EVALUATION OF WATER SUPPLY, WATER DEMAND AND WATER DEVELOPMENT OPPORTUNITIES FOR CEDAR CITY

FOR

CEDAR CITY CORPORATION

AND

UTAH DIVISION OF WATER RESOURCES

Submitted by:

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5160 Wiley Post Way
Salt Lake City, Utah

MARCH 1993

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ACKNOWLEDGMENT

This study was prepared under contract with **Cedar City Corporation.** Joint funding for the study was furnished by **Cedar City** and the **Utah Division of Water Resources** who also established a joint advisory review team for the study. Special appreciation is expressed to these team members and staff who gave much time and effort in attending review meetings in both in Cedar City and Salt Lake City, for review and input into planning alternatives, and in providing technical data for the study.

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EVALUATION OF WATER SUPPLY, WATER DEMAND AND WATER DEVELOPMENT OPPORTUNITIES FOR CEDAR CITY

Chapter I - Introduction

Purpose of this Evaluation

This report has been prepared at the request of Cedar City and the Utah Division of Water Resources to provide current information on the water supply, water usage, projected water demand and water development opportunities for Cedar City. It includes an assessment of existing water supplies that could be developed to meet growing needs within the Cedar City Valley drainage area and an updated evaluation of several transbasin diversion alternatives, some of which have been previously studied. These transbasin diversion alternatives include importation of water from the Upper Virgin River basin, Upper Santa Clara River basin and the Sevier River (Upper Mammoth Creek Basin). A preliminary evaluation of the amount of water that could be developed and the cost of development is given for each of the alternatives presented.

Background

Cedar City officials recognized years ago that the water supply within the Cedar City Valley and Coal Creek drainages would not meet the area's future water needs. Because of the limited water supply, officials began investigations into developing water from other basins for delivery into the Cedar City area. The problem was further accentuated in 1966 when the State Engineer closed Cedar City Valley to further appropriation of water because groundwater levels had declined for the previous 15 years. During the early 1950's, a discussion of including Iron County in the Dixie Project occurred. This was not fully investigated by the U.S. Bureau of Reclamation because it meant changing and delaying much of the work done on the Dixie Project.

The Utah Water and Power Board then appointed a committee to consider the needs of Washington and Iron Counties. Navajo Lake, which is located at the top of the Sevier and Virgin River drainages, was considered for a possible supply. In 1959, a water supply study of Navajo Lake was completed with funds provided by Cedar City, the Utah Water and Power Board, and the U. S. Geological Survey. The Navajo Lake diversion was eliminated from further consideration, even before the water supply study was complete, because of water right issues.

In August, 1953, Cedar City entered into an agreement with Washington County and the newly formed Kolob Reservoir and Storage Association (water users from Hurricane and Washington Fields). The agreement was to construct the Kolob Dam and Reservoir, with a capacity of 5,500 acre-feet (AF). Through this agreement Cedar City repaid 2/5 of the cost of constructing Kolob Reservoir and the agreement allowed Cedar City to acquire the entire water storage and supply in Kolob Reservoir, including provisions to divert additional water from Crystal Creek into Kolob Reservoir and then convey it to Cedar City when the Dixie project was completed.

Since the U. S. Bureau of Reclamation abandoned the Dixie project in the early 1960's, a substitute reservoir was investigated in order for Cedar City to acquire the entire water supply in Kolob Reservoir. Eight dam and reservoir sites on the North Fork of the Virgin River and tributaries were investigated, in a reconnaissance study conducted in the early 1970's, as possible sites for a substitute reservoir. Participation by Cedar City in constructing a substitute reservoir would then allow them to divert the entire Kolob Reservoir water supply to Cedar City. The North Fork study recommended detailed investigations be made on the Bulloch Dam site, located immediately east of the Zion National Park boundary, as a possible replacement reservoir.

A study was completed in 1982 by the Utah Division of Water Resources (UDWRe) of conveying water from Kolob Reservoir to Cedar City and considering Bulloch Dam for use by Washington County water users. The proposed project consisted of constructing Bulloch Dam, a tunnel and pipeline conveying water from Kolob Reservoir to Cedar City, a diversion structure on Crystal Creek, and a diversion tunnel conveying water from Crystal Creek to Kolob Reservoir. The project was presented to the Board of Water Resources in its May 1982 meeting, but was never authorized.

In 1984 an agreement, see Appendix A, between Cedar City and Washington County Water Conservancy District (WCWCD) outlined opportunities for Cedar City to develop water in the Virgin River Basin. A short summary of the agreement follows:

> Cedar City is purchasing storage in Quail Creek Reservoir from WCWCD to provide 3,340 AF annually to water users in the Hurricane Canal Company and St. George and Washington Canal Company. The storage is being purchased in 50 annual payments of $142,500. In exchange, Cedar City can have the right to divert the water developed and stored by Kolob Reservoir, as well as 1,600 AF annually of Crystal Creek primary water, and any high water right in Crystal Creek that they can acquire. This agreement recognizes that the first 600 AF annually stored in Kolob Reservoir is reserved for prior downstream rights.
>
> Under the 1984 agreement, if it is determined that transbasin conveyance of water from Crystal Creek and Kolob Reservoir to Cedar City is economically or environmentally infeasible, then Cedar City could divert up to 6,100 AF annually from springs in the Upper Virgin River Basin. One restriction that applies to the diversion from the springs is that not more than 533.33 AF can be diverted per month during July, August and September. Cedar City has until May 1993 to make a final decision to divert and convey water from Kolob reservoir and Crystal Creek. If Cedar City decides it is infeasible to divert and convey water from Kolob Reservoir, it will have one year, thereafter to decide upon the feasibility of developing the springs. If Cedar City decides not to construct facilities for transbasin diversion of water from the Upper Virgin River drainage, WCWCD will reimburse Cedar City for the amount paid plus interest, towards the cost of purchasing storage in the Quail Creek Project. WCWCD will then purchase Cedar City's two-fifths interest in Kolob Reservoir along with associated water rights.

Paragraphs 13 and 14 of the agreement clarify the legality of the agreement in relationship to the Constitution of Utah by noting that the agreement shall be considered as:

1. A temporary sale of surplus water.
2. An exchange of water rights and sources of supply of equal value.
3. The provisions of the agreement shall be construed to apply to inchoate water rights and sources of supply which have not been developed and cannot be developed in the best interests of Cedar City.
4. The financial obligations of the agreement are construed as a special fund obligation and not a general obligation in that they are secured by a revenue bond.

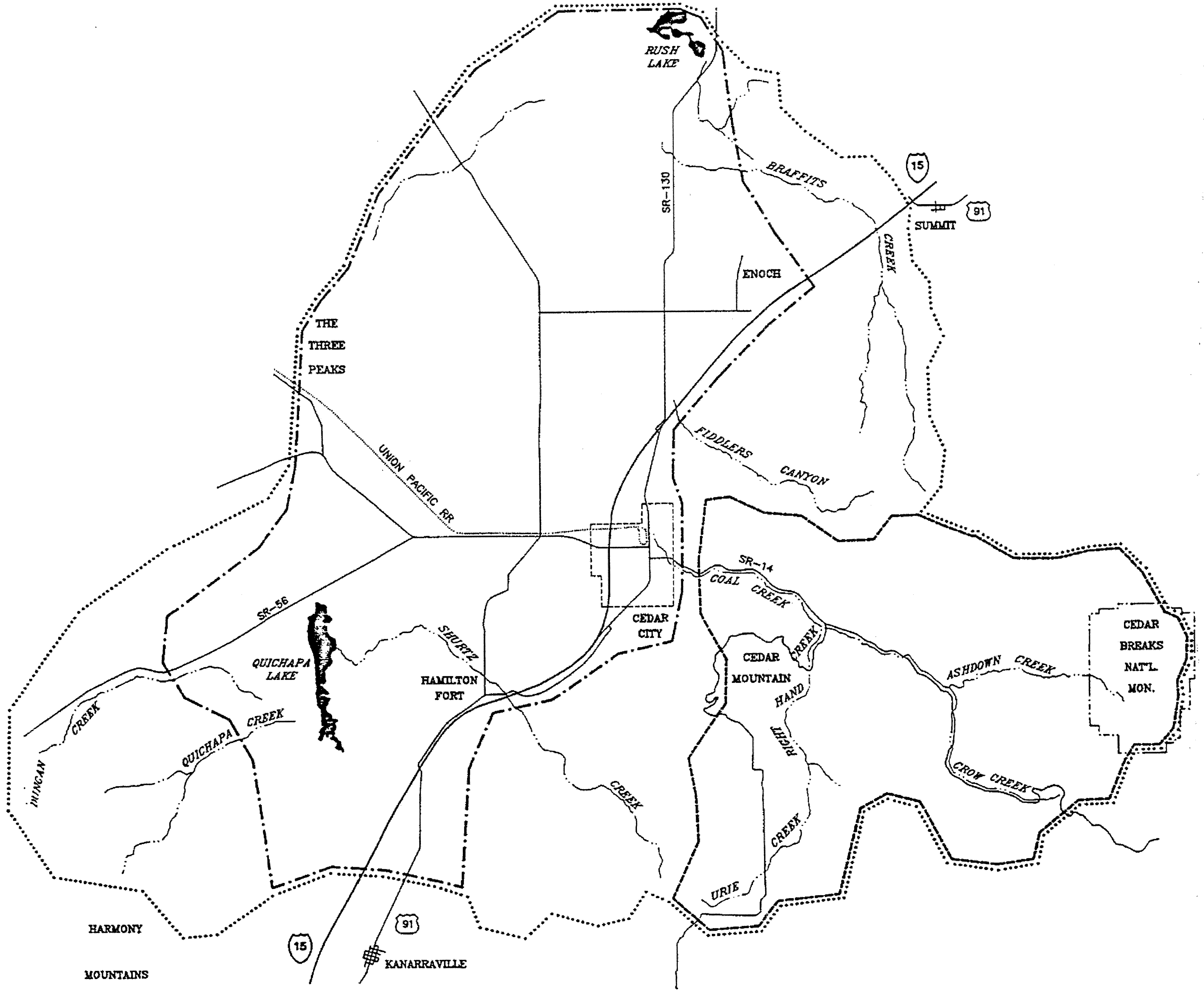
This 1984 agreement is important to Cedar City because it allows full development of its water rights in the Upper Virgin River Basin. The agreement also is important to the water users in Washington County because it specifies conditions and the time frame Cedar City must meet to implement the transbasin diversion from the Virgin River to Cedar City.

