountain Reservoir - Trailhead Reservoir - Greyrock Mountain P-S Project (Figure 11.4)

Plan C: Poudre Reservoir - Glade Tunnel - Glade Reservoir - Greyrock Mountain P-S Project (Figure 11.5)

Plan D: Footbridge Reservoir - Bypass Tunnel - New Seaman Reservoir - Glade Tunnel - Glade Reservoir - Greyrock Mountain P-S Project (Figure 11.6).

Plan E: Trailhead Reservoir - Existing North Poudre Diversion and Conveyance Facilities - Glade Reservoir - New Halligan Reservoir (Figure 11.7).

Variations featuring reduced power and storage capacity were developed for Plan B and Plan C. These have been designated Plans B1 and C1,which are shown on Figures 11.8 and 11.9, respectively.

Plans were formulated to cover a range of storage volumes and associated reservoir yields. The yield from regulating native storable flows varies with active reservoir storage as depicted on Figure 11.2. Yield increases fairly uniformly with increases in storage volume up to an active storage volume of 150,000 af. Above this "break point" the curve flattens and large increments in active storage produce relatively small increments of additional yield. For preliminary planning, it was assumed that an active storage of 150,000 af would be a "target" for regulating native storable flows. The firm yield from 150,000 af of active storage is about 25,000 af per year, about 70 percent of the estimated average storable flow of 37,000 af per year.

Storage also is needed in the Basin for additional Windy Gap and C-BT imports. Studies by the NCWCD indicate that 124,000 af of active storage is needed to provide a firm yield of at least 24,000 af per year. Further studies in the feasibility phase are expected to show that the yield from Windy Gap and C-BT flows may be in excess of 30,000 af per year. The 124,000 af of storage for additional Windy Gap and C-BT flows also was considered to be a "target" volume. Greeley and PRPA together own 240 Windy Gap units equivalent to about 24,000 af per year. As described in Section 4.4.2, the average Windy Gap supply is expected to be 48,000 af per year and each share is equivalent to 1/480th of the water supply produced annually by the project.

Certain plans provide the combined target storage of 274,000 af for native storable flows and additional Windy Gap and C-BT deliveries. Firm yield from 274,000 af of active storage is estimated to be 49,000 af per year. Other plans provide lesser active storage volumes and have correspondingly lower firm yields of new water to the Basin.

Windy Gap and C-BT water enter the Basin from the south via the Horsetooth Supply Channel. Terminal storage is at Horsetooth Reservoir which has a maximum normal water surface (NWS) below that of potential new storage facilities in the Basin. Indications are that exchanges can be employed to enable storage of additional Windy Gap and C-BT water in a mainstem reservoir or in an off-channel facility such as Glade. Windy Gap supplies were not included in the RIBSIM model because specific information on Windy Gap operation was not available when the model was being configured and calibrated. Therefore, it was not possible to confirm that exchanges could be effected. For this reason, plans involving storage for additional Windy Gap and C-BT include a provisional estimate for a pumping station and pipeline from Horsetooth Reservoir to a new storage facility.

The potential for pump-back of return flows at Greeley for further reuse in the Basin is described in a later section of this chapter, following descriptions of the alternative plans. Raising of dams at Horsetooth Reservoir to create additional storage capacity also is described following discussion of the pump-back concept.

As discussed previously, RCC dams were assumed for most of the canyon damsites and rockfill dams for the off-channel Glade site. Typical dam cross-sections for these dam types are presented on Figures 11.10 and 11.11.

11.5.1 Plan A: Portal Reservoir; Trailhead Reservoir; and Greyrock Mountain Pumped-Storage Project (Figure 11.3)

Portal Reservoir, maximum NWS El. 5630, would be the main storage reservoir. Trailhead Dam (maximum NWS El. 5630) would be used to separate the Greyrock Mountain Pumped-Storage lower power pool from the storage reservoir. With Trailhead Dam, the pump-turbines would be protected from excessive head variations which could preclude pumped-storage operation, while at the same time, permitting full use of the water in Portal Reservoir. Taking into account the presence of Trailhead Dam and also dead storage, the resulting live storage provided by Portal Reservoir would be approximately 259,000 af. This storage would provide a firm yield of 46,000 af per year, comprised of yield from native storable flows on the Poudre River (22,000 af/yr) and additional Windy Gap and C-BT flows (24,000 af/yr).

The maximum NWS for Trailhead Reservoir corresponds to that for Portal Reservoir (El. 5630). When Portal Reservoir is full, Trailhead Dam would be completely submerged except for its bridge.

Greyrock Mountain Pumped-Storage Project would have an installed capacity of 1800 MW and a continuous 12-hour generating capability of approximately 21,600 MWh.

11.5.1.1 Portal Dam and Reservoir

Portal Dam, located at the mouth of the canyon approximately 4.3 miles from the confluence with the North Fork, would rise approximately 440 ft above the present river elevation. It would be a conventionally constructed concrete gravity dam. The top of the dam would be at El. 5666 and have a crest length of 2200 ft. A site plan, dam profile, and reservoir area-capacity curve are provided on Figure 11.12.

The spillway crest would be at El. 5635, five feet above maximum NWS (El. 5630), in accordance with the State Engineer's requirements, and would be ungated. The PMF (327,000 cfs peak inflow) would be discharged without overtopping the dam. NWS El. 5630 provides maximum possible storage at the Portal site without encroaching on Poudre Park flood protection criteria.

The low-level outlet was sized to comply with the requirements of the State Engineer, as outlined in Section 11.3.3.

The low-level outlet would be positioned at El. 5350 (estimated 100-year sediment level) and fitted with a high pressure sluice gate for passing higher discharges. A steel pipe with upstream gates and a perforated sleeve valve would be provided for smaller discharges. The low-level outlet would be capable of meeting the total current cumulative downstream direct flow rights of 4,000 cfs, calls by South Platte users, and increased future demands. The low-level outlet, therefore, was sized for an assumed peak discharge of 6,500 cfs. This capacity would be studied further during the feasibility phase.

A tunnel and siphon for the North Poudre Supply Canal pass through Portal Reservoir. The tunnel (invert approximately El. 5413) is an 8 ft diameter horseshoe section lined with unreinforced concrete. Design capacity is 250 cfs. Preliminary analysis indicates that it would be more economical to plug this tunnel and provide a separate outlet works in the dam plus a gravity canal around the left abutment of Portal Dam to the existing North Poudre Supply Canal (Munroe Canal). The outlet, which would be about 8 ft in diameter fitted with high pressure sluice gates, is located at the left abutment at approximately El. 5415.

Diversion facilities during construction would consist of upstream and downstream cofferdams and cut-and-cover square conduits positioned to minimize interference with concrete placement operations. The facilities would be designed for a 1-in-25 year peak flood flow of 9500 cfs.

During the potential severe flood season from May to July at least a portion of the storage space could be kept available to provide flood protection. Specific information on the volume of large floods could not be located. The Corps of Engineers concluded in an earlier study (COE, 1981) that a 31,000 cfs peak flow having a frequency of 1-in-500 years could occur at the mouth of the canyon. A hydrograph of that flood is not included in the report.

To estimate the flow volume associated with this event, an approximate flood hydrograph was estimated using the 31,000 cfs peak flow, a 1000 cfs base flow, and a duration of 12 hours. The volume of this flood (approximately 1-in-500 years) would be about 10,000 to 15,000 af. This order-of-magnitude estimate indicates the character of floods occurring the in the canyon, i.e., floods have high peak discharges and relatively small flood volumes. Portions of floods could be stored in a canyon reservoir.

For example, 10,000 af could be completely contained within the top five feet of the reservoir plus the five feet freeboard to the spillway crest that is required by the State Engineer. A major flood disaster could be converted into a "windfall" surcharge storage benefit for the Basin. This benefit could be obtained with the Portal, Grey Mountain, and Poudre Reservoirs (in Plans A, B, C, B1, and C1) and to a lesser extent from reservoirs associated with Plans D and E, which have major storage space only on the North Fork and off-channel.

11.5.1.2 Trailhead Dam and Reservoir

Trailhead Dam (Figure 11.13), located on the Poudre about 0.7 miles upstream of the confluence with the North Fork, would provide a lower reservoir for the Greyrock Mountain Pumped-Storage Project. It would be a RCC gravity type structure.

The dam would serve the unusual function of dividing a reservoir in such a way that one part provides water supply storage (Portal Reservoir) while the other part serves as the lower reservoir for the pumped-storage project (Trailhead Reservoir). In this function, Trailhead Dam would be almost completely submerged when Portal Reservoir is full and would be a normal water retention structure when Portal Reservoir is empty.

To provide the 18,000 af needed for the pumped-storage project, Trailhead Reservoir would operate between maximum NWS El. 5630 and maximum power drawdown to El. 5565. Drawdown would be affected by flow in the river, and would normally be greatly reduced during the high flow months of May, June, and July when inflows to Trailhead Reservoir would tend to compensate for the water being circulated by the power project.

The dam would rise about 265 ft above the existing river bed to El. 5661 and have a crest length of 850 ft. The spillway would be designed to pass the PMF (158,000 cfs peak inflow) without overtopping the dam. The spillway crest would be at El. 5630, the maximum NWS.

The low-level outlet would comply with the State Engineer's requirements. A conduit fitted with high pressure sluice gates and a steel pipe fitted with a perforated sleeve valve would be provided. The intakes would be located at the upstream face of the dam at about El. 5390 (estimated 100 year sediment level). The low-level outlet would be operated to maintain normal river flows below Trailhead Dam and to control Trailhead Reservoir level in such a way that power station discharges would not be passed over the spillway under certain conditions. When the power station is operating at full load, discharge would be approximately 20,000 cfs. This discharge would have to be contained in Trailhead Reservoir when Portal Reservoir is below some critical elevation that would cause dangerous velocities in Portal Reservoir.

Diversion facilities would be as described for Portal Dam.

The existing tunnel supplying water to the North Poudre Supply Canal would be plugged to prevent flows from bypassing Trailhead Dam. The canal then would be supplied with water through a separate outlet in Portal Dam discharging to a new canal leading to the existing canal section, as shown on Figure 11.3.

11.5.1.3 Greyrock Mountain Pumped-Storage Project

The features of this potential development consist of: an upper reservoir at the Greyrock Mountain site; a lower reservoir for pumped-storage at the Trailhead Reservoir site on the mainstem Cache la Poudre; an underground powerhouse; and associated facilities such as dams, spillways, tunnels, shafts, and access roads. A development concept for this alternative, showing the upper and lower reservoirs and water conductor alignment is shown on Figure 11.3. A typical profile of the pumped-storage project is shown in Figure 11.14. The site would have sufficient reservoir storage capacity to accommodate 24,300 MWh of continuous operation (2025 MW over a 12-hour period). The site also was investigated for an energy storage capacity down to 5400 MWh of continuous operation (450 MW over a 12-

hour period). A preliminary evaluation indicated that lowest cost per kW would result from an installation totalling 1800 MW of installed capacity (21,600 MWh of continuous operation over a 12-hour period). The subsequent description relates to this installation. Preliminary basic data for the Greyrock Mountain-Trailhead Reservoir pumped-storage alternative are presented in Table 11.7.

Greyrock Mountain Reservoir, located in Section 25, T9N, R71W, would be impounded behind three RCC dams constructed to El. 7010 ft (maximum development). A general layout for these dams is provided on Figure 11.15.

The drainage area above the upper reservoir is only slightly larger than the reservoir itself. Therefore, sediment accumulation will be negligible. For planning, storage was provided in the upper reservoir for over-pumping; however, a spillway to accommodate over-pumping might be provided at some cost savings. Because of topographic conditions at the site, three dams would be required to create an upper reservoir. Two of the three dams would be about 300 ft high and the third dam would be 120 ft high. The reservoir would have a surface area of 200 acres at El. 6987 and a gross capacity of 27,500 af. The reservoir would operate between El. 6987 and El. 6875 providing an active storage volume of 18,000 af.

Trailhead Dam, located about one mile downstream from Poudre Park, would impound the lower reservoir. The dam and reservoir are described in the preceding section.

The horizontal distance between the two reservoirs would be about 6500 ft, providing a length-to-head ratio of 4.6 to 1.0 based on the gross head of about 1390 ft. Ratios in excess of 10 to 1 normally are considered to be unsuitable for pumped-storage developments. An average head of about 1330 ft would be developed. At the indicated capacity, the water conductor system would consist of two 31-ft diameter concrete lined tunnels. Steel lining would be provided for about 2400 ft at the downstream end of each tunnel. From the upper intake, the tunnels would slope at an angle of about five degrees over a distance of approximately 3500 ft. These tunnels would

TABLE 11.7

Preliminary Basic Data For The
Greyrock Mountain-Trailhead Reservoir
Pumped-Storage Alternative

	Greyrock Mountain		Trailhead Reservoir
Stream	Unnamed		Poudre
Drainage Area (mi^2)	.55		483
Development for 21,600 MWh Energy Storage			
Generating Capacity (MW)		1,800	
Energy Storage (MWh)		21,600	
Dam Height (ft)	300[1]		265
Dam Length (ft)	6,250[2]		690
Normal Pool Level (ft/msl)	6,987		5,630
Surface Area at Normal Pool (acres)	200		400
Total Storage at Normal Pool (af)	27,500		36,000
Active Storage at Normal Pool	18,000		18,000
Average Gross Head (ft)		1,385	
Horizontal Tunnel Length (ft) (2 tunnels, 31 ft diameter)		6,500	

(1) Height of highest two of three dams.
(2) Aggregate length of three dams.

intersect a vertical shaft of about 1150 ft which would intersect horizontal tunnels about 500 ft long leading to the valve chamber of the power station. The tail tunnels, each about 2000 ft long, would connect the draft tubes of the pump-turbines to the lower reservoir. For installations up to 900 MW, one power tunnel and tail tunnel could be used. From 900 MW up to a capacity of 1800 MW, two power and tail tunnels would be constructed.

Each water conductor would be protected by surge chambers located both upstream and downstream from the power station. The upstream surge chamber would be located at the vertical shaft portion of the high-head tunnel and consist of a chamber 500 ft high and 31 ft in diameter. It would be connected to the water conductor by a riser about 20 ft in diameter and 150 ft high. The downstream surge chamber also would have a diameter of 31 ft and would be 300 ft high. It would be vented to the ground surface through a shaft 850 ft high.

The power station would be located underground and consist of three chambers. The farthest upstream chamber would be the valve gallery followed by the generator hall, containing the pump/turbines and generator/motors, and the third chamber would be the transformer gallery. Ventilating shafts and an access tunnel also would be provided. Connection to the switchyard would be through a bus tunnel and shaft.

Selection of an underground power station was based on both possible space limitations and environmental aspects, primarily the latter. The only features visible to the public would be Trailhead Dam and Reservoir, an access road and parking area at an access tunnel portal, trashrack structure, and possibly a portion of the transmission facilities. Based on preliminary line-of-sight studies, the upper reservoir dam facing the river might be barely visible from relocated Route 14 at a point one mile downstream from Poudre Park. The power tunnels, powerstation, and outlet tunnels will, of course, not be visible. The outlet tunnels would be spaced apart to minimize turbulence in Trailhead Reservoir.

The power conductors would be brought to the surface in a vertical shaft from the powerstation. Designs could be devised to minimize the visual impact of surface transmission facilities.

Regarding the construction of the three upper reservoir dams, it is envisioned that all construction access would enter the upper reservoir area from the east or north and thus not be visible from Route 14.

11.5.1.4 Horsetooth Pump Station and Pipeline

The NCWCD brings Windy Gap and Colorado-Big Thompson (C-BT) water into the Basin via Horsetooth Reservoir. It may be possible to carry out an exchange between Horsetooth Reservoir waters and mainstem flows captured in Portal or Glade Reservoirs. Should it occur that an exchange is not possible, or only partially so, then Windy Gap and C-BT flows would have to be physically conveyed to one of these reservoirs. For the purposes of this Study it has been assumed, as an extreme case, that these new flows brought into the Basin would have to be conveyed physically to either Portal or Glade Reservoir from Horsetooth Reservoir.

The NWS of Horsetooth Reservoir is El. 5430. Portal Reservoir has an NWS at El. 5630, thus a pumping station and pipeline would be needed to deliver water to Portal Reservoir. Additional deliveries into the Basin are expected to average about 24,000 af/yr and maximum delivery in a single month could be in excess of 30,000 af, based on operational data provided by the NCWCD.

A pump station with a capacity of more than 300 cfs with a 78-inch diameter pipe, 29,000 ft long, has been adopted to meet the above conditions. The pump station would be connected to one of the two existing 72-inch diameter pipes which are now connected to two 72-inch diameter hollow jet valves. A potential pump station arrangement would leave the valve on the east side of the valve house in its present position. The west pipe would be extended downstream and to the west of the present valve house and would terminate at the new pump station. A bifurcation between the valve house and pump station would permit re-installation of the second valve.

The 78-inch diameter pump station discharge pipe would extend 29,000 ft, generally along the Charles Hansen Canal to Portal Dam. The discharge outlet would be located in the dam and would be equipped with an emergency closure gate.

11.5.1.5 Other Features

Route 14 would have to be relocated from the mouth of the canyon to Poudre Park. A preliminary alignment (9.5 miles in length) has been selected along the south side of the river. During the feasibility phase, detailed routing studies would be performed to determine the optimum alignment for the Route 14 relocation.

A conventional hydroelectric station could be constructed at Portal Dam This station might have a capacity of 16 MW.

Various utility and other facility relocations and land purchases would need to be made with construction of this and any other alternative.

North Poudre Tunnel No. 1 between Trailhead and Portal Reservoirs and North Poudre Tunnel No. 2 from Portal Reservoir to the east side of the mountain would have to be plugged. New facilities to supply the North Poudre Supply Canal from Portal Reservoir would be constructed.

11.5.1.6 Cost Estimate for Plan A

The structural plan elements associated with Plan A would have a construction cost of $1590 million, as presented in Table 11.8. At 8 percent interest rate and 30-year bond term, the total capital requirement is estimated to be $2200 million.

11.5.2 Plan B: Grey Mountain Reservoir; Trailhead Reservoir; and Greyrock Mountain Pumped-Storage Project (Figure 11.4)

Plan B essentially is a variation of Plan A with Grey Mountain Dam replacing Portal Dam. The maximum NWS would be at El. 5630 and total storage capacity would be 156,000 af.

11.5.2.1 Grey Mountain Dam and Reservoir

Grey Mountain Dam on the Poudre would be approximately 2 miles below the confluence with the North Fork. The top of the dam at El. 5660 would be 390 ft above the present river bed and would have a crest length of 1500 ft.

TABLE 11.8

Cost Estimates - Plan A
Structural Plan Elements

	Cost[5] ($ Million)
Portal Dam and Reservoir	462
Trailhead Dam[1]	52
Greyrock Mountain Pumped-Storage[2]	1017
Route 14 Relocation	14
Other Relocations and Land[3]	7
Horsetooth Pump Station and Pipeline	31
Conventional Hydroplant at Portal	8
Construction Cost	1591 ($1.6 billion)
Interest During Construction	382
Total Investment Cost	1973
Bond Reserve Fund	195
Bond Issuance Cost	30
Total Capital Requirement	2198 ($2.2 billion)
Annual Cost	
Debt Service	195
O, M & R	16[4]
Interest on Reserve Fund	(16)
Total Annual Cost	195 ($190 million)

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(1) To isolate a lower reservoir for pumped-storage.
(2) Includes upper reservoir and power facilities but not the lower reservoir. Transmission is excluded.
(3) Land and rights-of-way purchase and utility relocations.
(4) Excludes purchasing pumping energy for the pumped-storage project.
(5) Costs represent January, 1986 price levels and exclude transmission and mitigation.

Note: Construction costs include contingency and engineering and administration costs.

Active storage capacity would be 156,000 af and the expected firm yield would be 29,000 af per year. It was assumed that Grey Mountain Dam would be a conventional concrete gravity dam.

The spillway, low-level outlets, and diversion facilities would be similar to those described for Portal Dam except that the low-level outlets would be at about El. 5370. The general layout of potential facilities at the Grey Mountain site is provided on Figure 11.16.

11.5.5.2 Trailhead Dam and Reservoir

Trailhead Dam and Reservoir would be as described for Plan A.

11.5.2.3 Greyrock Mountain Pumped-Storage Project

The hydroelectric power project would be as described for Plan A.

11.5.2.4 Other Features

Route 14 would have to be relocated from a point near the mouth of the canyon. A preliminary alignment, 7.2 miles long, has been assumed along the south side of the river, as shown on Figure 11.4.

The Horsetooth Pump Station was assumed to be in Plan B because Grey Mountain Reservoir has sufficient capacity for the 124,000 af of storage needed for Windy Gap and Big Thompson diversions. Some additional yield (5000 af per year) would be obtained through regulation of a portion of native storable flows.

North Poudre Tunnel No. 1 would be plugged and new facilities constructed to supply the North Poudre Supply Canal from Grey Mountain Reservoir.

A conventional hydroelectric station could be considered for construction at Grey Mountain Dam. This station could have a capacity of 14 MW.

11.5.2.5 Cost Estimate for Plan B

The structural plan elements associated with Plan B would have a construction cost of $1330 million, as presented in Table 11.9. At 8 percent interest rate and 30-year bond term, the total capital requirement is estimated to be $1850 million.

11.5.3 Plan C: Poudre Reservoir - Glade Tunnel - Glade Reservoir - Greyrock Mountain Pumped-Storage Project (Figure 11.5)

In this plan, Glade Reservoir is the principal storage facility with Poudre Reservoir on the mainstem serving as the lower reservoir for the hydroelectric project. Poudre Reservoir also would provide some storage for water supply. A total of 274,000 af of storage would be provided and the expected yield would be 49,000 af per year.

11.5.3.1 Poudre Dam and Reservoir

Poudre Dam would be located on the Poudre about 0.3 miles downstream from the confluence with the North Fork. Poudre Reservoir serves four functions under Plan C which affect the selected maximum NWS.

1. Serves as lower reservoir for the Greyrock Pumped-Storage Project.
2. Provides adequate water surface elevation for discharge into Glade Reservoir.
3. Provides temporary storage for flood flows that exceed the capacity of Glade Tunnel.
4. Supplements Glade storage capacity.

The first function imposes limitations on reservoir operation. For the purposes of this Study, gross head variation on the pump-turbines has been kept within 20 percent of minimum gross head and the total lower reservoir (Poudre) fluctuation was limited to 80 ft.

The second function requires that Poudre Reservoir elevations be maintained sufficiently high to permit discharge into Glade while maintaining sufficient storage capacity in Glade.

TABLE 11.9

Cost Estimates - Plan B
Structural Plan Elements

	Cost[5] ($ Million)
Grey Mountain Dam and Reservoir	210
Trailhead Dam[1]	52
Greyrock Mountain Pumped-Storage[2]	1016
Route 14 Relocation	11
Horsetooth Pump Station and Pipeline	31
Other Relocations and Land[3]	8
Conventional Hydroplant	8
Construction Cost	1336 ($1.3 billion)
Interest During Construction	321
Total Investment Cost	1657
Bond Reserve Fund	164
Bond Issuance Cost	25
Total Capital Requirement	1846 ($1.8 billion)
Annual Cost	
Debt Service	164
O, M & R	13[4]
Interest on Reserve Fund	(13)
Total Annual Cost	164 ($160 million)

(1) To isolate a lower reservoir for pumped-storage.
(2) Includes upper reservoir and power facilities but not the lower reservoir. Transmission is excluded.
(3) Land and rights-of-way purchase and utility relocations.
(4) Excludes purchasing pumping energy for the pumped-storage project.
(5) Costs represent January, 1986 price levels and exclude transmission and mitigation.

Note: Construction costs include contingency and engineering and administration costs.

The third function requires that space be made available in Poudre Reservoir during high flow months to absorb major flood flow volumes until the Glade Tunnel could effect discharge into Glade Reservoir.

The fourth function, providing supplemental storage capacity subject to the limitations of the first and third functions, could be applied to supplement Glade storage.

The maximum NWS for Poudre Reservoir was selected to be El. 5590. Combined active storage (Poudre and Glade), excluding dead storage and flood control storage, would be 274,000 af. Pump-turbine criteria are satisfied. The top of Poudre Dam would be at El. 5626 with a crest length of 1300 ft. Its height above the river bed would be 290 ft. Poudre Dam would be an RCC structure.

A general layout of facilities at the Poudre site is provided on Figure 11.17. The spillway would be ungated and have its crest at El. 5590, five feet above maximum NWS. The PMF, with a maximum inflow of 327,000 cfs would be discharged without overtopping the dam.

The low-level outlet works would be as described for Portal Dam except that they would be located at El. 5440. The low-level outlet, in addition to maintaining downstream flows, would serve to control the Poudre Reservoir level so that power station discharges (approximately 20,000 cfs at full load) are contained by the reservoir, thus precluding dangerous flood conditions downstream.

Diversion facilities would be as described for Portal Dam.

Poudre Reservoir would have a storage capacity of 46,000 af for downstream uses in addition to providing 18,000 af of storage necessary for the Greyrock pumped-storage Project. The low-level outlet at El. 5440 would provide approximately 10,000 af of space for sedimentation. A conservation storage space between the low-level outlet (El. 5440) and minimum power pool

El. 5510 raises the power space and storage space to minimize water surface fluctuation. The volume of the conservation storage space is 23,000 af. Its use would initially curtail power output and finally would cause the generating units to be shut down. This would occur because of operating limitations on the generating units in terms of maximum head.

The pumped-storage project requires 18,000 af of storage, which can be located anywhere between El. 5510 and 5590. When the power pool is between El. 5510 and El. 5536, no water would be held for downstream use other than the 23,000 af held for emergencies. Maximum power pool elevation variation (26 ft) would occur under these conditions. If, however, the conservation water surface is above El. 5536, the power pool fluctuation would be less.

If, instead of the above arrangement, the minimum power pool elevation was made to coincide with the low-level outlet, the reservoir water surface would have to fluctuate 60 ft instead of a maximum of 26 ft. Under these conditions, storage space for downstream use would be limited to 16,000 af instead of 46,000 af because of pump-turbine head variation restrictions.

11.5.3.2 Glade Dam, Reservoir, and Tunnel

Glade Dam is an off-channel facility located about 1-1/2 miles north of Ted's Place in the vicinity of Hook and Moore Glade. For the purposes of this study, an embankment-type dam has been assumed, as shown on Figure 11.18. The top of dam would be at El. 5595 and have a crest length of 4,800 ft. With a maximum NWS at El. 5575, live storage would be about 228,000 af. This storage would be provided above the new outlet to the Munroe Canal system. This new outlet would be needed if Glade Dam were constructed.

A chute type spillway (crest elevation 5580) with a stilling basin would be provided to accommodate the PMF with a peak inflow of 83,000 cfs without overtopping the dam.

The low-level outlet would make use of the diversion tunnel described below. An intake tower fitted with high pressure sluice gates would be incorporated into the diversion facility design. The capacity would be sufficient to permit five feet of draw down from maximum NWS in five days. The State Engineer's requirement regarding mean annual peak discharge capability would be met by the Poudre Dam low-level outlet on the mainstem.

Diversion facilities would consist of an upstream cofferdam and an 18 ft diameter concrete lined tunnel designed for a 1-in-25 year flood of 4600 cfs.

Glade Tunnel would conduct mainstem and North Fork flows from Poudre Reservoir to Glade Reservoir. Tunnel length would be about 10,000 ft. A diameter of 8.5 ft has been used. There would be sufficient storage in Poudre Reservoir to absorb flood flows for discharge through the Glade Tunnel. The intake at Poudre Reservoir would be at approximately El. 5535 and would be fitted with high pressure sluice gates.

11.5.3.3 Greyrock Mountain Pumped-Storage Project

The pumped-storage project would be essentially as described in Plan A except that Poudre Reservoir replaces Trailhead Reservoir. The upper reservoir would provide 18,000 af of active storage equivalent to 22,300 MWh of energy storage. This is sufficient to operate the 1860 MW of generating capacity for 12 hours. Output under Plan C is slightly higher than for Plans A and B due to a small increase in average operating head.

5.3.4 Other Features

Portions of Routes 14 and 287 will have to be relocated. Preliminary alignments have been assumed. The relocation of Route 14 would be about 6 miles long and Route 287 about 8 miles long.

North Poudre Tunnel No. 1 would have to be plugged and facilities provided to the supply the Munroe Canal (North Poudre Supply Canal) from Glade Reservoir, as shown on Figure 11.5.

The Horsetooth Pumping Station development as described in Plan A would be included in Plan C. The pipeline would go to Glade Reservoir, a distance of approximately 29,000 ft.

Conventional hydroelectric stations of 9 MW and 2 MW capacity could be considered for construction at Poudre and Glade Dams, respectively.

11.3.5 Cost Estimate for Plan C

The structural plan elements associated with Plan C would have a construction cost of $1510 million, as presented in Table 11.10. At 8 percent interest rate and 30-year bond term, the total capital requirement is estimated to be $2100 million.

11.5.4 Plan D: Footbridge Reservoir; Bypass Tunnel; New Seaman Reservoir; Glade Tunnel; Glade Reservoir; and Greyrock Mountain Pumped-Storage Project (Figure 11.6)

This plan features a minimum diversion facility on the mainstem that would divert flows for storage in New Seaman and Glade Reservoirs. New Seaman Reservoir also would serve as the lower reservoir for the pumped-storage project. Footbridge Reservoir would have essentially no storage capacity and consequently downstream areas could not be protected from major mainstem floods. New Seaman Reservoir could be operated to provide protection against major North Fork floods. Total storage capacity would be 274,000 af. A firm yield of 49,000 af per year could be developed.

11.5.4.1 Footbridge Dam and Reservoir

The function of Footbridge Project would be to divert mainstem flows into New Seaman Reservoir. Footbridge Reservoir would have no significant storage capacity.

TABLE 11.10

Cost Estimates - Plan C
Structural Plan Elements

	Cost[5] ($ Million)
Poudre Dam and Reservoir[1]	67
Glade Tunnel	21
Glade Dam and Reservoir	301
Greyrock Mountain Pumped-Storage[2]	1050
Route 14 and Route 287 Relocations	17
Horsetooth Pump Station and Pipeline	31
Conventional Hydro at Glade	2
Conventional Hydro at Poudre	5
Other Relocations and Land[3]	17
Construction Cost	1511 ($1.5 billion)
Interest During Construction	363
Total Investment Cost	1874
Bond Reserve Fund	185
Bond Issuance Cost	28
Total Capital Requirement	2087 ($2.1 billion)
Annual Cost	
Debt Service	185
O, M & R	15[4]
Interest on Reserve Fund	(15)
Total Annual Cost	185 ($190 million)

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(1) Will serve both for water storage and for pumped-storage operation.
(2) Includes upper reservoir and power facilities but not the lower reservoir. Transmission is excluded.
(3) Land and rights-of-way purchase and utility relocations.
(4) Excludes purchasing pumping energy for the pumped-storage project.
(5) Costs represent January, 1986 price levels and exclude transmission and mitigation.

Note: Construction costs include contingency and engineering and administration costs.

Footbridge Dam (Figure 11.19) would be located on the Poudre 2.6 miles upstream of its confluence with the North Fork. For this Study, the maximum NWS has been set at El. 5630 to achieve maximum diversion capability to New Seaman Reservoir while satisfying the flood protection criteria established for Poudre Park. The top of dam would be at El. 5661, 130 ft above the present river bed. The dam would be an RCC structure. An ungated spillway crest would be at maximum NWS El. 5630 designed to pass the PMF (158,000 cfs peak inflow) without overtopping the dam. At El. 5630, the reservoir has a total storage volume of about 1800 af.

The low-level outlet works would not be provided in Footbridge Dam because this structure is not a storage facility. Diversion facilities could be used to dewater the reservoir during an emergency.

Diversion facilities would consist of upstream and downstream cofferdams and two 17-ft square conduits designed to pass a 1-in-25 year flood of 9,500 cfs.

11.5.4.2 Bypass Tunnel

A concrete lined tunnel 11 ft in diameter and approximately 9,200 ft long would convey mainstem flows to New Seaman Reservoir. Control gates would be provided at the intake. River flows exceeding this capacity would be passed over the spillway and either diverted downstream or discharged past the Greeley gage.

11.5.4.3 New Seaman Dam and Reservoir

New Seaman Reservoir would serve the same four functions as Poudre Reservoir in Plan C and the same operating restrictions would apply. New Seaman Dam would be located on the North Fork about 500 feet upstream from the mainstem confluence. Facilities at the New Seaman site are shown on Figure 11.20.

A maximum NWS El. 5600 at New Seaman was selected for tnis Study. The combined storage of New Seaman and Glade excluding dead storage and the 6000 af of capacity in the existing Seaman Reservoir would be 274,000 af. Pump-turbine criteria are satisfied. The top of New Seaman Dam would be at El. 5636 with a crest length of 1200 ft and a height above the river bed of 250 ft. New Seaman Dam would be a RCC structure. The conservation level would be at El. 5530. The spillway would be capable of passing the PMF of 222,000 cfs without overtopping the dam.

Low-level outlet works would be located at about El. 5470, the 100-year sediment deposition level. The low-level outlet would consist of a conduit fitted with high pressure sluice gates for higher discharges and a steel pipe fitted with a perforated sleeve valve for lower discharges. The intakes would be located in the upstream face of the dam and positioned at the abutment to minimize interference with concrete placement operations. The outlet works would be used to maintain downstream flows and to control New Seaman Reservoir levels so that power station discharges (approximately 20,000 cfs) are contained within the reservoir, thus precluding dangerous flood conditions downstream.

Diversion facilities would consist of upstream and downstream cofferdams and two 15-ft square reinforced concrete conduits designed to pass a 1-in-25 year flood of 4700 cfs.

11.5.4.4 Glade Dam, Reservoir, and Tunnel

These structures would be essentially as described for Plan C. The maximum NWS for Glade Reservoir would be at El. 5584 and provide live storage of 254,000 af above the new outlet works to the Munroe Canal.

11.5.4.5 Greyrock Mountain Pumped-Storage Project

The pumped-storage project would be essentially as described in Plan A except that New Seaman Reservoir on the North Fork would serve as the lower reservoir rather than Trailhead Reservoir on the Mainstem.

The horizontal distance between the upper and lower reservoir would increase to approximately 15,000 ft and the average gross head would be about 1380 ft. The length-to-head ratio is 11.9 to 1.0 which is slightly more than the normally accepted criterion for pumped-storage site selection.

The upper reservoir would have adequate storage to provide 12 hours of continuous output of the 1860 MW powerstation. Energy storage in the upper reservoir would be 22,300 MW.

Project alignment to New Seaman Reservoir would not be visible from the Mainstem canyon (Route 14) except for the upper reservoir dam, as described for Plan A.

The canyon of the North Fork is wider than that of the mainstem and so there is no space limitation for a surface powerhouse. However, for the purposes of this study and for similar environmental considerations as described under Plan A, an underground development has been assumed.

11.5.4.6 Other Features

The Horsetooth Pump Station development, as described in Plan A, would be included in Plan D. The pipeline would go to Glade Reservoir, a distance of approximately 29,000 ft.

Portions of Routes 14 and 287 would have to be relocated. New construction for Route 14 would be 3 miles long, and for Route 287, 8 miles long.

North Poudre Tunnel No. 1 would be plugged and facilities provided to supply the North Poudre Supply Canal from Glade Reservoir.

Conventional hydroelectric installations of 3 MW and 2 MW could be considered for construction at New Seaman Dam and Glade Dam, respectively.

11.5.4.7 Cost Estimate for Plan D

The structural plan elements associated with Plan D would have a construction cost of $1650 million, as presented in Table 11.11. At 8 percent interest rate and 30-year bond term, the total capital requirement is estimated to be $2270 million.

11.5.5 Plan E: Trailhead Reservoir; Existing North Poudre Supply Facilities; Glade Reservoir; and New Halligan Reservoir (Figure 11.7)

Plan E is intended to test the feasibility of adopting existing North Poudre facilities to convey mainstem flows to Glade Reservoir. It was assumed that the Greyrock Mountain Pumped-Storage project would not be built initially. New Halligan Dam would be provided to regulate North Fork flows.

The key to this plan is the discharge capacity of the North Poudre facilities. The difference in Trailhead and Glade reservoir elevations at any point in time determines discharge capacity. This constantly varying capacity, in turn, determines the portion of available flows that can be diverted into Glade Reservoir.

The existing North Poudre tunnels have 8 ft diameter, concrete lined horseshoe sections that have been designed as free-flowing tunnels (no pressure). A 7.5 ft diameter steel conductor, 18,500 ft long has been assumed for tunnel lining and to replace open canal sections to accommodate pressure flow. The average capacity of this conductor would be 450 cfs, depending primarily on the level of Glade Reservoir, and would capture about half of the long-term average available flow of 21,000 af per year on the Mainstem. The storage requirement at Glade would be about 60,000 af providing a yield of 10,000 af per year.

TABLE 11.11

Cost Estimates - Plan D
Structural Plan Elements

	Cost[5] ($ Million)
New Seaman Dam and Reservoir[1]	55
Footbridge Dam	18
Bypass Tunnel	24
Glade Dam and Reservoir	312
Glade Tunnel	21
Route 14 and Route 287 Relocations	12
Horsetooth Pump Station and Pipeline	31
Greyrock Mountain Pumped-Storage[2]	1152
Conventional Hydro at Glade	2
Conventional Hydro at New Seaman	3
Other Relocations and Land[3]	16
Construction Cost	1646 ($1.6 billion)
Interest During Construction	395
Total Investment Cost	2041
Bond Reserve Fund	202
Bond Issuance Cost	31
Total Capital Requirement	2274 ($2.3 billion)
Annual Cost	
Debt Service	202
O, M & R	16[4]
Interest on Reserve Fund	(16)
Total Annual Cost	202 ($200 million)

(1)Will serve both for water storage and for pumped-storage operation.
(2)Includes upper reservoir and power facilities but not the lower reservoir. Transmission is excluded.
(3)Land and rights-of-way purchase and utility relocations.
(4)Excludes purchasing pumping energy for the pumped-storage project.
(5)Costs represent January, 1986 price levels and exclude transmission and mitigation.
Note: Construction costs include contingency and engineering and administration costs.

11.5.5.1 Glade Reservoir

The maximum NWS would be at El. 5470 in order to provide 60,000 af of storage needed to regulate diverted available flow or meet a portion of the NCWCD storage need. This storage would be provided above the new outlet works to the Munroe Canal. Glade Dam would be essentially as described in Plan C.

11.5.5.2 Trailhead Reservoir

The maximum NWS would be set at El. 5500 to provide the hydraulic head needed to maximize the capacity of the water conductors from Trailhead Reservoir to Glade Reservoir. The dam would be as described in Plan A.

11.5.5.3 New Halligan Dam and Reservoir

New Halligan Dam (Figure 11.21) would be an RCC gravity type structure 230 ft high and located approximately 4000 ft downstream from the existing dam. The top of dam would be at El. 6484 and the spillway crest at El. 6453. Maximum NWS would be 5 ft below the spillway crest at El. 6448. Live storage above the low-level outlet is 53,000 af and the yield would be about 7000 af per year. The live storage volume excludes 6000 af of storage in the existing Halligan Reservoir.

The spillway would be designed to pass the PMF of 179,000 cfs without overtopping the dam.

The low-level outlets located at about El. 6350 would consist of a single barrel concrete cut and cover conduit fitted with high pressure sluice gates and steel pipe with a perforated sleeve valve for control of lower flow releases. The intakes would be located at the upstream face of the dam at a level above an estimated 100-year sediment deposition level.

Diversion facilities would consist of an upstream and downstream cofferdam and two 13-ft square cut-and-cover concrete conduits with a capacity of 3,700 cfs (1-in-25-year flood).

11.5.5.4 Other Features

Horsetooth Pump Station development as described in Plan A would be included in Plan E. The pipeline would go to Glade Reservoir, a distance of approximately 29,000 ft.

Portions of Routes 14 and 287 would have to be relocated. New construction for Route 14 would be 6 miles long and for Route 287 6.7 miles long.

North Poudre Tunnel No. 1 will have to be plugged and new facilities provided to supply water to the North Poudre Supply Canal.

Conventional hydroelectric installations having capacities of 1 MW and 2 MW could be constructed at Glade and New Halligan, respectively.

11.5.5.5 Cost Estimate for Plan E

The structural plan elements associated with Plan E would have a construction cost of $280 million, as presented in Table 11.12. At 8 percent interest rate and 30-year bond term, the total capital requirement is estimated to be $370 million.

11.5.6 Plan B1: Grey Mountain Reservoir; Glade Tunnel; Glade Reservoir; and Greyrock Mountain Pumped-Storage Project (Figure 11.8)

Plan B1 provides storage on the mainstem for pumped-storage operation and water supply with the major water supply storage provided off-channel at Glade. Total active storage would be 274,000 af and the firm yield from that storage would be 49,000 af per year.

TABLE 11.12

Cost Estimates - Plan E
Structural Plan Elements

	Cost[2] ($ Million)
Trailhead Dam and Reservoir	15
Glade Dam and Reservoir	153
Route 14 and Route 287 Relocations	16
Upgrade North Poudre Conveyance	20
Horsetooth Pump Station and Pipeline	31
New Halligan Dam and Reservoir	30
Other Relocations and Land[1]	13
Conventional Hydro at Glade	2
Conventional Hydro at Halligan	3
Construction Cost	283 ($280 million)
Interest During Construction	46
Total Investment Cost	329
Bond Reserve Fund	32
Bond Issuance Cost	5
Total Capital Requirement	366 ($370 million)
Annual Cost	
Debt Service	32
O, M & R	4
Interest on Reserve Fund	(3)
Total Annual Cost	33 ($33 million)

(1) Land and rights-of-way purchase and utility relocations.
(2) Costs represent January, 1986 price levels.
Note: Construction costs include contingency and engineering and administration costs.

11.5.6.1 Grey Mountain Dam and Reservoir

The Grey Mountain Dam and Reservoir would be essentially as described for Plan B. The top of the dam would be at El. 5621 and would be 350 ft above the present river bed. It was assumed that Grey Mountain Dam at this elevation would be an RCC structure. Future studies may show that a conventional concrete dam or an arch dam would be better suited to this particular site.

The spillway, low-level outlets, and diversion facilities would be similar to those described for Portal Dam, except that the low-level outlets would be at about El. 5370. Active storage capacity would be 54,000 af. The maximum NWS would be at El. 5585.

11.5.6.2 Glade Dam, Reservoir, and Tunnel

These structures would be essentially as described for Plan C. The maximum NWS for Glade Reservoir would be at El. 5570 and the live storage capacity would be 220,000 af.

11.5.6.3 Greyrock Mountain Pumped-Storage Project

The pumped-storage project would be essentially as described for Plans A and B except that Trailhead Reservoir would not be provided. Generating capacity would be 1800 MW and the 12-hour continuous output would be 21,600 MWh from an active storage for power of 18,000 af.

11.5.6.4 Other Features

Portions of Routes 14 and 287 would have to be relocated. Preliminary alignments have been assumed. The relocation of Route 14 would be about 7 miles long and Rout 287 about 8 miles long.

North Poudre Tunnel No. 1 would have to be plugged and facilities provided to supply the Munroe Canal (North Poudre Supply Canal) from Glade Reservoir.

The Horsetooth Pumping Station development as described in Plan A would be included in Plan C. The pipeline would go to Glade Reservoir, a distance of approximately 29,000 ft.

Conventional hydroelectric stations of 14 MW and 2 MW capacity could be considered for construction at Grey Mountain and Glade Dams, respectively.

11.6.5 Cost Estimate for Plan B1

The structural plan elements associated with Plan B1 would have a construction cost of $1530 million, as presented in Table 11.13. At 8 percent interest rate and 30-year bond term, the total capital requirement is estimated to be $2120 million.

11.5.7 Plan C1: Poudre Reservoir; Glade Tunnel; Glade Reservoir; Greyrock Mountain Pumped-Storage Project (450 MW)

Plan C1 is a reduced version of Plan C involving the same basic plan elements but with the elements scaled down to provide about one-half the active storage capacity for water supply and one-quarter of the pumped-storage generating capacity provided with Plans A through D and Plan B1. Under Plan C1, 144,000 af of active storage would be provided either for regulating storable native flows or for additional Windy Gap and C-BT imports, but not both. A new firm yield of about 24,000 af/yr would be developed. Pumped-storage capacity and energy production could be marketed locally. Demand forecasts developed for Task 7 (Harza, 1986) indicate that utilities in the region will have a need for additional peaking capacity of about 350 MW by the year 2000 and 950 MW by 2020.

TABLE 11.13

Cost Estimates - Plan B1
Structural Plan Elements

	Cost[5] ($ Million)
Grey Mountain Dam and Reservoir[1]	99
Glade Tunnel	21
Glade Dam and Reservoir	288
Greyrock Mountain Pumped-Storage[2]	1050
Route 14 and Route 287 Relocations	19
Horsetooth Pump Station and Pipeline	31
Conventional Hydro at Glade	2
Conventional Hydro at Grey Mountain	5
Other Relocations and Land[3]	17
Construction Cost	1532 ($1.5 billion)
Interest During Construction	368
Total Investment Cost	1900
Bond Reserve Fund	188
Bond Issuance Cost	28
Total Capital Requirement	2116 ($2.1 billion)
Annual Cost	
Debt Service	188[4]
O, M & R	16
Interest on Reserve Fund	(15)
Total Annual Cost	189 ($190 million)

(1) Will serve both for water storage and for pumped-storage operation.
(2) Includes upper reservoir and power facilities but not the lower reservoir. Transmission is excluded.
(3) Land and rights-of-way purchase and utility relocations.
(4) Excludes purchasing pumping energy for the pumped-storage project.
(5) Costs represent January, 1986 price levels and exclude transmission and mitigation.

Note: Construction costs include contingency and engineering and administration costs.

11.5.7.1 Poudre Dam and Reservoir

The Poudre Dam and Reservoir would be essentially as described for Plan C except that the maximum NWS would be at El. 5527. Active storage would be 30,000 af for water supply and 5000 af for pumped-storage operation.

11.5.7.2 Glade Dam, Reservoir, and Tunnel

These structures would be essentially the same as described for Plan C. The maximum NWS for Glade Reservoir would be at El. 5512 and the active storage capacity would be 114,000 af.

11.5.7.3 Greyrock Mountain Pumped-Storage Project

The pumped-storage project would be essentially as described in Plan A except only 450 MW of installed capacity would be provided and Trailhead Dam would not be needed. The average gross head would be 1390 ft. The upper reservoir would provide 4500 af of active storage equivalent to 5400 MWh of energy storage. This is sufficient to operate the 450 MW installation for 12 hours. The dams needed to create storage in the Greyrock Mountain upper reservoir would be about 100 ft lower than those the full pumped-storage development of 1800 MW (a one-third reduction in maximum dam height).

11.5.7.4 Other Features

Portions of Routes 14 and 287 would have to be relocated. Preliminary alignments have been selected. The relocation of Route 14 would be about 6 miles long and Route 287 about 8 miles long.

North Poudre Tunnel No. 1 would have to be plugged and facilities provided to supply the Munroe Canal (North Poudre Supply Canal) from Glade Reservoir.

The Horsetooth Pump Station and Pipeline, as described previously, may be needed in Plan C1 if Windy Gap and additional C-BT are stored in Glade Reservoir. Cost estimates for Plan C1 do not include this component.

Conventional hydroelectric stations of 9 MW and 2 MW capacity could be considered for construction at Poudre and Glade Dams, respectively.

11.5.7.5 Cost Estimates for Plan C1

The structural plan elements associated with Plan C1 would have a construction cost of $630 million, as presented in Table 11.14. At 8 percent interest rate and 30-year bond term, the total capital requirement is estimated to be $870 million.

11.5.8 Pump-Back Project From Cache la Poudre River Near Greeley

An estimate has been made of storable flows that occur from return flows in the lower Portion of the Basin for which there is little downstream demand. The 30-year study period from 1951 to 1980 was used for the analysis. It has been assumed that the storable flow would be zero for any month that South Platte calls were on for 90 percent or more of that month.

It is estimated that from 30,000 af to 50,000 af per year are available for storage under present conditions.

Two basic options exist for the use of these flows in the Basin.

1. Flows could be captured in some downstream facility such as the proposed Narrows, Hardin, or Beebe Draw Projects and exchanged.
2. Flows could be pumped back upstream for re-use in the Basin.

As a potential structural element in this Study, Option 2 is described herein. Average monthly flows appear to be fairly uniform, ranging from about 3000 af to almost 6000 af.

For the purposes of this Study, a 100 cfs pumping station capacity and a 60-inch diameter pipeline have been assumed. Pump-back could be all the way to a new storage facility such as Glade Reservoir, to an upstream location on the Poudre, or intermediate points such as the major canals. In

TABLE 11.14

Cost Estimates - Plan C1
Structural Plan Elements

	Cost[5] ($ Million)
Poudre Dam and Reservoir[1]	32
Glade Tunnel	21
Glade Dam and Reservoir	202
Greyrock Mountain Pumped-Storage[2]	335
Route 14 and Route 287 Relocations	17
Conventional Hydro at Glade	2
Conventional Hydro at Poudre	5
Other Relocations and Land[3]	17
Construction Cost	631 ($630 million)
Interest During Construction	150
Total Investment Cost	781
Bond Reserve Fund	77
Bond Issuance Cost	12
Total Capital Requirement	870 ($870 million)
Annual Cost	
Debt Service	77
O, M & R	12[4]
Interest on Reserve Fund	(6)
Total Annual Cost	83

(1) Will serve both for water storage and for pumped-storage operation.
(2) Includes upper reservoir and power facilities but not the lower reservoir. Transmission is excluded.
(3) Land and rights-of-way purchase and utility relocations.
(4) Excludes purchasing pumping energy for the pumped-storage project.
(5) Costs represent January, 1986 price levels and exclude transmission and mitigation.

Note: Construction costs include contingency and engineering and administration costs.

this latter case, pumping would only occur during months of irrigation demand. In the former case, the lower Basin storable flows would require much less storage space than the upper Basin storable flows and the yields from each are similar. It should be noted, however, that if irrigated acreage continues to decrease, lower Basin storable flows will decrease. Extensive use of sprinkler irrigation would have a similar effect because efficiency gains would reduce return flows.

An "interceptor" pipeline from Greeley to the Larimer and Weld Canal near Pierce along the existing Union Pacific Railroad line would have a construction cost of about $25 million. A pipeline along the Colorado and Southern Railroad line from Greeley to LaPorte would cost about $60 million. Pump-back of 24,000 af per year would cost about $130/af depending on the arrangement and assuming pumping each year. If the pipeline were operated as a drought protection facility (i.e., in frequent operation) the cost would be considerably higher, perhaps $700/af or more.

If water were pumped into a new storage reservoir such as Glade and stored for later use, the size of Glade Reservoir would need to be increased over that described for Plans C, D and E and the pump station costs would increase because of the higher pumping lift required to place water in storage. The water level in Glade Reservoir normally would be about 500 ft above the river level at LaPorte. The pipeline length would increase by 5 miles. Cost estimates for this arrangement were not prepared.

11.5.9 Raising Horsetooth Dam and Reservoir

The existing Horsetooth Reservoir is a terminal storage facility for delivery of C-BT water into the Cache la Poudre Basin. At NWS El. 5430, Horsetooth Reservoir has a gross storage volume of 148,000 af. The reservoir is created by four dams -- the main Horsetooth Dam and three saddle dams, Soldier Canyon, Dixon Canyon, and Spring Canyon dams. Advisory Committee inputs to the Study suggested the possibility of raising Horsetooth Reservoir.

A 32-foot raise of the NWS to El. 5462 would provide an additional 65,000 af of active storage which would cover the Windy Gap storage requirement. A 45-foot raise of the NWS to El. 5475 would provide an additional 124,000 af of active storage required for additional Windy Gap and C-BT water. Preliminary studies by the USBR (1977) indicate that the maximum practical height to which the Horsetooth dams could be raised is approximately 20 ft. This would provide an additional 32,000 af of storage capacity which is only one-half of the storage requirement for Windy Gap.

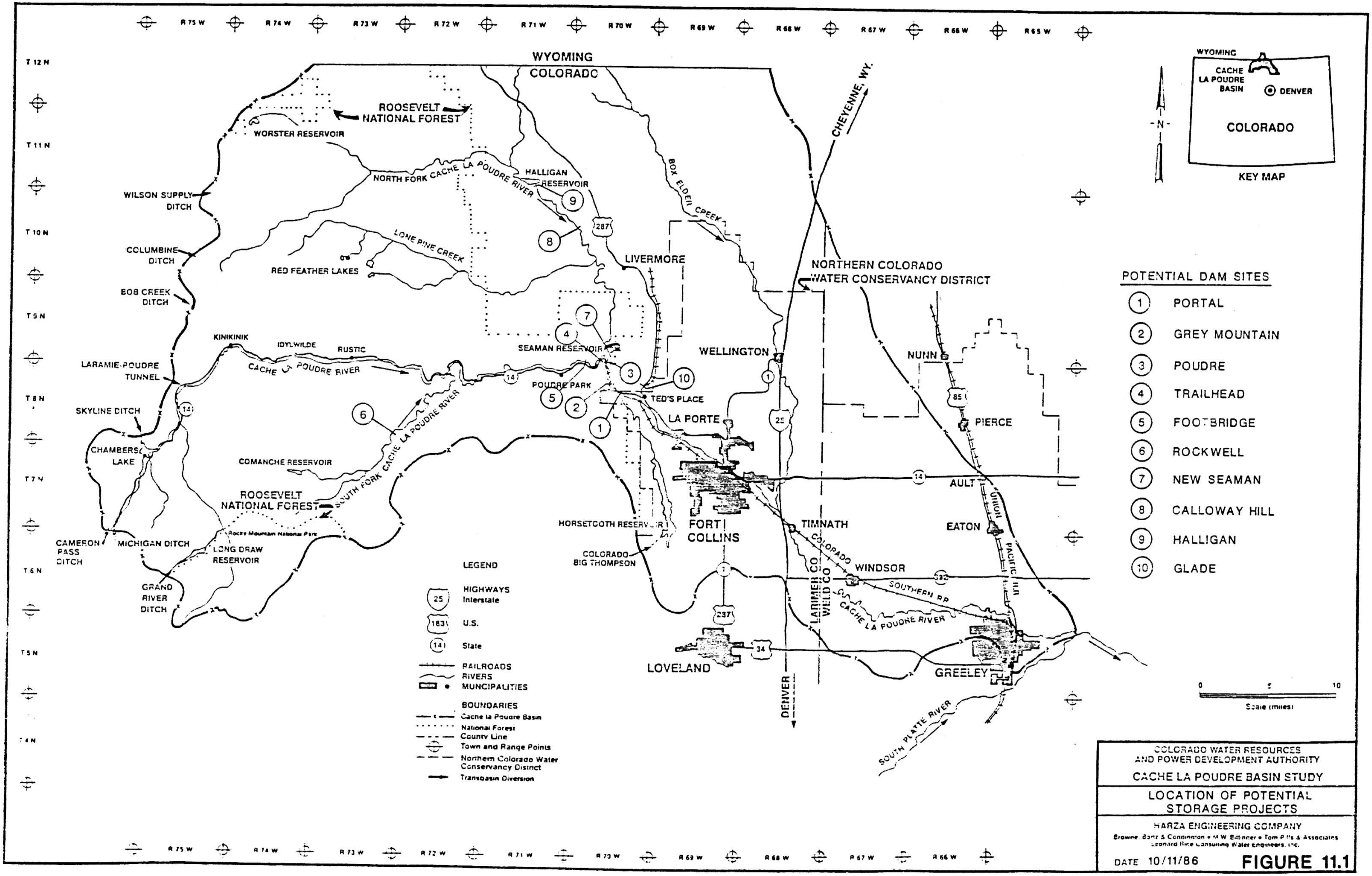
There are three factors affecting the technical feasibility of raising Horsetooth Reservoir which have led to eliminating this option from further consideration in the Study:

- Raising the NWS of Horsetooth Reservoir could affect the conveyance capacity of the Horsetooth supply channel from Flatiron Reservoir.

- Four embankment dams would need to be raised. The suitability of these dams for raising is uncertain. Also, the crest of the northernmost saddle dam (Soldier Canyon) is near its topographic limit.

- A raise to NWS El. 5475 would inundate portions of two communities at the southern end of the reservoir and portions of Lory State Park. A raise to NWS El. 5462 would reduce but not eliminate impacts to the two communities and Lory State Park.

A four-foot raise of dams forming the existing Horsetooth Reservoir is planned to bring the structures into compliance with safety requirements. This action will allow recovery of about 8000 af of storage capacity currently not being used because of restrictions on the maximum NWS of the reservoir. The raise will not affect conveyance facilities.



COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY

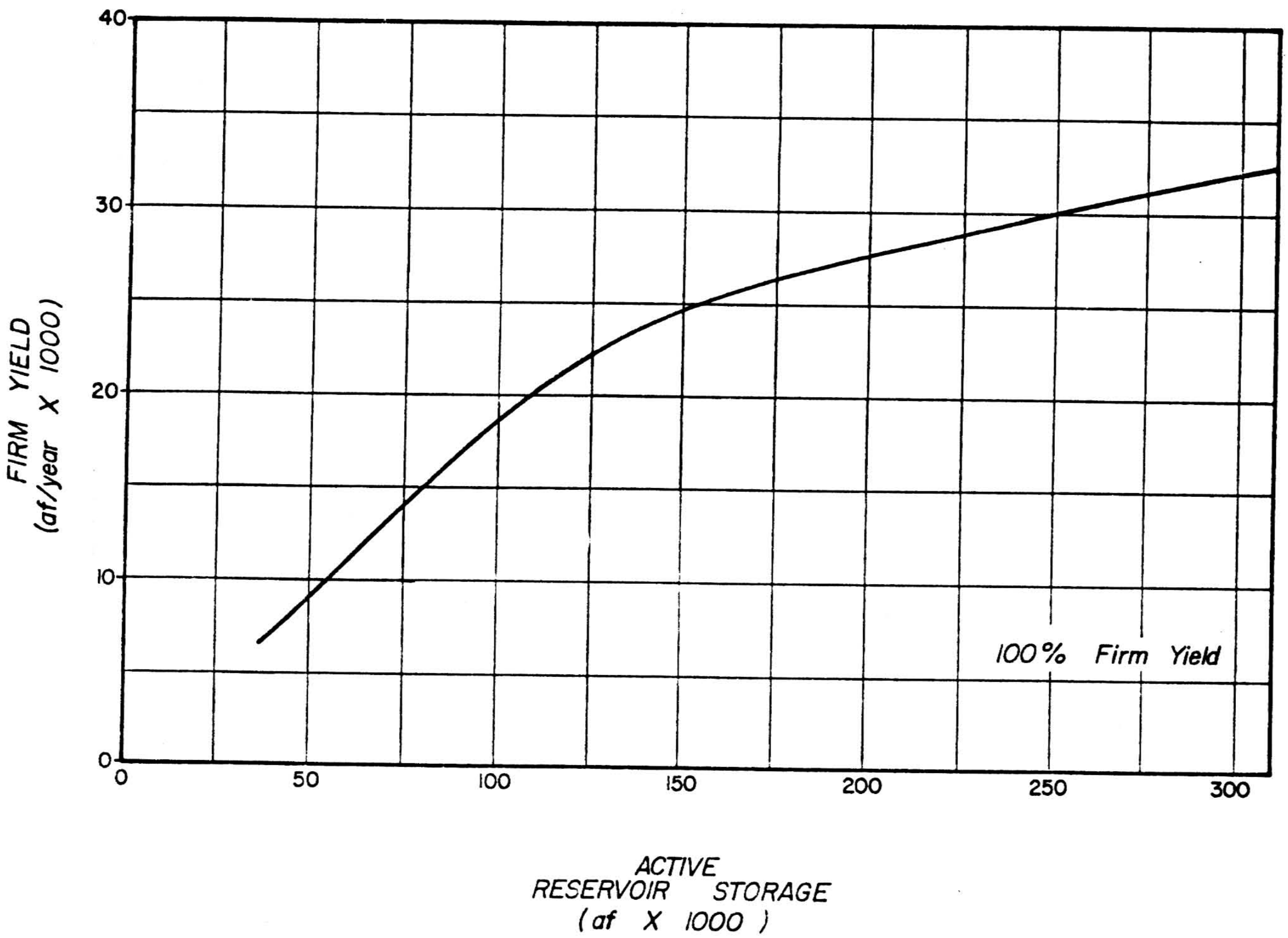
LOCATION OF POTENTIAL STORAGE PROJECTS

HARZA ENGINEERING COMPANY

Browne, Bortz & Coddington • M.W. Bittinger • Tom Pitts & Associates
Leonard Rice Consulting Water Engineers, Inc.

DATE 10/11/86

FIGURE 11.1



COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY

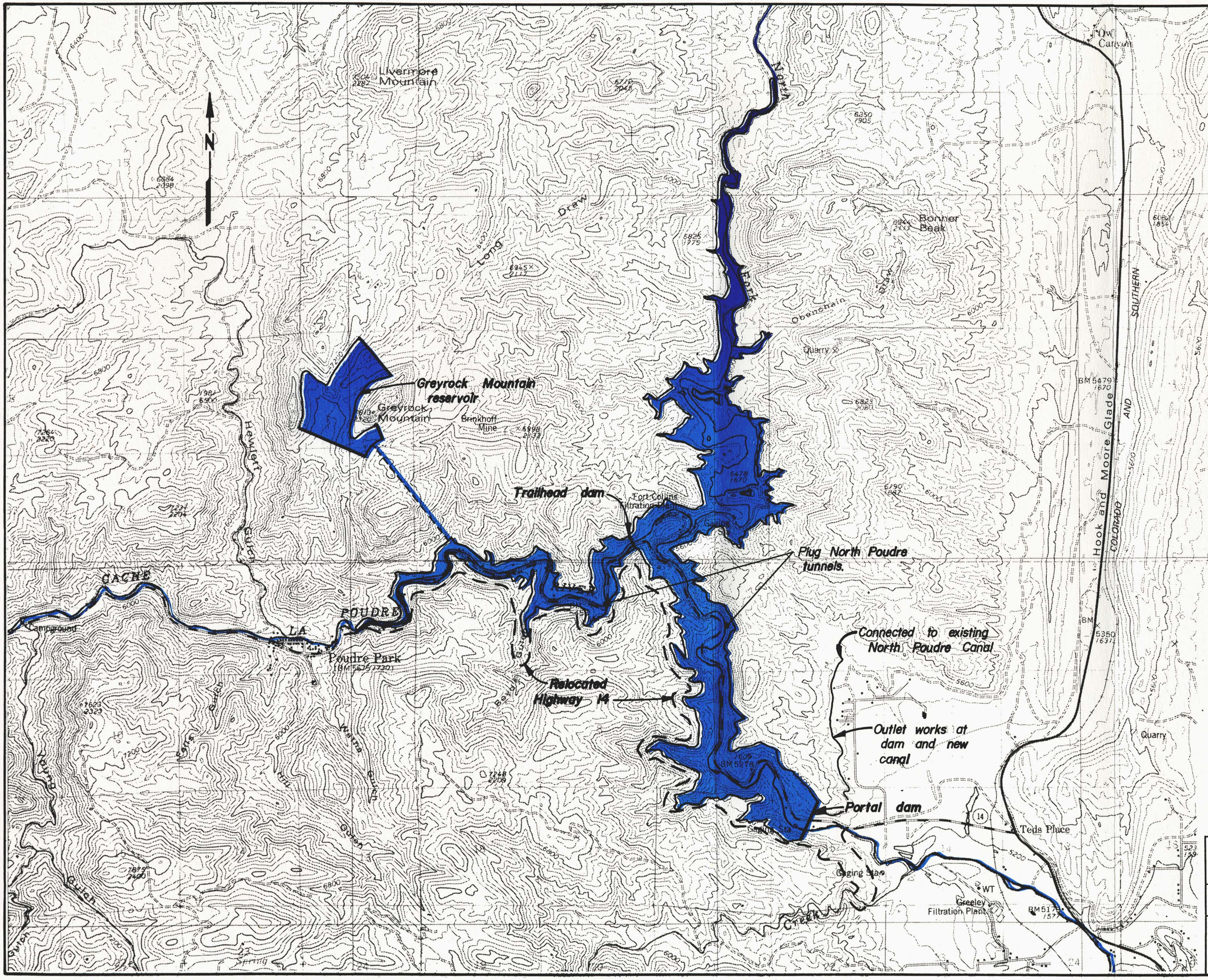
CACHE LA POUDRE BASIN STUDY

STORAGE VS. YIELD
CACHE LA POUDRE RIVER
AT CANYON MOUTH

HARZA ENGINEERING COMPANY
Browne,Bortz & Coddington • M W Bittinger • Tom Pitts & Associates
Leonard Rice Consulting Water Engineers,Inc.

DATE 3/6/86

FIGURE 11.2



1 MILE

3000 0 3000 6000 FEET

CONTOUR INTERVAL 80 FEET

COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY

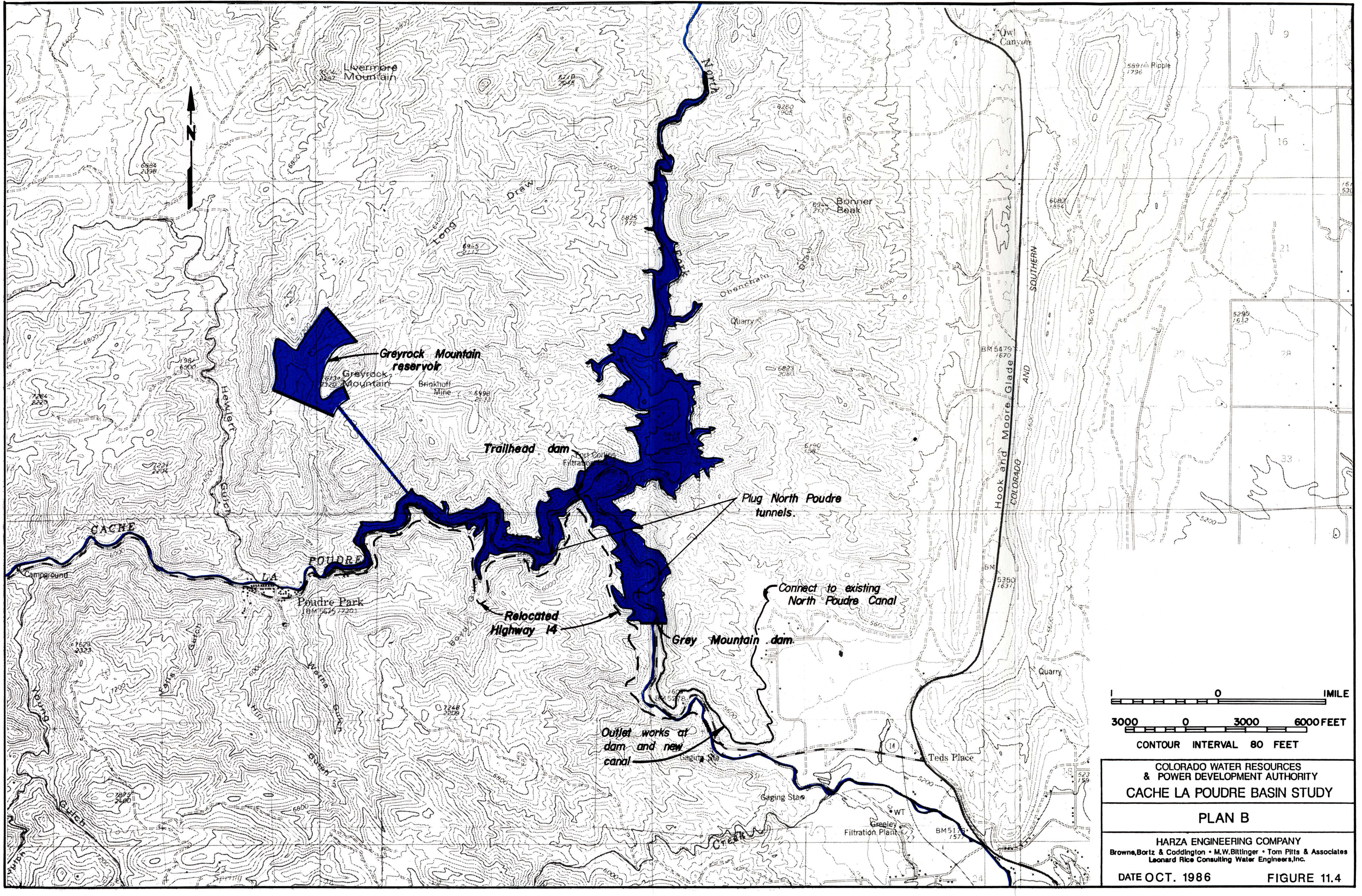
CACHE LA POUDRE BASIN STUDY

PLAN A

HARZA ENGINEERING COMPANY
Browne, Bortz & Coddington • M.W.Bittinger • Tom Pitts & Associates
Leonard Rice Consulting Water Engineers, Inc.

DATE OCT. 1986

FIGURE 11.3



1 0 1MILE

3000 0 3000 6000 FEET

CONTOUR INTERVAL 80 FEET

COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY

PLAN B

HARZA ENGINEERING COMPANY

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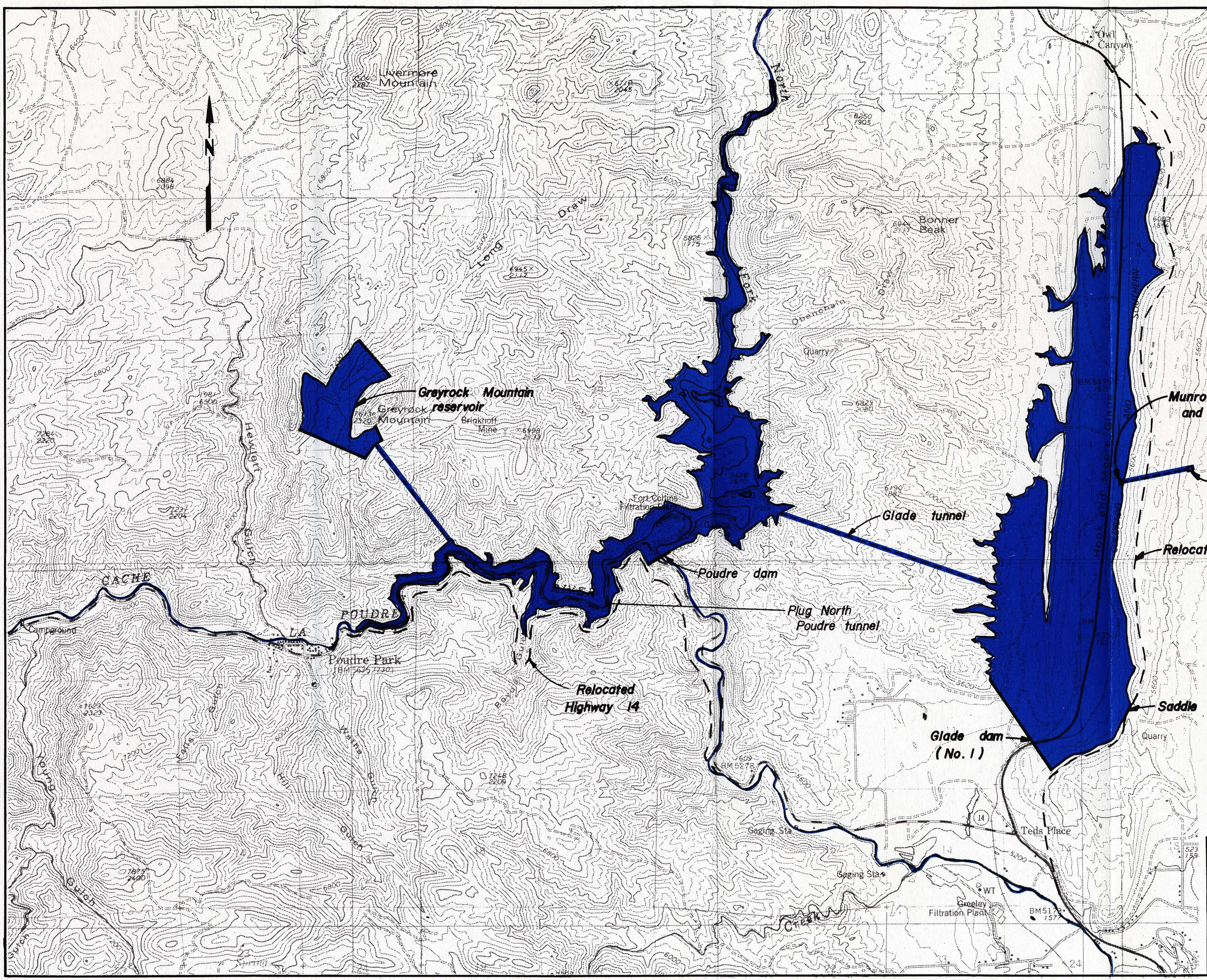
DATE OCT. 1986

FIGURE 11.4



COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY

PLAN C

HARZA ENGINEERING COMPANY

Browne, Bortz & Coddington • M.W. Bittinger • Tom Pitts & Associates
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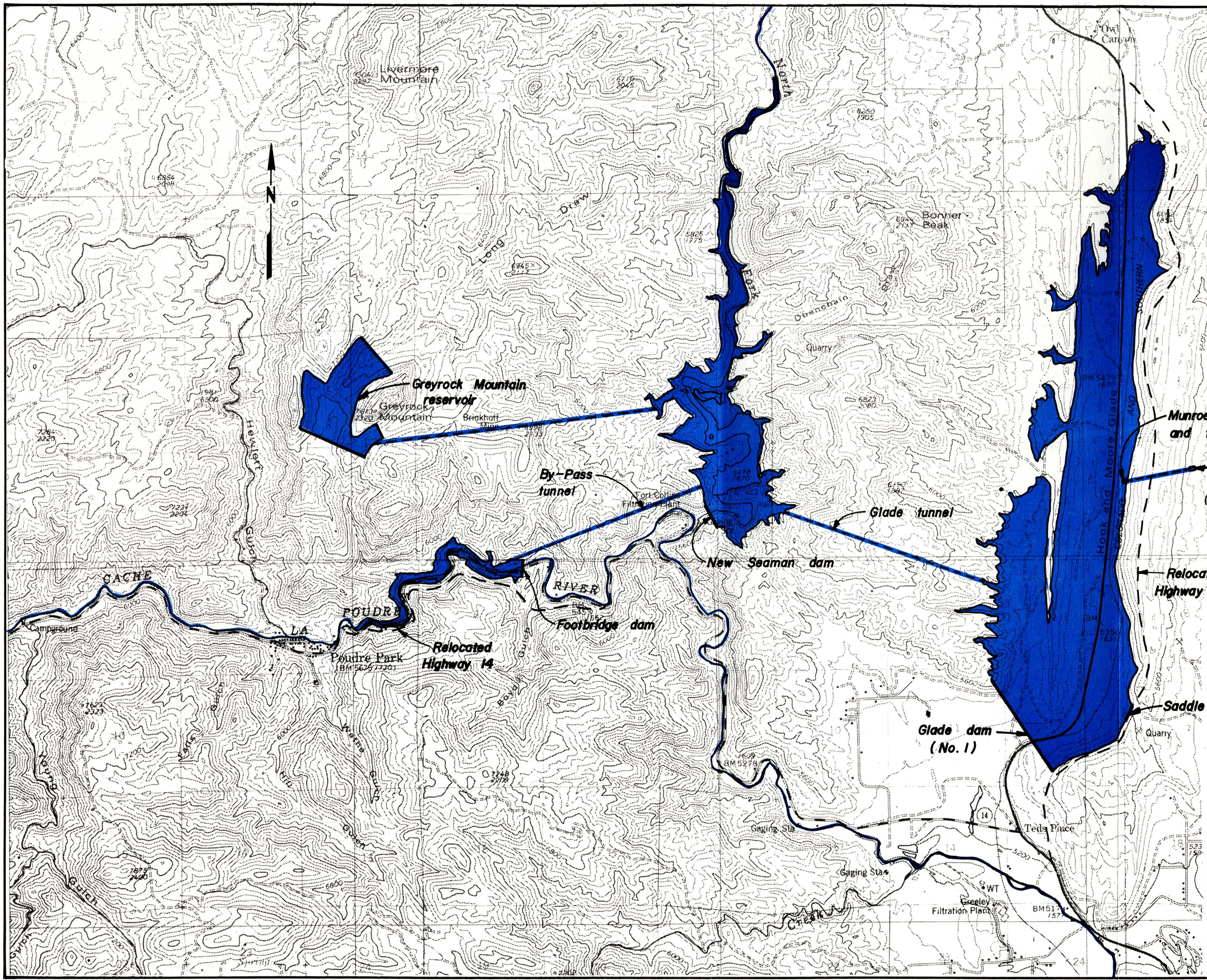
DATE OCT. 1986

FIGURE 11.5



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

PLAN D

HARZA ENGINEERING COMPANY
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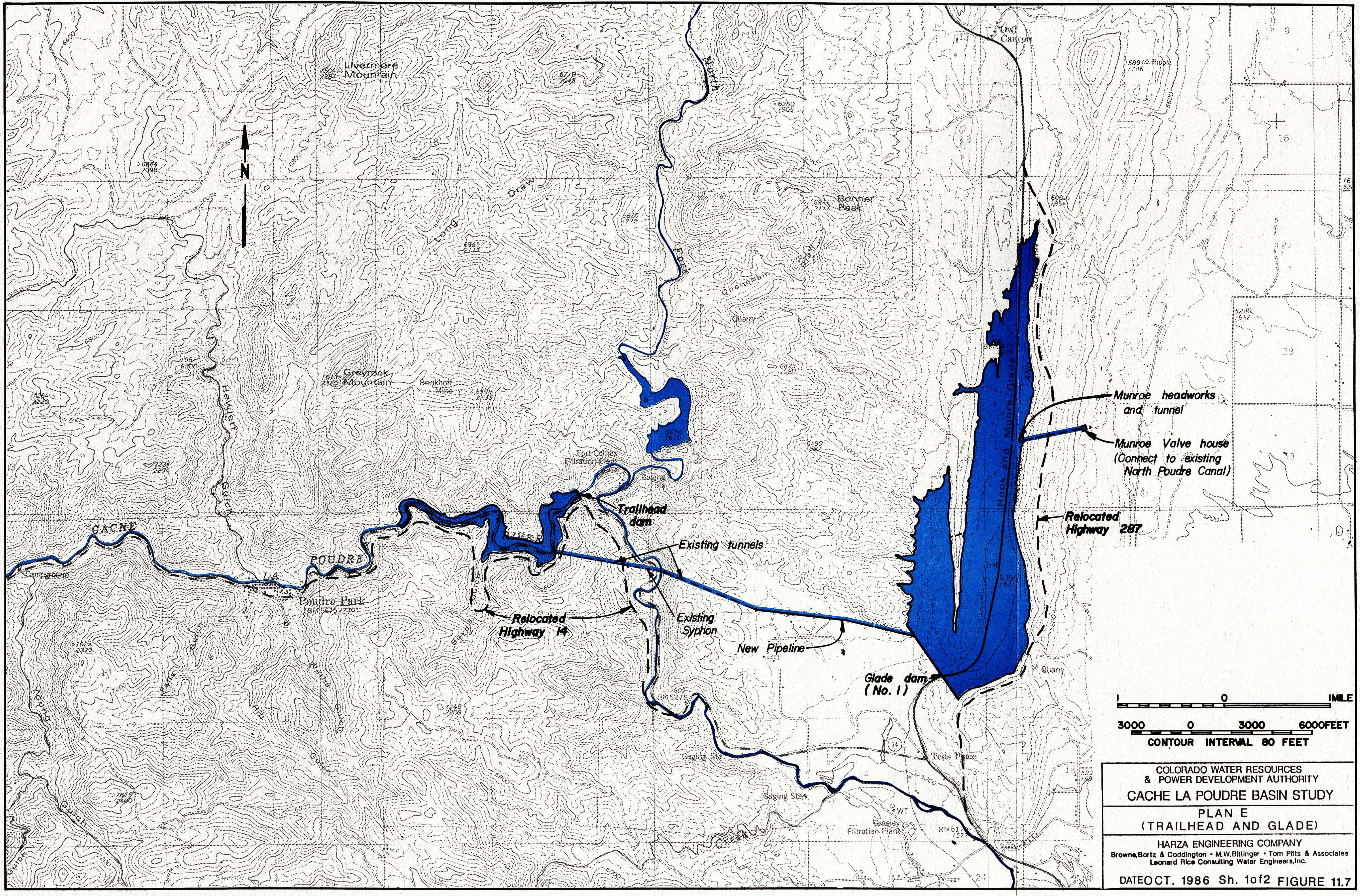
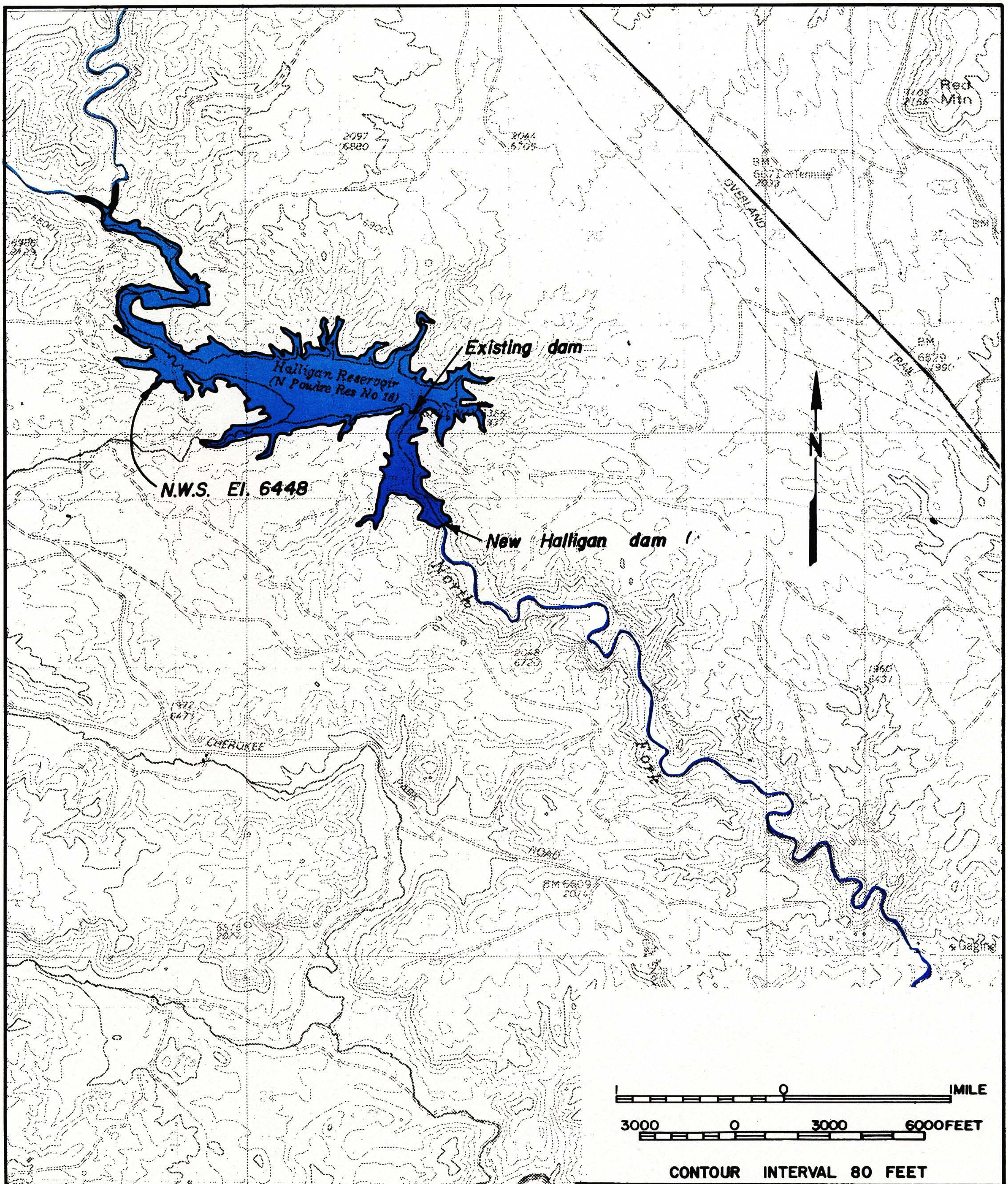
DATE OCT. 1986

FIGURE 11.6


Livermore Mountain
Greyrock Mountain
Bonner Peak
Long Draw
North Fork
Hewlett Gulch
CACHE LA POUDRE RIVER
Poudre Park
Fort Collins Filtration Plant
Trailhead dam
Existing tunnels
Existing Syphon
Relocated Highway 14
New Pipeline
Glade dam (No. 1)
Hook and Moore Glade
Munroe headworks and tunnel
Munroe Valve house (Connect to existing North Poudre Canal)
Relocated Highway 287
Owl Canyon
Quarry
Teds Place
Greeley Filtration Plant
Gaging Sta
N
1 0 1MILE
3000 0 3000 6000FEET
CONTOUR INTERVAL 80 FEET
COLORADO WATER RESOURCES & POWER DEVELOPMENT AUTHORITY
CACHE LA POUDRE BASIN STUDY
PLAN E
(TRAILHEAD AND GLADE)
HARZA ENGINEERING COMPANY
Browne,Bortz & Coddington • M.W.Bittinger • Tom Pitts & Associates
Leonard Rice Consulting Water Engineers,Inc.
DATE OCT. 1986 Sh. 1of2 FIGURE 11.7



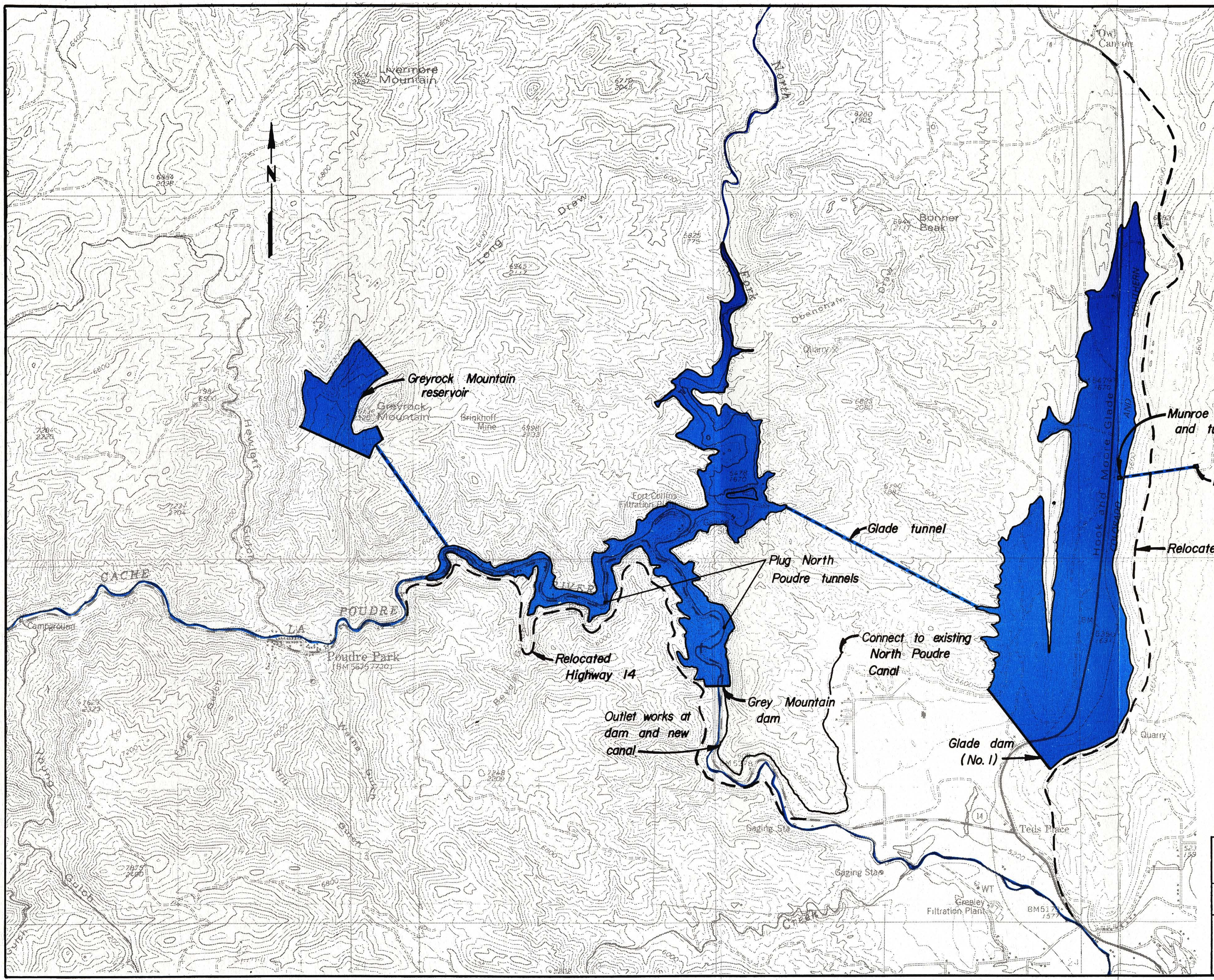
COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY

PLAN E
(HALLIGAN)

HARZA ENGINEERING COMPANY
Browne, Bortz & Coddington • M.W. Bittinger • Tom Pitts & Associates
Leonard Rice Consulting Water Engineers, Inc.