Description of Project Area

Figure 1, on the following page, is a Cedar City Area Drainage Map. It shows schematically the relationship between the entire Cedar City drainage area, that portion of the drainage area known as Cedar Valley and the Coal Creek drainage area which is the principal surface water source feeding the valley. It extends from Cedar City to Cedar Breaks National Monument.

Cedar City Valley is a structural depression primarily formed and bounded by faults generally trending northeast-southwestward. The high mountain areas bordering the Valley consist of elevated fault blocks, modified by erosion, and the Valley is underlain by downthrown blocks blanketed by materials eroded from the mountain areas. The alluvial deposits filling the Valley are the principal water bearing aquifer and provide a large, vital groundwater storage reservoir. Cedar City Valley is about 32 miles long and ranges from about 1 to 8 miles wide.

Most of the water flowing into the Valley originates as snowmelt runoff from the mountains to the east of the Valley and flows down Coal Creek, the only perennial stream entering the Valley. Other important but smaller streams are Shurtz Creek and Quichapa Creek which enter the southeast and southwest part of the Valley respectively. Water has historically left the Valley through 3 gaps in the surrounding hills. These are the Iron Springs and Mud Springs Gaps on the west side of the Valley and the Kanarra Creek drainage in the southern part of the Valley. These drainages occasionally conduct surface water from Cedar City Valley during extremely high flash flood conditions following excessive local precipitation. They also convey a very small amount of groundwater. However, for practical water development considerations, the Valley acts as a closed basin and all water which enters the Valley is consumed therein.



LEGEND

COAL CREEK DRAINAGE AREA	————
CEDAR VALLEY DRAINAGE AREA	—·—·—·
ENTIRE CEDAR CITY DRAINAGE AREA	··········

APPROX. SCALE:
1" = 2.5 MILES

FIGURE 1 I-4

CEDAR CITY
WATER SUPPLY EVALUATION

CEDAR CITY AREA
DRAINAGE MAP

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Design:
Drawn: STA
Checked:
Reviewed:

Date DEC. 1992 | Proj. # 1666– | Sht of

The principal use of water in the Valley is for agricultural purposes which depletes about 75% of the total water supply available. Municipal and industrial water depletions account for about 12% of the total water supply available and evaporation/evapotranspiration from fallow lands, phreatophytes, open water and mud flat areas account for about 10% of the depletion. Subsurface groundwater outflow from the basin is estimated to be about 3% of the total supply available. The increasing population growth in Cedar City Valley will continue to require an increasing supply of high quality municipal water.

Other Studies

As previously mentioned, Community Leaders have long recognized that the natural water supply within Cedar City Valley is limited both in quantity and quality and that there is a need for better utilization of the resource. This acknowledgement has resulted in a number of studies to better identify the available water resource and to evaluate problems associated with its development and use.

The most significant studies used as a background for this evaluation are referenced below:

1. Ground-Water Resources of Selected Basins in Southwestern Utah, Technical Publication No. 13, Utah State Engineer, 1966.

2. Ground-Water Resources of the Parowan-Cedar City Drainage Basin, Iron County, Utah, Technical Publication No. 60, Department of Natural Resources 1978.

3. Groundwater Conditions in Utah, Annual cooperative investigations reports prepared by U.S. Geological Survey with Utah Divisions of Water Resources and Water Rights.

4. Water Quality Inventory and Management Plan, Southwestern Utah, 208 Water Quality Report funded by EPA in cooperation with Five-County Association of Governments, April 1979.

5. Miscellaneous surveys and documentation of the Kolob Reservoir, proposed Crystal Creek tunnel and Cedar City transbasin diversion project prepared by Ralph Platt in the early 1950's. Information on file with Division of Water Resources.

6. Investigation of Transbasin Diversion From Upper Virgin River Basin to Cedar City, Utah, Division of Water Resources, June 1988.

7. Sprinkler Irrigation Project Alternatives for the Cedar City Valley Water Users Association, Division of Water Resources, 1986.

8. Water Use Data for Public Water Suppliers, Annual water use report published by Utah Division of Water Rights.

In addition to the above references, numerous other documents were reviewed to gain a better understanding of the water related problems and possible solutions in the Cedar City Valley area. Some of these problems are outlined on the following pages.

Table 1

PROJECTED POPULATION GROWTH IN CEDAR CITY VALLEY

Year	Population	Year	Population
1990	16,302	2006	22,724
1991	16,753	2007	23,153
1992	17,091	2008	23,775
1993	17,349	2009	24,399
1994	17,658	2010	24,888
1995	18,037	2011	25,251
1996	18,467	2012	25,577
1997	18,823	2013	25,883
1998	19,230	2014	26,187
1999	19,732	2015	26,486
2000	20,136	2016	26,749
2001	20,624	2017	27,007
2002	21,005	2018	27,259
2003	21,401	2019	27,515
2004	21,807	2020	27,776
2005	22,214		

table of population growth as reflected in the Table, but acknowledgement of the need to incrementally development new domestic water supplies to meet a corresponding incremental increase in population.

3. Surface Water Development

Development of surface water resources in Utah almost always require storage reservoirs to regulate the high seasonal and annual fluctuations in supply to meet the more steady demand requirements. It is desirable to locate the storage upstream of the major use areas to avoid pumping costs.

Coal Creek is the only perennial stream flowing into Cedar City Valley. A major portion of its headwaters originates in the barren and highly erodible Cedar Breaks area. This area is subject to frequent summer thunder storms and flash floods as well as fairly high levels of spring snowmelt runoff. These flash floods and high runoff levels usually carry very high sediment loads and often result in extremely heavy mud-rock flows. This condition has made it impractical to construct storage reservoirs directly on Coal Creek because they would fill up with sediment in a very short time. Pumping from the Cedar City Valley groundwater reservoir, the natural storage and regulating reservoir for Coal Creek, is therefore the most practical means for utilizing the bulk of the Coal Creek water supply.

There does, however, appear to be an opportunity to develop and store a relatively small portion of good quality water on the Urie Creek/Right Hand Canyon tributary to Coal Creek. This stream, although relatively small, is not subject to the high sediment loads of Coal Creek. It could be used as a treatable culinary supply for Cedar City without the cost of pumping. This opportunity has been explored in greater detail as a part of this study and evaluation and the results are summarized in Chapter V of this report.

4. Groundwater Quality

The water required to meet the growing population needs of Cedar City Valley will have to be of suitable quality to comply with State and Federal drinking water standards. In addition to the mountain springs serving Cedar City, reasonably good quality groundwater has been developed for culinary purposes by drilling wells in the Enoch area and the area west of Quichapa Lake. Much of the groundwater in the Valley, however, contains excessive concentrations of nitrates and/or sulfates and exceeds the recommended drinking water limits for total dissolved solids. There is a valid concern that additional pumping from the better water quality areas of the groundwater reservoir will cause the poorer quality waters to migrate into the areas containing the higher quality waters.

One option for better utilization of the total groundwater resource in the Valley is to pump domestic water from selected areas which have marginal water quality and treat it through an ion exchange (water softening) process to make it suitable for drinking water uses. This option has been explored in some detail as a part of this evaluation and is addressed in Chapter III.

Chapter II - Present and Future Water Demands

Agricultural Water Use Demands

Agricultural irrigation is the largest consumer of water in Cedar City Valley. In 1989, the Division of Water Resources prepared land and water use maps of all areas in Cedar City Valley which used water in excess of natural precipitation. These maps and land use data were used to prepare a water budget for the Valley and to define how much water in excess of natural precipitation is actually being consumed. This mapping was compared with 1960 aerial photos of Cedar City Valley to determine if any increase or decrease in irrigated areas has occurred since 1960. Some land usage has changed from agricultural to residential and apparently irrigation methods on much of the land has changed from flood irrigation to sprinkler irrigation. However, the over-all area being irrigated has not significantly changed since 1960.

To meet the growing municipal water demand, some agricultural water uses have been converted to residential water uses. It is expected that this trend will continue, at least for the next few years. Without transbasin importation of water into the Valley and with an apparent situation of groundwater mining, agricultural water uses would be expected to decline as it will likely be necessary for municipal uses to buy out the lower value agricultural uses not only to meet future demands but also to protect groundwater quality. If transbasin importation of water is implemented, the supply of water would likely increase enough that the agricultural water uses would decrease at a much slower rate and the impact on groundwater quality would be less due to a decrease in groundwater mining.

Municipal Water Use Projections

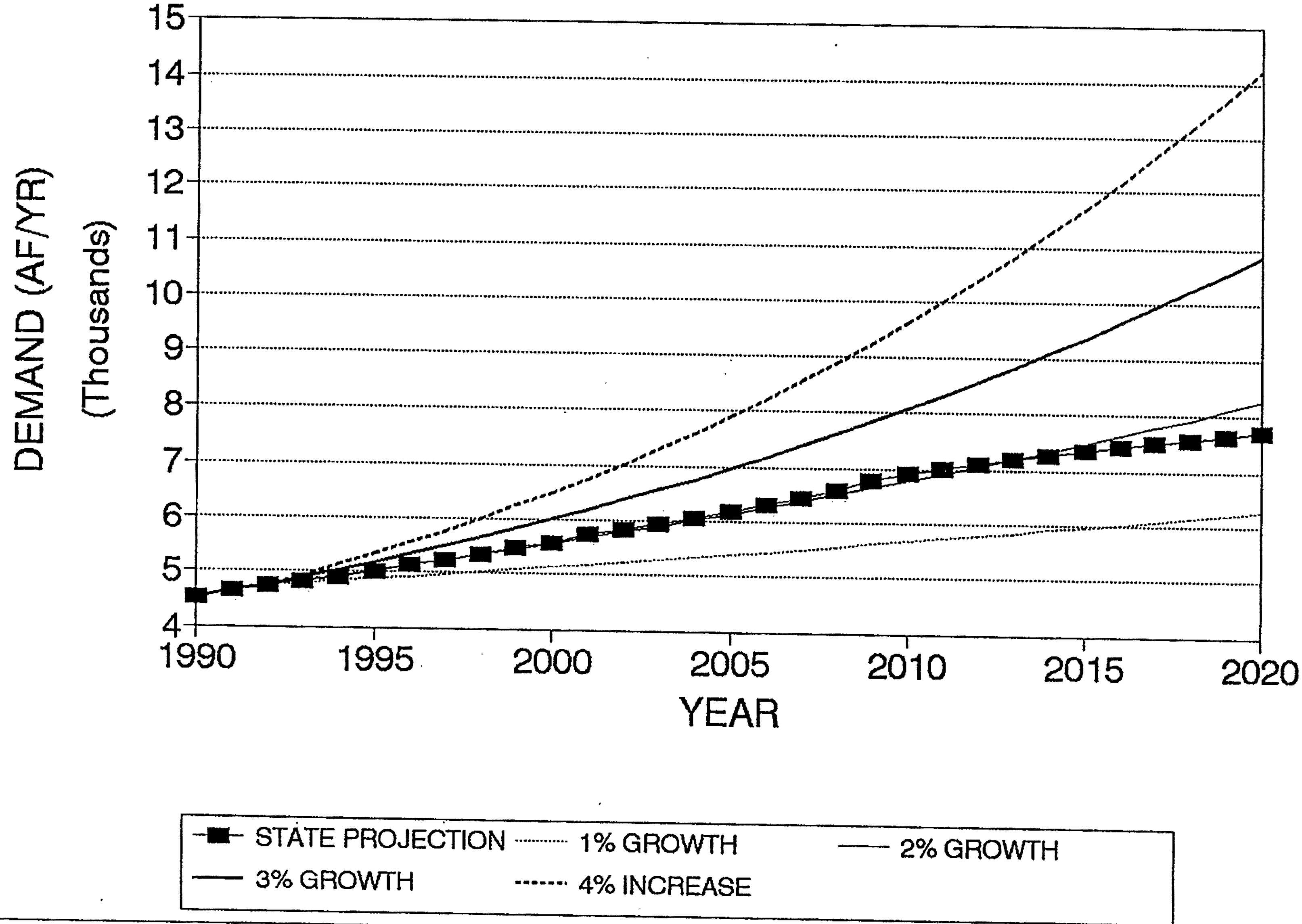
As previously discussed, municipal water delivery for Cedar City increased by 47% from 1981 to 1991. During the last 15 years, several other municipal water systems have also been organized in the Valley. These systems are Enoch, Monte Vista, Park West, Three Peaks, Pioneer Valley Water Co. and Rainbow Rancheros. Most of these systems, although relatively small when compared to the Cedar City system, have had comparable rates of growth in water deliveries over the past 5 years. These smaller systems have largely obtained their water through purchase of agricultural water rights and transferring them to municipal use.

Assuming that the future annual per capita demand for municipal water needs will remain the same as is currently being delivered to residents of Cedar City; namely 248 gallons per person per day, then the projected M&I water demand for Cedar City Valley will increase as shown in Figure 2 on the following page. This projection is based on the population growth previously shown in Table 1. The graph shows that the annual M & I water demand will increase from a current value of about 4500 acre feet per year to more than 7700 acre feet per year in the next 30 years. Based on the current rate of growth, this incremental water need increase may occur in less than 30 years.

Implementation of water conservation measures may decrease the required per capita water use for the valley. Water conservation measures should be explored as a means of increasing the efficiency of the water use in the valley. Some possible alternatives for

FIGURE 2

CEDAR VALLEY PROJECTED M&I WATER DEMAND



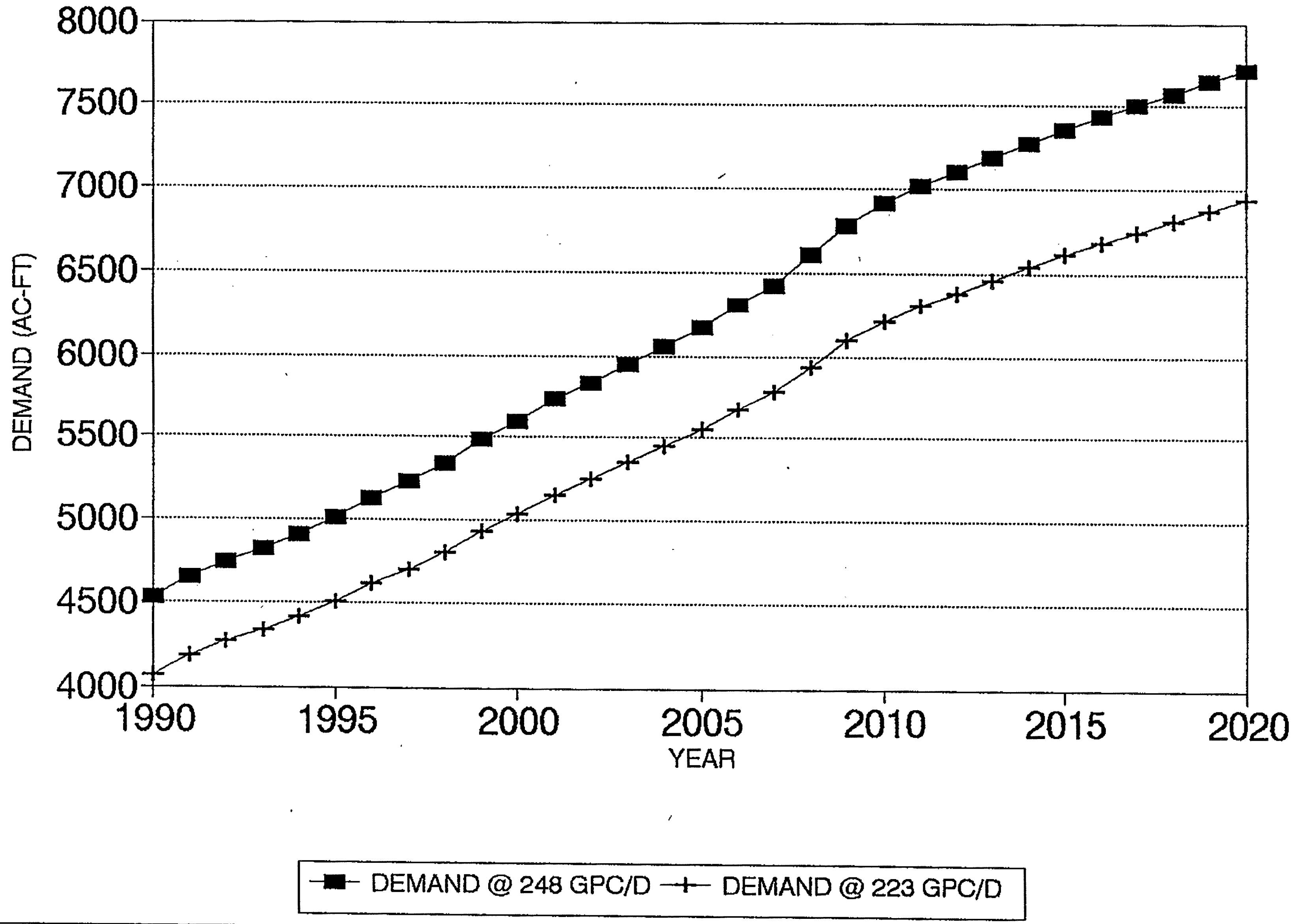
conserving high quality water include the following: limiting the area of ground that can be irrigated with culinary water; limiting the hours in which irrigation of residential lots can take place; adopting more aggressive fees for water as an incentive for the water users to conserve.

Some additional measures may include more careful control over the water that is diverted for irrigation. Water diverted into irrigation ditches that is not used and allowed to go down the ditch is only supplying water to the vegetation on the ditch banks and results in inefficient use of that water. It is very difficult to predict the effectiveness of these measures; therefore, it is difficult to estimate the amount of reduction in the per capita water use that would be expected if conservation measures are implemented. For purposes of comparison, we estimate that a reduction of about 10% will be experienced in the per capita water use. This results in a use of 223 gallons per person per day. Figure 3 shows a comparison of the projected M&I water demand for the two values of per capita water use.

Figure 2 also shows the water demand for differing growth rates of 1%, 2%, 3%, and 4%. If the growth rate changes or if the per capita water demand changes due to implementation of water conservation practices, then these curves could be used as tools to project future changes in municipal water demand.

FIGURE 3

CEDAR VALLEY M&I PROJECTED WATER DEMAND



Chapter III - Evaluation of Existing Groundwater Supply

Background

The main groundwater aquifer in Cedar City Valley is effectively a closed aquifer. It acts as a very large, efficient and valuable water storage reservoir. With the exception of a few subsurface outlets, the water which enters the main aquifer is contained. Leaky confined conditions exist in lower portions of the aquifer. Water movement upward is impeded by layers of relatively impermeable clay or silt. Water under pressure does flow through these layers. The confining layers are discontinuous at the edges of the valley which allows water through to the upper part of the aquifer. Water also enters the aquifer from infiltration of surface water and precipitation. The primary inflow is from Coal Creek. Other sources of inflow include, smaller surface tributaries, surface-water irrigation, and valley precipitation. For the purposes of determining a water budget, the inflow from the smaller surface tributaries includes the water that infiltrates the ground at higher elevations and enters the aquifer under artesian conditions as groundwater through the confining layers. It has been estimated that the volume of the aquifer is approximately twenty million acre-feet. The specific yield, the fraction of the total volume in the aquifer that can be freely extracted as groundwater, is estimated to be 0.1 or 10%. This amounts to a volume of two million acre feet for the total groundwater yield of the aquifer. In the years before the groundwater level dropped due to usage greater than the recharge rate; the contained water would escape as perched water in shallow lakes, wetlands, seeps and springs, which would then be subject to evaporation and evapotranspiration. In recent years, some of these surface discharges such as Iron Springs and Rush Lake have dried up.

The water in the aquifer is used for various purposes including municipal water supply, irrigation, domestic and stock watering. Presently, as described in Chapter I, the depletion of the groundwater reservoir at times has exceeded the rate of recharge and the supply of water in the aquifer is gradually becoming depleted. Several studies have been done as described in Chapter I to identify the water supply and to identify ways to better utilize the available water resources.