DATE OCT. 1986 Sh. 2 of 2 FIGURE 11.7

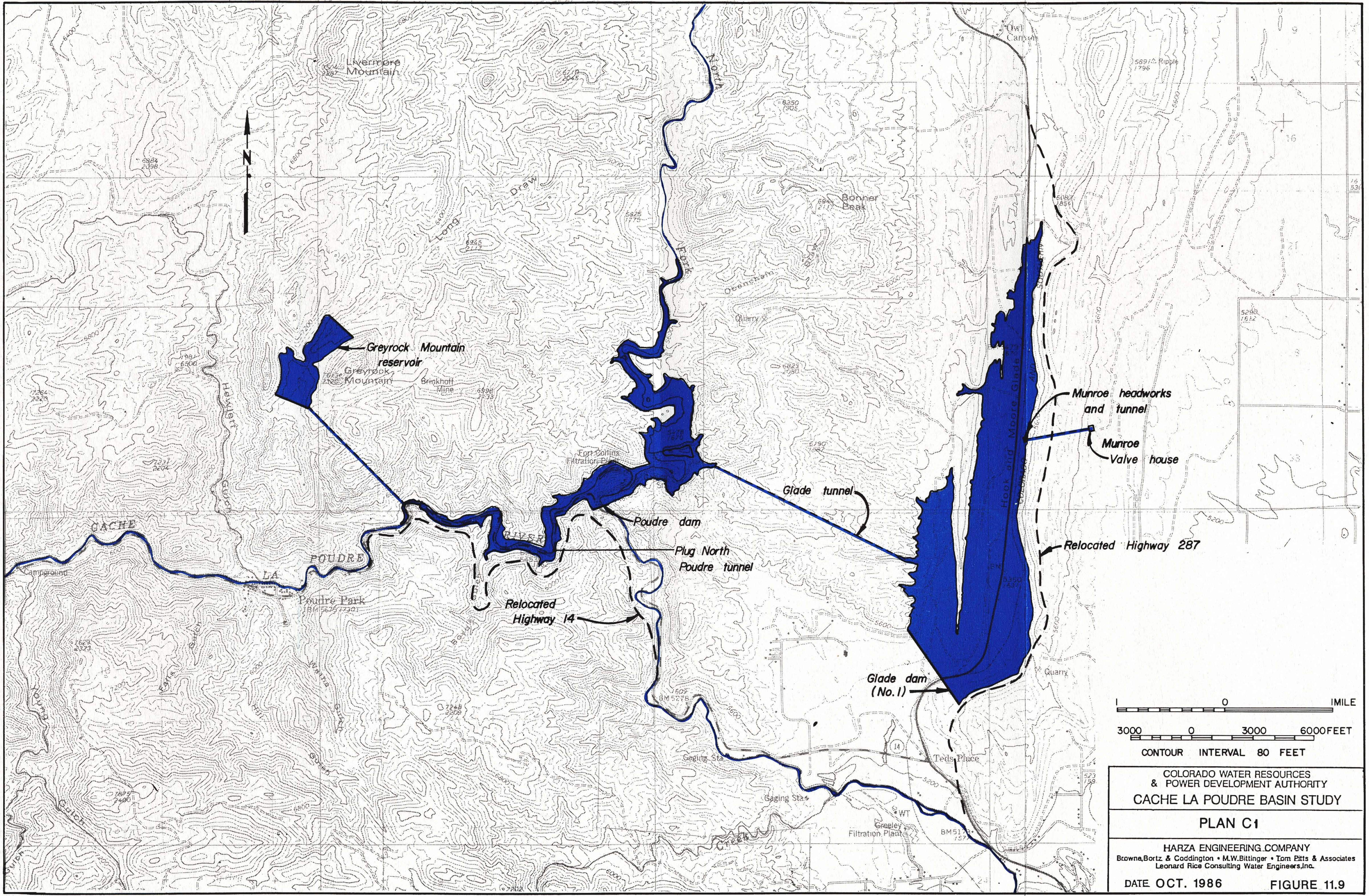


COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY
CACHE LA POUDRE BASIN STUDY

PLAN B1

HARZA ENGINEERING COMPANY
Browne, Bortz & Coddington • M.W. Bittinger • Tom Pitts & Associates
Leonard Rice Consulting Water Engineers, Inc.

DATE OCT. 1986 FIGURE 11.8



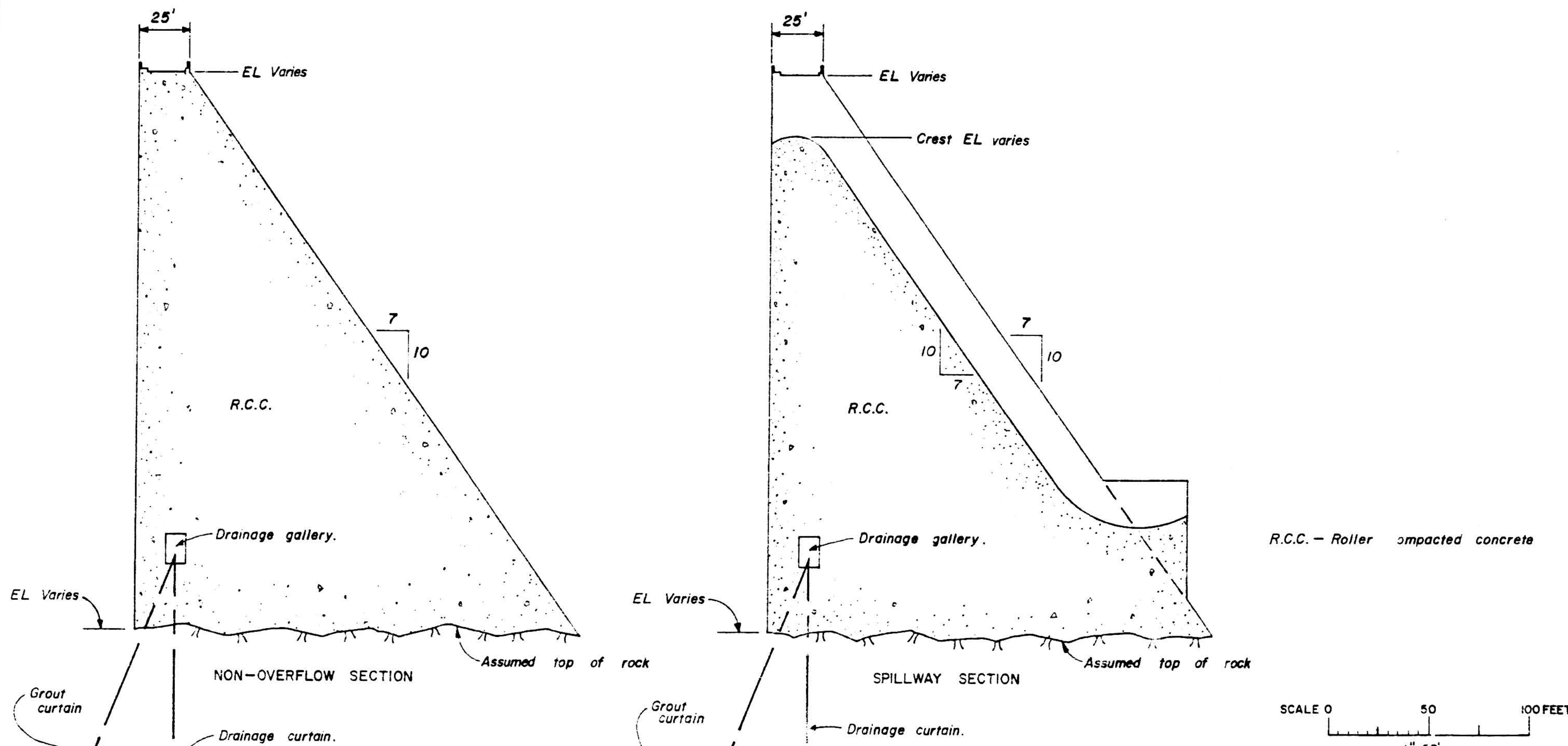
COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY
CACHE LA POUDRE BASIN STUDY

PLAN C1

HARZA ENGINEERING COMPANY
Browne, Bortz & Coddington • M.W. Bittinger • Tom Pitts & Associates
Leonard Rice Consulting Water Engineers, Inc.

DATE OCT. 1986

FIGURE 11.9



COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY

R.C.C. DAM SECTIONS

HARZA ENGINEERING COMPANY
Browne,Bortz & Coddington • M.W.Bittinger • Tom Pitts & Associates
Leonard Rice Consulting Water Engineers,Inc.

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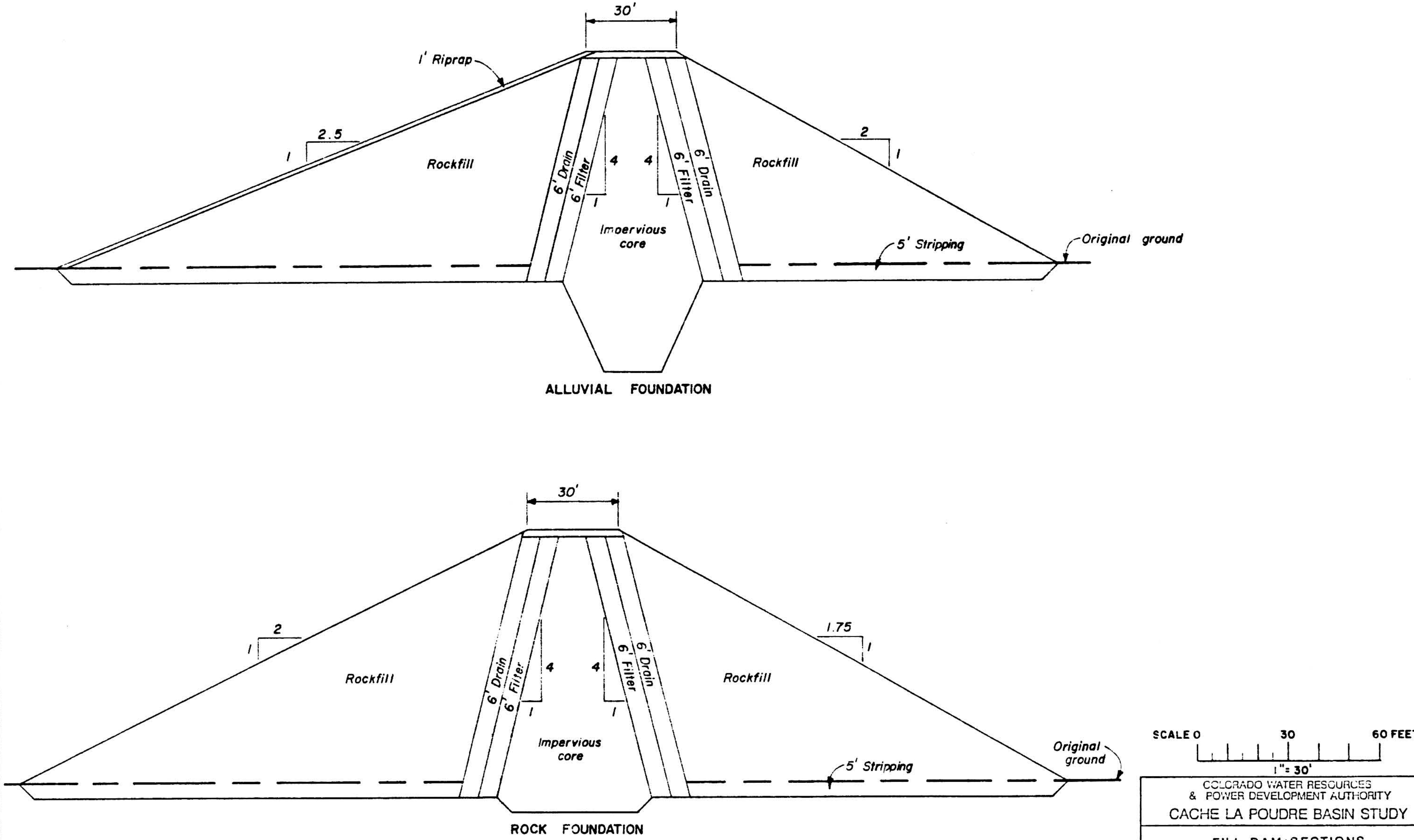
FIGURE 11.10



COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY

FILL DAM SECTIONS

HARZA ENGINEERING COMPANY
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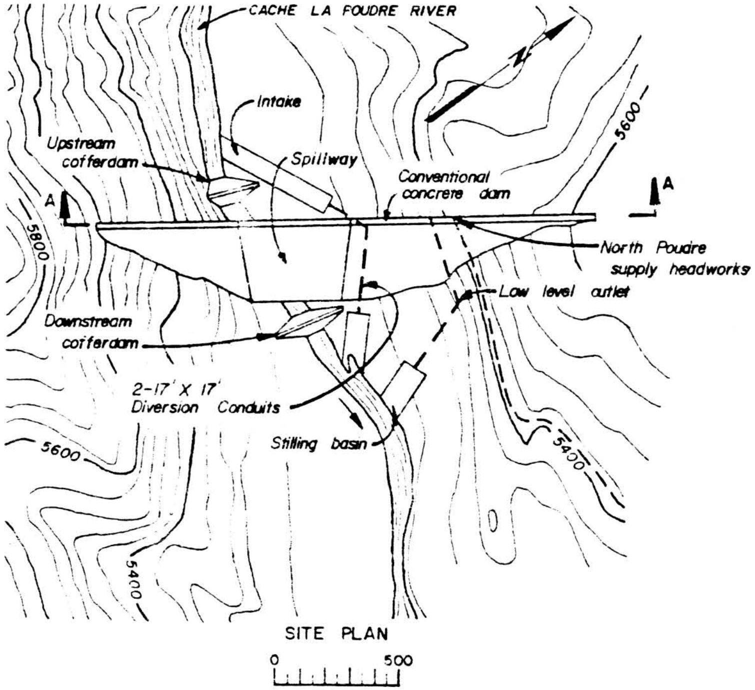
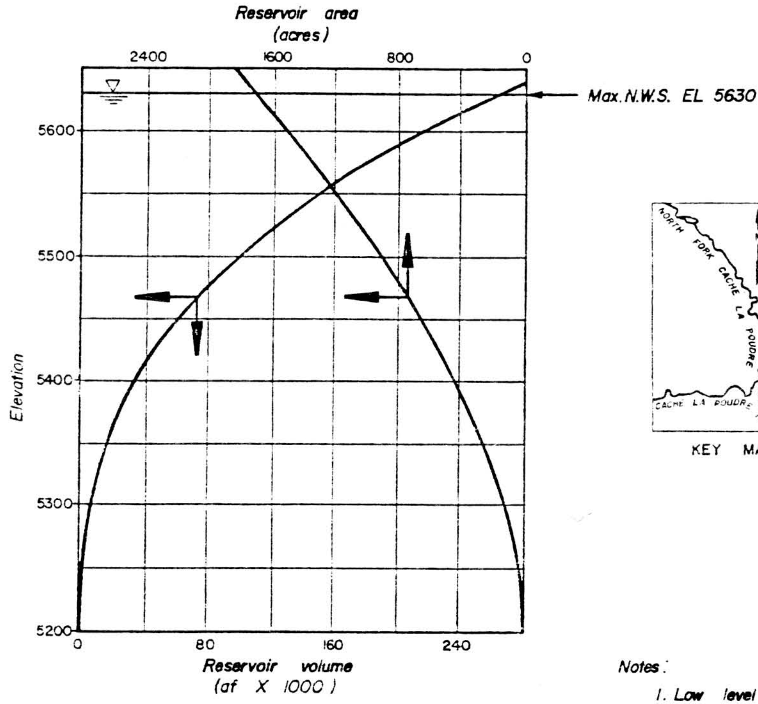
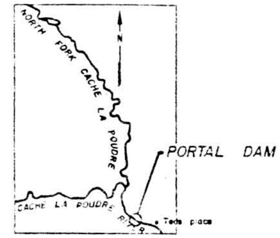
FIGURE 11.11



SITE PLAN



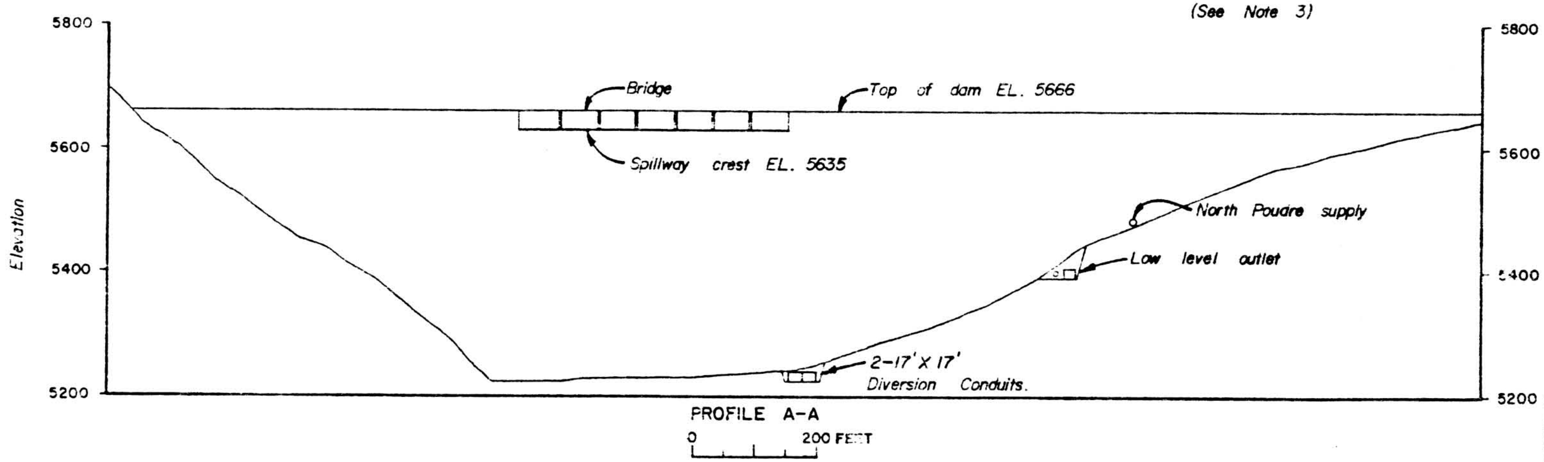
AREA—VOLUME CURVE
(See Note 3)



KEY MAP

Notes:

1. Low level outlet works consist of 15' X 15' conduit with sluce gates and a 42" dia. steel pipe with perforated sleeve valve.
2. Excludes trailhead reservoir volume and area.



PROFILE A-A

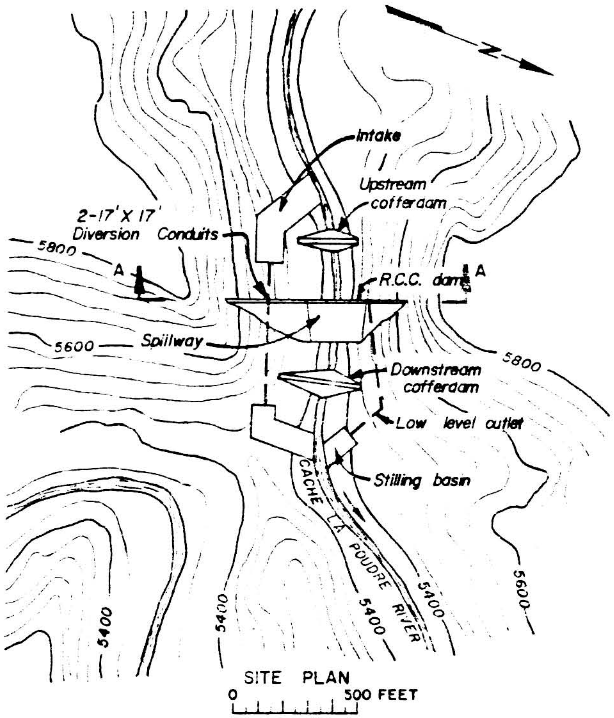
COLORADO WATER RESOURCES & POWER DEVELOPMENT AUTHORITY
CACHE LA POUDRE BASIN STUDY

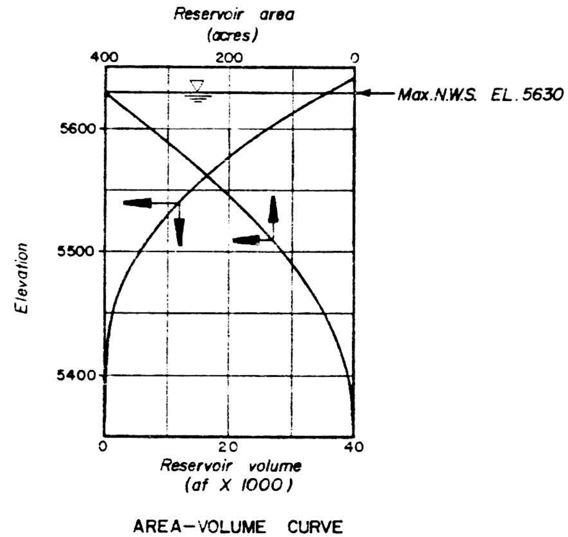
PORTAL DAM
PLAN AND PROFILE

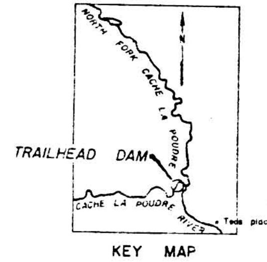
HARZA ENGINEERING COMPANY
Browne,Bortz & Coddington • M.W.Bittinger • Tom Pitts & Associates
Leonard Rice Consulting Water Engineers,Inc.

DATE

FIGURE 11.12

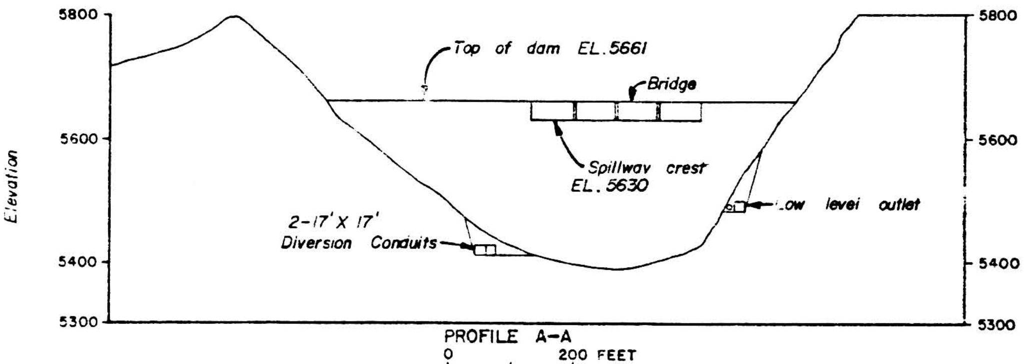






Notes:

1. Low level outlet works consist of 15' X 15' conduit with siuce gates and a 42" dia. steel pipe with perforated sleeve valve.



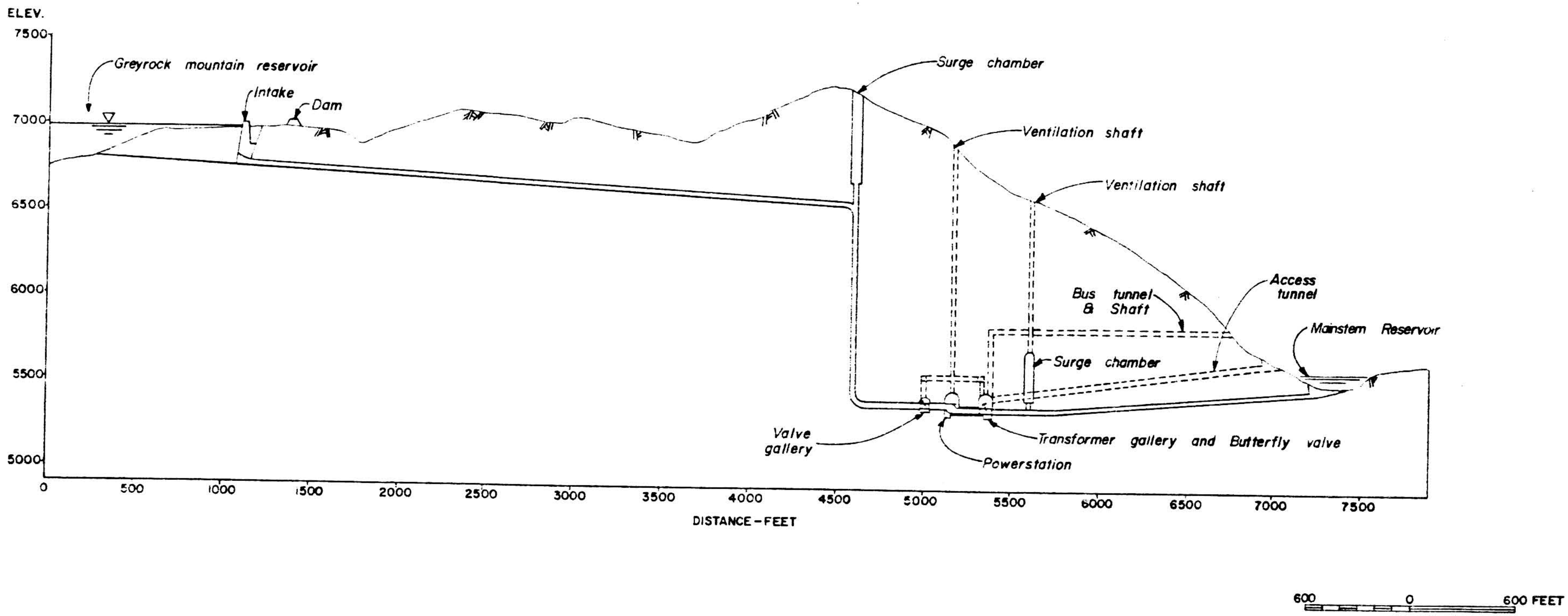
COLORADO WATER RESOURCES & POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY

TRAILHEAD DAM
PLAN AND PROFILE

HARZA ENGINEERING COMPANY
Browne,Bortz & Coddington • M.W Bittinger • Tom Pitts & Associates
Leonard Rice Consulting Water Engineers,Inc.

DATE 12/86 FIGURE 11.13



COLORADO WATER RESOURCES & POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY

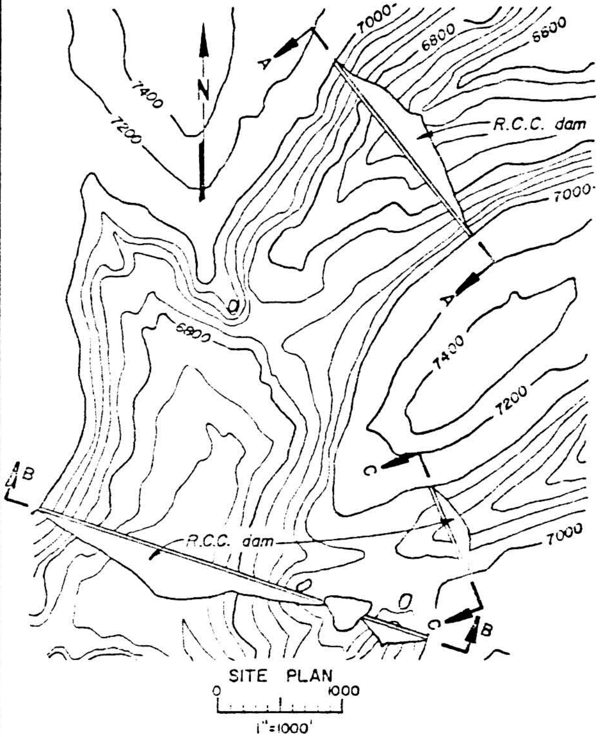
PROFILE OF GREYROCK-TRAILHEAD PUMPED-STORAGE PROJECT

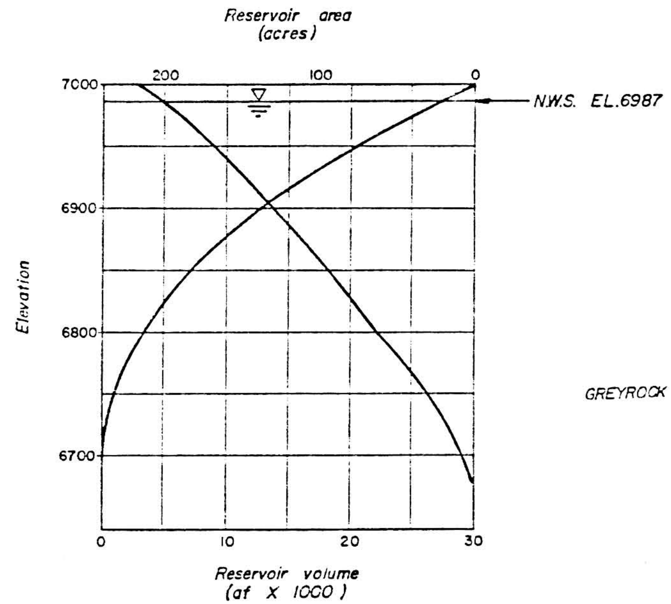
HARZA ENGINEERING COMPANY

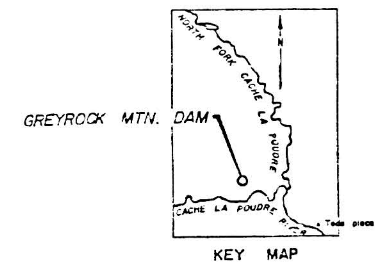
Browne, Bortz & Coddington • M.W. Bittinger • Tom Fitts & Associates
Leonard Rice Consulting Water Engineers, Inc.

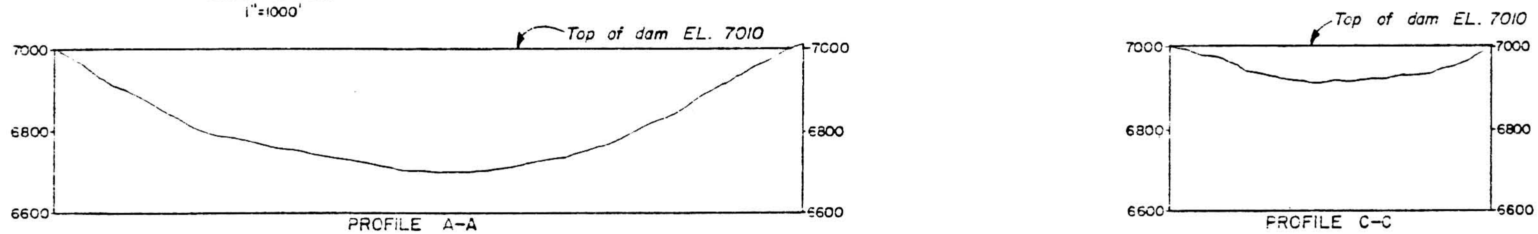
DATE 5/30/86

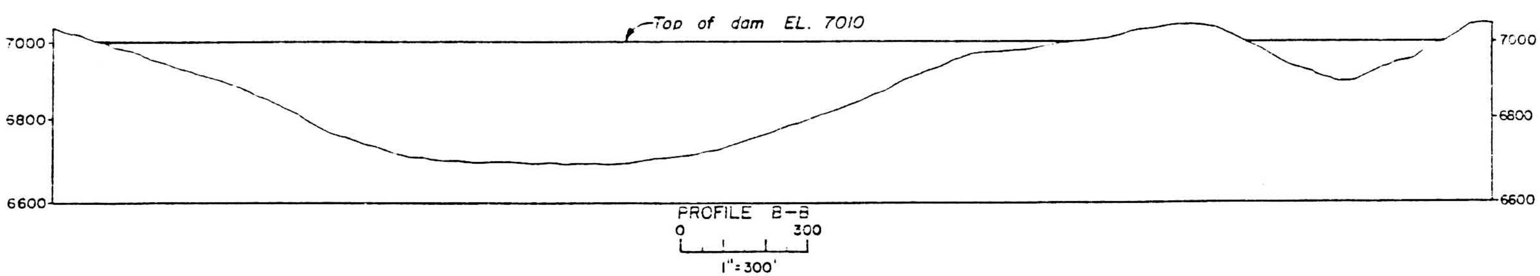
FIGURE 11.14











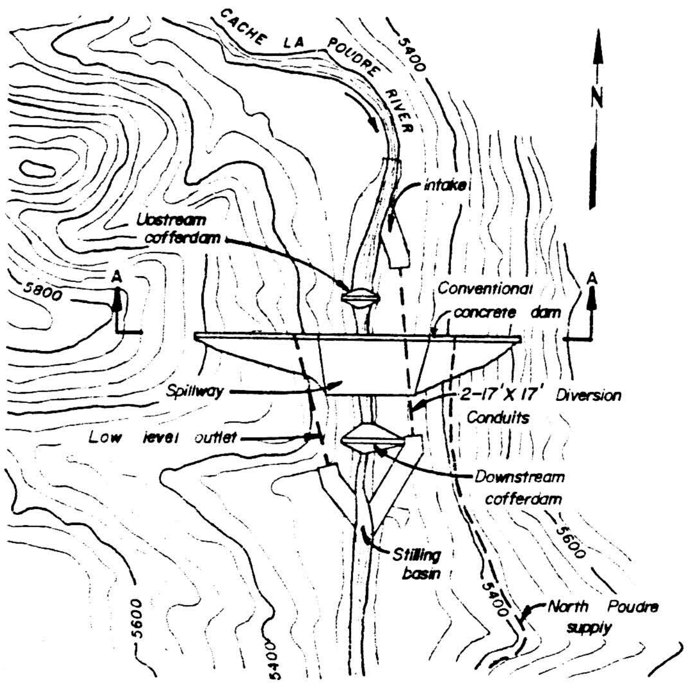
COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY

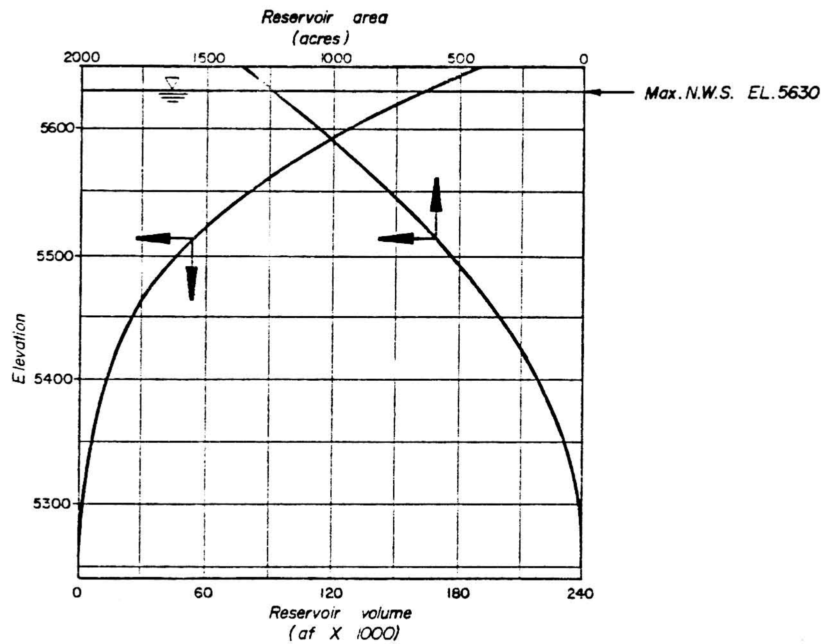
GREYROCK MOUNTAIN DAMS
PLANS AND PROFILES

HARZA ENGINEERING COMPANY
Browne,Bortz & Coddington • M.W.Bittinger • Tom Pitts & Associates
Leonard Rice Consulting Water Engineers,Inc.