Prior investigations and current observations give some information which helps in gaining an understanding of how the groundwater basin behaves. This understanding is vital in determining how to utilize and manage the water most effectively. Water is withdrawn from the groundwater reservoir (aquifer) during the summer when other sources have decreased and depletions have increased. The reservoir is recharged during the winter months and during spring runoff when flows are high and depletion is relatively low. Historically, however, the groundwater reservoir volume has been on a decline. One vital concern is that continued growth and demand on the water will cause "mining" of the groundwater which will continually deplete the source of water until the demands can no longer be met. The "mining" process will also cause a drawdown in the water level which could further diminish the water quality and increase pumping costs required to utilize the water.

Determination of Groundwater Storage and Supply

In determining the magnitude of possible groundwater "mining" on the Cedar City Valley groundwater reservoir, the standard reservoir storage or mass balance equation has been used. This basic equation states that over a given period of time the inflow volume minus the outflow volume equals the change in storage volume in the reservoir. Two methods were used to evaluate the mass balance equation over a period of time for the Cedar City Valley groundwater aquifer. These methods are as follows:

1. Correlation of Coal Creek Inflow Minus Groundwater Pumping With Changes In Storage.

   The intent of this method is to show a correlation between the flows in Coal Creek and the change in groundwater storage in the aquifer. The annual measured flows in Coal Creek minus the annual groundwater withdrawals (pumping) were compared to annual changes in groundwater storage. Coal Creek is considered to be the main source of inflow or recharge to the groundwater aquifer since it is the only perennial stream entering the Valley. Long term Coal Creek inflows average 25,560 acre-ft/year. Since other stream tributaries enter the valley but are relatively minor, it is assumed that Coal Creek flows represent trends in the inflow to the aquifer but not actual total inflow. When Coal Creek flows are above average, the flows from the other tributaries and precipitation are assumed to be above average and vice versa. Groundwater withdrawal (pumping) is assumed to be representative of the trends in outflow from the aquifer. When groundwater withdrawals are above average, the total outflow from the aquifer is above average and vice versa. Groundwater withdrawals (pumping) does not represent actual outflow from the groundwater reservoir however, since much of the pumped water is re-circulated to the reservoir after use. It should be noted that groundwater withdrawal is low when Coal Creek flows are high and that groundwater withdrawal is high when Coal Creek flows are low.

   Coal Creek flows were obtained from USGS stream gaging information. Annual groundwater withdrawals were taken from the annual USGS Groundwater Reports. The annual USGS Groundwater Reports also contain mapped changes in groundwater levels as measured in observation wells throughout the Valley. As an example, Figure 4 is a map of Cedar City Valley showing the change in water levels from March of 1989 to March of 1990. These maps were generated from the data obtained from observation wells throughout the valley. The volumetric change in groundwater storage was determined by calculating the total volume change in the aquifer for the year as depicted by the contours shown on the maps. The volume change was calculated based upon the area and change in water level for each of the contours. This gross change in volume was then multiplied by the specific yield (0.1) to get total change in volume of stored water in the groundwater reservoir for the year indicated.

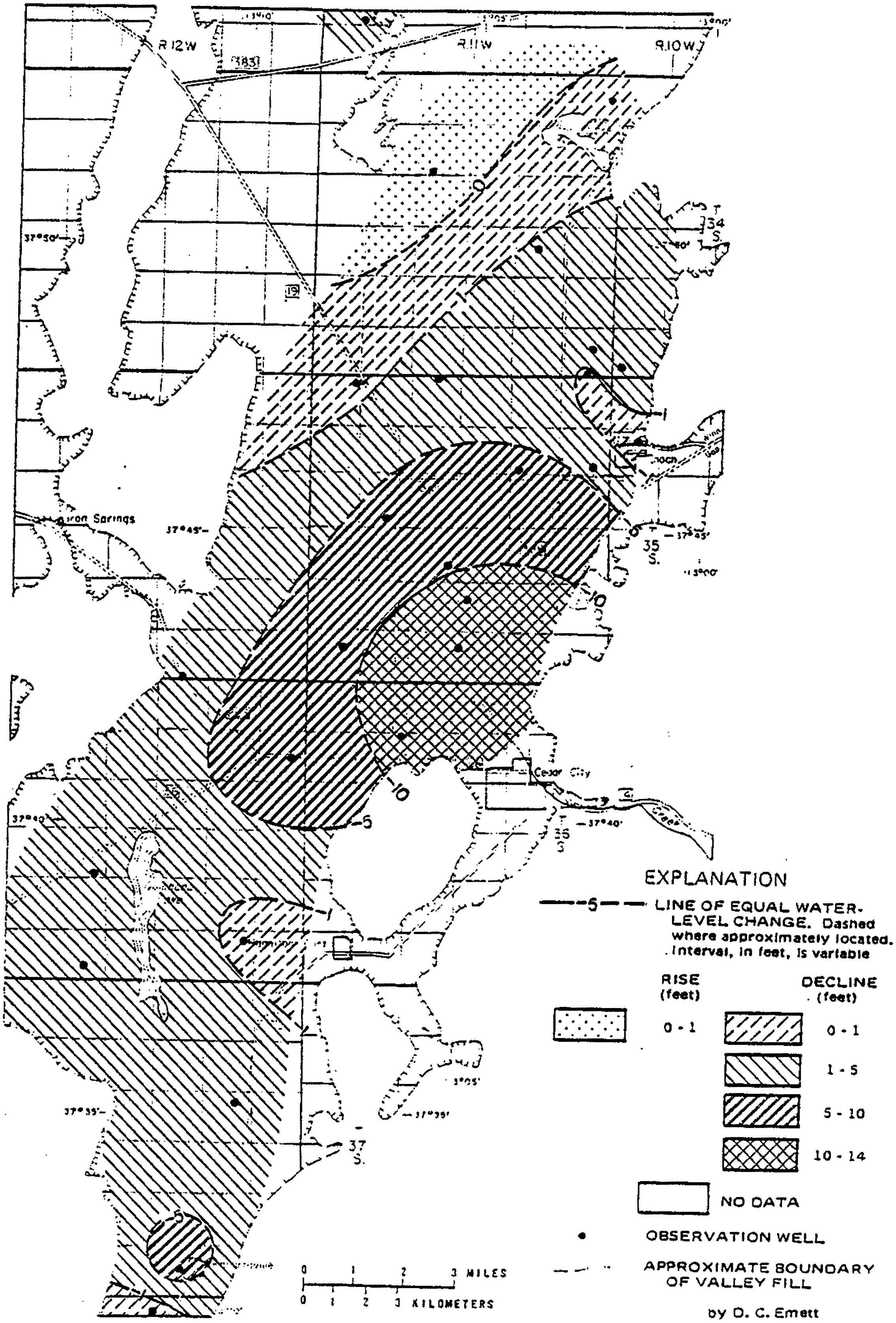


Figure 4 --Map of Cedar Valley, Iron County, showing change of water levels from March 1989 to March 1990.

The mass balance or storage equation was then applied for the period from 1965 through 1990 by using Coal Creek discharge (inflow), minus groundwater withdrawals (outflow), to reflect the change in storage as indicated by the maps of annual groundwater level change. Figure 5 is a graph showing the results of this correlation. The graph clearly indicates a fairly close correlation between Coal Creek inflow minus groundwater withdrawal to changes in groundwater storage. Or in other words, when the groundwater pumping exceeds the inflow from Coal Creek, water levels in the Valley decline and when the pumping is less than the Coal Creek inflow, water levels raise.

It should be noted that the effect of Coal Creek inflows on the groundwater storage is not experienced until some time after the flow is measured in the stream. There is also a 6 or 7 month lag time between the end of a water year and the month in which the observation wells are measured. Therefore the Coal Creek inflows used in the analysis for a given year are actually an average of the inflow for that year and the inflow from the previous year since the flow from the previous year is still influencing the groundwater storage. This produces a more accurate correlation between the groundwater storage and Coal Creek flows. During the 25 year time period reflected in Figure 5, the average annual Coal Creek inflow was 26,997 acre feet per year and the average groundwater withdrawal was 27,519 acre feet per year. With withdrawals slightly exceeding Coal Creek inflow during this time period, the data shown in Figure 5 substantiates that over all groundwater levels in Cedar City Valley are falling and groundwater "mining" is likely taking place. It should be noted that long term average Coal Creek inflows are only 25,560 acre feet per year, giving further credence to the fact that under present water use conditions in the Valley, groundwater mining is taking place.

2. Water Budget

The second method of evaluating the total water supply and use in Cedar City Valley was to develop a water budget for the Valley. Under the water budget approach, all possible data on water inflow or supply and water outflow or use in terms of consumption was collected and evaluated to determine if total use (consumption) was greater than the supply.

The water budget for Cedar City Valley was simplified by the fact that the groundwater basin is closed for practical purposes. As a closed basin, water lost in conveyance, irrigation and soil moisture holding capacity can be ignored because it returns to the basin and is not lost to the overall water system. The other parameters affecting the water budget were estimated from the available data as outlined below.

The water supply sources in Cedar City Valley include stream inflows, precipitation, and groundwater withdrawals. The stream inflow is primarily from Coal Creek. Actual data for other streams entering the Valley were not available. It was assumed that the flows in these streams will be high when Coal Creek flows are high and that they are low when Coal Creek flows are low. The fraction of the total inflow that is contributed by stream flows can only be estimated at best using conventional water

Cedar City Valley
Coal Cr. Flow vs. Change in GW Storage*

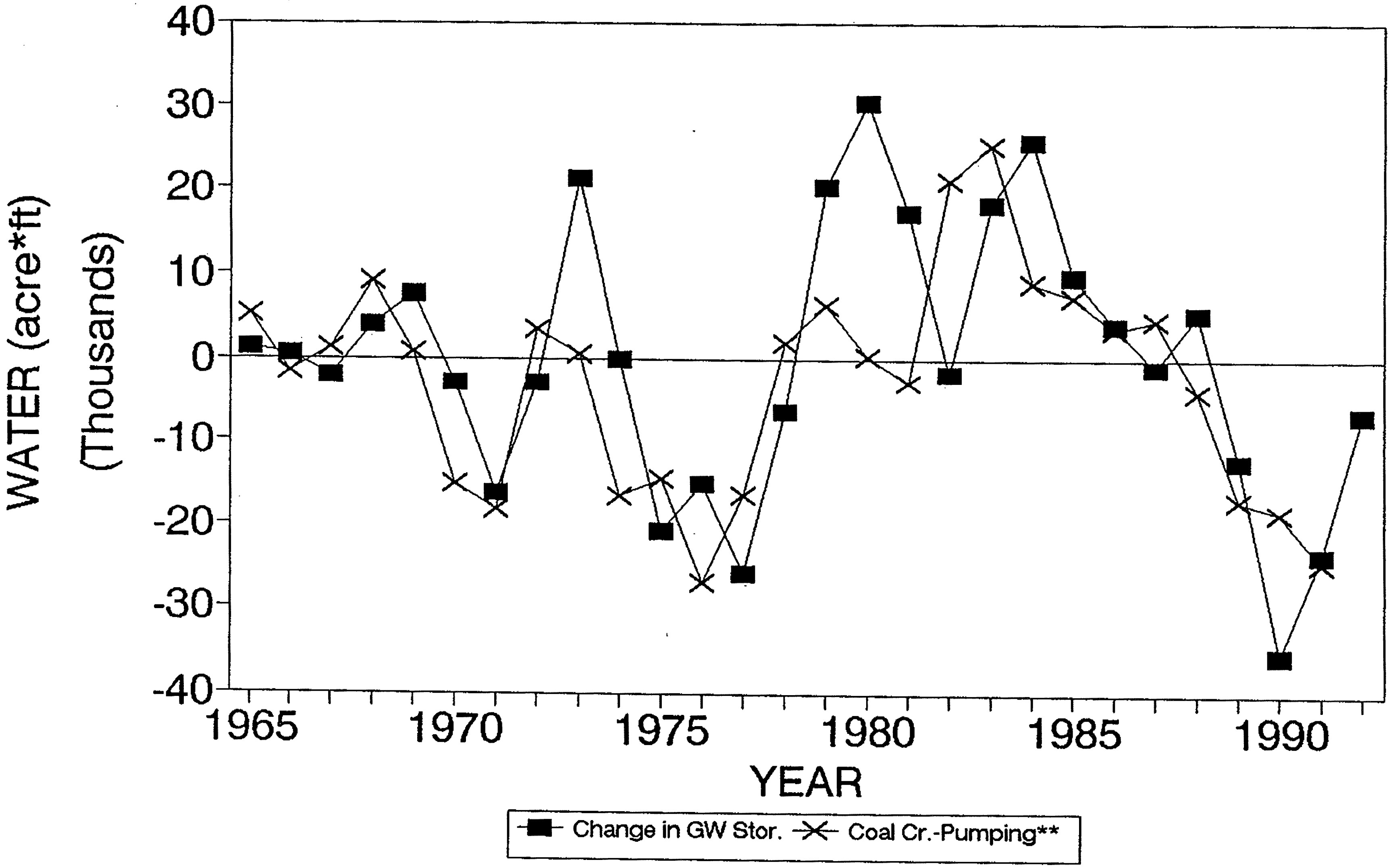


Figure 5

*Coal Creek flows are an average ot the current year and the previous year.

** Coal Creek inflow minus Groundwater pumping.

budget methods. The contribution of the tributaries other than Coal Creek was estimated to be about 21.2% of the Coal Creek flows. Using the observation well data to indicate changes in storage, these estimates can be adjusted and verified. With Coal Creek flows as an indicator of groundwater storage, assuming that other supplies and depletions remain constant, it can be shown that groundwater storage increases when the flows in Coal Creek are above average and that groundwater storage decreases when Coal Creek flows are below average. Precipitation in the Valley is measured at the Cedar City Airport. The fraction of the total inflow contributed by precipitation is based on precipitation efficiency. The efficiency has been estimated at 80 percent, that is 80 percent of the precipitation that falls on the land will be available for consumption or ground water storage. The other 20 percent is lost in evaporation or evapotranspiration.

Groundwater withdrawals are an outflow to the aquifer and application of the groundwater withdrawals for irrigation and other uses are an inflow to the aquifer. Accounting for them separately demonstrates the circulation of groundwater and the quantity which is utilized for consumptive use at the surface. Since the outflow is slightly larger than the inflow due to consumptive use of the water, the net result is an outflow to the water budget. The consumptive use of the groundwater withdrawals is the actual water budget outflow that is considered in the overall water budget.

The consumptive use of water includes irrigation, municipal, industrial, evaporation, and evapotranspiration (E_t). The majority of the water consumption is from irrigation. The municipal and industrial consumptive use was based upon 100 GPD per capita with 5 percent consumption and 95 percent recirculation, and an E_t calculation for lawns. The E_t for lawns was calculated estimating 50 percent of the residential areas as lawns and 30 percent of commercial land as lawns. Estimates were also based on 9 people per acre in residential areas and 20 people per acre in commercial areas. The datum for the population was based upon 1989 population estimates because that is when the land use data was collected. Increasing population creates greater demand on the water supply unless water is reallocated from agricultural to M&I usage, and will require the use of larger amounts of groundwater from storage to meet the demand. That is groundwater mining will need to increase to meet the demand.

The amount of water consumed by evapotranspiration on cropland has been historically calculated using the temperature based Blaney-Criddle equation. Recent research at Utah State University has improved the evapotranspiration calculation. This was accomplished by electronic weather stations located in Cedar City. These stations collect data that would allow for more complex methods of calculating E_t. This data was used to adjust the crop coefficients for various crops in Cedar City Valley for a specific time period. These calibrated crop coefficients were then used to calculate the consumptive use for the various types of agricultural crops.

The acreage of land used for different agricultural crops was determined from field mapping data collected by the Utah Division of Water Resources in 1989. The E_t, or total water consumption was then calculated using the calibrated crop coefficients.

Open water evaporation was calculated using pan evaporation coefficients. As more land is used for agriculture, the demand for irrigation water will increase and more groundwater storage will be needed to meet the demand.

As described in Chapter I, there are some small gaps in the Cedar City Valley groundwater basin that do allow for some groundwater flow out of the basin. These groundwater outflows were estimated from previous studies to be approximately 1500 acre-feet per year.

A water budget was used to determine the change in storage of the groundwater reservoir. The change in storage equals the inflows minus the consumption and groundwater outflow. Figure 6 shows pictorially the relationships between the supply, the various types of depletion, and the change in groundwater storage (supply). Figure 7 shows the water budget and compares the water budget to the change in groundwater storage determined from groundwater contours from observation well data.

Ten years of monthly data from 1980 to 1990 were used to adjust the contribution of tributaries to the basin. These adjustments to the water budget were required to insure it correctly represented the inflows and outflows affecting the groundwater storage.

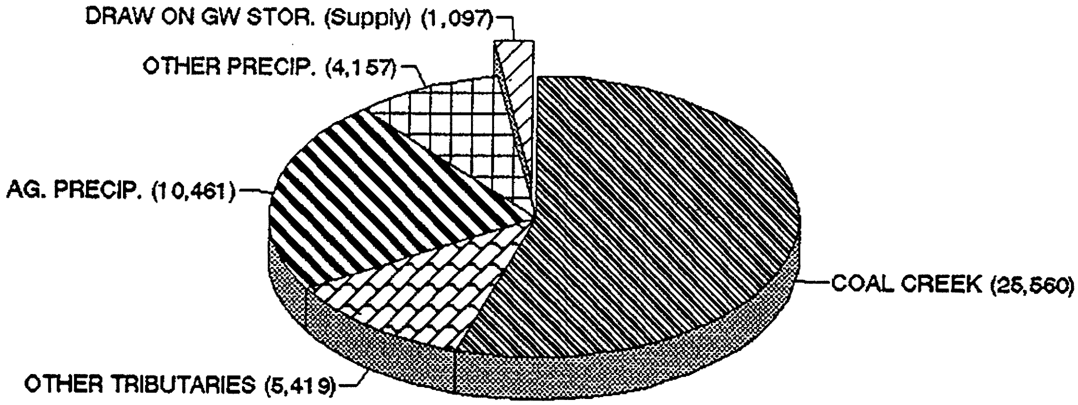
After adjusting the 10 year water budget model to the long term climatic conditions of Cedar City Valley, the groundwater basin has experienced an average of 1,088 acre-feet per year depletion due to "mining" for the long term climatic conditions represented by available records of streamflow, precipitation and land use.

Meeting Future Water Needs

The impact on groundwater supplies to meet anticipated population growth is a concern. Agricultural lands and water uses are gradually being changed to satisfy the growing M & I demand for water; however, based on a comparison of 1960 aerial photographs of Cedar City Valley with 1989 photos, the over-all use or consumption of water by agriculture since 1960 has not significantly changed. The trend in groundwater "mining" will likely continue in the future, especially without importation of water from another drainage basin or retirement of agricultural lands from production.

Groundwater "mining" may lead to a deterioration in water quality unless measures are taken to reduce use. Increased water demand due to the growing population could be somewhat alleviated by putting into practice conservation measures which would restrict areas devoted to outside irrigation; however, this would only be a delaying tactic to meet the water needs of the growing population. It appears that selective utilization and/or treatment of groundwater to serve the demand of the growing population may be necessary for future protection and use of the groundwater resource. This is further outlined in the following paragraphs.