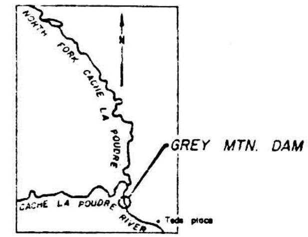
DATE 12/86 **FIGURE 11.15**



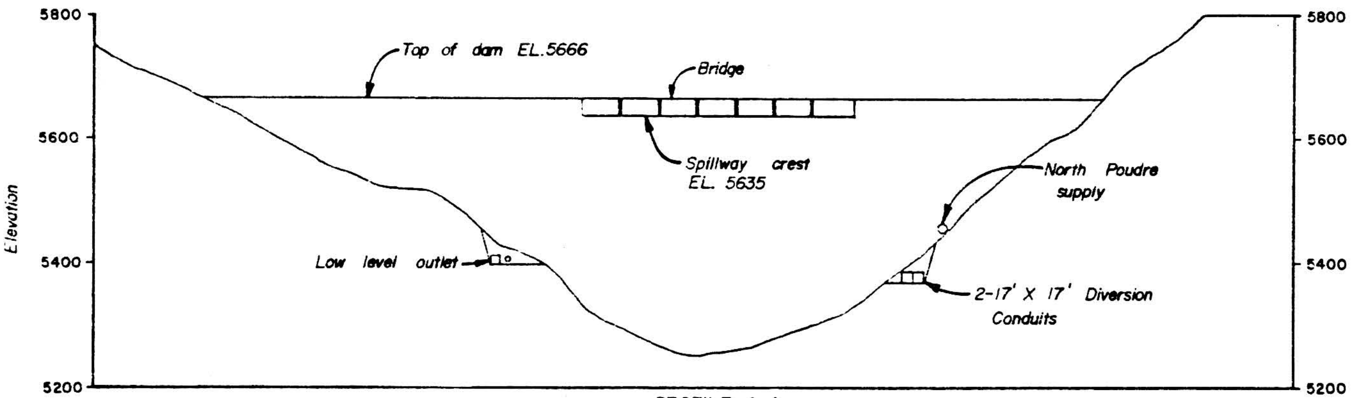
SITE PLAN



AREA--VOLUME CURVE



KEY MAP



PROFILE A-A

Notes:

1. Low level outlet works consist of 15' X 15' conduit with sluce gates and a 42" dia. steel pipe with perforated sleeve valve.

COLORADO WATER RESOURCES & POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY

GREY MOUNTAIN DAM
PLAN AND PROFILE

HARZA ENGINEERING COMPANY
Browne, Bortz & Coddington • M.W. Bittinger • Tom Pitts & Associates
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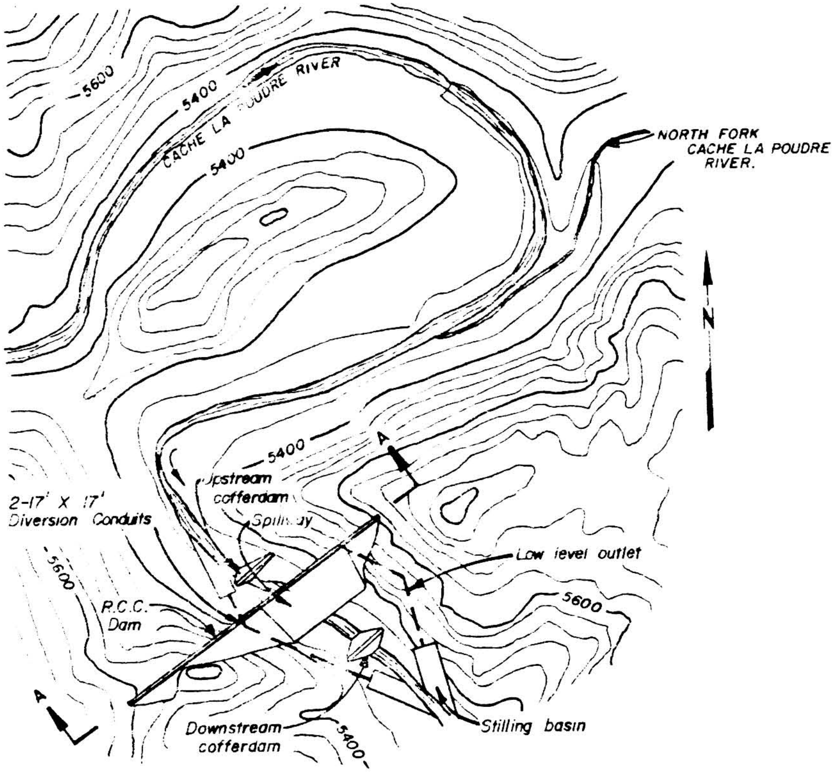
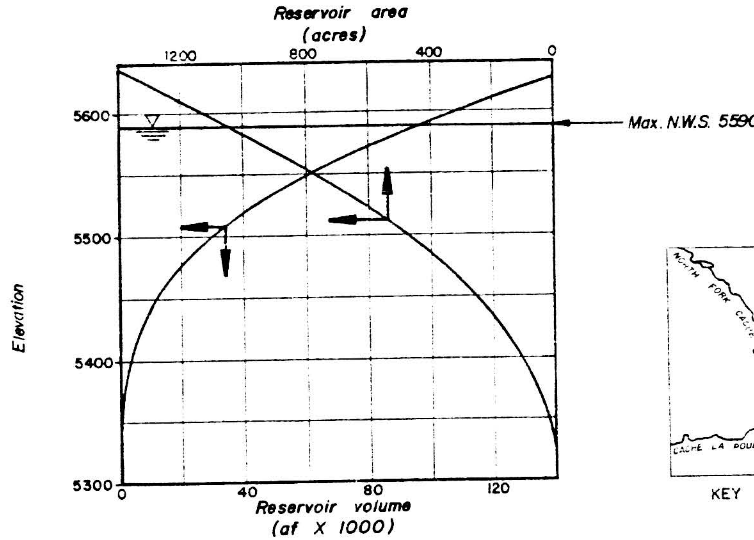
DATE 12/86

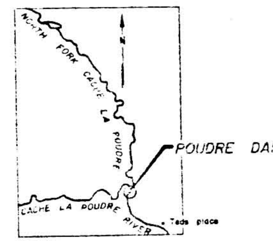
FIGURE 11.16



SITE PLAN



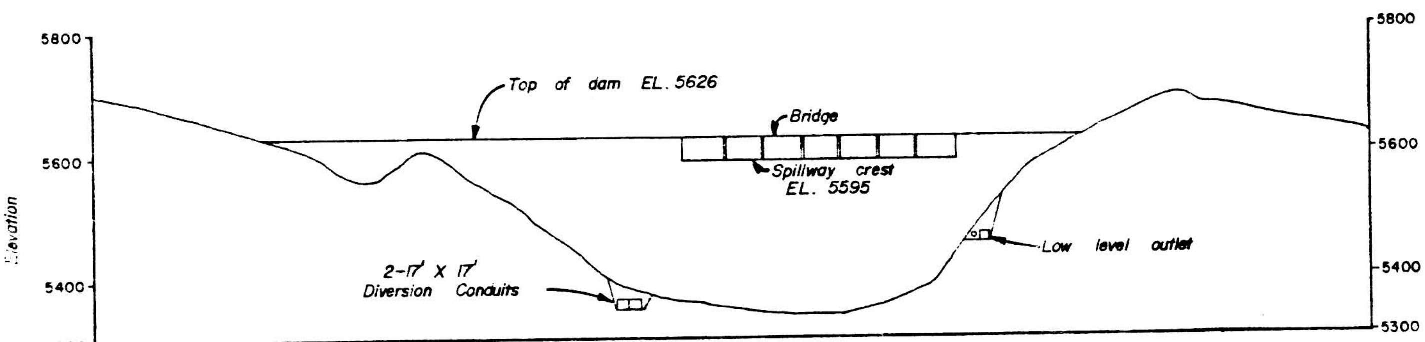
AREA-VOLUME CURVE



KEY MAP

Notes :

1. Low level outlet works consist of 15' X 15' conduit with sluce gates and a 42" dia. steel pipe with perforated sleeve valve.



PROFILE A-A

0 200 FEET

COLORADO WATER RESOURCES & POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY

POUDRE DAM
PLAN AND PROFILE

HARZA ENGINEERING COMPANY
Browne,Bortz & Coddington • M.W.Bittinger • Tom Pitts & Associates
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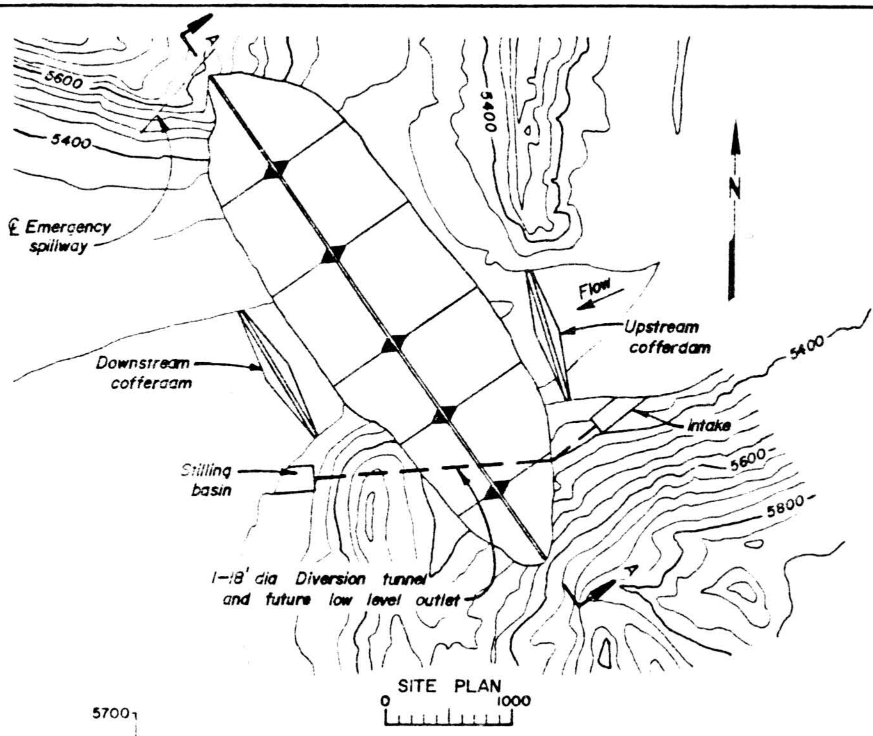
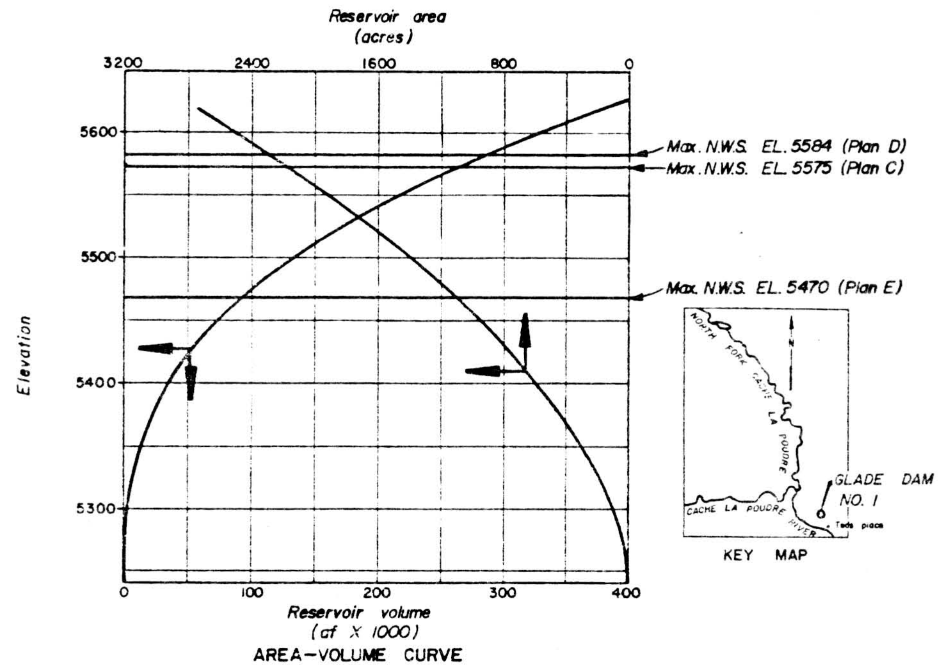
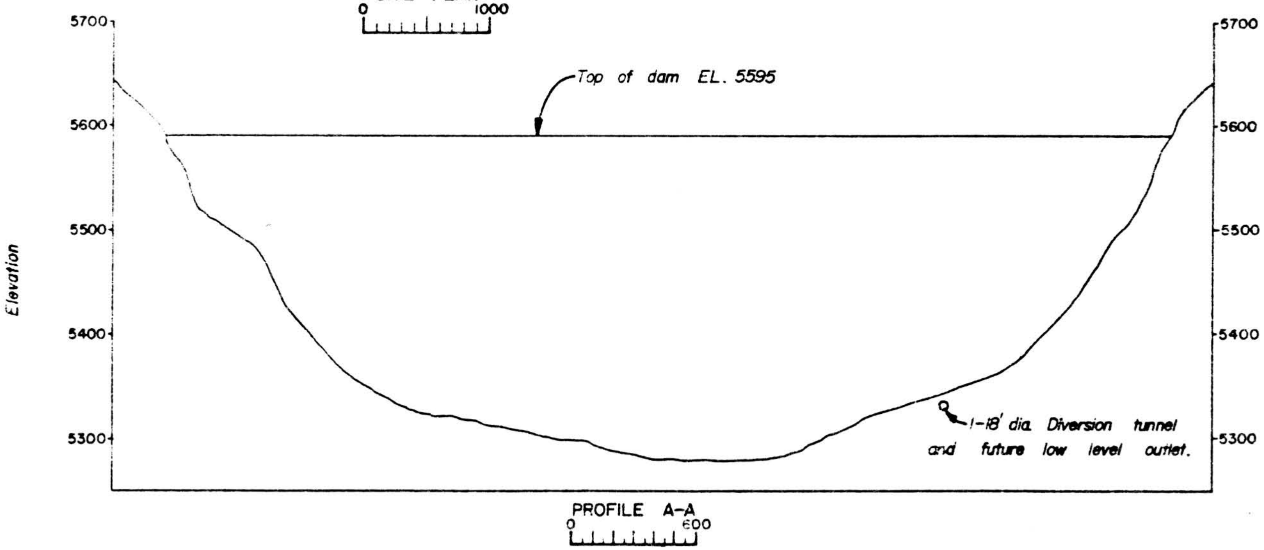
DATE 12/86

FIGURE 11.17







Notes:

1. Saddle dam not shown.

COLORADO WATER RESOURCES & POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY

GLADE DAM NO.1
PLAN AND PROFILE

HARZA ENGINEERING COMPANY
Brown, Bortz & Coddington • M.W. Bittinger • Tom Pitts & Associates
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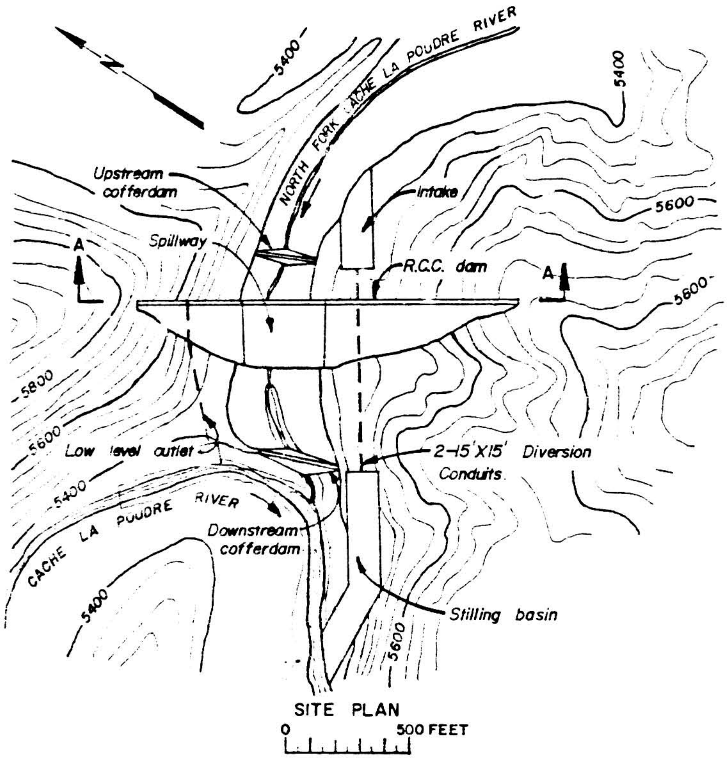
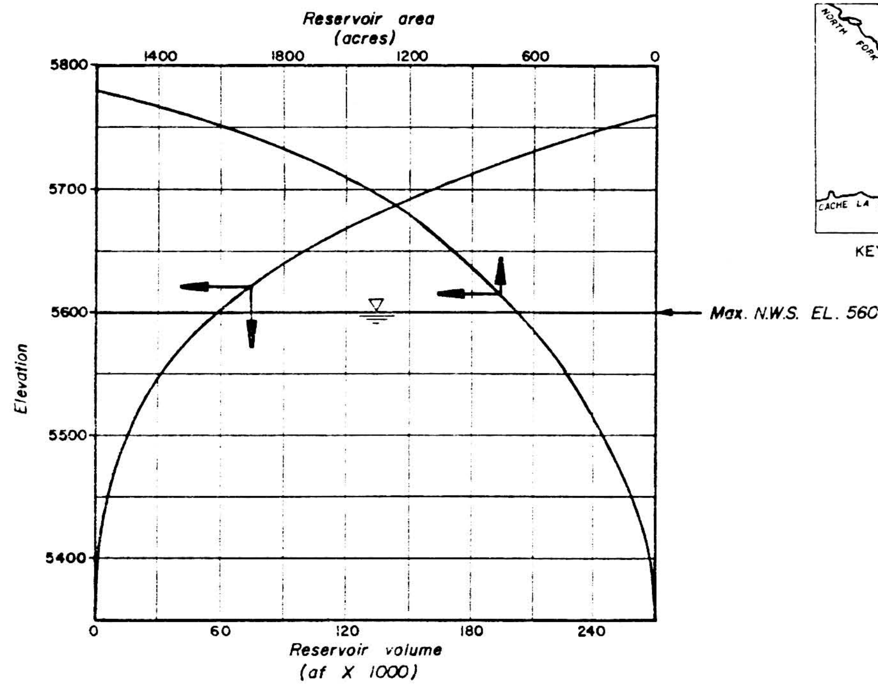
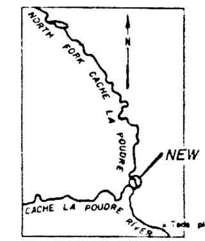
FIGURE 11.18

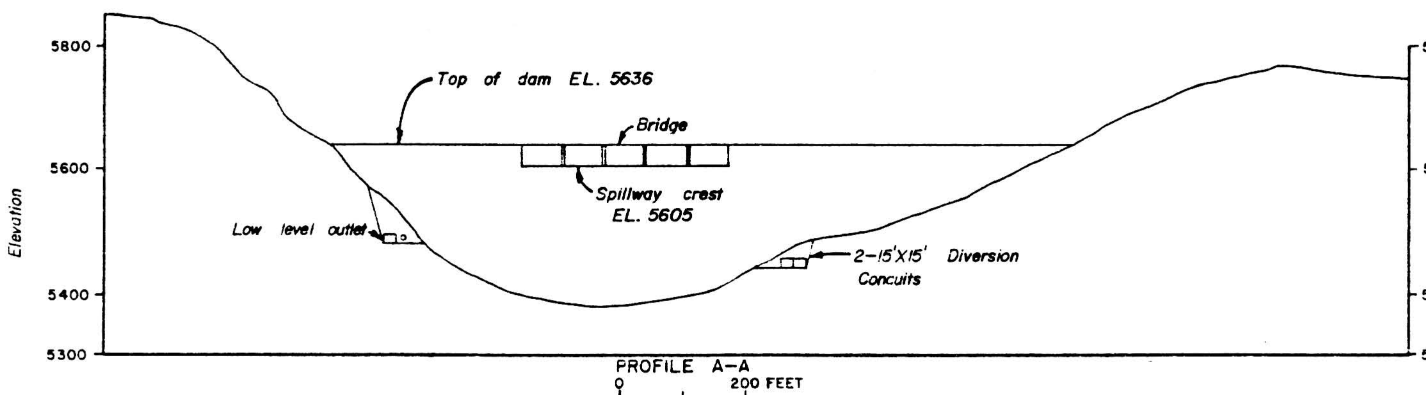




AREA–VOLUME CURVE



KEY MAP



Notes:

1. Low level outlet works consist of 15' X 15' conduit with sluce gates and a 42" dia. steel pipe with perforated sleeve valve.
2. Axis of dam is 3500 feet downstream from existing dam.

COLORADO WATER RESOURCES & POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY

NEW SEAMAN DAM
PLAN AND PROFILE

HARZA ENGINEERING COMPANY
Browne,Bortz & Coddington • W.W.Wheeler • Tom Pitts & Associates
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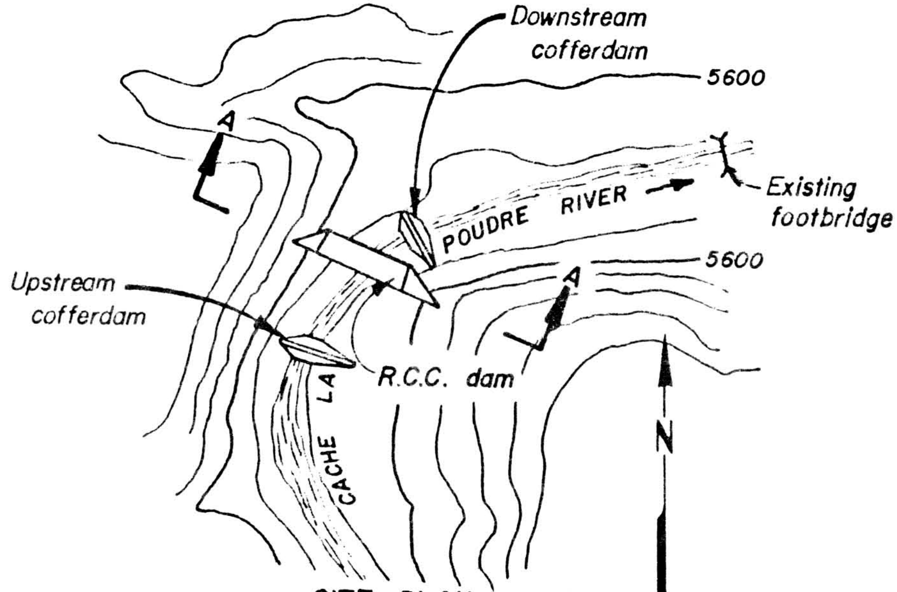
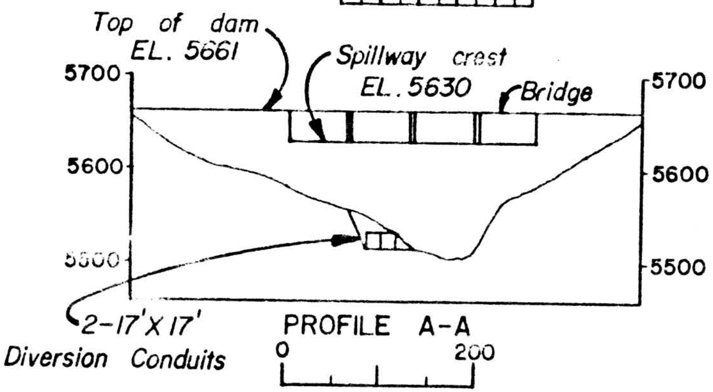
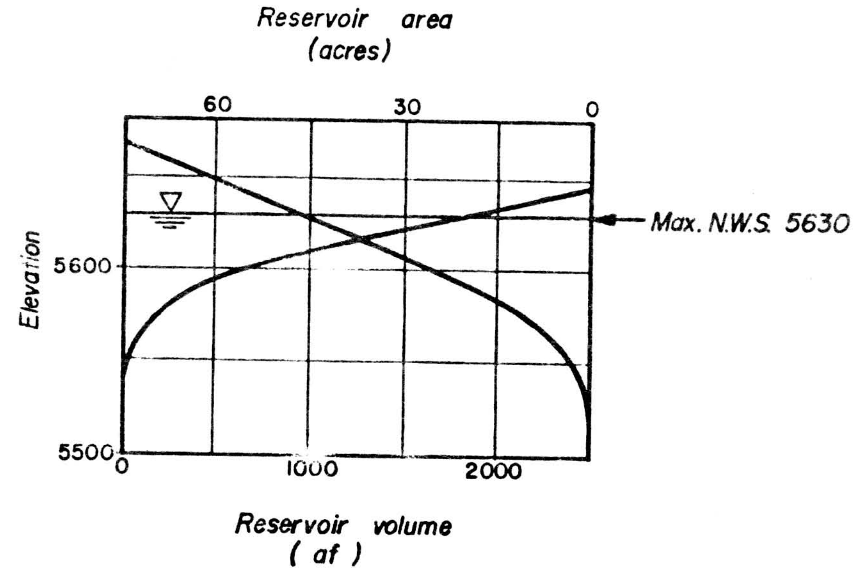
FIGURE 11.19



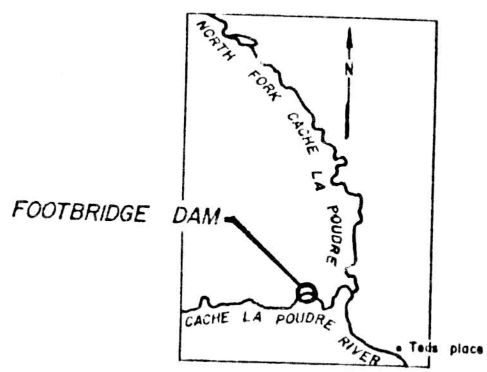
SITE PLAN



PROFILE A-A



AREA-VOLUME CURVE



KEY MAP

COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY

FOOTBRIDGE DAM
PLAN AND PROFILE

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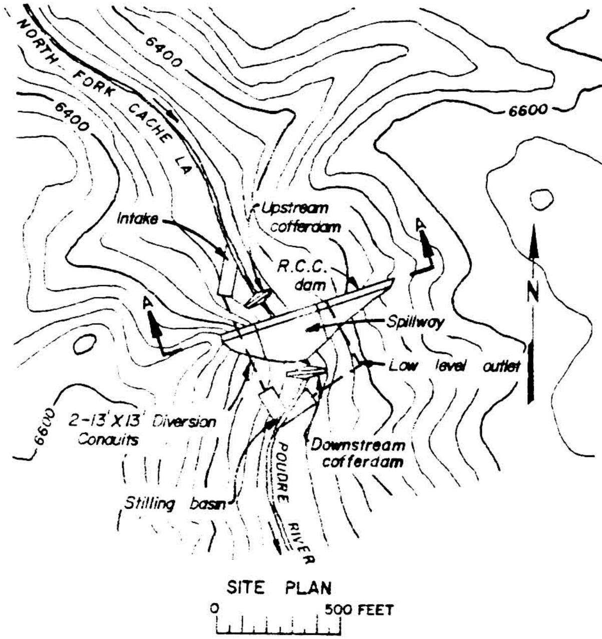
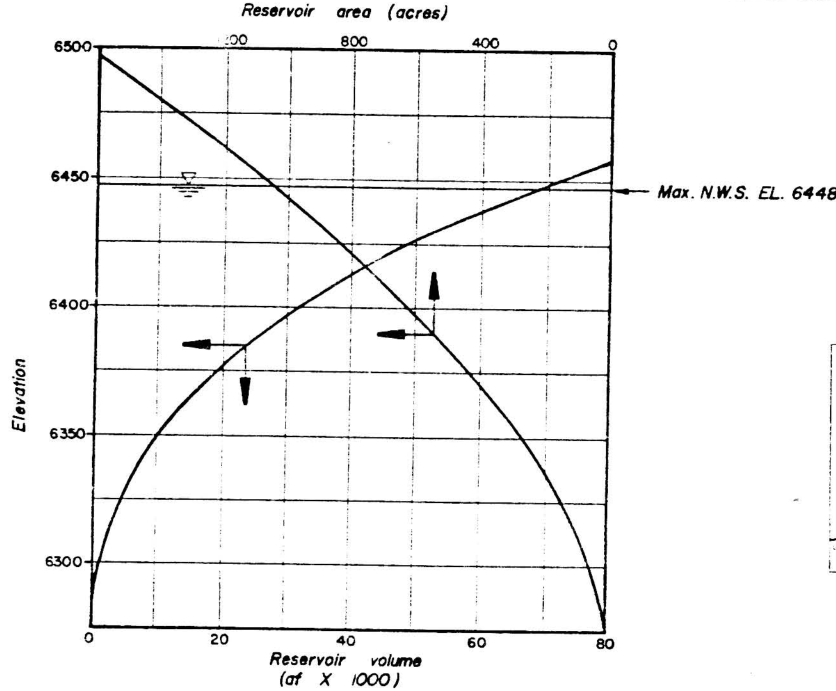
DATE 12/86

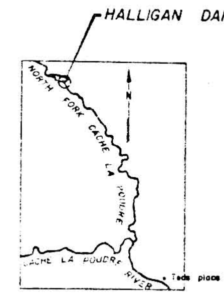
FIGURE 11.20



SITE PLAN



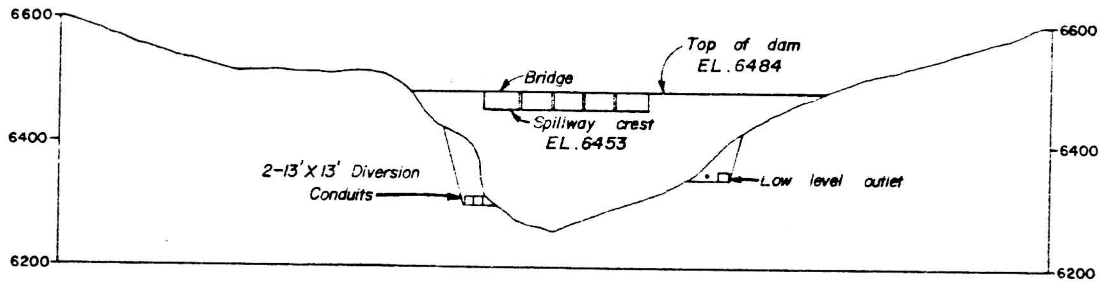
AREA-VOLUME CURVE



KEY MAP

Notes:

1. Low level outlet works consist of 15' X 15' conduit with sluce gates and a 42" dia. steel pipe with perforated sleeve valve.



PROFILE A-A

COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY

NEW HALLIGAN DAM
PLAN AND PROFILE

HARZA ENGINEERING COMPANY
Browne Bortz & Coddington • M.W.Bittinger • Tom Pitts & Associates
Leonard Rice Consulting Water Engineers,Inc.

DATE 12/86

FIGURE 11.21

Chapter 12

Evaluation of Alternative Plans

12.0 EVALUATION OF ALTERNATIVE PLANS

The seven alternative plans were evaluated systematically to identify positive and negative attributes. Technical, environmental, and economic factors were considered in the evaluation of alternatives.

12.1 TECHNICAL EVALUATION

The primary criteria used to measure the technical performance of the alternative plans include:

- Water storage and yield;
- Power output;
- Flood control opportunities;
- Water management flexibility;
- Operational reliability; and
- Risk of delay and increased cost during construction.

12.1.1 Water Storage and Yield

The plans involve various storage amounts and corresponding firm yields of new water. Approximately 274,000 af of storage would be required to develop a firm yield of 25,000 af/yr from storable native flows and 24,000 af/yr from Windy Gap and additional C-BT water. The storage amount of 274,000 af was viewed as a target storage amount in the initial plan formulations. Lesser storage volumes also were considered in several of the plans, as shown in Table 12.1

12.1.2 Power Output

Revenues from a pumped storage development will help to pay the costs of water development that will benefit the Basin and the northern Colorado region. A technically excellent site for a pumped-storage hydroelectric project exists in the vicinity of Poudre Park. An upper reservoir at Greyrock Mountain and a lower reservoir on the mainstem or the North Fork would be required. The size of the pumped-storage development would depend on the eventual market for power produced. Power from a large development (1800 MW) would be marketed primarily outside of Colorado, although some of the power likely would be marketed in Colorado. Power from a smaller development (e.g., 450 MW) could be marketed in Colorado and adjacent states in the Rocky Mountain Power Area by the time such a project could be on-line in the year 2000. Power output from each plan is provided in Table 12.1.

TABLE 12.1

Water Storage, Yield, and Power Output for Alternative Plans

Plan	Active Storage (af)	Firm Yield (af/yr)	Installed Capacity (MW)	On-Peak Energy Output[1] (GWh/yr)
A	259,000	46,000	1800	3150
B	156,000	29,000	1800	3150
C	274,000	49,000	1860	3260
D	274,000	49,000	1860	3260
E	119,000	17,000	0	0
B1	274,000	49,000	1800	3150
C1	144,000	24,000	450	788

(1) At 20 percent annual plant factor.

12.1.3 Flood Control Opportunities

Reservoirs associated with each plan could be designed to provide flood control benefits in addition to those that would accrue incidentally with operation of the reservoirs and because of surcharge storage. Maximum flood control benefits could be achieved with reservoirs regulating both the mainstem and the North Fork. If only one branch of the river is regulated flood control opportunities would be diminished greatly. Flood control opportunity is rated "High" for all plans except Plans D and E which do not control both mainstem and North Fork flows.

12.1.4 Water Management Flexibility

A new reservoir in the Basin, in addition to providing yield from native storable flow and new Windy Gap and C-BT water, will enhance the flexibility of managing water resources in the Basin as well as in the region served by the Northern Colorado Water Conservancy District. Those plans involving larger storage volumes are considered to provide more water management flexibility than those involving lesser volumes. As shown in Table 12.1, Plans C, D, and B1 provide the target storage amount of 274,000 af and Plan A (259,000 af) comes close. Therefore, these plans are rated equal in terms of enhanced water management. Plans B, E, and C1 provide about one-half or less of the storage available under the plans with larger reservoir storage. In terms of enhancing water management opportunities, these plans are rated lower than Plans A, C, D, and B1.

12.1.5 Operational Reliability

Operational reliability of the alternative plans pertains to both the non-structural and structural elements of each plan. Since the non-structural elements are common to each of the plans, their operational reliability would be the same for each. Operational reliability of the structural plan elements has been evaluated on the basis of such factors as efficiency of reservoir operation and the degree to which storable flows can be controlled to obtain the yields of additional water.

All spillways were assumed to have ungated crests and are designed to pass the probable maximum flood (PMF) without overtopping the dams. The PMF is 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. The use of ungated crests eliminates the possibilities of equipment failure and improper operation. Design capacities based on PMF's assures that the dams will not be overtopped and, therefore, will not be subject to failure due to overtopping. Thus the operational reliability of all spillways is excellent.

Operational reliability of the power facilities is considered to be the same for all plans as the designs would be essentially the same. All plans will require close control of lower reservoir and storage reservoir releases but no plan is seen to require special attention in this regard.

The timely identification and diversion of storable flows is an important aspect of operational reliability. Storable flows are erratic in their occurrence and often permit little time to detect and plan for their diversion. Plans A, B, B1, C, and C1 each of which includes a reservoir which controls both mainstem and North Fork flows, greatly facilitate the capture of storable flows because all flows (storable and non-storable) are under control until specific action is taken for their release. In the case of Plans D and E the opposite is true. Both of these plans would require prompt adjustment of tunnel intake gates to divert storable flows. The operational reliability of Plans D and E is therefore less than that for Plans A, B, B1, C and C1 in this regard.

12.1.6 Risk of Construction Delay and Cost Increase

An attempt has also been made to evaluate the risk of construction delays. The number of major structures comprising a plan and unusual or generally difficult construction methods were among the factors considered Evaluation of this risk can only be comparative in nature given that the structural layouts are still at a prefeasibility level.

Risk can be approximately related to the number of major structures comprising each plan. Power facilities, that is upper reservoir construction, water conductors, and powerstation, are common to all except Plan E, and therefore have not been considered in the comparison.

The level of geologic information now available does not permit differentiation of potential risks at each site. Based on limited available data, there are no known flaws that would prevent any of the sites from being used for their intended structures.

Plans A and B would appear to offer the least risk with regard to construction delay and cost overrun. Only two elements are involved in each. Plan B would have to be rated slightly better than Plan A because construction quantities are less and some core drilling has been carried out at the Grey Mountain site. As part of this Study, core drilling and seismic refraction/auger hole investigation programs were conducted at the Glade damsite which is common to many alternatives. This program was carried out because of uncertainties with regard to depth to rock and foundation conditions. Based on these preliminary investigations it is concluded that Glade is suitable damsite.

Plans C, B1, C1, and E all have three major structural elements and all but Plan E are considered to be subject to more risk than Plans A and B. Plan E would have a much smaller Trailhead Dam than Plans A and B. The North Poudre Conveyance, which would be modified under Plan E, is an existing facility, and installation of a new lining should involve minimal risk. Glade Dam is common to all plans in this group. Thus, Plan E is considered to have less potential risk than Plans C, B1, and C1. It is also considered to have less risk than Plans A and B. Plan C1 is essentially the same as Plan C, the only difference being the heights of Poudre and Glade Dams. This is the only basis for considering Plan C1 (lower dams) to involve slightly less risk for delay than Plan C (higher dams). Plan C and Plan B1, when compared with Plans A and B, have an additional element, Glade Tunnel. It is not possible at the present level of study to assign a greater or lesser risk to Glade Dam than to Portal or Grey Mountain Dams. Poudre Dam in Plan C is very similar to Trailhead Dam in Plans A and B.

Plan D has five major structural elements, two tunnels and three dams, and must be considered to involve more potential risk for delay and increased costs than any of the other plans. In addition, the water conductors for its power project are about twice as long as those associated with the other plans. This reinforces the conclusion regarding relative risks of Plan D.

12.2 ENVIRONMENTAL EVALUATION

12.2.1 Evaluation Process

Environmental evaluation in this study has focused on identification of impacts, issues of public concern as identified in various meetings, identification of means of offsetting impacts, and enhancement opportunities related to the environment that would be affected by each plan alternative. The evaluation was conducted at a reconnaissance level, and utilizes existing available information.

The environmental evaluation examines impacts of alternative plans on seven broad environmental categories; recreation, land use, vegetation, aquatic life, wildlife, cultural resources, and water quality. These broad categories address environmental concerns of the National Environmental Policy Act (NEPA) process.

Within the recreation category, indicators include the number of miles of whitewater boating, angling (including designated "Wild Trout" waters), hiking, and scenic driving. Indicators for the land use category include the number of private homesites, miles of highway and utility construction and relocation, and the amount of range and/or agricultural acreage. Vegetation category indicators include the number of miles of riparian vegetation and the existence of threatened and endangered plant species. Indicators for aquatic life and wildlife categories likewise include the presence of threatened and endangered species, as well as critical ranges and migration routes of certain species. Indicators for the cultural resources category consist of the number of known historic and prehistoric sites. Water quality category indicators include changes in water temperature, levels of dissolved oxygen, and eutrophication potential.

The Cache la Poudre from the headwaters to the canyon mouth is not considered to be a high quality fishery, due primarily to very low natural wintertime flows. Larger fish cannot survive under prolonged low-flow conditions because of poor habitat conditions. Opportunities exist to enhance the fishery and other recreational activities with a new water storage project.

12.2.2 Environmental Evaluation of Alternative Plans

Implementing any one of the seven alternatives would have impacts on the environments within and surrounding the major structural plan elements included in the plan. Because each plan includes the same set of non-structural elements, the environmental impacts, if any, of implementing non-structural elements would be the same and would not affect the relative ranking of the alternatives in terms of environmental impacts.

Table 12.2 provides a summary of the environmental impacts of the seven alternative plans.

12.2.2.1 Plan A

Plan A involves constructing the Portal and Trailhead Reservoirs which would inundate portions of the Mainstem and North Fork of the Poudre River. It would also involve constructing the off-channel Greyrock Mountain Reservoir. Together, the three reservoirs would inundate 2320 acres, including 8.3 miles of the Poudre and 3.0 miles of the North Fork. The principal environmental impacts associated with this alternative involve land use, recreation, and water quality.

Construction and operation of the three reservoirs would require the relocation of 9.5 miles of Colorado Highway 14 and public utilities in the highway corridor, as well as 20-30 residential and Forest Service cabins. An additional four miles of access road would be built during the construction of the reservoirs.

If implemented, the structural features of this plan would eliminate 4.7 miles of white-water boating, including 2.5 miles of primary white water

TABLE 12.2

Summary of Environmental Impacts
Comparison of Alternatives

	Plan A	Plan B	Plan C	Plan D	Plan E	Plan B1	Plan C1
AREA INUNDATION (Acres)							
Mainstem Poudre	1270	800	460	50	160	800	460
North Fork Poudre	850	850	600	700	1060	850	600
Off Poudre	200	200	2400	2480	1150	2400	2400
Total	2320	1850	3460	3230	2370	4050	3460
STREAM INUNDATION (Miles)							
Mainstem Poudre	8.3	6.4	4.7	2.0	3.7	6.4	4.7
North Fork Poudre	3.0	3.0	3.0	4.0	1.0	3.0	3.0
Total	11.3	9.4	7.7	6.0	4.7	9.4	7.7
RECREATION (Miles)							
Prime white-water	2.5	1.4	0.0	0.0	0.0	1.4	0.0
Other white-water	2.2	2.2	2.2	1.7	2.2	2.2	2.2
Wild Trout angling	4.7	3.4	1.7	0.0	0.8	3.4	1.7
Other angling	6.6	6.0	6.0	6.0	4.7	6.0	6.0
Scenic driving	6.0	6.0	5.0	3.0	3.0	6.0	5.0
Hiking	0.5	0.5	0.5	0.5	0.5	0.6	0.5
LAND USE							
Relocation US 287 (mi)	0.0	0.0	8.0	8.0	6.7	8.0	8.0
Relocation CO 14 (mi)	7.5	7.2	6.0	3.0	6.0	7.0	6.0
Access Roads (mi)	3.9	3.9	5.0	5.3	3.1	5.0	5.0
Utilities (mi)	9.5	7.2	14.0	11.0	12.7	15.0	14.0
Residences (mi)	20-30	20-30	20-35	20-35	20-35	20-35	20-35
Agriculture (ac)	0	0	2000+	2000+	2000+	2000+	2000+
VEGETATION							
Riparian (mi)[1]	10.5	9.0	7.5	6.0	4.7	9.0	7.5
T&E species	None[2]	None[2]	None[2]	None[2]	None[3]	None[2]	None[2]
WILDLIFE							
Critical Habitat	None	None	None	None	Yes[4]	None	None
T&E species	None	None	None	None	None	None	None
AQUATIC LIFE							
T&E species	None	None	None	None	None	None	None
(Also see above RECREATION:	Wild Trout and Other angling)						
CULTURAL RESOURCES							
Historic sites	13	11	13	12	14	13	13
Prehistoric sites	10	4	6	6	4	6	6
WATER QUALITY (MITIGATION NEED)							
Temperature	High	High	High	High	Medium	High	High
Eutrophication	High	High	High	High	Medium	High	High
Dissolved Oxygen	High	High	High	High	High	High	High

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(1) Includes both mainstem and North Fork.
(2) Potential range for Colorado butterfly plant and potential impact to bitterbrush/needle-and-thread plant association.
(3) Potential range for Colorado butterfly plant and several plant associations of state and federal interest.
(4) Big horn sheep.

boating. In addition, it would eliminate 4.7 miles of wild trout waters on the mainstem, and 6.6 miles of other cold water angling on the Mainstem and North Fork. Approximately 6 miles of scenic driving opportunity along the Poudre would be eliminated.

Construction and operation of the reservoirs could impact water quality. In addition to increased sediment loading during construction, the potential exists for modified water temperatures, reduced downstream dissolved oxygen levels, and eutrophication from nutrients in the North Fork.

Although this alternative would result in the inundation of 10.5 miles of riparian vegetation, wildlife and aquatic life habitats that would be eliminated or disturbed are not critical to the continued viability of local mammal, bird, and fish populations. Some wildlife species will be minimally disturbed, such as the golden eagle, wild turkey, elk, and mule deer.

There are no threatened and endangered flora or fauna known to exist within the reservoir sites, but there is potential habitat for the Colorado butterfly plant, which is under review for federal protective status. The reservoir areas are also potential range for the bitterbrush/needle-and-thread grass plant association which is considered by the Colorado Natural History Heritage Inventory to be critically imperiled in Colorado because of rarity. A site survey would be required to determine if these plants are present.

A literature search inventory of cultural sites lists 10 prehistoric and 13 historic sites registered with the state within the area of the reservoirs.

12.2.2.2 Plan B

This alternative involves Grey Mountain Reservoir and Trailhead Reservoir, which would inundate portions of the Poudre and North Fork of the

Poudre, and the off-channel Greyrock Mountain Reservoir. The three reservoirs would inundate 1850 acres, including 6.4 miles of the Poudre and 3.0 miles of the North Fork. The nature of the environmental impacts associated with this alternative are generally the same as for Plan A for land use, recreation, and water quality; however, the impacts typically do not occur over as many acres, nor involve as many miles of the mainstem of the Poudre as indicated in Table 12.2. For example, this alternative impacts fewer miles of primary white-water boating (1.4 miles), wild trout waters (3.4 miles), and riparian vegetation (9.0 miles). Although the Grey Mountain Reservoir inundates fewer miles of the river, the impacts of changed flow regime on the river could adversely impact white-water boating and wild trout waters.

12.2.2.3 Plan C

Plan C facilities include the Poudre Reservoir, which would inundate portions of the Poudre and North Fork, and the off-channel Glade and Greyrock Mountain Reservoirs. The three reservoirs would inundate 3460 acres, including 4.7 miles of the mainstem and 3.0 miles of the North Fork. Unlike Plans A and B, the majority of the acreage (2200 acres) is located at the Glade Reservoir site. The environmental impacts associated with this alternative are of the same type as those for Plan A, but do not occur over as many acres nor as many miles of the mainstem of the Poudre. This alternative eliminates no primary white-water boating, but it would inundate 2.2 miles of other white-water boating, plus 1.7 miles of wild trout water, and 7.5 miles of riparian vegetation. Although the Poudre Reservoir would not inundate primary white-water boating opportunities and eliminates fewer miles of wild trout water, a changed flow regime on the river could adversely impact boating and aquatic life.

This alternative would require the relocation of a total of nearly 14 miles of Colorado 14 and US 287 and accompanying private utilities. Several miles of a larger 115 kV electrical transmission line near the Glade Reservoir site would also have to be relocated in addition to the other private utilities.

12.2.2.4 Plan D

Plan D would include Footbridge Reservoir on the mainstem of the Poudre, New Seaman Reservoir on the North Fork, and the off-channel Glade and Greyrock Mountain Reservoirs. Including the 2280-acre Glade Reservoir, the four reservoirs would inundate 3230 acres, 2.0 miles of the Poudre, and 4.0 miles of the North Fork. Approximately 750 acres of the Poudre and North Fork would be inundated. The principal environmental impacts associated with this alternative are land use and water quality, and are similar in nature to those of Plan A. This alternative does not eliminate any white-water boating opportunities or wild trout waters; however, the changed flow regime could adversely impact boating and aquatic life.

This alternative would require the relocation of a total of about 11 miles of Colorado 14 and US 287 and accompanying private utilities. Several miles of a larger 115 kV electrical transmission line near the Glade Reservoir site would also have to be relocated in addition to the other private utilities.

12.2.2.5 Plan E

Plan E would include Trailhead Reservoir on the mainstem of the Poudre, the Halligan Reservoir on the North Fork, and the off-channel Glade Reservoir. Including the 1150-acre Glade Reservoir, the three reservoirs would inundate 2370 acres of land, 3.7 miles of the Poudre, and 1.0 mile of the North Fork. The principal environmental impacts associated with this alternative are similar in nature to those of Plan A. This alternative does not eliminate any white-water boating opportunities and only 0.8 mile of wild trout waters. However, the changed flow regime of the river could adversely impact the remaining 3.0 miles of wild trout waters and 4.7 miles of white-water boating opportunities.

This alternative would require the relocation of a total of 13.7 miles of Colorado 14 and US 287 and accompanying private utilities. Several miles of a larger 115 kV electrical transmission line near the Glade Reservoir site would also have to be relocated in addition to the other private utilities.

The construction of the Halligan Reservoir could have some impact on bighorn sheep winter range in the vicinity of the reservoir, if construction occurred during the winter months.

12.2.2.6 Plan B1

Plan B1 includes Grey Mountain Reservoir on the mainstem, off-channel storage at Glade Reservoir for water supply, and the off-channel Greyrock Mountain Reservoir for pumped-storage. Its implementation would affect the mainstem to about the same degree as Plan B. Off-channel effects would be similar to Plan C.

12.2.2.7 Plan C1

This is a reduced version of Plan C involving less storage capacity for water supply and pumped-storage hydroelectric generation. For preliminary evaluation, it was assumed that Plan C1 would have the same impacts as Plan C.

12.2.3 Environmental Evaluation Summary

The seven plans were ranked with respect to each other for environmental impacts. In ranking the plans, impacts to the mainstem of the Cache la Poudre River were given greater weight than impacts to the North Fork of the Cache la Poudre River or off-stream impacts. Almost all public comment during the Study was directed at impacts of the alternative plans on the mainstem of the Cache la Poudre River. Impacts to the North Fork are relatively uniform among the alternatives, almost all of which involve some reservoir and stream inundation on the North Fork. The majority of present recreational opportunities occur on the mainstem of the Poudre. The portion of the North Fork that would be affected by alternative plans is closed to public access.

Table 12.3 displays the relative environmental impacts of alternatives planned within each environmental category. Those plans having the same impact are given the same rank. For example, Alternatives D and E both impact the same number of known cultural resources and are both ranked number 3. A ranking of 1 indicates the most environmental impact, and a ranking of 5 indicates the least environmental impact.

TABLE 12.3
Relative Environmental Impact of
Alternative Plans By Environmental Category

	Ranking of Alternative Plans[(1)]				
Environmental Category	A	B, B1	C, C1	D	E
Recreation	1	2	3	5	4
Land Use	1	2	3	5	4
Vegetation	1	2	3	5	4
Aquatic Life	1	2	3	5	4
Wildlife	1	2	3	5	4
Cultural Resources	1	4	2	3	3
Water Quality	1	1	2	3	4

(1) Ranking of "1" indicates the highest relative environmental impact; ranking of "5" indicates the lowest relative environmental impact.

Table 12.4 shows the overall ranking of the alternative plans in terms of environmental impact.

It should be noted that these impact rankings are relative to each other, and do not imply, for example, that Alternative A has five times the impact of Alternative D.

TABLE 12.4
Overall Ranking of Alternative Plans by Environmental Impact

Ranking	Alternative Plan
1st	A
2nd	B, B1
3rd	C, C1
4th	E
5th	D

Well in advance of project construction, detailed environmental studies would be conducted in compliance with NEPA and Federal Energy Regulatory Commission (FERC) regulations if hydroelectric power is included. On-site biological surveys would be conducted to identify and quantify aquatic and terrestrial wildlife resources, and their habitats, which would be affected by the project elements. Field surveys of recreational use would be conducted to identify project impacts. Historical and archaeological resources would be located through intense ground surveys. Water quality monitoring programs and water quality modeling would be carried out to enable prediction of changes in water quality that could be caused by project operation. Following these assessments, mitigation needs and enhancement opportunities would be evaluated, and specific programs developed. Environmental data would be used to prepare an environmental assessment for submittal to the lead agency responsible for the Environmental Impact Statement (EIS). Following this submittal, the lead agency would prepare an EIS in compliance with NEPA, which includes requirements for public input.

12.2.4 Endangered Species on the Platte River

The Platte River in central and eastern Nebraska is used as nesting area and feeding habitat by two bird species protected under the Federal Endangered Species Act (the least tern and piping plover). A 59-mile reach of the Platte River in central Nebraska is designated as critical habitat for the whooping crane, an endangered species. The bald eagle utilizes the Platte River as overwintering habitat. The effects of additional water storage in the Platte Basin upstream from this habitat are being studied by a Federal/State coordinating Committee. The study will document habitat needs and identify ways to meet those needs that are not in conflict with future water development. Results from the study are expected by late 1987 well before feasibility studies for a water project in the Poudre Basin would be completed.

12.2.5 Enhancement Opportunities

Each of the alternative plans would offer new opportunities for flatwater recreation (such as boating, angling, and swimming), camping, picnicking, and development of commercial establishments at the reservoir sites. The Colorado Outdoor Recreation Plan indicates the need for new flatwater recreational opportunities in the study area. The popularity of Horsetooth Reservoir and other nearby reservoirs suggests that any new reservoir will receive extensive use.

A mainstem reservoir on the Poudre has the potential to become an outstanding fishery, as indicated by what has occurred at Spinney Mountain Reservoir on the South Platte River south of Denver. Spinney Mountain Reservoir has a statewide reputation and is producing trophy-sized trout, both in the reservoir and upstream of the reservoir during Spring and Fall spawning runs. Glade Reservoir would offer tremendously expanded opportunities for fishing and recreation, comparable to those at Horsetooth Reservoir, which attracts 178,000 visitors per year, according to data of the U.S. Bureau of Reclamation.

Although many legal and institutional issues would have to be overcome, reservoir construction provides for the future opportunity to enhance stream fisheries both above and below a mainstem reservoir with increased flow releases during winter months. While it is premature to propose specific mitigation or enhancement measures, releases from high mountain reservoirs potentially could be made during the winter months to avoid fish kills that now occur. These releases could be stored in a new mainstem facility for subsequent downstream use. With proper management, a new storage reservoir also could create an excellent tailwater fishery that could extend through Fort Collins. This latter enhancement probably would require modification of degraded sections of the existing stream channel below the canyon mouth through Fort Collins and arrangements to store flow maintenance releases in a plains reservoir. Both enhancements would require the resolution of water rights concerns and additional storage capacity in the proposed reservoirs. Further, no studies have been made as yet to determine how much water would be needed to undertake these enhancements and whether this water could be made available when needed. These topics would be addressed in the feasibility phase if a project in the Poudre Basin moves forward.

Alternatives B and C offer opportunities to provide whitewater boating below the reservoirs if water is available for flow releases, and existing put-in and take-out sites are improved. Primarily studies indicate that reservoir releases could be used to extend the whitewater boating season and/or to improve the quality of the whitewater boating experience by providing higher flows at specified times. Again, water rights concerns would need to be resolved prior to implementing this enhancement.

High mountain reservoir releases and creation of a tailwater fishery would enhance the recreational experience on over 60 miles of stream. The largest reservoir on the mainstem would inundate about eight miles of stream on the mainstem of the Poudre.

Private homesites and land would be purchased at fair market value and existing highway and utility corridors could be relocated, with the visual impact reduced through careful attention to site planning.

Existing cultural sites could be excavated and recorded or isolated from project construction and/or operation. Water quality impacts could be reduced by providing multiple-level intake structures at the dams. These structures enable water to be withdrawn from various levels within a reservoir in order to provide releases that have acceptable temperature and dissolved oxygen levels.

12.3 ECONOMIC EVALUATION

The economic performance of each plan was evaluated based on a present value analysis of economic benefits and economic costs. Economic costs for implementing each plan would include construction costs, annual operation, maintenance, and replacement (O,M&R), lost recreation opportunities, real estate, and other environmental losses. Benefits from implementing each plan would be derived from: the sale of capacity and energy produced by the pumped-storage installation (except in the case of Plan E) and any small conventional, run-of-river hydropower produced at the dams; sale of water; recreation opportunities afforded by the new reservoirs; possible replaced stream recreation at another location, particularly downstream from a mainstem dam; land development around reservoirs; and flood control.

12.3.1 Economic Costs

Costs that were quantified for the economic analysis include: project costs both construction and O,M&R; outlays for purchasing dwellings that would be inundated; and benefits from stream-based recreational opportunities that would be lost because of inundation. Cost estimates for transmission facilities were not included because the costs for transmission line construction were assumed to be offset by the benefits that would accrue from having the new transmission facilities in place. Costs for environmental mitigation and enhancement measures also were not included. At present, it is not known what types of measures would be implemented should a project move forward. Mitigation and enhancement costs are expected to be relatively small in comparison to overall project costs and they would be about the same regardless of the plan.

12.3.1.1 Project costs

Estimated construction costs for each plan are provided in Chapter 11 and summarized in Table 12.5. Costs of bond issuance are not included in the economic analysis. Investment cost, capital requirements, and annual cost estimates are presented for each plan in Chapter 11, based on a nominal interest rate of eight percent (three percent real interest rate and five percent inflation). These are provided for comparative purposes only and do not relate directly to the economic analysis described in this chapter. In the economic analysis, a real interest rate was applied to keep all cost and benefit estimates, including debt service, in 1986 dollars. A real interest rate of three percent was used.

TABLE 12.5
Construction and Operation,
Maintenance and Replacement Costs

Plan	Construction Costs ($ Million)	Annual O,M&R ($ Million)
A	1,590	16
B	1,340	13
C	1,510	15
D	1,650	16
E	283	4
B1	1,530	16
C1	630	12

The timing of each cost and benefit is vital in this analysis because all dollars must be discounted from the year they are expended or received to 1986, present value dollars. Hence, dollars spent or received in the distant future are worth less than costs or benefits that occur in the immediate future.

Based on current plan definitions, construction would not likely be completed until the late 1990s or the year 2000. Projected time requirements for larger projects might be: three to five years for permitting; about two years for engineering; about one year for letting of contracts; five to six years for construction; and about two years from the first generation unit in operation to full power.

For the larger projects, it was assumed that reservoirs would begin filling and the first power units would go on line in the year 2000. O,M&R costs were assumed to begin the first year of power operation and continue to the end of the evaluation period, year 2050. For the smaller plan developments, completion might be as early as the mid-1990s.

12.3.1.2 Dwelling Unit Inundation Costs

Each of the structural plans involve reservoirs that would inundate the structures, facilities, and other human activity focal points that currently exist in the respective reservoir areas. Engineering cost estimates have accounted for the major structures that will be impacted,including roads, utilities, existing water conveyance facilities, as well as land costs. Homes, ranches, and small businesses would also be inundated and are examined separately. As a general dollar quantification of this impact, the aggregate dollar value of the inundated homes is estimated for each plan.

Estimating this cost required identifying the number of homes in the reservoir areas of each plan and applying a unit dollar value. The homes affected range from small structures in poor condition to large new houses.

Realtors and appraisers in the area were hesitant to try to estimate home values due to lack of comparable sales. Values were said to range from $15,000 to $75,000 with the exception of four large year-round dwellings in the $200,000 to $500,000 range. Listed sale prices or appraised values were applied for the larger homes. Other dwellings were assumed to be worth $60,000 on average. These figures are intended only to represent preliminary estimates for this prefeasibility level study. These values specifically are not relevant to potential negotiations for property acquisition for water resource development. Table 12.6 summarizes these costs. Impacts to residents of Poudre Park have not been quantified.

TABLE 12.6
Dollar Losses from
Dwelling Unit Inundation

Plan	Number of Homes Inundated	Cost ($ Million)
A	35	3.2
B	33	3.1
C	33	3.1
D	24[1]	2.5
E	31	3.0
B1	29	2.9
C1	27	2.7

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[1] Includes several homes directly below Footbridge Dam.

12.3.1.3 Cost of Lost Recreation

Each of the five alternative plans includes a reservoir in the lower reaches of the Cache la Poudre Canyon. This would lead, in varying degrees, to the loss of certain water-based recreation activities. Stream trout fishing and white-water boating are the activities most likely affected.

A total of 2,000 and 5,000 annual fishing and white-water user days, respectively, are estimated to occur annually on affected reaches of the Cache la Poudre River. These were estimates provided by the Colorado Division of Parks and Outdoor Recreation and the Colorado Division of Wildlife. Walsh, Sanders and Loomis (1985) estimated recreational use of the Cache la Poudre to be increasing at 2.2 percent annually. Recreational capacity limits this growth from continuing without bound. Using this growth rate, user days in the year 2000 would be 2700 and 6800 for fishing and white water activities, respectively. Costs associated with lost recreation are based upon these figures.

It is assumed that the maximum number of miles available for fishing and white-water recreation are 12.3 and 4.7, respectively. On average, this translates to 240 and 1,450 user days per mile for fishing and white water activities on the Cache la Poudre. The various plans would range from the complete loss of fishing and white water activities under Plan A to moderate loss under Plan C to modest lost under Plan D. Annual fishing and white water recreation days lost are obtained by multiplying user days per mile by the number of miles lost for each plan.

The Water Resources Council (1983) provides unit day value (UDV) estimates for general and specialized recreation. General recreation activities include the majority of outdoor activities typically requiring the development and maintenance of convenient access and proper facilities, such as tent and trailer camping, warm water boating and fishing, swimming and picnicking. Specialized recreation activities are more limited, intensity of use is low, and more knowledge and skill is required. Trout fishing, big game hunting, pack trips and white-water boating, for example, are considered specialized activities. Values per user day range from $3 to $21. A higher UDV value is associated with specialized activities in comparison to general activities. At the prefeasibility level, no attempt was made to scale the qualitative value of the recreation experience; the maximum values were applied. Fishing activity and white-water boating on the Cache la Poudre are assumed to generate a maximum UDV of $21 in 1986 dollars.

Several recent studies using other approaches substantiate the estimates of the Water Resources Council. These studies found values per user day for recreation typical of the Cache la Poudre ranging from $10 to $24 (Walsh, Sanders and Loomis, 1985; Vaughn and Russell, 1982; and Walsh, Ericson, Arosteguy and Hansen, 1980).

Annual costs of lost recreation were derived by multiplying lost fishing and white-water boating user days by $21. Losses are recognized for each year from initiation of construction through the end of the study period, year 2050. Results are shown in Table 12.7.

TABLE 12.7
Lost Dollar Recreational Benefits

	Plan A	Plan B	Plan C	Plan D	Plan E	Plan B1	Plan C1
Annual Fishing days lost	2,700	2,250	1,840	1,430	1,300	2,010	1,600
Annual white water days lost	6,800	5,210	3,180	2,460	3,180	5,210	3,180
Annual fishing benefits lost ($1000) (@ $21/day)	57	47	38	30	27	42	33
Annual white water benefits lost ($1000) (@ $21/day)	143	109	67	52	67	110	67
Total Annual Lost Benefits ($1000)	200	156	105	82	94	152	100

The allocation of lost recreational visitor-days to particular miles of the river implies greater precision than is possible at this level of study. More importantly, the dollar losses associated with stream fishing and white water boating represent a comparative index of total recreational losses. Scenic driving, hiking, picnicking and other recreational pursuits might also be diminished. Further, the translation of recreational losses into dollar terms is difficult, given the broad human and social value which can be placed on such pursuits by certain individuals.

12.3.2 Economic Benefits

Economic benefits for each plan were quantified for pumped-storage hydroelectric power, conventional hydroelectric power, additional water supplies, and flat-water recreation. Other potential benefits associated with flood control, stream-based recreation, land development, and enhanced water management were not quantified at this time. These benefits could not be realized unless there are specific commitments by the project developer.

12.3.2.1 Pumped-Storage Benefits

All but one of the plans includes pumped-storage facilities. These facilities would produce peak power and energy while consuming off-peak energy. It was assumed that the pumped storage project would operate at 20 percent plant factor (i.e., the plant would be generating on-peak energy about 20 percent of the time each year). This is consistent with the operating experience at several pumped-storage developments in the U.S.

Certain important qualifications to the revenue estimation procedure for pumped-storage operation need to be understood. Projections indicate a shortfall in peaking capacity in Colorado by the year 2000. The need for additional peaking capacity in the region might reach about 450 MW by 2000 and 940 MW by 2020. An 1,800 MW facility in operation by 2000 would likely sell a large portion of its power outside of Colorado, whereas a 450 MW installation in operation by 2000 would sell its power within the region. Wheeling costs on existing transmission lines, costs of building new transmission lines, and line losses might reduce the value of the power. Conversely, the use of new or existing transmission facilities might afford the opportunity to transmit existing resources from one utility to another in a different region of the country profitably by taking advantage of load curve diversity. Given the magnitude of these unknowns, transmission costs and benefits are excluded from the analysis. Further, a generic facility and marketplace must be assumed at this reconnaissance level, even though actual prices can only be determined if specific utility customers in the U.S. commit to support the pumped-storage project.

Table 12.8 identifies actual firm demand and energy purchases in 1985 and several calculations of avoided cost.

TABLE 12.8
Selected Electricity Prices
for Demand and Energy

	Demand Charge ($/kW-mo)	Energy Charge ($/kWh)	Combined Price ($/kWh @ 20% Load Factor)
Firm Power Purchases, 1985			
Public Service Company of Colorado (PSC)	7.02	0.013	0.061
Tri-State Members	13.71	0.0198	0.114
Tri-State Generation and Transmission	15.34	0.0226	0.128
Avoided Cost			
PSC (Purchase from Cogenerators, 1986)	19.38	0.01603	0.149
Tudor Study (Avoided cost of coal-fired Cycling Plant, 1982)	24.17	0.015	0.181
Combined Cycle Plant Costs in Midwest	5.79	0.411	0.081

The selection of prices to apply in the analysis is based largely upon the uncertainties associated with the pumped-storage project and its likely market which is outside Colorado. The combined cycle plant costs for a Midwestern facility were selected because this approach:

- Represents an estimate at the lower end of the range of price of power;
- Uses avoided cost for a large facility typical of major markets in the U.S. based upon 1986 conditions; and
- Adopts a constant price, excluding a real escalation factor for the future price of power.

An estimate of $0.081/kWh combined demand and energy price (at 20 percent load factor) was applied to determine the value of on-peak generation by the pumped storage project. This reflects a demand charge of $5.79/kW-mo and energy charge of $0.411/kWh. Off-peak power sells for about $.01 per kWh in the local market. A cost of $0.0184 was used for the purchase price of off-peak energy, based on analysis of nuclear and coal-fired facility data in the Midwest. Annual pumped-storage benefits range from $175 to $181 million as shown in Table 12.9.

TABLE 12.9
Dollar Estimation of Pumped-Storage Benefits

	Plans A,B,&B1	Plans C & D	Plan C1
Demand			
Capacity (MW)	1,800	1,860	460
Months	x 12	x 12	x 12
kW-mo	21,600,000	22,320,000	5,520,000
$/kW-mo	x 5.79	x 5.79	x 5.79
Annual revenue from demand charges	$125,100,000	$129,200,000	$ 32,000,000
Peak Energy			
Capacity (MW)	1,800	1,800	4,600
hours/yr	x 8,760	x 8,760	x 8,760
Load factor	x 20%	x 20%	x 20%
Peak energy (GWh)	3,154	3,259	806
$/kWh (peak)	0.0411	0.0411	0.0411
Annual revenue from peak energy sales	$129,600,000	$133,900,000	$ 33,000,000
Pumping Energy Required (GWh)	4,321	4,464	1,104
$/kWh (off peak)	0.0184	0.0184	0.0184
Annual Cost	$79,500,000	$82,100,000	$ 20,300,000
Net Annual Energy Revenue	$50,100,000	$51,800,000	$ 12,700,000
Total Annual Revenue	$175,200,000	$181,000,000	$ 44,700,000

12.3.2.2 Conventional Hydropower

The plans include between 3 MW and 16 MW of capacity to take advantage of run-of-river power potential. The hydropower facilities would produce energy from the reservoir releases. The relatively small quantities of power and energy produced would likely be sold in the local market. Public Service Company rates for purchases from cogenerators were $19.38 per kW-month and $0.01603 per kWh in 1985. These rates are assumed to approximate potential benefits from small-scale conventional hydropower in Colorado. Potential benefits are provided in Table 12.10.

TABLE 12.10
Estimated Benefits from
Conventional Hydropower by Plan

	Plan A	Plan B,B1	Plan C,C1	Plan D	Plan E
Capacity (MW)	16	14	11	5	3
Plant Factor (%)	32	31	31	34	34
Annual revenue from power ($ Million) (@ $19.38/kw-mo x plant factor)	1.2	1.0	0.8	0.4	0.2
Energy (GWh)	45	38	30	15	9
Annual revenue from energy ($ Million) (@ .01603/kWh)	0.71	0.6	0.5	0.2	0.1
Total annual revenue ($ Million)	1.9	1.6	1.3	0.6	0.3

12.3.2.3 Additional Water Supplies

The alternative plans include different potentials for developing new water supplies, storing Windy Gap and C-BT water and improving water management capabilities throughout the Basin. The economic analysis only quantifies the benefits from additional firm annual yield.

Three approaches were used to estimate the value of water for irrigation, as indicated in Chapter 7. Calculation of economic losses based upon a financial model of farm operations identified economic losses of $170 to $300 per af under Series 3. These estimates were confirmed by a review of the historic losses from the 1930s drought and from benefits of the C-BT Project. Analysis of actual agricultural water rentals found typical prices of $20 to $50 per af of net consumptive use. Rental prices in dry years increased to as much as $150 per af. Based upon the Task 5 research, a value of $250 per af is applied in the benefit-cost analysis for the value of water in periods of severe shortages.

In addition to providing drought protection, additional storage could make water available to irrigators later in the season when supplies are short. The net value of adding water supplies in critical months and decreasing supplies in months of excess is based upon observed rental prices in the basin. A mid-range value of $30 per af is assumed for additional water supplies made available in normal years.

There is a 16 percent probability of being in one year of a 1-in-25 year drought having a four-year duration. The weighted average value of additional water supply for irrigation is computed as follows: ($250 per af x 0.16) + ($30 per af x 0.84) = $65 per af.

Estimated annual benefits of additional water supplies are provided in Table 12.11 for each plan.

TABLE 12.11
Annual Benefits of Additional
Water Supplies by Plan

	A	B	C,D,B1	E	C1
Firm water (af)	46,000	29,000	49,000	17,000	24,000
Average value per af ($)	65	65	65	65	65
Annual benefit ($ Million)	3.0	1.9	3.2	1.1	1.6

12.3.2.4 Flat-Water Recreation Benefits

Construction of a reservoir would create new recreation opportunities and enhance certain existing activities. Estimates of benefits accruing from reservoir construction are based on user day values of Horsetooth Reservoir, a major Front Range facility and a perceived close substitute for reservoirs included in the alternative plans. An average UDV from selected activities is then applied to user day estimates for the alternative plans to arrive at benefit estimates from reservoir construction. Separate costs for recreational amenity development are not deducted because these might be offset by user fees and secondary recreational benefits in the area. Beyond this prefeasibility level study, a closer examination of recreational developer costs, concessions, fees and secondary impacts would be desirable.

Estimated user days for the proposed new reservoirs are apportioned according to reservoir length and the experience at Horsetooth Reservoir which has averaged 178,000 visits per year since 1980. This translates to an average of 89,000 user days per year. Horsetooth is approximately 12.5 miles long, providing 7,120 user days per mile. Using the 2.2 percent annual growth rate as estimated by Walsh, Sanders and Loomis (1985) user days would reach 9700 per mile annually by the year 2000. Without information on user days by recreation activity, a simple arithmetic average of hiking, camping, picnicking, boating, water sports and general fishing unit day values was obtained and adjusted to 1986 prices. Further analysis of recreation demand capacity and user day values is recommended for any future studies. An average value of $9 per user day was applied. As presented in Table 12.12, Plans C and D provide projected annual benefits of $829,000 while Plan E provides $400,000 in benefits. While the average value per user day is lower than the existing stream-based recreation in the area, potential recreational use benefits appear to be higher.

TABLE 12.12
Potential Flat Water Recreation
Benefits Under the Five Plans (Annual)

	Plan A	Plan B	Plan C,D	Plan E	Plan B1	Plan C1
Reservoir lengths (miles)	7.0	5.0	9.5	4.5	8.0	6.5
Total annual user days @ 9,700 per mile	67,900	48,500	92,200	43,700	77,600	63,100
Annual benefits ($) @ $9.00 per UDV	611,000	437,000	829,000	393,000	698,000	568,000

12.3.2.5 Replaced Stream Recreation

There is a possibility that certain stream-related recreational activities can be created with the reservoir developments, replacing to some extent the lost recreational opportunities from upstream inundation. These amenities might include stream fishing, white-water boating, and a cold water fishery downstream from a mainstem reservoir. The creation of these recreational opportunities would require:

1. Reservoir operations and water releases timed to benefit fisheries and white water boating;
2. Commitment to enhance streamflows downstream from the dam, possibly through Fort Collins;
3. Access from private lands to the river; and
4. Commitment to make releases from mountain reservoirs in winter to enhance the fishery above a new mainstem storage facility.

Depending on the plan and development strategy, these improvements might offer a number of positive attributes.

12.3.2.6 Land Value and Development

Front Range reservoirs such as Horsetooth, Lake Estes, Carter Lake, and Pinewood Reservoir are sites of significant real estate development. Three of the alternative plans include construction of Glade Reservoir in the hogback just north of Ted's Place and approximately 10 miles west of Wellington. This site might provide significant opportunities for real estate development, based on the experience at Horsetooth Reservoir. The construction of a reservoir might enhance amenities such as environmental quality and aesthetics of scenery and provide easy access to water-based activities. This added value would be capitalized into property values. Alternatively, the reservoir developer might condemn land adjacent to the site and make lands available for sale. The proceeds might go to retiring debt associated with the project construction.

Preliminary research has found that the existence of Horsetooth adds a minimum of $3,000 to $5,000 to the value of local residential lots, depending on proximity to the lake. This would be a one-time benefit at the time of development. With three and one-half to five miles of potential development on the east side of Glade Reservoir, assuming two lots per 100 foot frontage, $1.8 to $2.6 million in benefits could result depending on the plan.

12.3.2.7 Flood Control Benefits

Based upon a detailed 1981 U.S. Corps of Engineers study, 30 major floods on the Cache la Poudre have been recorded in the last one hundred years. Except for Seaman and Halligan Reservoirs on the North Fork of the Cache la Poudre River, existing reservoirs were found to have little individual effect on flood flows. Further, operation of the existing reservoirs results in their being nearly full in June, giving little extra storage capabilities during the flood season.

The entire 100-year floodplain from the mouth of the canyon to the South Platte encompasses 12,700 acres. Most of the floodplain lands are used for cropland, pasture or rangeland. Some sand and gravel mining operations as well as highways and railroad facilities are located within the floodplain. Portions of Bellvue, LaPorte, Fort Collins and Greeley also lie within the 100-year floodplain of the Cache la Poudre. Other communities such as Wellington have been at risk due to flooding of tributaries in the plains.

The Corps of Engineers (COE, 1981) estimated current potential flood damage to buildings and contents in LaPorte, Fort Collins, and Greeley to average over $1 million per year as shown in the Table 12.13.

TABLE 12.13
Potential Urban Damage from
Cache la Poudre Floods

Community	Average Annual Probable Flood Damage (Adjusted to 1986 dollars)
LaPorte	$ 118,000
Fort Collins	862,000
Greeley	148,000
Total	$1,128,000

The estimates shown in Table 12.13 include the potential damage to buildings and contents. They exclude damage to streets and utilities, emergency or clean up costs, agricultural losses, future growth, and higher valued land uses that may occur in the future. A conservatively low estimate of the total annual benefit of flood protection might be double the annual damages calculated by the COE (1981).

Flood control benefits were not included in the benefit-cost calculations because allocations of flood control storage volume were not made. Inclusion of flood control storage is subject to further study at the feasibility level when operating policies and project purposes would be clearly defined. It should be noted, however, that even without dedicated storage for flood control, a mainstem reservoir below the North Fork confluence would provide incidental flood control.

12.3.3 Summary of Benefits and Costs

Based on the above estimates and assumptions, each separate benefit and cost was projected for the seven plans independently from 1986 through 2050. The annual benefits and costs are then discounted back from the year they occur to 1986 dollars. As indicated previously in this section, certain benefits and costs are not carried forward into the summary analysis.

Table 12.14 presents the economic benefit-cost summary. Plans A through D and Plan B1 show a substantial excess of benefits over costs, roughly in the same order of magnitude: $1.7 to $2.0 billion in 1986 dollars. Hence, each of these are promising from an economic standpoint. The bulk of the costs stem from project construction, and the majority of the benefits are attributable to the pumped-storage component. About two-thirds of the costs for Plans A through D are for pumped storage. Plan E does not have a pumped storage component. Plan E has a negative benefit-cost comparison because the water supply and other benefits are small in relation to costs. Plan C1 includes a smaller pumped-storage facility, resulting in lower net benefits of $0.2 billion.

Internal rate of return is a financial measure of the attractiveness of a particular dollar investment. In essence, it measures the rate of return, as measured in benefits, of the dollars which would have to be invested to complete any of the plans. Plan B offers the highest rate of return at 9.5 percent; the lowest positive rates are Plans A and D at 8.1 percent. Plans A, B, C, B1, and D offer opportunities for debt financing. Plan C1 has a rate of return of 4.7 percent and may offer opportunities for debt financing. Plan E exhibits a negative internal rate of return.

TABLE 12.14

Present Value of Benefits and Costs for the Respective Water Resource Development Plans ($ Million)

	Plan A	Plan B	Plan C	Plan D	Plan E	Plan B1	Plan C1
PV Benefits (@ 3%)							
Pumped storage	3,096	3,096	3,199	3,199	0	3,096	852
Conventional Hydro	34	28	23	11	6	28	25
Water Supplies	47	32	50	50	23	50	29
Flat Water Recreation	9	7	13	13	5	11	10
Stream Recreation	*	*	*	*	*	*	*
Land Development	**	**	*	*	*	*	*
Flood Control	*	*	*	**	**	*	*
Enhanced Water Management	*	*	*	*	*	*	*
Total	3,186	3,163	3,285	3,273	34	3,185	916
PV Costs (@ 3%)							
Construction	1,176	987	1,117	1,216	234	1,132	486
O&M	283	230	265	283	85	283	229
Lost Recreation	4	3	2	2	2	3	2
Lost Dwellings	3	2	2	2	2	2	2
Environmental Losses	*	*	*	*	*	*	*
Total	1,466	1,222	1,386	1,503	323	1,420	719
Net Present Value	1,720	1,941	1,899	1,770	(289)	1,765	197
Internal Rate of Return	8.1%	9.5%	8.7%	8.1%	(-)	8.4%	4.7%

* Not quantified for comparative summary analysis.
** Not applicable.
(-) Negative
Note: 1. All dollars are stated in 1986 terms, discounted back to present value using a 3 percent real interest rate.
2. Costs and benefits of measures to enhance winter streamflows and to create a viable fishery downstream through Fort Collins, as well as other possible enhancements, have not been quantified.

Chapter 13

Conclusions and Recommendations

13.0 CONCLUSIONS AND RECOMMENDATIONS

13.1 INTRODUCTION

The Cache la Poudre Basin Planning Study was initiated in mid-1985 and performed over a 16-month period by a consulting team under the management of the Colorado Water Resources and Power Development Authority. The overall purpose of the Study was to establish whether a need will exist for water in the Basin over the foreseeable future; and if such a need exists, what would be the general nature of the non-structural measures and structural project components that might optimize water and power resource development in an environmentally sound manner. A key component of the study was to ascertain whether conventional or pumped-storage hydropower could be integrated into a water storage project to contribute to repayment of water project costs.

The Cache la Poudre Basin Planning Study fully incorporates previous resource planning efforts in the region, especially the Wild and Scenic River Designation. Structural project alternatives have only been examined for those segments of the river that, through compromise with environmental and other interests, have not been precluded from consideration for water and hydropower development.

13.2 MAJOR FINDINGS AND CONCLUSIONS

The Cache la Poudre Basin Study accomplished the objectives established at the outset. Key findings are summarized below:

- In average runoff years, existing water supplies will likely be sufficient to meet needs under most future development scenarios in the Basin. This is likely because agricultural water supplies will continue to be transferred to expanding M&I uses in the Basin. However, under a 1-in-25 year drought, a 250,000 af shortage of consumptive use is projected, translating into a $40 to $150 million economic loss to the Basin depending upon how these shortages are managed.

- Developable water resources exist from four sources: storable native flows, additional diversions from the West Slope (Windy Gap and C-BT), groundwater, and return flows. In aggregate, additional developable water supplies amount to about 100,000 af per year.

- Given the present surpluses of power, there is no current need for additional electricity generation for Colorado or the Rocky Mountain Region. After the year 2000, new peaking power production facilities will be needed; the most economically efficient alternatives are expected to be developed first. It appears that a pumped-storage hydroelectric facility in the Basin could meet these future demands.

- A broad spectrum of non-structural water resource development alternatives were evaluated as part of this study. A number of these deserve further detailed analysis, and others are viable as emergency measures. Twelve non-structural measures have been found to be the most promising. A number of these measures, however, will require important commitments by water management institutions in the Basin. Certain ones will require complementary structural water resource development to achieve maximum benefit.

- Several structural water resource development options were identified and analyzed. This led to formulation of seven alternative plans, each of which included the 12 non-structural elements found to be the most promising. The plans cover a range of water storage capacities and hydroelectric generating capacities. With extensive public input, these plans were carefully evaluated from a technical, environmental, and economic standpoint.

TABLE 13.1

SUMMARY EVALUATION OF ALTERNATIVE PLAN A

Technical Factors	Environmental Factors: Impacts	Environmental Factors: Mitigation Measures and Enhancement Opportunities	Economic Factors
• Non-structural plan elements provide approximately 198,000 af during a 1-in-25 year drought of 4 years duration, thus reducing the total shortage (449,000 af) by 44 percent. • Structural plan elements increase water supplies 46,000 af per year of which 24,000 af would be new water from the Windy Gap and C-BT projects. • Portal reservoir provides 259,000 af of live storage. This excludes waters behind Trailhead Dam and essentially equals the storage objective of 274,000 af. • Trailhead Dam permits independent operation of Portal reservoir (water supply) and Trailhead reservoir (lower hydropower reservoir). • Portal reservoir could provide flood control for the plains. • Portal reservoir would enhance water management opportunities in the Basin and region. • Portal reservoir could control winter releases from high mountain reservoirs to enhance upstream fishery and release flows to enhance downstream boating and fishery. • Timely identification and diversion of storable flows is facilitated because Portal reservoir controls mainstem and North Fork flows. • The hydropower pumped-storage facility with 1800 MW installed capacity provides twelve hour continuous output of 21,600 MWh and an annual average energy production of 3150 GWh. The average gross head would be approximately 1330 ft and the ratio of horizontal length of water conductor to head is 4.9 to 1.	• The three reservoirs would inundate about 2710 surface acres. This alternative would inundate the most miles of the Poudre River, including about 8.3 miles of the mainstem and 3.0 miles of the North Fork. • Major impacts to land use would include the inundation of 20 to 30 private homesites, about 12.9 miles of state highway and public utilities, and the construction of about 3.9 miles of new access road. • No threatened and endangered species of fish, wildlife, or plant have been found within the project sites. No critical habitats would be affected by the reservoirs, although about 10.5 miles of riparian habitat along mainstem and North Fork would be inundated. • Construction and operation of the reservoirs could cause adverse changes in water quality, including modified temperatures, lowered dissolved oxygen, and reservoir eutrophication. • Major impacts to recreation would be the loss of about 4.7 miles of whitewater boating, 10.5 miles of stream angling, and the elimination of about 0.5 miles of hiking and 6.0 miles of scenic driving. (Current estimates of minimum annual use include 5000 whitewater boaters, 2000 angling days, and 6000 hiking visits.) • At least 13 historic and prehistoric sites would either be inundated or disturbed by the construction of the reservoirs.	• The existing state highway and private utilities would be relocated south of the main reservoir site. • Private homesites and property would be purchased at fair market value. • Water quality problems could be minimized through (1) dams with multiple level water outlets and (2) reduced water retention time in the reservoirs. • Whitewater boating above the Portal Reservoir could be enhanced through the construction of new put-in and take-out sites for the general public near Mishawaka and Poudre Park. • With a mainstem storage reservoir, water releases from high mountain reservoirs could enhance stream angling above reservoir during fall and winter months. Angling below the dam could also be enhanced year around through added water releases. Public access sites (parking and trail system) for fishing could be constructed along reservoir and river. • Development of additional recreational facilities on the upstream Wild and Scenic river segments. • Access to existing Greyrock Trail could be from a bridge across the reservoir or a new segment near Poudre Park. Trail segments near Greyrock Reservoir would be relocated, or an entirely new trail could be constructed to the east. • Existing cultural sites would be excavated and recorded or isolated from project construction or operation.	• Present value benefits exceed costs for Plan A by $1,720 million based upon a three percent real discount rate. • The real internal rate of return is 8.1 percent. This high rate of return suggests financial feasibility at real interest rates approaching eight percent. • Annual revenues from pumped-storage would approximate $175 million. Another $1.9 million in conventional hydropower revenues would be generated each year. • Annual benefits from additional water supplies would average $3.0 million. Water management opportunities within the basin would be enhanced. • Annual benefits from flat water recreation might total $0.6 million; the value of lost stream recreation might be $0.2 million per year. Enhancement of other stream recreation might be possible. • Little opportunity for land development is evident. Significant flood control benefits could be offered.