CEDAR CITY VALLEY WATER BUDGET
Mean Ann. Supply 46,694 (ac-ft)



CEDAR CITY VALLEY WATER BUDGET
Mean Ann. Depletion 46,694 (ac-ft)

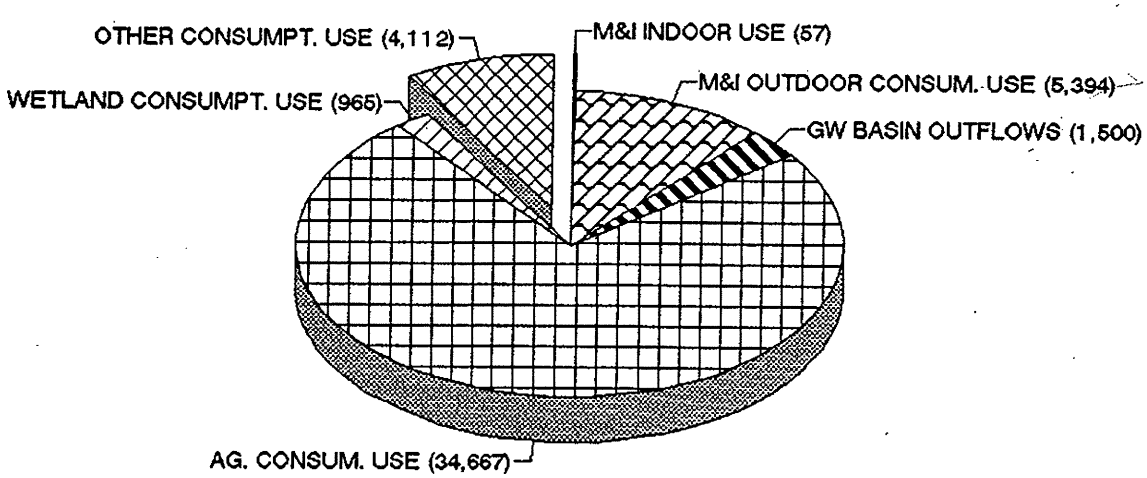


Figure 6

NOTE: OTHER PRECIP. AND OTHER CONSUMPTIVE USE REFERS TO IDLE, FALLOW, AND OPEN LAND THAT IS MAPPED BUT IS NOT AGRICULTURAL. OTHER PRECIP. ALSO INCLUDES PRECIP ON WETLANDS.

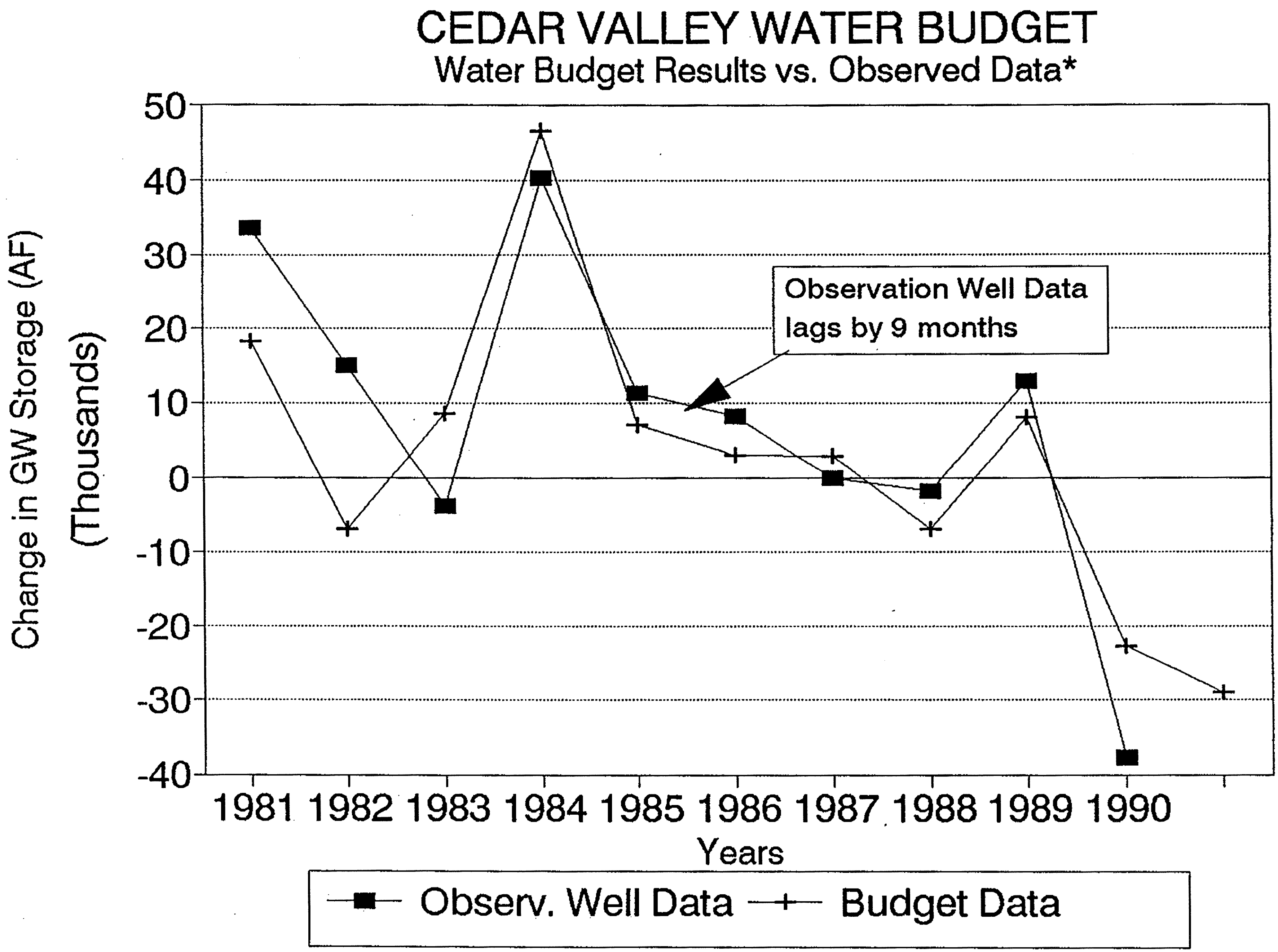


Figure 7

* Change in groundwater storage calculated from the Water Budget compared to the observed change in groundwater storage

Groundwater Quality

The groundwater quality in Cedar City Valley ranges from good to poor depending on the location of the groundwater source. The quality of the groundwater is best west of Quichapa Lake and in the area near Enoch. The water near Enoch is not quite as good as the water west of Quichapa Lake. Cedar City currently has domestic wells which tap these high quality groundwater sources.

The map on the following page is a reproduction of the U.S. Geological Survey Map showing specific conductance and the chemical quality of the ground water in Parowan and Cedar City Valley drainage basins. It appears that future development and withdrawal of groundwater for culinary purposes should generally take place in those areas where the specific conductance is less than 1000. This is generally shown in the area extending from north and west of Enoch and along the West side of Cedar City Valley to near Hamiltons Fort. There may be water sources in this area that will not require treatment or that can be mixed with better quality waters in lieu of treatment; however, this evaluation has considered treatment of groundwater as a likely requirement for its future use as a culinary water resource.

When utilizing this groundwater, some effort should be made to protect the better quality areas by minimizing migration of the poorer quality water in the better quality areas. One possible solution would be to pump water from strategic locations in the valley to draw down the water in a more uniform manner and minimize groundwater gradients toward the good quality areas. This will probably require pumping from areas of fair quality water which will sacrifice overall quality of the pumped water but will help maintain the water quality in the good areas for a longer period of time. Care should be taken to sample the water quality of a source before purchasing the water so that only the water meeting the minimum criteria established will be used.

Treatment Alternatives

After analyzing the results of the past samples from the many wells in the Cedar City Valley area, it can be seen that many of the wells would not be suitable for human consumption based on the following criteria:

1. Sulfates are greater than 500 mg/l.
2. Total Dissolved Solids(TDS) are greater than 1000 mg/l.
3. Nitrates are greater than 10 mg/l.

In addition, the water is very hard in many of the wells. It is recommended that the hardness of water be softened to less than 200 mg/l to prevent problems with scaling in pipes and fixtures in homes and businesses as well as an increase in the use of soaps and detergents. Sodium and chloride levels in a few of the wells are also higher than the recommended levels to prevent harm to soils or plant life.

With the imminent population growth in Cedar City Valley, the increased use of ground water may cause a deterioration in the water quality. Some of the wells now being used for agricultural purposes may have to be purchased for the residential and commercial uses. In anticipation of the possible utilization of the groundwater to handle the increased demand, treatment to bring the groundwater to acceptable levels of the constituents mentioned above have been studied. Methods to reduce hardness, sulfates and nitrates, and TDS, were examined on a conceptual basis and cost estimates were prepared for the likely scenario of softening the water.

Hardness

There are three methods by which hardness can be removed from water as follows:

1. Precipitative Softening
2. Ion Exchange
3. Reverse Osmosis

Precipitative Softening. By raising the pH of water through the addition of lime and sometimes soda ash, the calcium carbonate and magnesium hydroxide become insoluble and are settled out in sedimentation basins. Relatively speaking, it takes about one part of lime to reduce one part of carbonate hardness, and two parts of lime to reduce one part of non-carbonate hardness. The level to which the hardness is removed depends upon what the community can live with.

Ion Exchange. While this method can be used on a large scale, it generally is used on smaller systems or in individual homes and businesses to soften water. It is effective but has two major drawbacks. First it increases the TDS in the water because it exchanges sodium ions for calcium and magnesium ions and in addition dissolves chloride into the water. Sodium can be a health problem for people, but generally speaking, people consume far more sodium in their food than they ever could in the salt-softened water.

The second major drawback is that both the water and the brine from the systems winds up in the wastewater. Usually, this would not be a major problem, but with the Cedar Valley area being a closed basin, all water in the area eventually will wind up in the groundwater and possibly in an aquifer. Wastewater plants do a very good job in removing most organic materials, but conventional plants do not remove dissolved inorganic solids such as salt or hardness.