TABLE 13.1 (Continued)
SUMMARY EVALUATION OF ALTERNATIVE PLAN A

Technical Factors	Environmental Factors: Impacts	Environmental Factors: Mitigation Measures and Enhancement Opportunities	Economic Factors
		• Reservoirs would create new opportunities for angling in the reservoir and for boating, hiking, camping, and picnicking development operated either by public agencies or private concessionaires. • Other potential enhancement options that might be considered if a project were implemented in the Basin include: 1. Development of a river corridor park and fishery enhancement to ensure more convenient public access to the river. 2. Development of recreational facilities on the North Fork. 3. Develop a Poudre Canyon Resource Center that would provide facilities for conferences and retreats, conservation education, and reservoir water quality research. 4. Prepare a comprehensive river recreation management plan for the Poudre River. 5. Develop unique public access and facilities along the reservoir and river specifically for the physically disabled. 6. Fund tourism and recreation research and promotions to increase awareness of other local attractions and services. 7. Provide low interest loans to commercial rafting operations to permit their relocation or retraining/re-equipping for other recreational services.	

TABLE 13.2

SUMMARY EVALUATION OF ALTERNATIVE PLAN B

Technical Factors

- Non-structural plan elements provide approximately 198,000 af during a 1-in-25 year drought of 4 years duration, thus reducing the total shortage (449,000 af) by 44 percent.
- Structural plan elements increase water supplies 29,000 af per year which would be new water from the Windy Gap and C-BT projects (24,000 af) and some new yield from native storable flows.
- Structural plan elements do not satisfy the water supply storage objective of 274,000. Plan B could be expanded later to include Glade reservoir and satisfy the storage requirement.
- Trailhead Dam permits independent operation of Grey Mountain reservoir (water supply) and Trailhead reservoir (lower hydropower reservoir).
- Grey Mountain reservoir could provide flood control for the plains.
- Grey Mountain reservoir would enhance water management opportunities in the Basin and the region but to a lesser extent than Plan A.
- Grey Mountain Reservoir could control winter releases from high mountain reservoirs to enhance upstream fishery and release flows to enhance downstream boating and fishery.
- Timely identification and diversion of storable flows facilitated because Grey Mountain reservoir controls mainstem and North Fork flows.
- The hydropower pumped-storage facility with 1800 MW installed capacity provides a twelve hour continuous output of 21,600 MWh and an annual energy production of 3150 GWh. The average gross head is approximately 1390 ft and the ratio of the horizontal length of water conductors to head is 4.9 to 1.

Environmental Factors

Impacts

- The three reservoirs would inundate about 2160 surface acres, including about 6.4 miles of the mainstem and 3.0 miles of the North Fork.
- Major impacts to land use, vegetation, wildlife, water quality, recreation, and cultural resources are essentially the same as in Alternative A, but to a lesser extent. In comparison, the Grey Mountain Reservoir would inundate fewer miles of whitewater boating (3.6 miles), stream angling (9.4 miles), and riparian habitat (9.0 miles), and fewer cultural sites (11 historic and 4 prehistoric).

Mitigation Measures and Enhancement Opportunities

- Major enhancement options are essentially the same as in Alternative A.
- In addition to the new whitewater boating sites above the reservoir, new put-in and take-out sites for the general public could also be constructed below the Grey Mountain Reservoir, if adequate water releases can be timed to provide periods of weekend rafting.

Economic Factors

- Present value benefits exceed costs for Plan B by $1,940 million based upon a three percent real discount rate.
- The real internal rate of return for Plan B is 9.5 percent. Financial analysis indicates total capital requirements of $1,538 million. Annual payments including O&M would total $88 million based upon a three percent real interest rate and 30 year repayment period. Repayment analysis indicates financial feasibility at real interest rates as high as seven percent.
- Annual revenues from pumped-storage would be about $175 million. Conventional hydropower revenues might total $1.6 million per year.
- Annual benefits from additional water supplies would average $1.9 million. Water management opportunities would be somewhat enhanced.
- Flat water recreation benefits might be $0.4 million per year while lost stream recreation might represent a $0.2 million annual cost. Enhancement of other stream recreation might be possible.
- Little opportunity for land development is evident; significant flood control benefits could be offered.

- A preferred plan of future development (Plan C) was selected, as described in Section 13.3. This plan represents the best combination of structural measures based on technical, economic, and environmental analyses. Certain environmental losses would occur under this preferred plan, including habitat, recreational resources, and other inundation losses. However, new recreational opportunities could be created and existing recreation could be significantly enhanced. New water supplies would be available to the Basin, and important flood control benefits could be achieved. The plan is also consistent with the Federal Wild and Scenic River designation.

- Economic benefits for the selected plan substantially exceed costs, both from a total project and Basin perspective. The economic rate of return is sufficiently attractive to anticipate interest from financial backers assuming the pumped-storage feature will attract major utility financial commitments. Potential revenues from the pumped-storage hydropower component could pay a major portion of project costs.

13.3 SELECTION OF PREFERRED PLANS

The Authority required that two plans be selected; a preferred plan and an alternative. Plan C was recommended as the preferred plan and Plan B was recommended as the alternative. These recommendations were reviewed in detail with the Authority and have been discussed with the Advisory Committee at two meetings both of which were attended by the public.

All plans have been analyzed and evaluated on the basis of their technical, environmental and economic characteristics,as described in Chapter 11 and summarized in Tables 13.1 through 13.7. No single plan has been found which ranks first in each of the three categories. Some plans rank higher technically or environmentally, others are more attractive in their economic aspects. Selection therefore has been based on obtaining the best balance of technical, environmental, and economic aspects.

TABLE 13.3

SUMMARY EVALUATION OF ALTERNATIVE PLAN C

Technical Factors

- Non-structural plan elements provide approximately 198,000 af during a 1-in-25 year drought of 4 years duration, thus reducing the total shortage (449,000 af) by 44 percent.
- Structural plan elements increase water supplies 49,000 af per year of which 24,000 af per year would be new water from the Windy Gap and C-BT Projects.
- Structural plan elements satisfy the water supply storage objective of 274,000 af. Poudre Reservoir has 43,000 af of space assigned to water supply storage and 18,000 af of space assigned to the hydropower project. Glade Reservoir has 231,000 af of live storage for water supply.
- Poudre Reservoir could provide flood control for the plains.
- Poudre and Glade Reservoirs would enhance water management opportunities in the Basin and the region.
- Poudre Reservoir could release flows to enhance downstream boating and fishery.
- Timely identification and diversion of storable flows will be facilitated because Poudre Reservoir controls mainstem and North Fork flows.
- The hydropower pumped-storage facility with 1860 MW installed capacity provides a twelve-hour continuous output of 22,300 MWh and an annual energy production of 3260 GWh. Average gross head is 1410 ft and the ratio of horizontal length of water conductor to head is 4.9 to 1.

Environmental Factors

Impacts

- The three reservoirs would inundate about 3525 surface acres, including about 4.7 miles of the mainstem and 3.0 miles of the North Fork. About 2600 of the total acres inundated are located off of the Poudre River at the Glade site.
- Major impacts to land use, vegetation, wildlife, water quality, recreation, and cultural resources are also essentially the same as in Alternative A, but to a lesser degree. In comparison, the Poudre Reservoir would inundate fewer miles of whitewater boating (2.2 miles), stream angling (7.7 miles), riparian habitat (7.5 miles), and fewer cultural sites (13 historic and 6 prehistoric). However, it would also inundate more miles of state and federal highway and public utilities (17.9 miles) and about 2000 acres of agricultural and/or range land associated with the Glade Reservoir site.

Mitigation Measures and Enhancement Opportunities

- Major enhancement options are essentially the same as in Alternative A.
- In addition to the new whitewater boating sites above the reservoir, new put-in and take-out sites for the general public and commercial outfitters could also be constructed below the Poudre Reservoir.
- The Glade Reservoir would create more flatwater recreational opportunities, including a warm water fishery, boating, camping, and picnicking.

Economic Factors

- Present value benefits exceed costs for Plan C by $1,899 million based upon a three percent real discount rate.
- Plan C achieves a real rate of return of 8.7 percent. Financial analysis indicates capital requirements of $1,780 million. Annual payments of $101 million would be required under a three percent real interest rate and 30 year repayment period. Based upon revenue potential, the project could be financed at real interest rates of at least seven percent.
- Annual revenues from pumped-storage total $181 million. This is higher than Plans A and B because of greater installed capacity. Conventional hydropower might produce $1.3 million in annual revenues.
- Annual benefits from additional water supplies would average $3.2 million. Enhanced opportunities for water management would be created.
- Flat water recreation benefits might total $0.8 million per year. Lost benefits related to stream recreation might be $0.1 million per year. Enhancement of other stream recreation might be possible.
- Opportunities for land development at Glade Reservoir are evident. Significant flood control benefits could be achieved.

TABLE 13.4

SUMMARY EVALUATION OF ALTERNATIVE PLAN D

Technical Factors

- Non-structural plan elements provide approximately 198,000 af during a 1-in-25 year drought of 4 years duration, thus reducing the total shortage (449,000 af) by 44 percent.
- Structural plan elements increase water supplies 49,000 af per year of which 24,000 af per year would be new water from the Windy Gap and C-BT Projects.
- Structural elements satisfy the water supply storage objective of 274,000 af. New Seaman has 20,000 af of space assigned for water supply storage and 18,000 af of space assigned to the hydropower project. Glade Reservoir has 254,000 af of live storage for water supply.
- New Seaman Reservoir could provide flood control for North Fork flows. Mainstem flows would remain uncontrolled.
- New Seaman and Glade Reservoirs would enhance water management opportunities in the Basin and the region.
- New Seaman Reservoir could control winter releases from high mountain reservoirs to enhance upstream fishery and release flows to enhance downstream boating and fishery.
- Timely identification and diversion of storable flows will be difficult because Footbridge Reservoir cannot provide temporary control of mainstem flows. Waste can be expected. New Seaman Reservoir will facilitate identification and diversion of storable North Fork flows.
- The hydropower pumped-storage facility with 1860 MW installed capacity provides a twelve-hour continuous output of 22,300 MWh and an annual energy production of 3260 GWh. Average gross head would be approximately 1380 ft and the ratio of horizontal length of water conductor to head is 10.9 to 1.

Environmental Factors

Impacts

- The four reservoirs would inundate about 3310 surface acres, and would inundate the fewest miles of the Poudre River, including about 2.0 miles of the mainstem and 3.0 miles of the North Fork. Like Alternative C, about 2600 of the total acres inundated are located off of the Poudre River at the Glade site.
- Major impacts to land use, vegetation, wildlife, water quality, recreation, and cultural resources are also essentially the same as for Alternative A, but to a lesser degree. In comparison, the New Seaman Reservoir would inundate about 14.3 miles of state and federal highways and public utilities, 2000 acres of agricultural and/or range land, and 6.0 miles of stream angling and riparian habitat. Fewer cultural sites would be affected (12 historic and 6 prehistoric) and the fewest miles of whitewater boating (1.7 miles).

Mitigation Measures and Enhancement Opportunities

- Major enhancement options are essentially the same as in Alternative A, except that major reservoir opportunities would be shifted to those possible at Glade Reservoir.
- In addition to the new whitewater boating sites above the reservoir, new put-in and take-out sites for the general public and commercial outfitters could also be constructed below the New Seaman Reservoir (if water releases are in the area of 1500 cfs).
- The Glade Reservoir would create more comparable flatwater recreational opportunities, including a warm water fishery.

Economic Factors

- At $1650 million, this is the most expensive of the four major hydropower generation plans.
- Present value benefits exceed costs for Plan D by $1,770 million based upon a real discount of three percent.
- The real internal rate of return for Plan D is 8.1 percent. This rate of return indicates favorable financing potential.
- Annual revenues from pumped-storage would total $181 million. Limited conventional hydropower potential is evident; annual revenues might average $0.6 million.
- Benefits from additional water supplies would average $3.2 million per year. Because of limited main stem storage, opportunities for improved water management might be less than for other plans.
- Flat water recreation benefits might be $0.8 million per year, while lost stream recreation might be valued at $0.1 million per year. Enhancement of other stream recreation might be possible.
- Opportunities for land development at Glade Reservoir are evident. Potential flood control benefits are minimal because of limited main stem storage.

TABLE 13.5

SUMMARY EVALUATION OF ALTERNATIVE PLAN E

Technical Factors

- Non-structural plan elements provide approximately 198,000 af during a 1-in-25 year drought of 4 years duration, thus reducing the total storage (449,000 af) by 44 percent.
- Structural plan elements increase water supplies 17,000 af per year, comprising 10,000 af derived from the mainstem diversions to Glade reservoir and 7,000 af derived from North Fork flows stored at New Halligan reservoir.
- Structural elements do not satisfy the water supply objective of 274,000 af. Glade reservoir provides 60,000 af of live storage and New Halligan reservoir provides 59,000 af of live storage.
- Trailhead Dam acts as a diversion structure. It could be raised in the future in hydropower were installed.
- No flood control of mainstem flows. New Halligan reservoir could be operated for flood control of North Fork flows.
- Glade and Halligan reservoirs would enhance water management opportunities but to a lesser extent than Plans A, C, and D.
- Glade reservoir could control winter releases from high mountain reservoirs to enhance upstream fishery on the mainstem. Releases from Glade reservoir could enhance fishery beginning at a point approximately 2 miles downstream from the mouth of the canyon. Enhancement of flows for boating and fishery downstream from the confluence can only be achieved by releases from New Halligan reservoir.
- Timely identification and diversion of mainstem storable flows will be difficult because Trailhead reservoir cannot provide temporary control of mainstem flows. Waste can be expected.
- Hydropower would not be included initially in this Plan. It could be added later.

Environmental Factors

Impacts

- The three reservoirs would inundate about 3770 surface acres, including about 3.7 miles of the mainstem and 1.0 mile of the North Fork. Like Alternative C, about 2400 of the total acres inundated are located off of the Poudre River at the Glade site.
- Major impacts to land use, wildlife, water quality, recreation, and cultural resources are also essentially the same as for Alternative A, but to a lesser degree. In comparison, this alternative would inundate about 13.6 miles of state and federal highways and public utilities, 6.0 miles of stream angling and riparian habitat, and 2.2 miles of whitewater boating. It would affect the fewest miles of stream angling (5.5 miles) and riparian habitat (4.7 miles). It would affect the most acreage of agricultural and/or range land (about 3000 acres).

Mitigation Measures and Enhancement Opportunities

- Major enhancement options are essentially the same as in Alternative A, except that major reservoir opportunities would be shifted to those possible at Glade Reservoir.
- In addition to the new whitewater boating sites above the reservoir, new put-in and take-out sites for the general public and commercial outfitters could also be constructed below the present Fort Collins water treatment facility.
- The Glade and Halligan Reservoirs would create more flatwater opportunities, including a warm water fishery, boating, camping, and picnicking.

Economic Factors

- Present value costs of Plan E exceed benefits by $289 million at a three percent real discount rate. Costs were found to exceed benefits even at a zero discount rate.
- A negative internal rate of return is evident for Plan E. The project could not be financed without additional sources of subsidy.
- No pumped-storage facilities are included in the plan. About $0.3 million in conventional hydropower revenues could be generated each year.
- Annual benefits from additional water supplies would average $1.1 million. Because of limited main stem storage, opportunities for improved water management might be less than for other plans.
- Flat water recreation benefits might be $0.4 million per year. Lost stream recreation might represent economic costs of $0.1 million per year. Enhancement of other stream recreation might be possible.
- Lands might be developed at Glade Reservoir. Flood control benefits would be less than other plans due to limited main stem storage.

TABLE 13.6

SUMMARY EVALUATION OF ALTERNATIVE PLAN B1

Technical Factors	Environmental Factors: Impacts	Environmental Factors: Mitigation Measures and Enhancement Opportunities	Economic Factors
• Non-structural plan elements provide approximately 198,000 af during a 1-in-25 year drought of 4 years duration, thus reducing the total shortage (449,000 af) by 44 percent. • Structural plan elements increase water supplies by 49,000 af per year which would be new water from the Windy Gap and C-BT projects (24,000 af) and from native storable flows (25,000 af). • Structural plan elements satisfy the target water supply storage objective of 274,000 af. Grey Mountain Reservoir provides 60,000 af live storage and Glade Reservoir provides 214,000 af of live storage. In addition Grey Mountain Reservoir provides 18,000 af of storage for the hydropower project. • Grey Mountain reservoir could provide flood control for the plains. • Grey Mountain and Glade reservoirs would enhance water management opportunities for the Basin and the region. • Grey Mountain reservoir could release flows to enhance downstream boating and fishery. • Timely identification and diversion of storable flows will be facilitated because Grey Mountain reservoir controls mainstem and North Fork flows. • The hydropower pumped-storage facility with 1800 MW installed capacity provides a twelve-hour continuous output of 21,600 MWh and an annual energy production of 3150 GWh. The average gross head is approximately 1390 ft and the ratio of the horizontal length of water conductors to head is 4.9 to 1.	• The mainstem reservoir would inundate somewhat less surface area on the mainstem but more off-channel than the reservoirs in Plan B. About 6.4 miles of the mainstem and 3.0 miles of the North Fork would be affected. • Major impacts to land use, vegetation, wildlife, water quality, recreation, and cultural resources are essentially the same as in Alternative A, but to a lesser extent. In comparison, the Grey Mountain Reservoir would inundate fewer miles of whitewater boating (3.6 miles), stream angling (9.4 miles), and riparian habitat (9.0 miles), and fewer cultural sites (11 historic and 4 prehistoric).	• Major enhancement options are essentially the same as in Alternative A. • In addition to the new whitewater boating sites above the reservoir, new put-in and take-out sites for the general public could also be constructed below the Grey Mountain Reservoir, if adequate water releases can be timed to provide period of weekend rafting.	• Present value benefits exceed costs for Plan B1 by $1,770 million based upon a three percent real discount rate. • Plan B1 achieves a real rate of return of 8.4 percent. This suggests financial feasibility of the project. • Annual revenues from pumped-storage would total $175 million. Conventional hydropower revenues might be $1.6 million per year. • Benefits from additional water supplies would average $3.2 million per year. Water management opportunities would be enhanced. • Flat water recreation benefits might be $0.7 million per year while lost stream recreation might represent a $0.2 million annual cost. Enhancement of other stream recreation might be possible. • Opportunities for land development at Glade Reservoir are evident. Significant flood control benefits could be achieved.

TABLE 13.7

SUMMARY EVALUATION OF ALTERNATIVE PLAN C1

Technical Factors

- Non-structural plan elements provide approximately 198,000 af during a 1-in-25 year drought of 4 years duration, thus reducing the total storage (449,000 af) by 44 percent.
- Structural plan elements increase water supplies by 24,000 af per year which would be new water from the Windy Gap and C-BT Projects.
- Structural plan elements satisfy the target water supply storage objective of 274,000 af. Poudre Reservoir has 43,000 af of space assigned to water supply storage and 18,000 af of space assigned to the hydropower project. Glade Reservoir has 231,000 af of live storage for water supply.
- Poudre Reservoir could provide flood control for the plains.
- Poudre and Glade Reservoirs would enhance water management opportunities but to a lesser extent than Plans A, C, D, and B1.
- Poudre Reservoir could release flows to enhance downstream boating and fishery.
- Timely identification and diversion of storable flows will be facilitated because Poudre Reservoir controls mainstem and North Fork flows.
- The hydropower pumped-storage facility with 460 MW installed capacity provides a twelve-hour continuous output of 5520 MWh and an annual energy production of 806 GWh. Average gross head is 1390 ft and the ratio of horizontal length of water conductor to head is 4.9 to 1.

Environmental Factors

Impacts

- The three reservoirs would inundate somewhat less surface area than Plan C but would affect about 4.7 miles of the mainstem and 3.0 miles of the North Fork. Most of the inundated area would be located off of the Poudre River at the Glade site.
- Major impacts to land use, vegetation, wildlife, water quality, recreation, and cultural resources are also essentially the same as in Alternative A, but to a lesser degree. In comparison, the Poudre Reservoir would inundate fewer miles of whitewater boating (2.2 miles), stream angling (7.7 miles), riparian habitat (7.5 miles), and fewer cultural sites (13 historic and 6 prehistoric). However, it would also inundate more miles of state and federal highway and public utilities (17.9 miles) and 2000 acres of agricultural and/or range land associated with the Glade Reservoir site.

Mitigation Measures and Enhancement Opportunities

- Major enhancement options are essentially the same as in Alternative A.
- In addition to the new whitewater boating sites above the reservoir, new put-in and take-out sites for the general public and commercial outfitters could also be constructed below the Poudre Reservoir.
- The Glade Reservoir would create more flatwater recreational opportunities, including a warm water fishery, boating, camping, and picnicking.

Economic Factors

- Present value benefits exceed costs for Plan C1 by $197 million based upon a three percent real discount rate.
- The real internal rate of return for Plan C1 is 4.7 percent. Financial analysis indicates total capital requirements of $719 million. Annual payment of $46 million would be required. Comparison of payments with project revenues suggest financial feasibility at a real interest rate of three percent. The project might not be feasible under higher real interest rates, however.
- Annual revenues from a scaled down pumped-storage facility would be about $45 million. Revenues from conventional hydropower would average $1.3 million per year. Because of the smaller project size, operation could begin several years earlier than the large plans, increasing the present value benefits over the study period.
- Annual benefits from additional water/supplies would average $1.6 million per year. Water management opportunities within the basin would be enhanced.
- Flat water recreation benefits might total $0.6 million per year while lost stream recreation might be $0.1 million per year. Enhancement of other stream recreation might be possible.
- Opportunities for land development at Glade Reservoir are evident. Significant flood control benefits could be achieved.

13.3.1 Preferred Plan

Plan C, comprising Poudre Reservoir, Glade Tunnel and Reservoir, and the pumped-storage project, represents the best balance between technical, environmental, and economic factors. It has been recommended as the preferred plan.

Principal reasons for selecting Plan C are:

1. Satisfies the target storage objective of 274,000 af.
2. Permits optimum arrangement of the pumped-storage features.
3. Structurally it leaves mainstem below the confluence essentially unaffected.
4. Tailwater fluctuations due to power operation are less than or equal to those for other plans.
5. Flood control of both the mainstem and North Fork flows is possible.
6. Possible to enhance upstream and downstream recreational opportunities.
7. Only one dam is needed on the river in the canyon. Other plans require two dams.
8. Plan C is economically feasible and offers second highest rate of return.

Plan C has neither the most nor the least potential environmental impact of the five plan alternatives. Alternative C would inundate 460 acres (4.7 miles) of the mainstem of the Cache la Poudre River, 600 acres (3.0 miles) of the North Fork of the Poudre, and 2600 acres off-channel at the Glade Reservoir site.

Poudre Reservoir would directly impact about 2.2 miles of whitewater boating (currently about 5000 user days according to the Colorado Division of Parks and Outdoor Recreation) and 6.0 miles of angling (currently about 2000 user days according to the Colorado Division of Wildlife)--including

1.7 miles of designated "Wild Trout" water. It would require the relocation of about 5.0 miles of scenic driving (Colorado Highway 14) and a 0.5 mile segment of hiking along Greyrocks Trail (currently about 6000 user days). A total of 7.5 miles of riparian vegetation would be eliminated.

Plan C would require significant highway and utility relocations of 17.9 miles, and would require the purchase of 33 private homes.

As part of the Study, a subsurface exploration program was conducted at the Glade site. This program included three drill holes (NX size) totalling 336 feet in length, 2500 feet of seismic refraction survey, and auger holes provide confirmation about the depth to rock along the Glade dam axis. Results of the field explorations are given in Appendix E. Although more investigations would be needed for the feasibility study, it is concluded at the prefeasibility level that Glade is a suitable damsite.

13.3.2 Alternative Plan

Plan B has been recommended as the alternative to Plan C. Storage provided under Plan B would, as a minimum, be sufficient to capture either storable native flows or additional Windy Gap plus C-BT diversions and also lend itself to future water storage expansion. The principal reasons for selecting Plan B as the alternative rather than one of the other plans are:

1. Provides sufficient storage for either storable flows or new Windy Gap plus C-BT diversions.
2. Storage capacity could be increased in the future by the addition of Glade Reservoir.
3. Permits optimum arrangement of the pumped-storage features.
4. Flood control of both mainstem and North Fork flows is possible.
5. Possible to enhance upstream and downstream recreational opportunities.
6. Requires a significantly lower initial investment of capital.
7. Plan B is economically feasible and offers the highest rate of return of any plan studied.

Plan B ranks second in terms of overall adverse environmental impact. It would inundate 800 acres on the mainstem of the Poudre River (6.4 miles), and 850 acres on the North Fork of the Poudre. A total of 1.4 miles of primary whitewater boating would be eliminated, and 2.2 miles of other whitewater boating. Wild trout angling stream totaling 3.4 miles would be inundated, along with 6.0 miles of other cold-water angling, including cold water angling on the North Fork of the Poudre. About 6.0 miles of Colorado Highway 14 would be relocated, and 0.5 miles of the Greyrocks Hiking Trail would have to be relocated.

About 25 residences would need to be purchased, and 9.0 miles of riparian vegetation would be impacted by this alternative. A total of 15 known historic and prehistoric sites would be affected by facilities in Plan B.

13.3.3 Other Plans

Plans A and B1 were eliminated because neither represented a reasonable alternative to Plan C. Both are essentially equal to Plan C in storage and power characteristics but inferior with regard to environmental impacts and rate of return.

Plan D was eliminated because of its consequences on the pumped storage project. It provides the lower reservoir for the pumped storage project on the North Fork instead of the mainstem thus approximately doubling the length of water conductors. The direct cost of the power facility would be increased by about 10 percent. The economic viability of Plan D is dependent on the attractiveness of the power facility in comparison to many other potential projects being proposed to utility companies. A plan that is dependent on a weakened pumped-storage facility is therefore not a reasonable alternative to Plan C. For this reason, Plan D was not selected.

Plan C1 represents an initial phase of Plan C in which the installed power capacity is reduced to meet only the future regional needs. Storage capacity is sufficient for either storable flows or Windy Gap plus C-BT diversions but not both. The concept of staged development of Plan C could be investigated during feasibility studies for Plan C.

Plan E provides a total of 60,000 af of storage in Glade Reservoir and 59,000 af of storage at Halligan Reservoir. The storage capacity at Glade is insufficient for additional Windy Gap and C-BT diversions and Halligan Reservoir, because of its location, may not be suitable for storing Windy Gap and C-BT diversions.

13.4 FINANCIAL ANALYSIS OF THE PREFERRED PLAN

Total construction for Plan C costs are $1,510 million (1986 dollars) over a 13-year period. Interest is accrued throughout this period. Revenue bonds might be issued in the year 2000 with the costs of the bond reserve fund and bond issuance incurred in that year. The outstanding principal would total $1,780 million in the year 2000. Based on a 30-year repayment period and a three percent real interest rate (eight percent nominal interest rate less five percent inflation), annual debt service payments of $89 million (in 1986 dollars) would be required. Annual O&M costs would total $15 million but $3 million in interest would be earned each year on the bond reserve fund, resulting in net annual O&M payments of $12 million. Total annual payment would be $101 million. Assuming constant annual payment, outstanding principal declines to $1,370 million by 2010, $824 million by 2020, and $87 million by 2030. Debt service in that last year would be met from use of the bond reserve fund.

Preliminary analysis indicates that pumped-storage and conventional hydropower could carry the entire $101 million annual payment burden for Plan C. Conventional hydropower revenues might contribute $1.3 million per year toward repayment, while the burden on pumped storage would total $99.7 million per year. This annual burden would represent 55 percent of pumped-storage revenues. Under this scenario, the Basin would receive at least $5.2 million in net benefits per year from additional water supplies, recreation, and flood control.

Project financing also was analyzed using different real interest rates. For example, payments of $171 million are required under a seven percent real interest rate (12 percent nominal rate less five percent inflation). The $182 million in projected revenues from pumped-storage and conventional hydropower support annual payments for Plan C even under a seven percent real interest rate.

13.5 FINANCING REALITIES FOR PROJECTS IN THE CACHE LA POUDRE BASIN

It is extremely important that the water users in the Basin strengthen their cooperative spirit to develop their water resource options in the Basin that best fulfill the needs consistent with financing opportunities. It will only result in many years of delay and increased costs if both sides of an opposing viewpoint are not willing to constructively discuss those issues, as successfully carried out in the Advisory Committee Meetings, and hopefully arrive at an acceptable compromise.

The Authority is empowered to sell revenue bonds that must be serviced from the revenue stream derived from a project. These financial arrangements are consistent with the present water development conditions in Colorado; namely, <u>a project must essentially be able to carry itself financially</u>. In Colorado there is no present major state subsidy available for developing large water projects. Federal involvement in water project development has declined substantially. However, there may be future opportunities to subsidize water users with the joint development of pumped-storage hydropower in the Basin. It is important to note that the project may be financable through the sale of revenue bonds. There would be no additional ad valorem taxes for this project from the Northern District's tax base.

Some discussion during the study centered on capturing as much water as possible. However, if additional storage capacity is provided to capture more water during a wet year, the cost per af of yield starts going up very rapidly due to the large storage space, or carry over storage, that may only be filled once every 10 to 20 years. It is apparent that the costs of developing new structural facilities at over $500 per af per year are well beyond the repayment ability of agricultural water users.

13.6 RECOMMENDATIONS

It is recommended that both Plan C and the best alternative plan, Plan B, be carried to the feasibility level, the second step in the development process. Should financial support for this next step materialize, a number of critical issues identified in this Study can be thoroughly explored.

13.6.1 The Feasibility Study Process

The feasibility study process would begin with the identification of and financial commitment from project proponents. In most instances, the project proponents for a major undertaking of this nature would be drawn from among the project beneficiaries. These were identified as part of the prefeasibility study to include electric utilities and their customers, Basin water users, flood control beneficiaries, recreational water users, and the State of Colorado. Funding for a feasibility study could come, in part, from water users in the Basin, the NCWCD, and the State of Colorado via the Authority. It is expected, however, that the bulk of the funding would need to come from electric utilities wishing to participate in the hydropower development.

The hydropower beneficiaries would only fund the feasibility study if the perceived benefit from future power resources was significant. Depending upon the outcome of the feasibility study, ultimate bond financing could be achieved only with long-term, irrevocable commitments from the utility backers and thus avoiding the need for pledging the tax base in the Basin.

13.6.2 Feasibility Study Overview

The recommended feasibility study would probably take as long as two to three years to complete. The cost of the feasibility would vary depending on permitting and licensing requirements but it could cost about $10 million. In essence, this level of study would provide considerable detail about the project and a complete examination of the major issues expressed about the project by the public and the various interest groups.

Much more work must be accomplished to assess the viability of each plan element within a full scale feasibility study. For example, little groundwater data are available, particularly with respect to current pumping amounts and water quality. A data collection effort initiated in the near future would provide baseline data needed in a full-scale feasibility study. Aerial mapping in the vicinity of potential damsites should also be conducted now to support later activities.

Initial investigations indicate that revenues from the pumped-storage hydropower operation would be necessary to support project costs. This basinwide study did not fully examine whether the power market could absorb this power or whether this project is more attractive than competing new power facilities. In the final analysis, electric utilities that could utilize this power would have to come forward to ensure payment of project costs before any facilities could be constructed.

Cost estimates for new transmission lines were not included in the plan evaluations. New DC transmission lines were assumed to provide benefits in excess of their costs. They would generate revenues through interregional marketing of power and their construction may be feasible even without a pumped-storage component.

Insufficient information is available to assess the full positive and negative effects of the preferred plan on the local environment, particularly recreational activities. Additional baseline data on the environment and existing recreational uses of the Poudre River are necessary. This data collection effort has been initiated by the NCWCD for the Poudre River below Poudre Park. This information should be reviewed at the start of the feasibility study and additional data should be collected if necessary.

12.6.3 Summary

This basinwide study defined a combination of structural and non-structural measures for the sound development of water and hydropower resources in the Cache la Poudre Basin. Non-structural measures were selected by screening 32 potential elements. Recommended structural facilities were selected from more than 30 elements, including storage, conveyance, and hydroelectric power facilities. In summary, the preliminary analysis demonstrates the strong technical and economic feasibility of the recommended plans. Environmental effects associated with implementing each plan and potential environmental enhancement opportunities were identified at a preliminary level of detail. Future investigations can now move beyond the basinwide view to evaluate Plans C and B in much greater detail. As required by the Plan of Study, a Scope of Services and schedule for the Phase III feasibility study was prepared. This Scope of Services is contained in a separate document.

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GLOSSARY AND ABBREVIATIONS

A

absolute water right - A water right that has been perfected and placed to beneficial use.

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

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

acre-foot (af) - The volume of water, equal to the quantity required to cover an acre of land to a depth of 1 foot, equivalent to 43,560 cubic feet or about 326,000 gallons. An acre-foot of water can supply the water needs of a typical family of four for about one year.

acre-feet per year (af/yr) - The flow rate of water equal to 0.00138 cubic feet per second for one year.

adjudication - A judicial proceeding in which a priority is assigned to an appropriation and a decree issued defining the water right.

afterbay - A channel, short stretch of stream, or small reservoir conducting water away from a water turbine or into which a hydropower plant discharges.

alluvium - Clay, silt, sand, gravel, or detritus material deposited by running water.

amphibolite - Metamorphic rock formed by metamorphism of basalt and rocks of similar composition.

appropriation - The volume or flow of water that is legally allocated to an individual, municipality, corporation, or government entity for an identified beneficial use.

aquifer - A geologic formation that contains sufficient saturated permeable material to yield water to wells and springs.

arable land - Fit for or cultivated by farming. Land which, when properly prepared for agriculture, will have a sufficient yield to justify its development.

artificial recharge - The addition of water to the ground water reservoir by activities of man, such as irrigation or induced infiltration from streams, wells, or spreading basins.

augmentation - Enlarging or increasing the quantity of an item such as increasing the flow of a stream or river.

augmentation plan - A requirement of the 1969 Water Right Determination and Administration Act covering tributary ground water. An augmentation plan allows each well owner to provide replacement (augmentation) water to the stream at times when a senior right would be "calling out" his well.

average flow - The arithmetic mean of flow rates over a period of time, usually one year.

B

basalt - A dark, fine-grained extrusive rock composed primarily of feldspar and pyroxene.

base load capacity - A constant load over a period in time.

basement - The rock complex generally consisting of igneous and metamorphic rocks. Where not exposed, overlain unconformably by sedimentary strata. The crystalline crest of the earth.

basin - The drainage or catchment area of a stream or lake.

basin rank - A number used in Colorado by the State Engineer in the tabulation of decreed water rights to indicate the relative standing of a decreed right with respect to all other decreed rights within a water division.

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

beneficial use - The use of that amount of water that is reasonable and appropriate under reasonable efficient practices to accomplish, without waste, the purpose for which the diversion is lawfully made and without limiting the generality of the foregoing, shall include impoundment of water for recreational purposes, including fishery or wildlife.

benefits (economic) - The increase in economic value produced by the addition of a project, typically represented as a time stream of value produced by the generation of consumable resources.

biotite - A complex silicate of potassium, iron, aluminum and magnesium.

brecciated - Highly angular and coarse rock components.

C

calibration - Usually a trial and error procedure of adjusting simulation model coefficients such that results from the model provide a reflection of the actual system.

call - The placing of a request by a senior priority to the Water Commissioner to shut down junior priorities so that the senior is able to divert its full entitlement. In such cases, junior priorities are curtailed or "called out."

capability - The potential to produce resources, supply goods and services, and allow resource uses under a given level of management intensity and assumed set of management practices.

capacity - The power output or load that a turbine-generator, station, or system is capable of producing.

capacity value - That part of the market value of electric power that is assigned to dependable capacity.

compact - A contract between states of the Union, entered into with the consent of the National Government, and in water, defining the relative rights of two or more states on an interstate stream to use the waters of that stream.

conditional decree - A decree of the court awarding a priority date of appropriation to use water even though actual taking and use of the water is delayed until a future time, usually until a project is constructed.

conditional water right - A right to perfect a water right with a certain priority upon the completion with reasonable diligence of the appropriation upon which such water right is based.

conduit - A channel for conveying water or fluid.

conglomerate - A cemented elastic rock containing gravel- or pebble-sized rounded fragments.

conservation storage - Storage of water for later release for useful purposes such as municipal water supply, power, or irrigation in contrast with storage capacity used for flood control.

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.

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

conveyance loss - The loss of water from a conduit or open channel due to leakage, seepage, evaporation or evapotranspiration.

correlation - The process of establishing a relation between a variable and one or more related variables. Correlation is simple if there is only one independent variable; multiple, if there is more than one independent variable. For gaging station records, the usual variables are the short-term gaging station record and one or more long-term gaging station records.

costs (economic) - The stream of value required to produce the uesired 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.

cost effective - The least cost method of achieving a specified output or objective.

Creager's C - A coefficient characteristic, such as the determined value of an enveloping curve, used in flood study analysis that will give an estimate of the maximum flood from a given drainage basin.

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.

crop irrigation requirement - The amount of water required at the farm field level to supplement natural precipitation in satisfying the crops consumptive use.

cubic feet per second (cfs) - A measure of a moving volume of water at the flow rate of water equal to 724 acre-feet per year or 449 gallons per minute.

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

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

D

dead storage - The volume in a reservoir below the lowest controlable level. Not susceptible to gravity release.

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.

deep percolation - The drainage of soil water by gravity below the maximum effective depth of the root zone.

delivery efficiency - The volume of water delivered to the farm divided by the volume diverted from the source. Both conveyance losses and storage losses are subtracted from the source waters in deriving the farm deliveries.

depletion - Net rate or quantity of water taken from a stream or ground water aquifer and consumed by beneficial and non-beneficial uses. For irrigation or municipal uses, the depletion is the headgate or well-head diversion less return flow to the same stream or ground water aquifer.

developed recreation site - A land allocation designation for environments that have been substantially modified for campgrounds, ski areas, etc.

developed water - Water so situated that it would not, but for man's actions, contribute materially to either a natural stream or to a non-tributary ground water, but is placed under control of man by some such artificial works as a mine or a tunnel.

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

direct flow right - A right defined in terms of discharge and which must be put to use more or less promptly following diversion from the source.

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).

discounting - The process of finding the present value of a series of future cash flows, opposite of compounding.

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.

diversion dam - A barrier across a stream built to turn all or some of the water into a diversion channel or conduit.

diversion records - Record of the daily flow in cubic feet per second for a ditch or other diversion structure. Compiled by the District Water Commissioner, ditch rider or other water official, diversion records are generally on file and available for review at the State Engineer's Office.

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.

drainage basin - A part of the surface of the earth that is occupied by a drainage system, which consists of a surface stream or a body of impounded surface water together with all tributary surface streams and bodies of impounded surface water.

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.

drought - There is no universally accepted quantitative definition of drought; generally, each investigator establishes his own definition. For the Cache la Poudre Basin Study, drought was defined as a year or series of consecutive years with below average runoff.

dryland farming - Growing of crops without the aid of additional water through irrigation.

E

Eastern Slope - That portion of Colorado lying east of the Continental Divide.

effective precipitation - The amount of rain that falls during the growing season and is available for growth of crops. Effective precipitation is a portion of the total precipitation that falls during the growing season and is a function of the type of soil, the time period in which each rain falls, and its intensity. Thus, effective precipitation usually is less than precipitation measured at a given point.

electric system - The physically connected generation, transmission, distribution, and other facilities operated as an integral unit under a control, management, or operating supervision.

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.

enlargement - A subsequent right awarded to a ditch or structure enlarging the amount granted originally. More than one enlargement may be awarded to a ditch or structure and each enlargement will have a priority related to the date it was appropriated and applied to beneficial use. Enlargements may be absolute or conditional.

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.

erosion - The group of processes whereby earth or rock material is loosened or dissolved and removed from any part of the earth's surface.

evaporation - The physical process by which a liquid or solid is transformed to the gaseous state which in irrigation usually is restricted to the change of water from liquid to gas.

evapotranspiration - The combined processes by which water is transferred from the earth surface to the atmosphere; evaporation of liquid or solid water plus transpiration from plants (see consumptive use).

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.

F

farm headgate irrigation efficiency - The volume of water consumed by crops divided by the volume of water delivered to the farm.

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

feasibility study - An investigation performed to formulate a project and definitively assess its desirability for implementation.

Federal Energy Regulatory Commission (FERC) - an agency in the Department of Energy which licenses non-Federal hydropower projects and regulates interstate transfer of electric energy.

firm water supply (or yield) - An assured minimum supply of water (or yield) under the most adverse water year supply conditions.

firm energy - The energy generation ability of a hydropower plant under adverse hydrologic conditions for the time interval and period specified for a particular system load.

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.

forebay - The upper water impoundment or reservoir from which water is discharged to a hydroelectric generating plant.

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

G

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.

gage height - The height of the water surface above the gage datum. Gage height is often used interchangeably with the more general term, "stage," although gage height is more appropriate when used with a gage reading.

gaging station - A particular site on a stream, canal, lake or reservoir where systematic observations of gage height or discharge are made.

generator - A machine that converts mechanical energy into electrical energy.

geographical - Pertaining to the surface of the earth, including its form, development, and the phenomena that take place thereon.

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.

geomorphology - The branch of both physiography and geology which deals with the form of the earth, the general configuration of its surface, and the changes that take place in the evolution of landforms.

gigawatt-hours (GWh) - One million kilowatt-hours.

glaciation - Alteration of the earth's solid surface through erosion and deposition by glacial ice.

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

graben - A block, generally long compared to its width, that has been downthrown along faults relative to the rocks on either side.

granite - Quartz-bearing igneous rock characterized by granular texture and having feldspar as the chief mineral.

granodiorite - Close relative of granite.

gross head - The gross difference in elevation between the headwater surface above and the tailwater surface below a hydroelectric power plant, under specified conditions.

ground water - For administrative purposes, ground water is usually defined as any water not visible on the surface of the ground under natural conditions.

ground water outflow - The part of the discharge from a drainage basin that occurs through the ground water. The term "under-flow" is often used to describe the ground-water outflow that takes place in valley alluvium (instead of the surface channel) and thus is not measured at a gaging station.

ground water recharge - Inflow to a ground water reservoir.

ground water reservoir - An aquifer or aquifer system in which ground water is stored. The water may be placed in the aquifer by either artificial or natural means.

H

headgate - A physical structure on a stream through which water is diverted into a ditch.

head losses - Reductions to the gross difference in elevation between water surfaces upstream and downstream from a hydroelectric power plant due to friction of the flow of water through a penstock or conduit and changes in direction or velocity of the flow.

headwaters - Source of water in a stream.

headworks - Structure at the head of a channel or conduit for diverting water into the channel.

historic use - The documented diversion and use of water by a water right holder over a period of years.

hogback - A ridge produced by highly tilted strata.

horst - A block of the earth's crust, generally long compared to its width, that has been uplifted along faults relative to the rocks on either side.

hydroelectric plant or 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.

hydrologic study period - A period of time specified for the selection of data for analysis. The base period should be sufficiently long to contain data representative of the averages and deviations of the averages that must be expected in other periods of similar and greater length. As an example, the U.S. Weather Bureau computes values of average, heavy, and light monthly precipitation from data observed during the base period 1931-1960. For ground-water studies, the base period should begin and also end at the conclusion of a dry trend so that the difference between the amount of water in transit in the soil at the ends of the base period is minimal.

I

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

impervious - An adjective describing a material through which water either cannot pass or through which it passes with great difficulty.

infiltration - Water moving into the ground from a surface supply such as precipitation or irrigation.

installed capacity - The total of the capacities shown on the nameplates of the generating units in a power plant.

instream flows - A prescribed level(s) of streamflow, usually expressed as a stipulation in a permit authorizing a dam or water diversion, which can be met with bypass flows.

intrusion - A body of plastic solid or magmatic igneous rock that is emplaced within older rock.

inundate - To flood or cover with water.

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.

irrigation system efficiency - The ratio of the volume of water consumed by crops divided by the volume of water diverted from the source.

irrigation return flow - Applied water which is not consumptively used and returns to a surface water or ground water supply. In water right litigation, the definition may be restricted to measurable water returning to the stream from which it was derived.

irrigation water requirement - The quantity of water, exclusive of effective precipitation, that is required for various beneficial uses.

isohyet - A line on the surface of the earth, as represented on a map, connecting all points of equal precipitation. Also called "isohyetal line" and "isopluvial line."

J

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

joint use storage (or capacity) - That storage (or capacity) which is shared by more than one use on a time (or some other priority) basis.

K

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.

L

lateral - A minor ditch headgating off the main ditch used to direct water onto the land. A ditch may have many laterals, depending on the amount of acreage irrigated, the slope of the land, and the rate of seepage losses.

load - The amount of power needed to be delivered at a given point in an electric system.

load factor - The ratio of the average load during a designated period to the peak or maximum load occurring in that period.

loss - The difference between the amount of water that is actually placed on the land and the amount of water that was physically diverted to the headgate. Losses usually are from seepage and evaporation.

M

market value - The value of power at the load center as measured by the cost of producing and delivering equivalent alternative power to the market.

mean annual flow - The average or yearly flow of a stream.

megawatt (MW) - One thousand kilowatts.

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

metamorphic rock - Includes all those rocks which have formed in the solid state in response to pronounced changes of temperature, pressure, and chemical environment.

mitigate - To lessen the severity.

N

natural flow - The rate of water movement past a specified point on a natural stream from a drainage area for which there have been no effects caused by stream diversion, storage, import, export, return flow or change in consumptive use caused by man-controlled modifications to land use. Natural flow rarely occurs in a developed country.

net benefits - The result of subtracting total costs from total benefits.

net head - The adjusted gross head on a power plant, accounting for reductions due to head losses.

non-consumptive use - A use of water that does not reduce the supply, such as for hunting, fishing, boating, water-skiing, and swimming.

non-tributary ground water - Water that is not part of a natural stream as established through geologic and hydrologic facts. The factual determination of "non-tributary" usually involves the length of time the impact of withdrawal would take to reach the stream and the amount of impact relative to the total volume of surface flow impacted.

O

observation well - A non-pumping well used for observing the elevation of the water table or the piezometric surface.

out-of-priority storage option - The ability to store water before one has the right according to his court decree to do so.

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

P

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

pan evaporation - The depth of water evaporation for a pan of standard dimensions over a specified time period, normally expressed as inches per unit of time.

pasture - Land that is currently improved for grazing by irrigation or other means.

peaking capacity - That part of a system's generating capacity which is operating during the hours of highest power demand within the system.

peak load - The maximum load in a stated period of time.

pediments - Areas along the face of the uplifted mountain ranges, which are generally relatively gently sloping and which have been formed by several factors including sheet erosion and deposition, stream braiding, etc. The general slope of these areas is governed by the slope and erodability of the underlying bedrock formations.

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

permeability - A term used to describe the ability of water or other liquid to move through a porous formation under the action of a gradient. The facility with which a fluid will move through a formation is greater for some than for others. For a given bed, the permeability is expressed by a constant K representing the flow through unit area, in unit time under the influence of a unit 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.

phreatophyte - A water-loving plant which consumes a substantial amount of water without corresponding benefits to mankind, such as cottonwood trees or salt cedars.

physiography - The study of the genesis and evolution of land forms.

piedmont - Lying or formed at the base of mountains.

plant factor - Ratio of the average load to the installed capacity of the plant, usually expressed as an annual percentage.

plateau - A relatively elevated area of comparatively flat land which is commonly limited on at least one side by an abrupt descent to lower land.

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.

precipitation - The discharge of water, in liquid or solid state, out of the atmosphere.

prefeasibility study - An investigation performed to evaluate available resources and to define alternative resource development options so that the best plan of development can be identified.

present worth - The value today of a future dollar or stream of dollars, discounted at the appropriate rate.

priority - The relative seniority of a water right as determined by its adjudication date and appropriation date. In some cases, other factors are also involved in determining priority. The priority of a water right determines its ability to divert in relation to other rights in periods of limited supply.

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.

R

rate of return(on investment) - The interest rate at which the present worth of annual benefits equals the present worth of annual costs.

recreation visitor days - Twelve visitor hours, which may be aggregated continuously, intermittently or simultaneously by one or more persons.

reliability council - One of nine regions in which power suppliers coordinate their output to prevent electrical power shortage.

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

return flow - Unconsumed water which returns to its source or some other water body after its diversion as surface water or its extraction from the ground.

return period - In statistical analysis of hydrologic data, assuming that observations are equally spaced in time, and, choosing the interval between two successive observations as unit of time, return period is the reciprocal of 1 minus the probability of a value equal to or less than a certain value. Where the interval between observations is a year, a return period of 100 years for example means that, on the average, in the long run, not more often than once in 100 years is an event of this magnitude, or greater, expected to occur.

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.

roller compacted concrete (RCC) dam - A dam consisting essentially of an inner or enclosed low cement content concrete mixture which is compacted within a pre-formed higher cement content concrete shell.

run-of-the-river (plant/hydroelectric generation) - A power plant that uses natural flows or flows released for other purposes to generate power.

S

sandstone - A cemented or otherwise compacted detrital sediment composed predominantly of sand-sized quartz grains.

saturated thickness - The thickness of an aquifer in which the void space is filled with water.

schist - A medium or coarse-grained metamorphic rock with subparallel orientation of the micaceous minerals which dominate its composition.

sediment - Solid material, both mineral and organic, that in suspension has been transported from its site of origin by air, water, or ice.

sedimentary rocks - Rocks formed by the accumulation and compaction of sediment in water or from air.

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.

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.

seepage - (1) The slow movement of water through small cracks, pores, interstices, etc., of a material into or out of a body of surface or subsurface water. (2) The loss of water by infiltration into the soil from a canal, reservoir, or other body of water, or from a field. Seepage is generally expressed as flow volume per unit time.

seismic - Pertaining to an earthquake or earth vibration.

seismicity - The phenomenon of earth movements or seismic activity.

shale - A laminated sediment in which the constituent particles are predominantly of the clay grade.

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

siltstone - Shale comprised of silt-sized grains.

spillway - Overflow channel of a dam.

stochastic procedure - A procedure involving chance or probability: probabilistic.

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.

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

storage right - A right defined in terms of the volume of the water which may be diverted from the flow of the stream and stored in a reservoir or lake to be released and used at a later time either within the same year or a subsequent year.

stream - A general term for a body of flowing water. In hydrology the term is generally applied to the water flowing in a natural channel as distinct from a canal. More generally, as in the term streamgaging, it is applied to the water flowing in any channel, natural or artificial.

Relation to Time

- Ephemeral - One that flows only in direct response to precipitation, and whose channel is at all times above the water table.
- Intermittent or Seasonal - One which flows only at certain times of the year when it receives water from springs or from some surface source such as melting snow in the mountainous areas.
- Perennial - One which flows continuously.

Relation to Ground Water

- Gaining - A stream or reach of a stream that receives water from the zone of saturation.
- Insulated - A stream or reach of a stream that neither contributes water to the zone of saturation nor receives water from it. It is separated from the zones of saturation by an impermeable bed.
- Perched - A perched stream is either a losing stream or an insulated stream that is separated from the underlying ground water by a zone of aeration.

strike (geology) - A line formed by the intersection of a horizontal plane and a geologic stratum.

strike slip - The component of the movement parallel with the fault strike.

supplemental irrigation water - Additional water applied to irrigate crops over and above that historically or normally used, which could be beneficially used to increase the crop yield or to support growing higher value crops.

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

switchyard - An area, usually fenced, containing equipment for routing the flow of electrical power.

T

tailrace - A channel for conveying discharged water from a hydroelectric power plant.

tailwater level - Water level in the channel below or downstream from a powerhouse or water control structure.

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.

thermal plant - A generating plant which uses heat to produce electricity. Such plants may burn coal, gas, oil, or use nuclear energy to produce thermal energy.

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.

topography - The physical features of a district or region, especially the relief and contour of the land.

total consumptive use - The amount of water, regardless of its source, used by the crops during the growing season. It is the amount of water that is physically removed from the stream's system and is not available for other users on the stream.

trans-basin diversion - The removal of the water of a natural stream from its natural basin into the natural basin of another stream.

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.

transmission - The act or process of transporting electric energy in bulk.

transmission line - A facility for transmitting electrical energy at high voltage from one point ot another point. Transmission line voltages are normally 115 kV or larger.

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

tributary - Any stream which contributes water to another stream.

tributary ground water - Seepage, underflow, and percolating water that will eventually become part of the natural stream. A natural stream's waters include water in the unconsolidated alluvial aquifer of sand, gravel and other sedimentary materials, and all other waters hydraulically connected thereto, which can influence the rate or direction of movement of the water in that alluvial aquifer or natural stream. In Colorado, all ground water is presumed to be tributary unless proved otherwise.

tundra - A level or undulating treeless plain characteristic of the arctic regions.

turbine - The part of a generating unit which is spun by the force of water or steam to drive an electric generator. The turbine usually consists of a series of curved vanes or blades on a central spindle.

<u>V</u>

virgin flow (or native flow) - The flow of a river that would occur in the absence of human activities.

visit - A significant amount of time spent by one individual at a particular recreation facility during a 24-hour period.

visitor-day - Consists of 12 visitor hours which may be aggregated continuously, intermittently, or simultaneously by one or more persons at a recreation facility.

<u>W</u>

water development - The process of building diversion, storage, pumping and/or conveyance facilities to apply water to beneficial use.

water right - A right to use, in accordance with its priority, a certain portion of the waters of the State by reason of the appropriation of the same.

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

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

water supply, basin - For the Cache la Poudre Basin Study, basin water supply is defined as that quantity of surface and ground water which could be made available for all users in the basin. This quantity would include transbasin diversions, natural flow, ground water, and the reuse of these waters.

water table - The upper limit of the part of the soil or underlying rock material that is wholly saturated with water.

water year - The 12-month period October 1 through September 30. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 1959, is the "1959 water year."

water yield (or 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.

Western Slope - That portion of Colorado lying west of the Continental Divide.

wheeling - Transportation of electricity by a utility over its lines for another utility; also includes the receipt from and delivery to another system of like amount but not necessarily the same energy.

wilderness - Under the 1964 Wilderness Act, wilderness is undeveloped Federal land retaining its primeval character and influence without permanent improvements or human habitation. It is protected and managed so as to preserve its natural conditions which: 1) generally appear to have been affected primarily by the forces of nature with the imprint of man's activity substantially unnoticeable, 2) has outstanding opportunities for solitude or a primitive and confirmed type of recreation, 3) has at least 5,000 acres or is of sufficient size to make practical its preservation, enjoyment, and use in an unimpaired condition, and 4) may contain features of scientific, educational, scenic, or historical value as well as ecologic and geologic interest.

ABBREVIATIONS AND ACRONYMS

af - acre-feet
ASAU - All sources/all uses (demand)
Authority - Colorado Water Resources and Power Development Authority
BLM - Bureau of Land Management
C-BT - Colorado-Big Thompson Project
CCWCD - Central Colorado Water Conservancy District
CDLG - Colorado Division of Local Government
CDOW - Colorado Division of Wildlife
CDPOR - Colorado Division of Parks and Outdoor Recreation
cfs - cubic feet per second
CLRS - Colorado Livestock Reporting Service
CLPWUA - Cache la Poudre Water Users Association
COE - U.S. Army Corps of Engineers
CSU - Colorado State University
CWCB - Colorado Water Conservation Board
CWQCC - Colorado Water Quality Control Commission
ELCO - East Larimer County Water District
Elevation - El.
Feet - ft
FERC - Federal Energy Regulatory Commission
GASP - Ground Water Appropriators of the South Platte River Basin, Inc.
gpd - gallons per day
gpm - gallons per minute
GWh - gigawatt hours, equivalent to 1,000 MWh
kV - kilovolt
kW - kilowatts, equivalent to 1000 watts
kWh - kilowatt-hour
LWRCOG - Larimer and Weld Regional Council of Governments
M&I - Municipal and Industrial
mgd - million gallons per day
MSL - mean sea level
MW - megawatts, equivalent to 1,000,000 watts (capacity term)
MWh - megawatt hours (energy term)
NCWCD - Northern Colorado Water Conservancy District (also the Northern District)
NCWA - Northern Colorado Water Users Association
NPIC - North Poudre Irrigation Company
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
PRPA - Platte River Power Authority
RIBSIM - River Basin Simulation Model
sq. mi. - square miles
SWA - State Wildlife Area
UNC - University of Northern Colorado

U.S. BEA - U.S. Bureau of Economic Analysis
USBR - United States Bureau of Reclamation
USGS - United States Geological Survey
WSS - Water Supply and Storage Company
yr - year

Appendix E

Geology

APPENDIX E

GEOLOGY

1.0 INTRODUCTION

This chapter presents a general discussion of the geology of the potential reservoir sites and specific information about the Glade site at which subsurface investigations were performed.

The bedrock in most of the Basin area is part of the Precambrian metamorphic basement complex forming the core of the Front Range. This basement complex includes metasedimentary rock mixed with granitic rock, granite and biotite gneiss and schist, amphibolite, and large bodies of intrusive igneous rock such as granite or granodiorite. The area is one of youthful topography consisting of deep, V-shaped canyons incised into an old erosional surface that forms the broad, upland foothills located between the plains and the main mountain ranges to the west.

Along the eastern margin of the project area, a series of sedimentary beds have been upturned and folded by mountain building episodes that formed the Rocky Mountains. These sedimentary rocks consist of sandstone, siltstone, shale, and limestone ranging in age from Pennsylvanian to Cretaceous. The hard, resistant sandstone and limestone beds form sharp, hogback ridges that trend north-south along the edge of the Front Range. The interbedded shale and siltstone units usually form valleys or gentle slopes.

The Precambrian igneous and metamorphic rocks are jointed and faulted to varying degrees of intensity, but in general the rock is hard, exceptionally strong, and fairly massive. No geologic features have yet been found that would have an adverse effect on any of the proposed damsites. The proposed damsites in the sedimentary rocks are acceptable for earth or rockfill structures but would probably require more foundation exploration and treatment than dams in the igneous or metamorphic rocks.

2.0 TECTONIC HISTORY

The tectonic history of Colorado spans about 1800 million years and includes several Precambrian episodes of intense orogenic activity that was accompanied by the emplacement of granitic batholiths, volcanism, folding, and faulting. In late Paleozoic time, fault-bounded highlands similar to the present Rocky Mountains were uplifted and later leveled by erosion during the early Mesozoic. The low relief terrain prevailed through mid Mesozoic time and then subsided to permit marine invasion in the late Mesozoic. At the end of the Mesozoic, the area of the present Colorado Rocky Mountains was covered with sedimentary rocks up to 9000 ft thick.

Cenozoic tectonic activity consisted mainly of the following two episodes: (1) the Laramide orogeny, which started in late Cretaceous time and lasted until about 50 million years ago; and (2) mid Pliocene (Neogene) block faulting, which occurred from 5 to 25 million years ago. A period of crustal stability occurred between these two episodes that was characterized by a vast, low-relief erosional surface that was covered, in some areas, by thick deposits of volcanic rocks.

After the end of Laramide activity, erosion had reduced the uplifts to a surface of low relief that extended over northern and central Colorado. Extensive volcanism then occurred throughout most of Oligocene time. By early Miocene time, most of the late Eocene erosion surface was buried by volcanic rocks and related clastic deposits hundreds of feet thick. Block faulting, accompanied by volcanic eruptions, began in New Mexico and south-central Colorado in early Miocene time, or about 28 million years ago. The faulting and eruptive activity continued through Miocene and Pliocene time and in places extended into the Quaternary. The faulting created grabens in which datable sedimentary and volcanic deposits accumulated. These, together with displacements of the late Eocene erosion surface and overlying Oligocene volcanics, provide a record of the timing and magnitude of the faulting.

Although the fault movements that formed the Front Range are mainly Laramide, the faults are mostly of Precambrian origin. The eastern margin of the range, in common with the rest of the Rocky Mountain Front, is a distinctly Laramide feature, although locally controlled by Precambrian structure, such as faults, folds, and broad shear zones. Generally, the tectonic record indicates a decrease in fault and earthquake activity, in terms of intensity and frequency of recurrence, eastward from the Pacific Coast to the Rocky Mountains. With the exception of the Colorado Plateau and the Rio Grande Rift, the Rocky Mountain Province has been, since Mesozoic time, the least active of the western Cordilleran tectonic elements.

3.0 SEISMICITY

The possibility of regional or local earthquakes constitutes a seismic risk that must be considered in designing structures such as dams and large buildings. One of the important preliminary steps in evaluating seismic risk is to compare and correlate the recorded earthquake history with the local and regional geology. This provides much of the information needed to select earthquake magnitudes to be used in the design of large civil structures. Two selected earthquakes often used in the design of large structures are the Maximum Credible Earthquake (MCE) and the Operating Basis Earthquake (OBE). The MCE is defined as the largest earthquake that could conceivably occur in the tectonic setting in which the project is located. The OBE is an earthquake that could cause damage, but would not significantly curtail the operation of a facility.

A preliminary seismic risk evaluation for various proposed damsites on the Cache la Poudre River and its tributaries involved the following basic steps: (1) literature and map review; (2) a field review of previous geologic mapping, including additional study of major faults mapped by others; (3) airphoto and LANDSAT image studies to define or confirm fault occurrence; and (4) a study of the regional earthquake record. Any fault that has been designated as potentially active by others may later require more detailed study that could include trenching, core drilling, or both. An active, or potentially active fault near a proposed civil structure can affect the design and ultimate cost of the project.

3.1 FAULTS AND SHEAR ZONES

Faults and shear zones occur in the metamorphic and igneous rocks of the Cache la Poudre Basin area but are relatively rare in the sedimentary rocks along the eastern slope of the Front Range. Most of the faults are small and of limited extent, but a few are significantly extensive and can be traced for 15 to 20 miles or more. Shear zones are extensive, broad zones of sheared, broken, and weathered rock that may have indistinct boundaries and are often difficult to accurately define.

Some of the major faults and shear zones in the area are shown on Figure E.1 and include the Poudre River fault, the Bellvue fault, the Kramer Ranch fault, the Hewlett Extension fault, the North Fork fault, and the Livermore fault. The most extensive shear zones are the Elkhorn Creek shear zone, the Poudre River shear zone, and the Skin Gulch shear zone. All of these faults and shear zones are thought to be of Precambrian age with recurrent movement during the Laramide orogeny or possibly later.

3.2 EARTHQUAKES

The Front Range is considered to be a relatively stable tectonic unit where there have been no recorded earthquakes larger than a Richter magnitude of 5.0 within the 110 year period of record. Detailed seismotectonic studies in the central Front Range also document that faults showing late Quarternary movement have not yet been discovered (Geotechnical Advisory Committee, Denver Water Department, 1986). Figure E.2 is a NOAA plot of 267 earthquakes in Colorado and Wyoming. An arbitrary radius of 200 miles around the Basin area would only include the southern one-half of Wyoming; therefore, the earthquakes for the Teton Range and Yellowstone National Park are not shown. Figure E.2 shows that one low magnitude earthquake occurred within a radius of 25 miles of Seaman Reservoir and that only six other low magnitude events, including one 3.9-4.9 earthquake, have occurred within a radius of 50 miles.

A concentration of seismic events were recorded about 60 miles south-southeast of the project area during the 1960s (Figure E.2). These events are known as the Rocky Mountain Arsenal earthquakes and are discussed in some detail by Kirkham and Rogers (1981). It is probable that the Rocky Mountain Arsenal earthquakes were artificially induced by injecting fluid wastes down a well 12,040 ft deep at pressures exceeding 5000 psi. Fault-plane solutions indicate that these earthquakes may have occurred on a nearly vertical fault that trends NW and that has right-lateral strike-slip movement. The depth of the earthquakes ranged between 4.5 and 5.5 km (2.8 - 3.4 miles) and the maximum Richter magnitude was 5.5 (Kirkham and Rogers, 1981). Because of the distance from the Basin, a potential 5.5 magnitude earthquake at the Rocky Mountain Arsenal would not be considered in selecting an earthquake design magnitude for the Cache la Poudre area.

3.3 FAULTS AND EARTHQUAKES

According to Kirkham and Rogers (1981), Colorado can be divided into six seismotectonic provinces. The Cache la Poudre Basin is located in the northern part of the Eastern Mountain Seismotectonic Province where Kirkham and Rogers estimate a Maximum Credible Earthquake having a Richter magnitude of 6 to 6.75 (Kirkham and Rogers, 1981). Their estimate is based on fault lengths and displacements, recency of movement, historical earthquakes, stress-strain information, and comparisons with other areas that have similar seismotectonic characteristics. They briefly mention the only fault in this province that is known to disturb late Quarternary deposits. This fault is located at Spinney Mountain, about 110 miles south of the Cache la Poudre study area.

As shown on the Greeley $1^{\circ} \times 2^{\circ}$ Geologic map, about 35 faults have been mapped within a 25-mile radius of the study area, and, within a radius of 50 miles, about 100 faults have been mapped (Braddock and Cole, 1978, USGS Open File Report 78-532). None of these faults within a radius of 50 miles can be correlated with any of the recorded earthquakes shown on Figure E.2. With the exception of the Rocky Mountain Arsenal events and one earthquake near the Golden fault, no definite correlation can be made between faults and earthquakes for a radius of at least 100 miles around the Cache la Poudre area (Kirkham and Rogers, 1981, Plate 3).

3.4 ACTIVE FAULTS

3.4.1 General

Active, or "capable" faults, have been defined several ways; however, for this report, the following definition from Kirkham and Rogers (1981) will be used. This definition is also used by the Corps of Engineers and the Nuclear Regulatory Commission. A capable fault has one or more of the following characteristics:

1. Movement at or near the ground surface at least once within the past 35,000 years or movement of a recurring nature within the past 500,000 years.
2. Macro-seismicity instrumentally determined with records of sufficient precision to demonstrate a direct relationship with the fault.
3. A structural relationship to a capable fault according to characteristics 1 or 2 of this paragraph such that movement on one could be reasonably expected to be accompanied by movement on the other.

A potentially active fault near the project area has been plotted by Kirkham and Rogers (1981, Plate 1, No. 171*). This fault is about five miles north of a proposed damsite at Poudre Park and about 10 miles northwest of another damsite at the Kramer Ranch. It trends east-west for about 28 miles from near the town of Livermore to a few miles north of the town of Glen Echo. The fault is indicated as offsetting Tertiary sedimentary rocks and being covered by undisturbed Holocene deposits. For ease of discussion, fault No. 171 is called the Livermore fault in this report.

3.4.2 The Livermore Fault

The Livermore fault was first named by Cavender (1951) who included it as part of his Masters thesis at the University of Colorado. He describes the fault as being 2 to 15 ft wide, about 5-1/4 miles long, and approximately vertical. An obscure, poorly preserved fault scarp of unknown age occurs entirely in Precambrian rocks about 1 mile southwest of the old townsite of Livermore (Cavender, 1951).

The Livermore fault was later studied in more detail by Connor while preparing a Ph.D. thesis at the University of Colorado. He describes fault activity that occurred in Laramide time and shows that the Livermore fault is apparently cut off at the west end by the north trending Hewlett Extension Fault. His geologic map shows the Livermore fault as being slightly more than 3 miles long (Connor, J.J., 1962, Fig. 33, Plate I). The Hewlett Extension Fault is probably the North Poudre Fault described by Cavender (1951) who states that it intersects the Livermore Fault at its west end but that the area of intersection is not well exposed.

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* This fault is incorrectly numbered on Plate I. The list of faults on p. 167 (Kirkham & Rogers, 1981, p.167) shows the fault as No. 171, not No. 71. The Township-Range-Section location also corresponds with fault No. 171.

The length of Fault 171 (Kirkham and Rogers, 1981) is apparently the result of connecting the Livermore fault with the Elkhorn Creek shear zone as shown by Abbot on the Big Narrows Quadrangle (Abbott, 1976, GQ-1323). The area between the eastern end of the Elkhorn Creek shear zone and the western end of the Livermore Fault covers about 6 miles and has never been adequately studied. Preliminary studies in this area have not indicated any connection between the Elkhorn Creek shear zone and the Livermore fault, nor has any geologic or topographic evidence yet been found to justify such a connection.

Based on a thorough literature review and preliminary geologic mapping, fault 171 as shown by Kirkham and Rogers (1981, Plate 1) may be a compilation error that misstates both the age and length of the fault. The Elkhorn Creek shear zone is a Precambrian structure that may have been activated at least twice since the Precambrian, the second time was probably during the Laramide orogeny (Abbott, 1979, GQ - 1323). The Livermore fault is about 3 miles long and is cut off at its west end by the Hewlett Extension fault as previously described. Separating these two faults is an area of five to six miles wide in which no evidence of a possible connection has been found, although more field work in this area remains to be done. No evidence of offset within any sedimentary rocks overlying the trace of the Livermore fault has yet been found. The fault scarp southwest of Livermore also requires more study in an effort to date its most recent movement and to determine if it meets the criteria of an active fault. This additional study will be needed at a later planning stage when a specific project (or projects) has been selected and designed. At this time, basic earthquake design criteria will be determined and the MCE and OBE magnitudes and accelerations will be selected.

Another "potentially active fault" plotted by Kirkham and Rogers, (1981, Plate 1, 42Ts/Q) occurs about 37 miles southwest of the study area where it trends north-south for 26 miles. This fault is formally named the Laramie River Fault. Because of its greater distance from the Cache la Poudre study area, and because no specific project structures have yet been designed, the Laramie River Fault is not discussed in this report.

4.0 GENERAL GEOLOGIC DESCRIPTIONS OF DAMSITES

The following sections describe the general geologic conditions at various reservoir sites under study. Dam axes, reservoir locations, and geologic sections are identified for several of the sites on Figures E.3 and E.4. Geologic descriptions of the Trailhead and Footbridge damsites are not provided but these sites have geologic conditions similar to those occurring at the Poudre site (Section 4.7).

4.1 CALLOWAY HILL DAM

This proposed damsite is located on the North Fork at the Cache la Poudre river about 4 miles downstream from the existing Halligan Dam. The dam axis crosses a steep, V-shaped, extremely narrow gorge cut into the Precambrian Sherman Granite. This rock appears to be intensely jointed at the surface, but at depths of less than 15 to 20 ft, the joints become tight and the rock appears to be massive. The rock is hard and fresh and stands well in steep slopes and vertical cliffs. An old irrigation tunnel is on the left abutment of the site and has been standing unsupported in hard, jointed rock for many years. No geologic problems are apparent and the site appears to be suitable for construction of a dam. The major problem would be one of construction access in the narrow gorge.

4.2 HALLIGAN SITES

Three possibilities have been considered for increasing storage at the existing Halligan dam area. These are: (1) increasing the height of the existing dam; (2) building a new dam at Site B, about 1/4 mile downstream of Halligan Dam; and, (3) building a new dam an additional 1/2 mile downstream of Site B. All sites are on the North Fork of the Cache la Poudre River.

These sites are all located in rock of the Precambrian Sherman granite. This rock is intensely jointed to massive at the surface, but usually the joints become tight and the rock becomes generally massive at depths below 15 or 20 ft. The rock is slightly weathered to fresh and is very hard; no geologic problems that would affect a dam foundation are apparent and these sites appear to be suitable for construction of dams.

4.3 GREYROCK MOUNTAIN SITE

This site (Figure E.3) is the upper reservoir for a proposed pumped-storage hydroelectric project. The lower reservoir would be on the Cache la Poudre river just downstream of the village of Poudre Park. The upper reservoir would be in the high mountains about two miles north of Poudre Park. The machine hall, power tunnels, tailrace tunnels, and other power facilities would be located underground between the upper and lower reservoirs.

The upper reservoir would be formed by three dams that would span broad, U-shaped valleys and high mountain meadows. The rock in this area is mostly Precambrian quartz monzonite that has intruded the metamorphic and older igneous rocks of the Front Range (Figure E.4). This rock is hard, fresh, and massive and more than adequate for the proposed dams. The underground power facilities, the lower reservoir, and the lower reservoir dam would be in the quartz monzonite and in metamorphic rocks similar to those at the New Seaman damsite. These rocks are acceptable for the surface and underground facilities and would require minimum support for the underground excavations. No adverse geologic features were observed during preliminary geologic mapping, although if this proposed site is considered for more detailed planning and perhaps construction, then extensive core drilling and other geologic studies would be required.

4.4 PORTAL DAM SITE

Portal Dam would be located 1.6 miles west of "Teds Place" along Highway 14 (Figure E.3). In this area, the canyon of the Cache la Poudre

River ends and the terrain changes to broad alluvial and colluvial plains and small hills. The dam axis crosses a broad, asymetric canyon where the southern side is about twice as steep as the northern side (Figure E.4). The dam and reservoir area involves Precambrian metamorphic and igneous rock of the northern Front Range. These rocks consist generally of granite, granite gneiss, biotite-amphibolite gneiss and schist, and small intrusive masses ranging from pegmatite to diorite. Weathering rarely affects the rock to depths of more than 20 or 30 ft, and, below the weathered zone, the rock is hard, fresh, massive, and acceptable for a concrete dam. Features such as adverse joint patterns, faults, or shear zones, were not observed at the site during preliminary geologic mapping and the site appears to be suitable for construction of dam.

4.5 NEW SEAMAN DAM

This site is on the North Fork of the Cache la Poudre River about 600 ft northeast of the Fort Collins water filtration plant. The dam would be located in a broad, asymetrical canyon where the west side is about twice as steep as the east side. The damsite, and most of the proposed reservoir, involves Precambrian metamorphic and igneous rock of the northern Front Range. These rocks consist mostly of granite, granite gneiss, biotite and amphibolite gneiss and schist, and small intrusive masses ranging from pegmatite to diorite. Generally, weathering rarely affects the rock to significant depths, and, beneath the weathered zone, these rock varieties are hard, fresh, massive, and more than adequately competent for a large concrete dam. Structural features, such as adverse joint patterns, faults, or shear zones, were not observed during preliminary geologic mapping and the site appears suitable for construction of a dam.

4.6 GREY MOUNTAIN SITE

This site is located on the Cache la Poudre River about 1.5 miles upstream from the previously mentioned Portal dam site. Three sites within a short interval of the canyon were examined, with the middle site being selected for more detailed study. This site is located in a broad V-shaped canyon eroded in metamorphic and igneous rocks of the northern Front Range.

The middle site was studied by the Bureau of Reclamation and by a thesis student from the Colorado School of Mines. The Bureau of Reclamation study included three core holes and some refraction seismograph traverses. The above work was reviewed by Harza, including an examination of the rock samples from the core holes and a day of field mapping by two geologists. Based on the field study and a review of previous work by others, this site appears to have no geologic problems of any significance and can be considered suitable for construction of a dam. Additional core drilling would be required during the feasibility study and design stage.

4.7 POUDRE DAM SITE

The proposed Poudre damsite is on the Cache la Poudre River about 1.5 miles upstream of the Grey Mountain site, or about 0.5 miles south of the Fort Collins water filtration plant. The dam would be located in a broad, asymetrical canyon where the northeast side is nearly twice as steep as the southwest side. The damsite, and all of the reservoir area involves Precambrian metamorphic and igneous rock of the northern Front Range. These rocks consist mostly of granite to granodiorite, granite gneiss, biotite and amphibolite gneiss and schist, and small intrusive masses ranging in composition from pegmatite to diorite. Weathering rarely affects the rock to significant depths, and, beneath the weathered zone, the above rock varieties are usually hard, fresh, massive, and more than adequately competent for a large concrete dam. Structural features, such as extensive, adverse joint systems, faults, or shear zones, were not observed during preliminary geologic mapping and the site appears to be suitable for construction of a dam.

4.8 GLADE DAM SITE

The proposed Glade site is located about one mile northeast of the mouth of the Cache la Poudre Canyon. The axis of this proposed dam crosses the southern end of a north trending valley that is cut predominantly in Permian to Cretaceous sedimentary rocks (Figure E.4). The right abutment consists of Precambrian metamorphic rocks similar to those previously described at the Poudre Dam site. The rest of the foundation, and the left abutment, involves shale, siltstone, sandstone, calcareous sandstone, and limestone beds that strike generally north-south and dip to the east at angles between 15 and 30 degrees. The valley forming the reservoir is bisected by sharp hogback ridges consisting of the Fountain, Ingleside, and Satanka Formations of Permian age.

The Bellvue fault complex occurs a few hundred feet south of the dam axis, and is associated with folding and faulting in the Cretaceous south Platte and Dakota Formations that occur in the large hill immediately south of the Glade site. These structures are of no concern to the proposed Glade Dam. The complex stratigraphy along the axis will require a core drilling and water pressure testing program that will provide complete stratigraphic coverage across the valley so that the physical properties and potential leakage of the various rock units can be adequately evaluated. However, the foundation conditions are considered to be adequate for a proposed rockfill dam.

4.9 ROCKWELL

This dam site is on the South Fork Cache la Poudre River. It is located on the USGS 7-1/2 minute Rustic topographic sheet in the SE 1/4 of Section 25. This dam site, and all of the proposed reservoir areas involves Precambrian metamorphic and igneous rocks of the northern Front Range. These rocks consist of granite, granite gneiss, biotite and amphibolite gneiss and schist, and small intrusive bodies ranging from pegmatite to diorite. Weathering rarely affects the rock to significant depths, and, beneath the weathered zone, the rock is usually hard, fresh, and massive. This site appears to be suitable for construction of a dam.

5.0 GEOLOGY OF GLADE DAMSITE

Glade Reservoir is the principal water storage facility for five of the seven plans investigated during the course of the Cache la Poudre Basin Study, including Plan C which was selected as the preferred plan for future water development in the Basin. Prior to undertaking the Study, little was known about the geology of the Glade damsite. Unlike the canyon sites, rock outcrops are not visible on the surface. Uncertainties existed with respect to the depth of overburden and the folding and faulting at the damsite which are inferred from surface conditions at the damsite and rock outcrops located away from the damsite. Therefore, a limited geological investigation was made of the damsite. It consisted of three core holes (350 feet total length of NX core) and 2500 feet of seismic refraction survey.

5.1 LOCATION AND GEOLOGIC SETTING

Glade damsite is located about one mile north of the intersection of Highways 14 and 287. The reservoir formed by Glade Dam would extend about five miles north of the dam occupying two broad, flat-floored valleys eroded in sandstone, siltstone and shale beds of the Front Range sedimentary rock sequence. A sharp ridge of sandstone and limestone upstream from the dam separates the two valleys. The dam would be an embankment structure about 4800 ft long and 310 ft high.

5.2 STRATIGRAPHY

Most of the foundation involves eastward dipping beds that were folded upward during mountain-building episodes that formed the present Rocky Mountains. The right abutment consists of granite gneiss and pegmatite of the Precambrian Idaho Springs Formation. The axis of the dam trends southeast from the right abutment (Figure E.5) and involves sedimentary rocks extending from the Pennsylvanian Fountain Formation to the lower Cretaceous South Platte Formation. These rock units consist of sandstone, siltstone, shale, and limestone. Sandstone is the most predominant rock type, followed by siltstone and shale. Limestone beds occur in the Ingleside and Morrison Formations but are relatively thin and only constitute a small portion of the total lithology.

About two miles of the western edge of the reservoir involves igneous and metamorphic rocks of the Idaho Springs Formation. Most of the reservoir would be contained by the same sedimentary rock formations listed above.

5.3 STRUCTURE

The geologic structure in the dam and reservoir area consists basically of folding and faulting. In the reservoir area, the major structural element consists of monoclinal folding where the various sedimentary rock formations strike north-south and dip from 15 to 30 degrees to the east. The hard sandstone and limestone beds that are resistant to erosion form the prominent "hogback" ridges that are a common topographic feature along the Front Range of Colorado. The easily eroded siltstone and shale beds form the broad valleys that occur between the ridges.

In the foundation area of the dam, the geologic structure is more complex and involves both folding and faulting. Most of the folding and faulting is covered by thick overburden and is inferred by projecting observed geologic features that appear in outcrops farther away. The entire valley floor traversed by the damsite consists of 20 to 55 ft of alluvium, colluvium, and talus that extends from the canal on the right abutment to beyond the highway on the left abutment. Within this covered area, two branches of the Bellvue fault and the North Fork fault are mapped as inferred faults by Braddock and projected as shown on Figure E.5.

5.4 SEISMIC REFRACTION SURVEY

The purpose of the seismic survey was to obtain depth and configuration of bedrock, seismic wave velocities of the various bedrock units, and the location of projected faults. Eleven seismic refraction lines were occupied along the proposed dam axis.

The refraction survey was conducted using a Geometrics Model ES-1210, 12-channel, signal enhancement seismograph.

The eleven seismic refraction lines provide essentially continuous coverage along the dam axis. Some overlap was used on lines 1 through 5 and includes a cross-line at auger hole 3, normal to the dam axis as shown on Figure E.5. A data gap of about 500 ft occurs where the dam axis crosses Highway 287. It was not possible to do seismic work near or over the highway because traffic vibration distorted instrument readings.

Results of the seismic survey are plotted on Figure E.6 and show compressional shock wave (P-wave) velocities for different materials, transition zones between significant velocity changes, probable fault or shear zones, and depth and configuration of the bedrock surface.

Overburden along the dam axis consists of colluvium, talus, and landslide debris on the abutments and alluvium in the valley. The P-wave velocity for all of the overburden averages 2000 ft/sec which indicates a loose, poorly consolidated, fine-grained, non-saturated material.

The bedrock P-wave velocities vary considerably along the dam axis from the right abutment to the left abutment (Figure E.6). The high velocity northwest of auger hole 1 on the right abutment corresponds well with the probable velocity of weathered igneous and metamorphic rock of the Idaho Springs Formation. The transition zone between auger holes 1 and 2 may represent the weathered contact between the metamorphic rock and sandstone of the Fountain Formation or it could represent minor faulting.

The seismic cross-line at auger hole 3 also shows a P-wave velocity change that is separated by a transition zone. This transition zone is also near core hole B and probably represents the North Fork Fault that was confirmed by core hole B. The apparent bedrock P-wave velocity anomaly at cross-line 3 versus the velocities between auger holes 2, 3, and 4 are not very significant (9000 to 10,500 ft/sec) and can probably be explained by slight differences in bedrock hardness or by errors caused by rock surface configuration and different depths to rock.

Bedrock P-wave velocities from auger hole 2 to about 150 ft northwest of auger hole 6 are generally in the 9000-9600 ft/sec range. This velocity would probably correlate with the hard, conglomeratic lower sandstone beds of the Fountain Formation. The P-wave velocities southeast of the transition zone between auger holes 5 and 6 drop to the 5800-6500 ft/sec range. This abrupt velocity change is difficult to explain with the data at hand. The transition zone could be a fault and the lower velocity could represent upper, weathered, poorly-cemented beds of the Fountain Formation. From auger hole 6 to hole 9, the bedrock P-wave velocity is 6500-7000 ft/sec which probably represents sandstone of the Fountain or Ingleside Formation.

In the vicinity of auger hole 10, two seismic lines show bedrock P-wave velocities changing from 4500 ft/sec through 6800 ft/sec to 9000 ft/sec. These velocity changes are separated by two transition zones, one on each side of auger hole 10. The lower velocities would probably correlate with weathered shale and sandstone of the Morrison Formation. The 9000 ft/sec velocity could represent a hard sandstone bed in the Morrison Formation or hard sandstone of the Entrada Formation where it may have been faulted upward against the Morrison. The transition zones near auger hole 10 are very likely to be caused by the Bellvue Fault zone that is known to occur in this area.