Reverse Osmosis. This method is generally used to desalt water on ships, coastal areas, or in manufacturing processes where a high quality water is necessary such as in circuit board manufacturing. RO is accomplished by forcing feedwater through semipermeable membranes. On a large scale basis, only a portion of the flow would be sent through the RO units in order to blend the water to an acceptable TDS or hardness level. RO will remove almost all of the TDS in the water which includes the hardness. The major drawbacks to this method are the energy cost and the percent reject. The water must be brought to a pressure of up to 400 psi in order to remove the dissolved solids. To remove these solids, At least 10 percent of the feed water input must be used to flush the membranes. What to do with this 10 percent is also a major problem. Either large evaporation ponds must be built, or

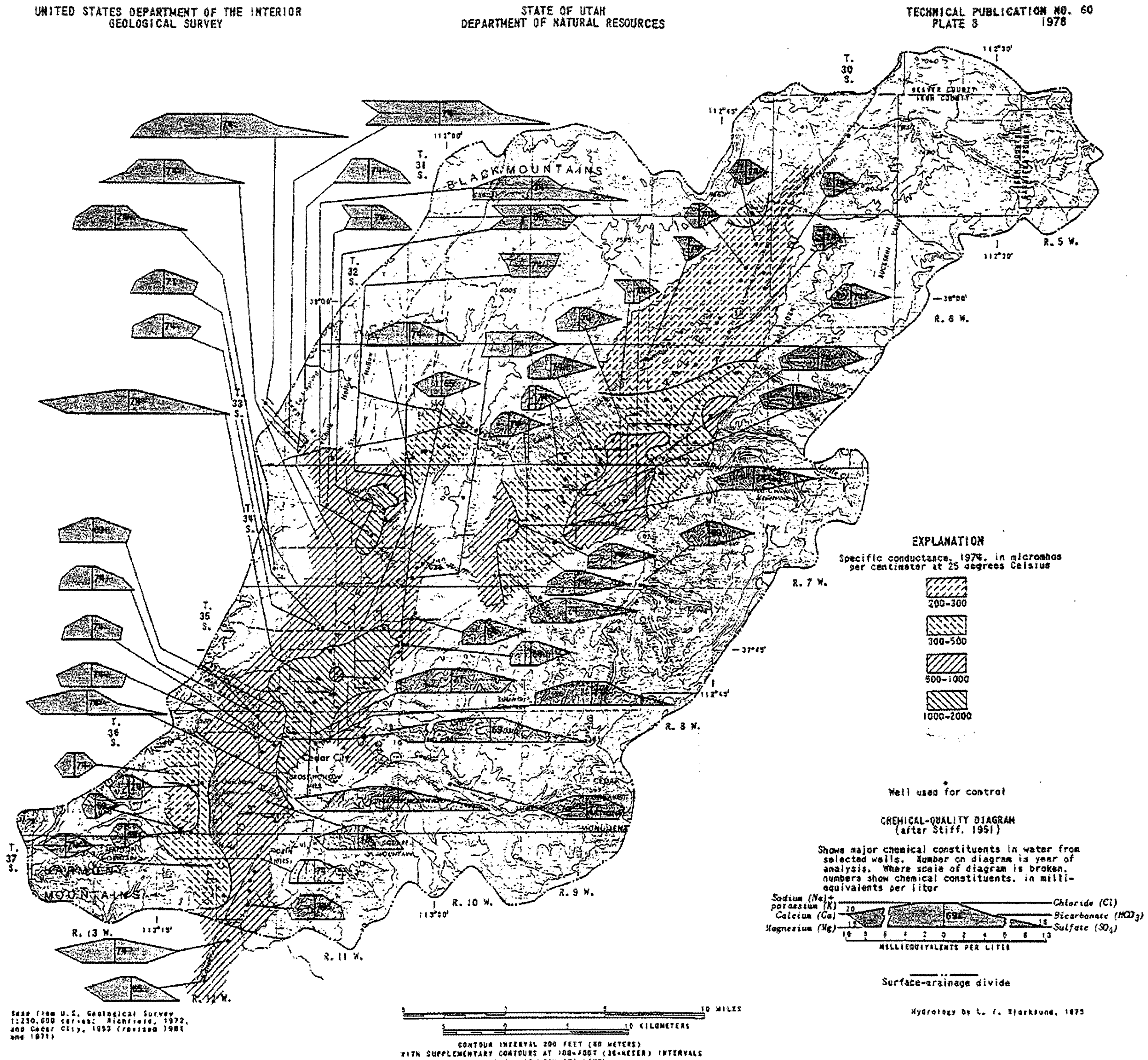


FIGURE 8

Map showing specific conductance and the chemical quality of the ground water in Parowan and Cedar City drainage basins. Iron County, Utah the water is sent to the wastewater plant which can also cause problems as described above.

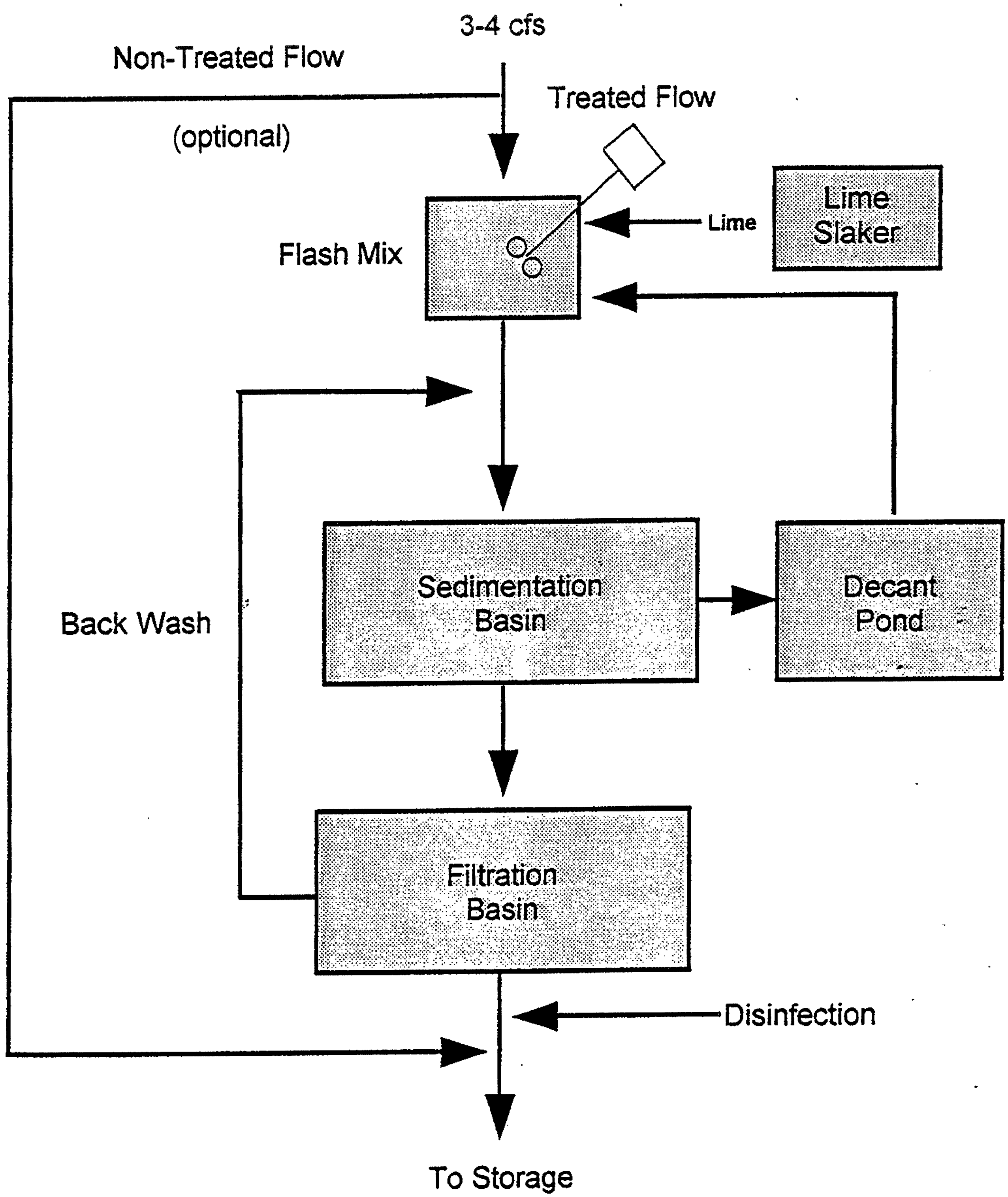
Of the three methods, the most practical is lime softening. Besides being the most economical, it is also the most environmentally safe method.

Treatment Process

Lime softening consists of either the use of hydrated lime or quicklime that has to be slaked. For the amounts of lime that would be needed for a plant large enough to treat 8 to 9 cfs, and in order to remove about 500 mg/l of hardness, a lime slaking facility would be more economical. Figure 9 shows a typical flow diagram for a lime softening plant. As can be seen, besides adding lime, sedimentation must be used to remove the lime sludge, and a filtration unit must be used to remove turbidity. Table III-1 shows a cost estimate of a typical softening plant of the size proposed. It must be remembered that this estimate is based on the concept only and there are many factors that could raise or lower the price depending upon the location, size, quality, the degree of treatment required.

Table III-1
COST ESTIMATE
LIME SOFTENING PLANT

ITEM	COST
1. Lime Slaker, feeder, silo	$300,000
2. Flash Mixer	40,000
3. Sedimentation Basin	300,000
4. Filtration Unit	800,000
5. Misc. Piping and Valves	350,000
6. Decant Pond	200,000
7. Site Work	200,000
8. Electrical and Control	300,000
9. Buildings	500,000
10. HVAC	100,000
11. Disinfection	60,000
12. Pumping Stations	350,000
TOTAL	$3,500,000