5.5 AUGER DRILLING

A large truck-mounted auger drill was used to drill vertical holes along the seismic survey lines. The main purpose of the auger drilling was to confirm depth to bedrock as determined by the seismic survey. A secondary purpose was to determine the composition of overburden material.

Some of the auger holes correlate well with bedrock depth as indicated by the seismic survey, but the depths to bedrock determined by both methods vary five to ten percent for most of the holes. The largest difference occurs at auger hole 9 where the seismic depth to rock is 30-35 ft and the drill hole depth is 54 ft.

Material in the valley is generally a clayey-silty sand to silty sand with minor amounts of gravel. Significant thicknesses of gravel were found only in auger hole 6 (24 ft), auger hole 8 (8 ft), and auger hole 9 (18 ft). Bag samples were taken in auger holes 4, 6, and 11.

5.6 CORE DRILLING

Three core holes were located and oriented such that they would have the best possible chance of drilling across the inferred faults shown on Figure E.5. Angle holes were drilled to obtain the maximum possible horizontal component as well as vertical depth; angle holes usually give maximum data on the nature and properties of the rock being drilled. The truck-mounted auger rig was also used for the core drilling. The core holes are identified by letters to differentiate them from the numbered auger holes. Core logs are provided in the Task 9 Summary Report.

5.6.1 Core Hole A

This hole was oriented S 55 W and angled 65 degrees (from horizontal) to drill across the West Bellvue Fault and to provide information on the nature and properties of bedrock. Sandstone was encountered at an unusual overburden thickness of about 57 ft (49 ft vertical). Core recovery in the light gray to yellowish gray, well-cemented sandstone was 90-100 percent to a depth of 75 ft. A fault occurs between 75 and 88 ft (13 ft) along the core. The fault is mostly in hard, dark gray siltstone that is sheared, slickensided, and brecciated. Dense, clayey, fault gouge is abundant and is probably responsible for about 50 percent core loss between 83 and 88 ft. This fault is almost certain to be the targeted West Bellvue Fault. The attitude and true thickness of this fault cannot be determined by only one drill hole.

Between 88 and 95 ft, the core consists of alternating beds of sandstone and shale. From 95 ft to 148 ft (53 ft) the core consists of light gray to pinkish gray, well-sorted, fine to medium grained sandstone. At 148 ft the rock changes to pink sandstone with irregular zones of tan to olive color. The sandstone is poorly cemented and friable. From 158 to the bottom of the hole at 168 ft, the sandstone becomes less friable and more massive and changes from pink to dark red.

The rock from 57 ft to about 148 ft is probably sandstone and shale of the Morrison Formation, although the sandstone between 95 ft and 148 ft is unusually thick for sandstone beds in this formation. The pink to red sandstone between 148 ft and 168 ft is probably the upper Entrada Formation that directly underlies the Morrison Formation.

5.6.2 Core Hole B

This hole was oriented N 20 E at an angle of 55 degrees (from horizontal) so as to cross the North Fork Fault where it intersects the proposed dam axis. Dark red sandstone was encountered at about 38 ft beneath a vertical overburden thickness of 30 ft. Rock affected by the North Fork Fault was encountered in the first coring run where slickensided sandstone and siltstone of the Fountain Formation was cored between 41 and 48 ft.

The interval from 41 to 96 ft (55 ft) is considered to be the North Fork Fault and appears to be entirely within the Fountain Formation. Core recovery varies from a low of 10 percent to a high of 45 percent. Besides the soft, sandy-clay fault gouge that easily washes away during drilling, other evidence of faulting includes slickensides with sheared and brecciated fragments of hard sandstone, limestone, and chert. A zone of undisturbed sandstone occurs between 88 and 93 ft, but the interval from 93 to 96 ft has slickensiding at each end and consists of hard, massive, coarse-grained, calcareous sandstone containing fragments of limestone. The rock appears to have been sheared and brecciated but was later "re-healed" to become hard and massive. From 96 ft to the bottom of the hole at 128 ft, the core consists of undisturbed sandstone.

The presence of limestone fragments throughout the fault zone described above is an interesting aspect of this part of the North Fork Fault. The limestone fragments are probably from the Ingleside Formation that overlies the Fountain Formation. The fault movement for the east-west portion of the North Fork Fault in the project area is indicated as having the north side faulted upward relative to the south side (see Broin, 1952 discussion of Kramer Ranch Fault). If this was the only sense of movement, it would be impossible for limestone fragments to become engulfed in the fault gouge near core hole B. However, at some time during the tectonic history of the Front Range, it is likely that fault movement opposite to that indicated (north side down) could have occurred, and this would account for limestone fragments in the fault gouge.

5.6.3 Core Hole C

Core hole C was positioned so as to drill across the intersection of the North Fork Fault and the West Bellvue Fault. The hole was drilled at an angle of 50 degrees (from horizontal) and with a bearing of N 85 E. Weathered siltstone was encountered at a depth of 25 ft (19 ft vertical) but was so friable that no core was recovered until a depth of 30 ft was reached.

The 135 ft of rock penetrated by this hole consisted of red, fine-grained, friable to well-cemented sandstone and beds of friable, dark red siltstone of the Satanka Formation. Sandstone constituted about 87 ft of the core and siltstone amounted to 48 ft of the core. There are several zones of badly broken core associated with core loss. These zones were caused by closely spaced joints or by intervals of friable, poorly cemented sandstone. No good evidence of faulting was seen in the core.

The actual location of the two faults targeted by core hole C is covered by thick alluvium, especially in the vicinity of the proposed dam. The inferred location of these faults (Figure E.5) is shown by dotted lines that are projected from outcrops located 1/2 to 1 mile away. Apparently the faults are located such that hole C missed them or they may not actually exist in the area drilled.

5.6.4 Water Pressure Tests

Water pressure tests were performed in core holes A and C. The presence of soft, friable rock in the upper part of hole B did not offer a firm interval to seat the packer. Also, the risk of losing the hole by pulling the rods through the fault zone and inserting a packer was considered too high to warrant an attempt to perform a pressure test.

Pressure tests were performed in holes A and C by placing a single, inflatable packer at a certain location above the bottom of the hole and pumping water at different pressures into the hole. The pumping pressure and water flow was measured by conventional gages and meters. The duration of most of the tests was three minutes.

Without exception, the intervals tested indicated rock of very low permeability. The highest water takes at a pressure of 60 psi were 0.03 gpm/ft for an interval of 68 ft in hole A and 0.03 gpm/ft for an interval of 110 ft in hole C. The highest take was 0.13 gpm/ft at a pressure of 120 psi in hole A.

5.7 CONCLUSIONS REGARDING THE GLADE DAMSITE

The preliminary foundation study at Glade Damsite utilized a combination of seismic refraction surveys, auger drilling, and angle-hole core drilling. This combination provided prefeasibility level subsurface information. No adverse conditions were found during the preliminary subsurface exploration that would preclude consideration of the Glade damsite for a major storage project. However, extensive additional studies would be required at the feasibility level. These studies would include more core drilling, water pressure testing, soil sampling and testing, and detailed geologic mapping of the reservoir area.

The seismic surveys and auger drilling established the depth of overburden at the damsite area. Overburden material consists mostly of silty sand, silty clayey sand and minor amounts of poorly graded, sandy-silty gravel. In the drainage area northeast of the Kramer Ranch, large areas of inorganic silt and fine clayey sand may be encountered. The seismic P-wave velocity of 2000 ft/sec indicates loose, fine-grained material that would be compressible and probably subject to differential settlement under loading.

The bedrock P-wave velocities along the dam axis vary from a high of 10,500 ft/sec to a low of 4500 ft/sec. In conjunction with the limited core drilling, the P-wave velocities indicate sound rock that has adequate bearing capacity for the proposed dam. The seismic data also shows transition zones between rock of different P-wave velocities. These transition zones may represent either different rock properties or the results of faulting. At least two of the transition zones (near auger hole 3 and auger hole 10) are easily correlated with known faults.

Core drilling was planned to provide information on rock properties beneath the dam and to explore for faults inferred to occur in the damsite area by Braddock (1973). The North Fork fault was encountered by core hole

B and the West Bellvue Fault was encountered by core hole A. In both holes the fault gouge material that was recovered was obviously compressible and easily washed away by the drilling. These, and possibly other unknown faults, will be crossed by the dam. Conventional foundation treatment methods will probably be adequate in these areas.

The limited water pressure tests in two of the core holes indicate rock of low permeability. The rock units at the damsite and enclosing the reservoir consist of the igneous and metamorphic rocks of the Idaho Springs Formation as well as sandstone, siltstone, shale, and thin limestone beds in geologic formations from the Fountain to the Morrison (Figure E.4). All of these formations are probably of very low permeability and no significant reservoir leakage is expected.

The auger drilling indicated considerable thicknesses of fine-grained, clayey-silty sand that would probably provide impervious core material for the dam. Sources of sand and gravel have not yet been determined, but would probably be available from commercial gravel pits in the area. The best source for crushed rock and riprap could be from the commercial limestone and sandstone quarry operating in the Owl Canyon area about eight miles north of the damsite. A local quarry could also be located in the Ingleside Formation that occurs in the ridge that divides the reservoir.

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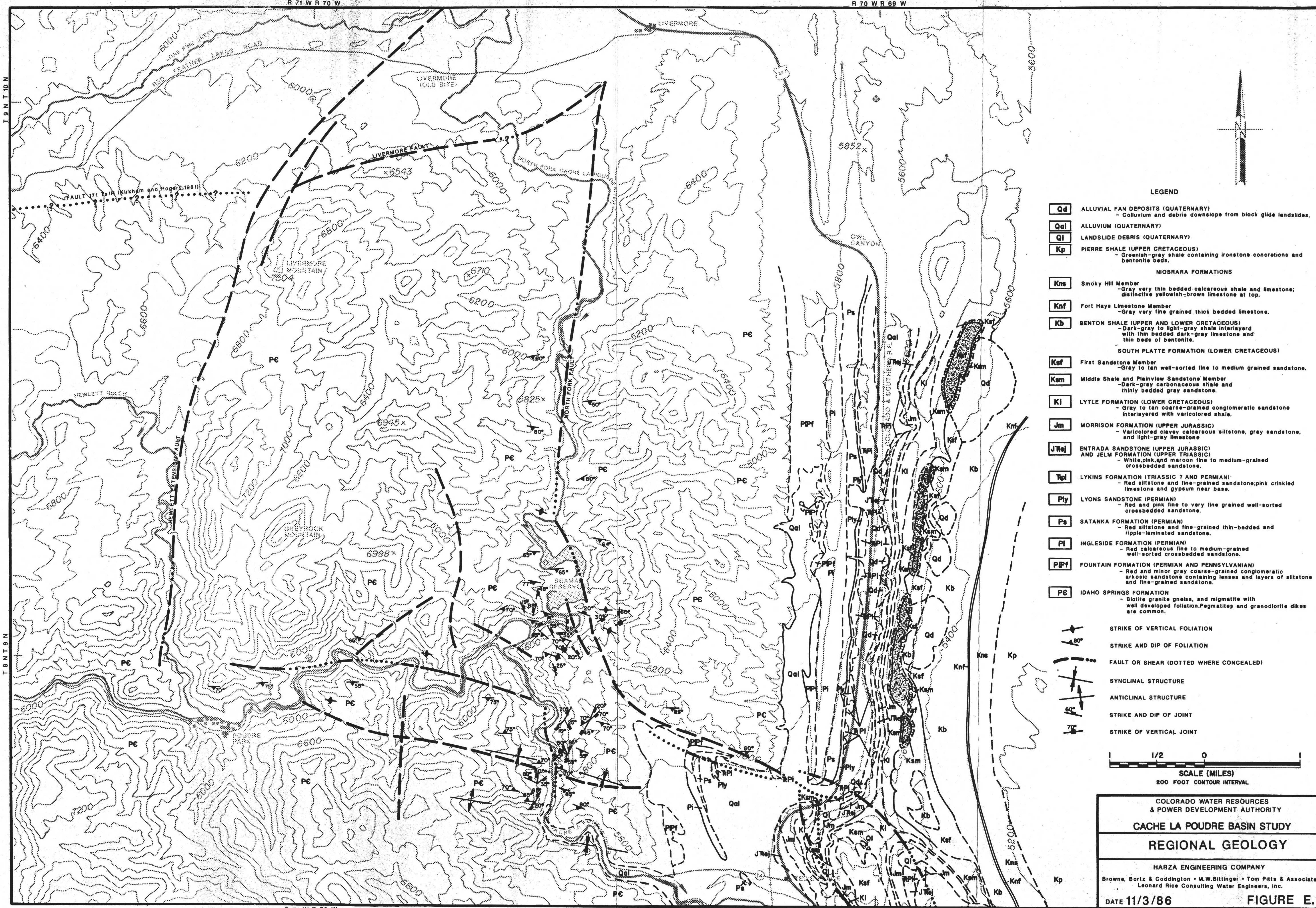
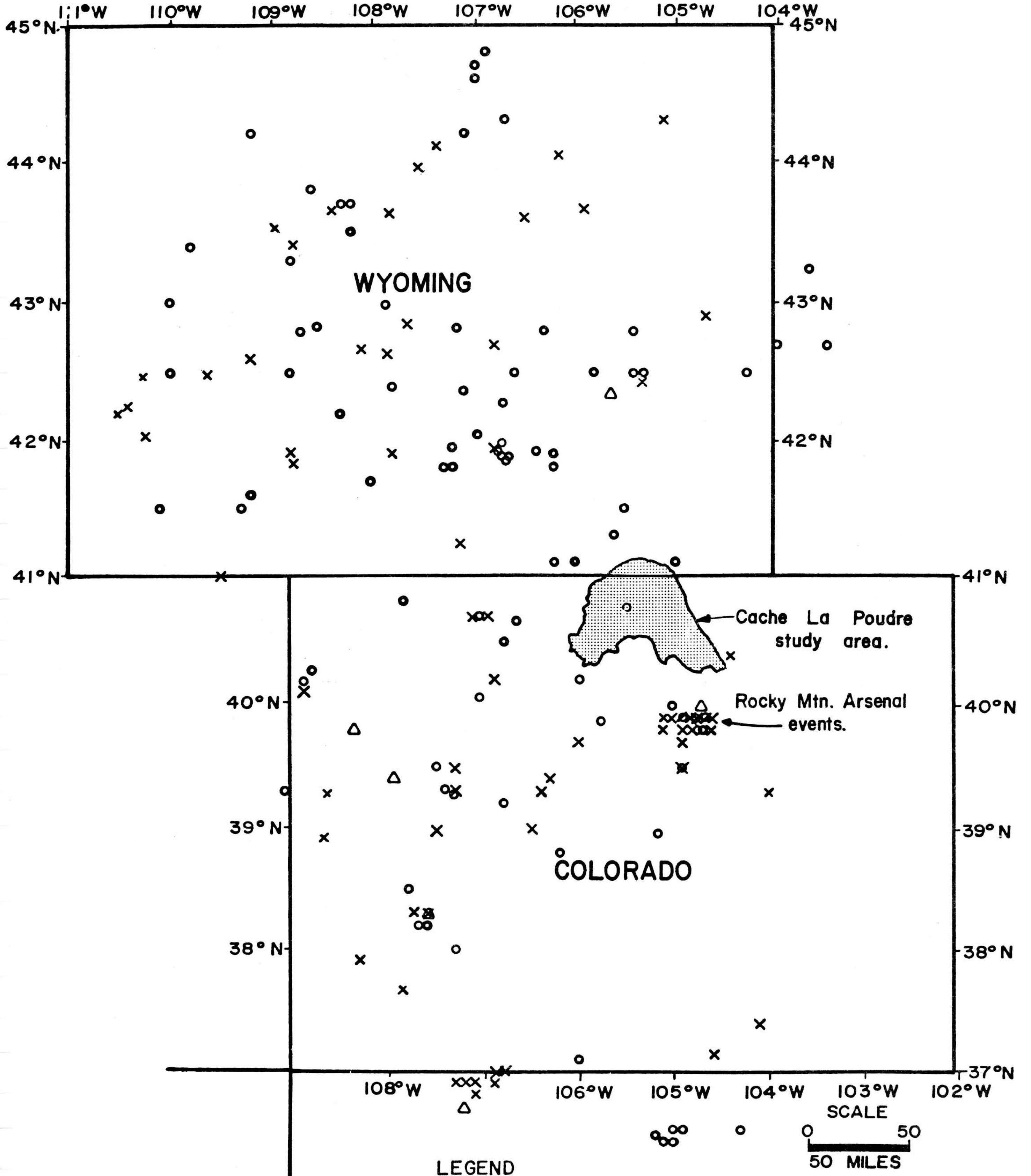

R 71 W R 70 W
R 70 W R 69 W
T 9 N T 10 N
T 8 N T 9 N
LIVERMORE
LIVERMORE (OLD SITE)
RED FEATHER LAKES ROAD
LIVERMORE FAULT
NORTH FORK FAULT
HEWLETT EXTENSION FAULT
HEWLETT GULCH
FAULT 171 ts/R (Kirkham and Rogers,1981)
LIVERMORE MOUNTAIN 7504
GREYROCK MOUNTAIN
OWL CANYON
POUDRE PARK
LEGEND
Qd ALLUVIAL FAN DEPOSITS (QUATERNARY) - Colluvium and debris downslope from block glide landslides.
Qal ALLUVIUM (QUATERNARY)
Ql LANDSLIDE DEBRIS (QUATERNARY)
Kp PIERRE SHALE (UPPER CRETACEOUS) - Greenish-gray shale containing ironstone concretions and bentonite beds.
NIOBRARA FORMATIONS
Kns Smoky Hill Member -Gray very thin bedded calcareous shale and limestone; distinctive yellowish-brown limestone at top.
Knf Fort Hays Limestone Member -Gray very fine grained thick bedded limestone.
Kb BENTON SHALE (UPPER AND LOWER CRETACEOUS) -Dark-gray to light-gray shale interlayerd with thin bedded dark-gray limestone and thin beds of bentonite.
SOUTH PLATTE FORMATION (LOWER CRETACEOUS)
Ksf First Sandstone Member -Gray to tan well-sorted fine to medium grained sandstone.
Ksm Middle Shale and Plainview Sandstone Member -Dark-gray carbonaceous shale and thinly bedded gray sandstone.
Kl LYTLE FORMATION (LOWER CRETACEOUS) - Gray to tan coarse-grained conglomeratic sandstone interlayered with varicolored shale.
Jm MORRISON FORMATION (UPPER JURASSIC) - Varicolored clayey calcareous siltstone, gray sandstone, and light-gray limestone
JTRej ENTRADA SANDSTONE (UPPER JURASSIC) AND JELM FORMATION (UPPER TRIASSIC) - White,pink,and maroon fine to medium-grained crossbedded sandstone.
TRPl LYKINS FORMATION (TRIASSIC ? AND PERMIAN) - Red siltstone and fine-grained sandstone;pink crinkled limestone and gypsum near base.
Ply LYONS SANDSTONE (PERMIAN) - Red and pink fine to very fine grained well-sorted crossbedded sandstone.
Ps SATANKA FORMATION (PERMIAN) - Red siltstone and fine-grained thin-bedded and ripple-laminated sandstone.
Pi INGLESIDE FORMATION (PERMIAN) - Red calcareous fine to medium-grained well-sorted crossbedded sandstone.
PIPf FOUNTAIN FORMATION (PERMIAN AND PENNSYLVANIAN) - Red and minor gray coarse-grained conglomeratic arkosic sandstone containing lenses and layers of siltstone and fine-grained sandstone.
P€ IDAHO SPRINGS FORMATION - Biotite granite gneiss, and migmatite with well developed foliation.Pegmatites and granodiorite dikes are common.
STRIKE OF VERTICAL FOLIATION
STRIKE AND DIP OF FOLIATION
FAULT OR SHEAR (DOTTED WHERE CONCEALED)
SYNCLINAL STRUCTURE
ANTICLINAL STRUCTURE
STRIKE AND DIP OF JOINT
STRIKE OF VERTICAL JOINT
1/2 0 1
SCALE (MILES)
200 FOOT CONTOUR INTERVAL
COLORADO WATER RESOURCES & POWER DEVELOPMENT AUTHORITY
CACHE LA POUDRE BASIN STUDY
REGIONAL GEOLOGY
HARZA ENGINEERING COMPANY
Browne, Bortz & Coddington • M.W.Bittinger • Tom Pitts & Associates
Leonard Rice Consulting Water Engineers, Inc.
DATE 11/3/86
FIGURE E.1



LEGEND

MAGNITUDE

- o 0.00 M 3.99
- x 3.99 M 4.99
- △ 4.99 M 7.99

NOTE:

267 earthquakes plotted

COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY

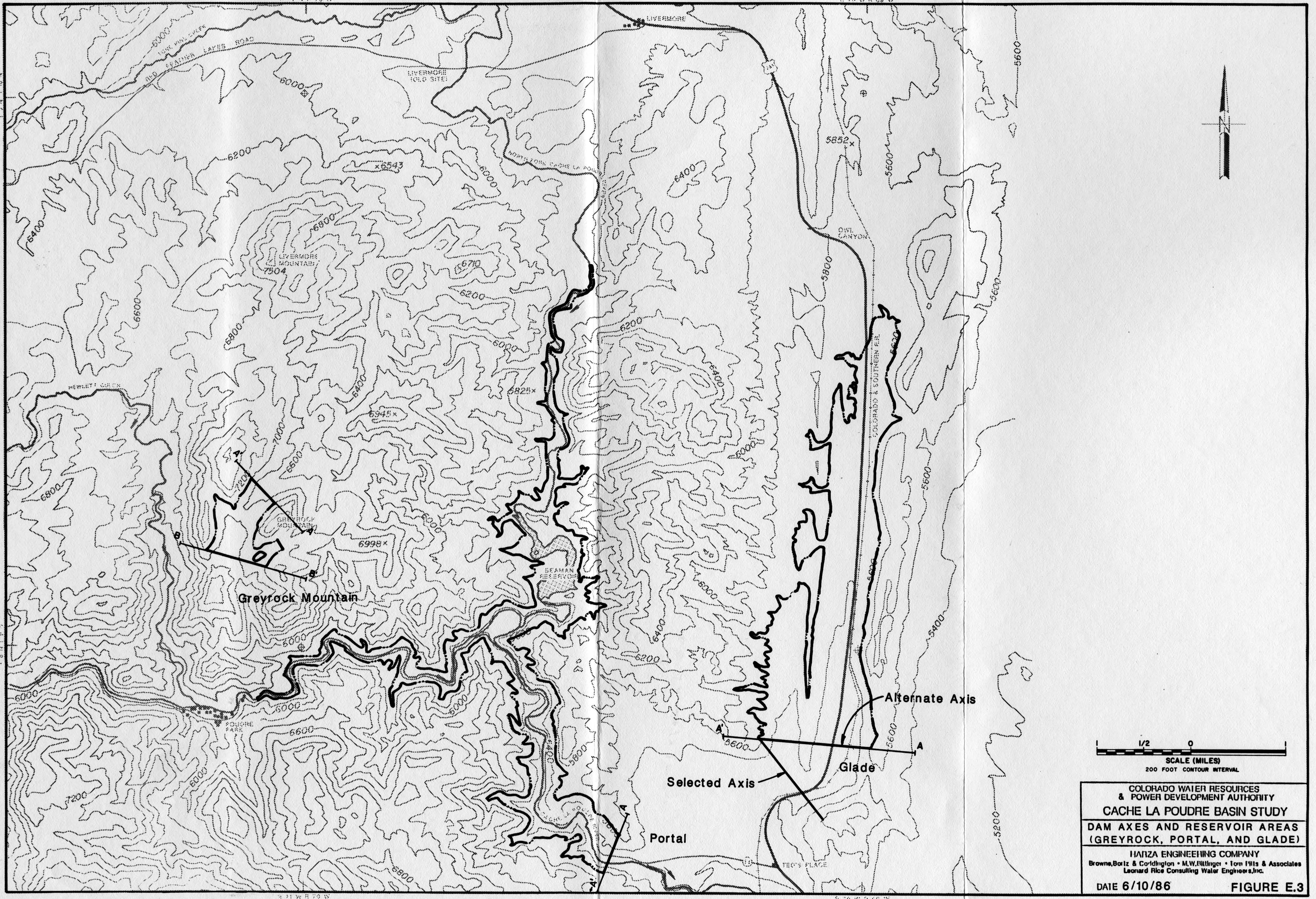
EARTHQUAKE OCCURRENCES

HARZA ENGINEERING COMPANY

Browne, Bortz & Coddington • M.W. Bittinger • Tom Pitts & Associates
Leonard Rice Consulting Water Engineers, Inc.

DATE 6/4/86

FIGURE E.2



COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY

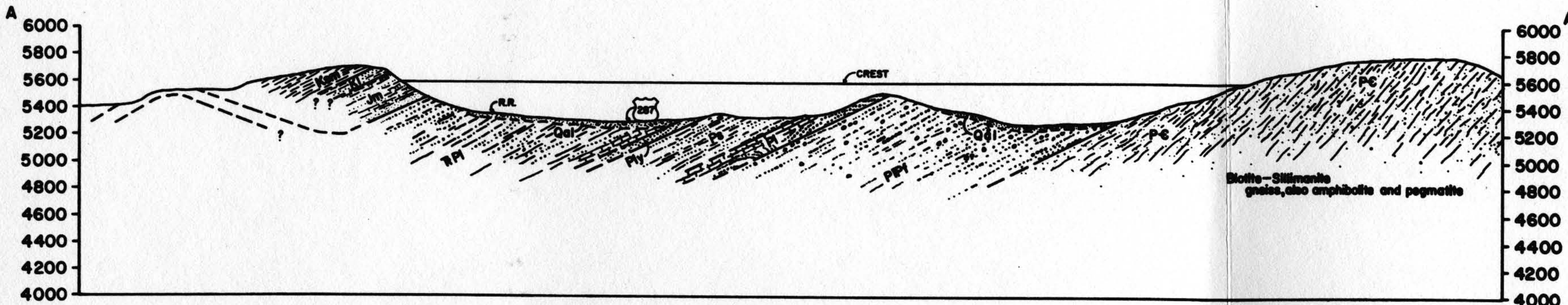
CACHE LA POUDRE BASIN STUDY

DAM AXES AND RESERVOIR AREAS
(GREYROCK, PORTAL, AND GLADE)

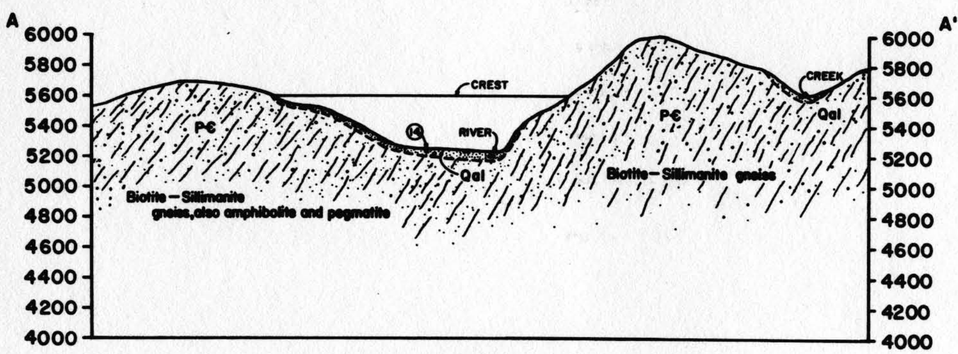
HARZA ENGINEERING COMPANY
Browne, Bortz & Coddington • M.W. Bittinger • Tom Pitts & Associates
Leonard Rice Consulting Water Engineers, Inc.

DATE 6/10/86

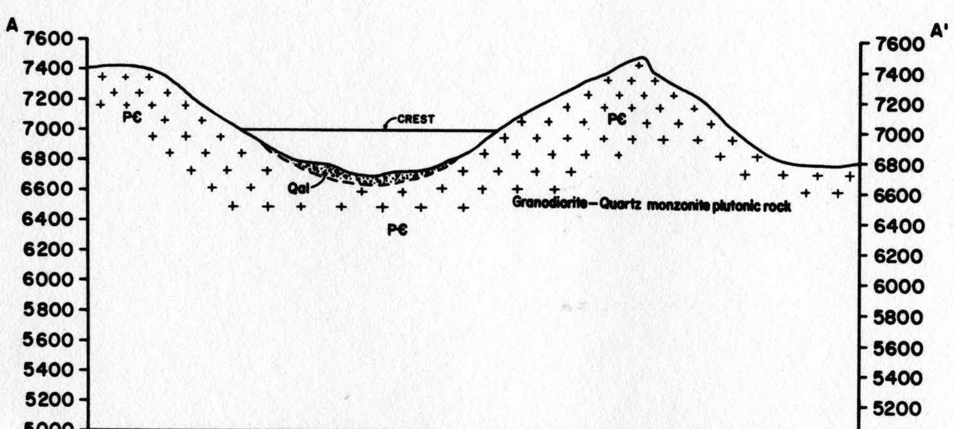
FIGURE E.3



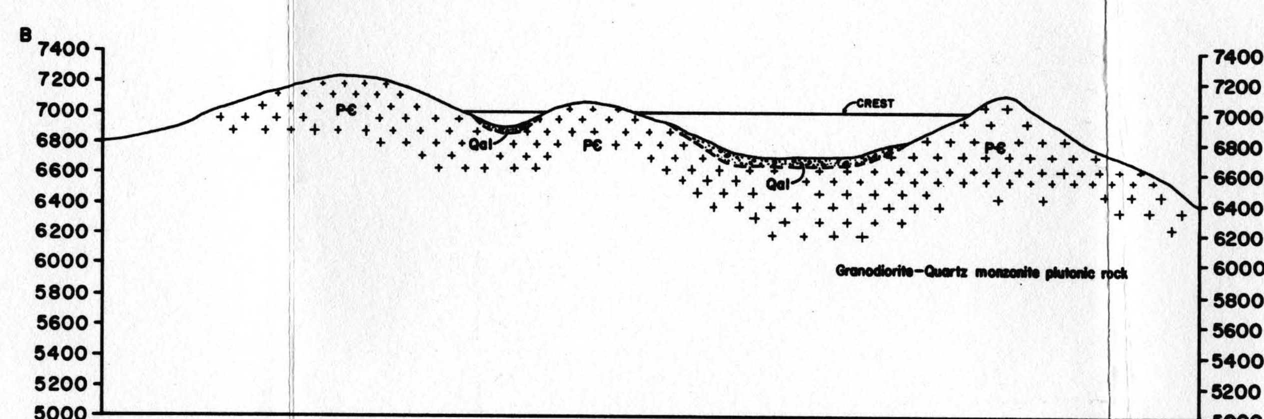
GLADE DAMSITE
CROSS SECTION A–A'(LOOKING S)



PORTAL DAMSITE
CROSS SECTION A–A'(LOOKING E)



GREYROCK MOUNTAIN DAMSITES
CROSS SECTION A–A' (LOOKING NE)



GREYROCK MOUNTAIN DAMSITES
CROSS SECTION B–B'(LOOKING S)

LEGEND

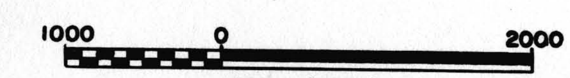
- **Qd** — ALLUVIAL FAN DEPOSITS (QUATERNARY)
  - Colluvium and debris downslope from block glide landslides.
- **Qal** — ALLUVIUM (QUATERNARY)
- **Ql** — LANDSLIDE DEBRIS (QUATERNARY)
- **Kp** — PIERRE SHALE (UPPER CRETACEOUS)
  - Greenish-gray shale containing ironstone concretions and bentonite beds.

NIOBRARA FORMATIONS

- **Kns** — Smoky Hill Member
  - Gray very thin bedded calcareous shale and limestone; distinctive yellowish-brown limestone at top.
- **Knf** — Fort Hays Limestone Member
  - Gray very fine grained thick bedded limestone.
- **Kb** — BENTON SHALE (UPPER AND LOWER CRETACEOUS)
  - Dark-gray to light-gray shale interlayerd with thin bedded dark-gray limestone and thin beds of bentonite.

SOUTH PLATTE FORMATION (LOWER CRETACEOUS)

- **Ksf** — First Sandstone Member
  - Gray to tan well-sorted fine to medium grained sandstone.
- **Ksm** — Middle Shale and Plainview Sandstone Member
  - Dark-gray carbonaceous shale and thinly bedded gray sandstone.
- **Kl** — LYTLE FORMATION (LOWER CRETACEOUS)
  - Gray to tan coarse-grained conglomeratic sandstone interlayered with varicolored shale.
- **Jm** — MORRISON FORMATION (UPPER JURASSIC)
  - Varicolored clayey calcareous siltstone, gray sandstone, and light-gray limestone
- **JTRej** — ENTRADA SANDSTONE (UPPER JURASSIC) AND JELM FORMATION (UPPER TRIASSIC)
  - White,pink,and maroon fine to medium-grained crossbedded sandstone.
- **TRPl** — LYKINS FORMATION (TRIASSIC ? AND PERMIAN)
  - Red siltstone and fine-grained sandstone;pink crinkled limestone and gypsum near base.
- **Ply** — LYONS SANDSTONE (PERMIAN)
  - Red and pink fine to very fine grained well-sorted crossbedded sandstone.
- **Ps** — SATANKA FORMATION (PERMIAN)
  - Red siltstone and fine-grained thin-bedded and ripple-laminated sandstone.
- **Pl** — INGLESIDE FORMATION (PERMIAN)
  - Red calcareous fine to medium-grained well-sorted crossbedded sandstone.
- **PIPf** — FOUNTAIN FORMATION (PERMIAN AND PENNSYLVANIAN)
  - Red and minor gray coarse-grained conglomeratic arkosic sandstone containing lenses and layers of siltstone and fine-grained sandstone.
- **P€** — IDAHO SPRINGS FORMATION
  - Biotite granite gneiss, and migmatite with well developed foliation.Pegmatites and granodiorite dikes are common.



COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY

GEOLOGIC SECTIONS (GREYROCK, PORTAL, AND GLADE)

HARZA ENGINEERING COMPANY
Browne,Bortz & Coddington • M.W.Bittinger • Tom Pitts & Associates
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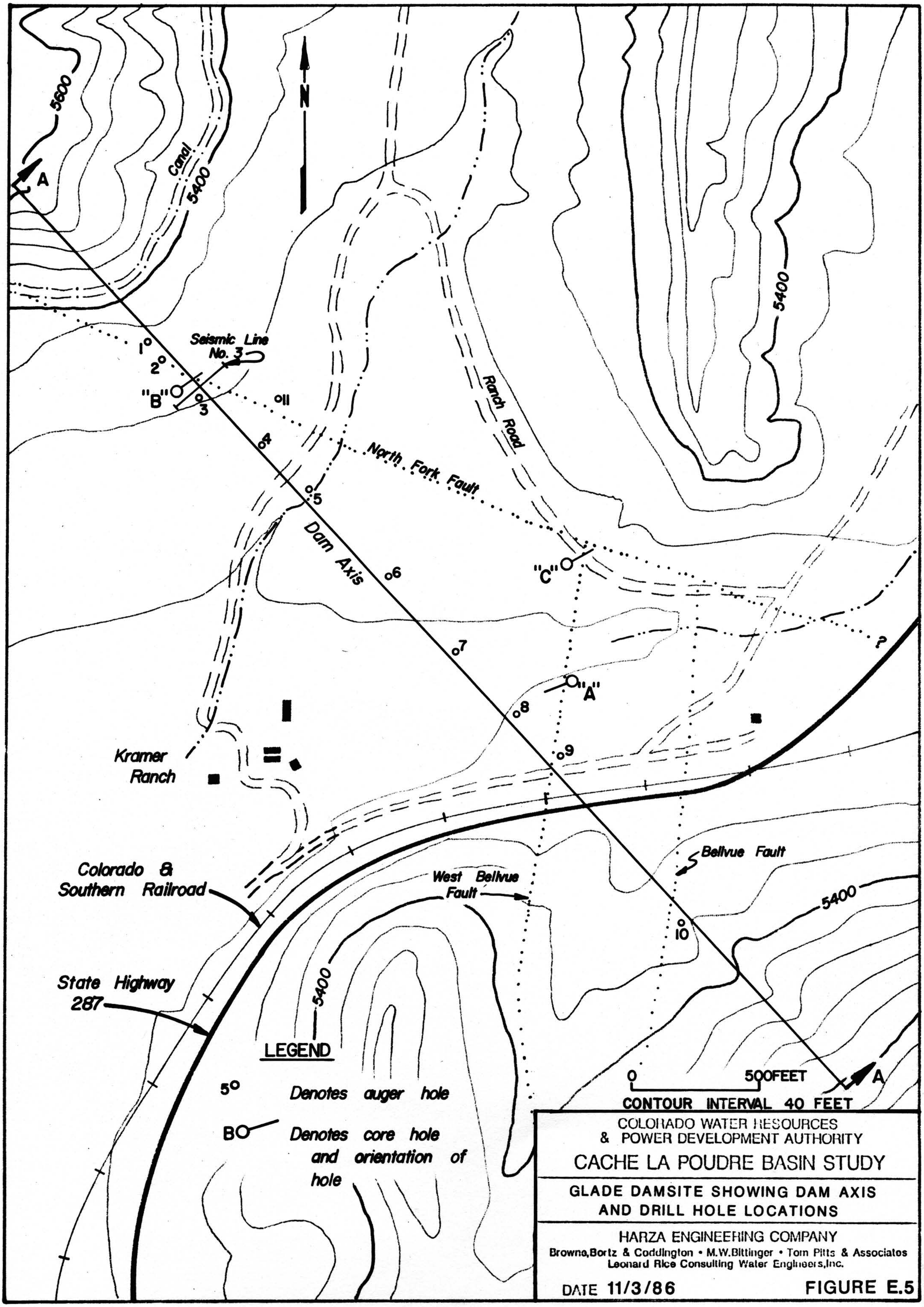
FIGURE E.4



COLORADO WATER RESOURCES
& POWER DEVELOPMENT AUTHORITY

CACHE LA POUDRE BASIN STUDY

GLADE DAMSITE SHOWING DAM AXIS AND DRILL HOLE LOCATIONS

HARZA ENGINEERING COMPANY
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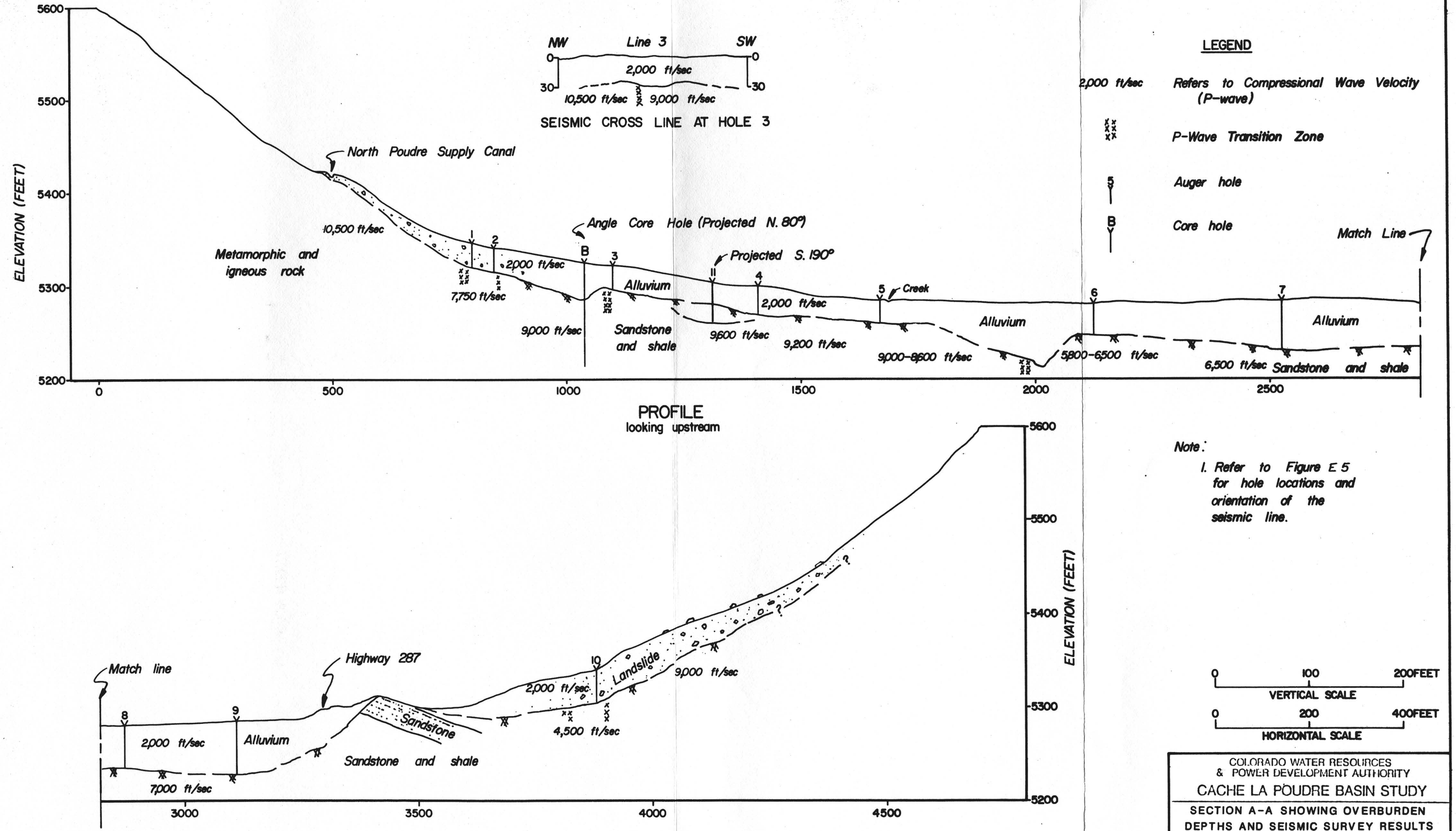
FIGURE E.5



COLORADO WATER RESOURCES
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CACHE LA POUDRE BASIN STUDY

SECTION A-A SHOWING OVERBURDEN DEPTHS AND SEISMIC SURVEY RESULTS

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FIGURE E.6