LIME SOFTENING TREATMENT PROCESS

FIGURE 9

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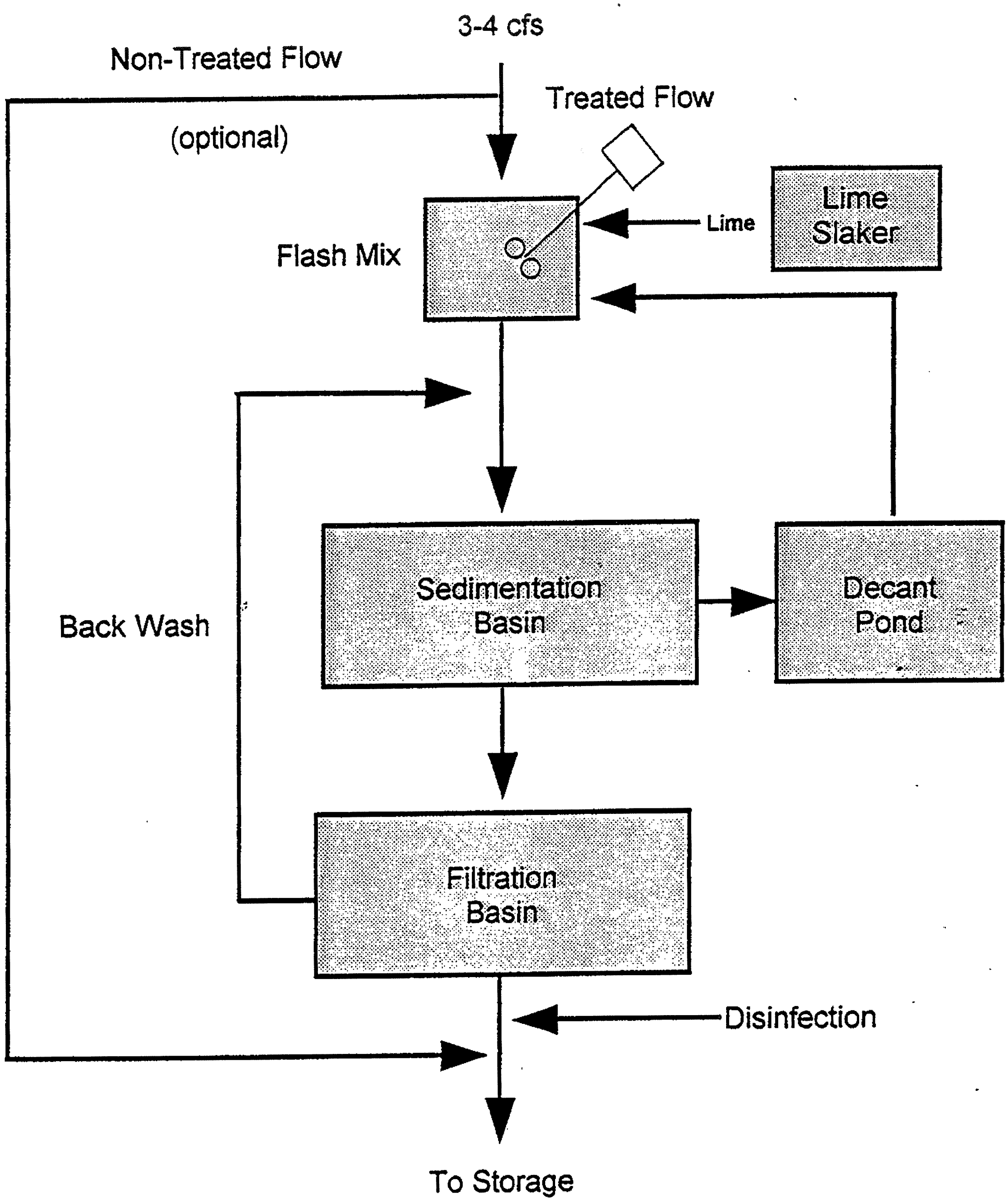
10. HVAC	100,000
11. Disinfection	60,000
12. Pumping Stations	350,000
TOTAL	$3,500,000



LIME SOFTENING TREATMENT PROCESS

FIGURE 9

Table III-2 shows the operational and maintenance costs including the finance charges based on a 20 year loan at 5%.

Table III-2
OPERATIONS AND MAINTENANCE COSTS
LIME SOFTENING PLANT/YEAR

ITEM	COST
1. Personnel	$225,000
2. Lime cost at $400/day	325,500
3. Power	135,000
4. Misc. Supplies	112,500
5. Repairs and Replacement	112,500
6. Mgmt. and Sampling	112,500
7. Finance Charge	452,250
TOTAL	$1,478,250

This O&M cost comes to about $0.70/1000 gallons based on the total above and a flow of 9 cfs.

Nitrate and Sulfates. The removal of nitrates and sulfates is most effectively done through the use of Ion Exchange. However, to remove nitrates and sulfates would require the use of special resin which can be fouled if the hardness is not removed before. As can be seen, nitrate and sulfate removal can be expensive. The best way to mitigate nitrates and sulfates is to blend the water with a higher quality water to lower the concentrations to an acceptable level. At this time it is not recommended that nitrates and sulfates be removed due to the high cost and the environmental problems that would result from the brine. It would appear that there are enough good water sources available to not have to treat for sulfates and nitrates at this time.

Total Dissolved Solids(TDS). Removing TDS is best done by the use of Reverse Osmosis which has been described before. Again, as with nitrates and sulfates, the best way to mitigate for TDS is to blend the water with better quality water.

Cost Estimate

The table on the following page has an itemized cost estimate for developing the groundwater as an alternative. This requires purchasing agricultural water rights and transferring them to municipal rights, and retiring the land from agricultural use. Items 8,9, and 10 of the estimate refer to this purchase of water rights. Items 8 and 9 are for the acquisition of rights to pump water from high quality and medium quality areas respectively. Item 10 is for acquisition of rights which will no longer be utilized so that groundwater mining will be reduced.

PRELIMINARY COST ESTIMATE

CEDAR CITY

ALTERNATIVE 0

GROUNDWATER DEVELOPMENT

GROUNDWATER RECHARGE

ITEM NO.	DESCRIPTION	UNIT	EST'D QUANTITY	UNIT PRICE	TOTAL COST
1	Mobilization	LS	JOB	LS	100,000
2	Pipeline Easement	LF	90000	0.75	67,500
3	10″ Pipeline	LF	90000	13.00	1,170,000
4	Valves	EA	18	700.00	12,600
5	Wells	EA	3	75000.00	225,000
6	Pumping Stations	EA	3	50000.00	150,000
7	Electrical	EA	3	20000.00	60,000
8	High Quality Water	AF	4000	1000	4,000,000
9	Medium Quality Water	AF	2500	500	1,250,000
10	Low Quality Water	AF	3500	500	1,750,000
11	Water Treatment Plant (Lime Softening)	LS	JOB	LS	3,500,000
		SUB TOTAL			$12,285,100
		ENGINEERING 10%			$1,228,510
		CONTINGENCY 15%			$1,842,765
		TOTAL			$15,356,375

CEDAR CITY WATER STUDY

COMPARISON OF ALTERNATIVES

ALTERNATIVE		COST COMPARISON: WITHOUT HYDROPOWER – PRESENT VALUE TOTAL COST ($)	WITHOUT HYDROPOWER – PRESENT VALUE COST PER ACRE FOOT ($/AF)	WITH HYDROPOWER – PRESENT VALUE TOTAL COST ($)	WITH HYDROPOWER – PRESENT VALUE COST PER ACRE FOOT ($/AF)	WATER SUPPLY: TRANS-BASIN AVG. ANNUAL SUPPLY (AF/YR)	WATER SUPPLY: TOTAL AVG. ANNUAL SUPPLY (AF/YR)	APPROVING AGENCIES – FEDERAL: EIS or EA Required	CORP OF ENGINEERS 404 PERMIT	FERC LICENSE W/HYDROPOWER ONLY	FOREST SERVICE SPECIAL USE PERMIT	BLM SPECIAL USE PERMIT	PARK SERVICE RESERVED WATER RIGHT ISSUE	USF&WS – ENDANGERED SPECIES ISSUES	STATE: WATER RIGHT ISSUES	STATE LANDS RIGHT OF WAY	UDOT / RIGHT OF WAY OR CROSSING REQUIRED	WILDLIFE RESOURCES ISSUES OTHER THAN USF&WS	OTHER: COUNTY PERMITS	PRIVATE LAND ACQUISITION
ALTERNATIVES WITH APPROXIMATELY 6500 AF TRANSBASIN DIVERSION																				
3b	Kolob Reservoir – Cedar City Diversion Crystal Creek Tunnel	45,634,076	7,021	43,921,076	6,757	6,500	6,500	X	X	X		X	H	H	L	X	X	L	X	X
3c	Kolob Reservoir – Cedar City Diversion Crystal Creek Canal	24,272,592	3,734	22,559,591	3,471	6,500	6,500	X	X	X		X	H	H	L	X	X	M	X	X
7	Quail Creek Reservoir Pumping	28,830,609	4,435	28,830,609	4,435	6,500	6,500	X				X			L	X	X	L	X	X
ALTERNATIVES WITH APPROXIMATELY 3000 TO 4000 AF TRANSBASIN DIVERSION																				
2a	Right Hand Canyon – Urie Creek Reservoir Crystal Creek Diversion by Canal	23,232,351	3,705	19,009,607	3,032	3,970	6,270	X	X	X		X	H	H	L	X	X	M	X	X
2b	Right Hand Canyon – Urie Creek Reservoir Crystal Creek Diversion by Canal & Pipeline	23,272,294	4,012	19,360,998	3,338	3,500	5,800	X	X	X		X	H	H	L	X	X	M	X	X
2c	Right Hand Canyon – Urie Creek Reservoir Crystal Creek Diversion by Pipeline	24,987,197	4,462	21,205,459	3,786	3,300	5,600	X	X	X		X	H	H	L	X	X	M	X	X
3a	Kolob Reservoir – Cedar City Diversion	18,433,518	6,145	19,047,049	6,349	3,000	3,000	X	X	X		X	H	H	L	X	X	L	X	X
4	Deep Creek – Mill Creek Tunnel	64,612,421	18,783	64,612,421	18,783	3,440	3,440	X	X		X	X	H	H	M		X	L		X
6a	Pine Valley – Pinto Creek Diversion New Castle Reservoir	15,868,111	4,371	15,868,111	4,371	3,630	3,630	X	X		X	X			H		X	L	X	X
6b	Pine Valley – Pinto Creek Diversion Pinto Creek Reservoir	18,154,079	5,001	18,154,079	5,001	3,630	3,630	X	X		X	X			H		X	L	X	X
8	Ash Creek Reservoir Pumping Groundwater Recharge	13,913,552	4,638	13,913,552	4,638	3,000	3,000	X							L		X	L		X
ALTERNATIVES WITH NO TRANSBASIN DIVERSION																				
0	Cedar City Valley Groundwater Development	22,262,163	3,425	22,262,163	3,425	0	6,500	X							L					X
1	Right Hand Canyon – Urie Creek Reservoir	13,659,060	5,939	12,523,661	5,445	0	2,300	X	X	X		X			L	X	X	M	X	X
SEVIER RIVER WATER TRANSBASIN DIVERSION																				
5	Upper Mammoth Creek – Castle Creek Reservoir Navajo Lake	26,448,431	7,779	24,078,171	7,082	3,400	3,400	X	X	X	X	X			H		X	M	X	X

LEGEND

- L Indicates Lower level of concern.
- M Indicates medium level of concern.
- H Indicates high level of concern.
- X Permit/etc. Required

Chapter IV - Yield Evaluation and Treatment of Potential Surface Water Supplies

Purpose

The quantity of water that might be developed from each potential surface water source must be determined in order to make a viable comparison between the various development alternatives. Since most of the potential sources have only limited measurement records, or none at all, it was necessary to estimate the amount of water that could be developed at each source by field observation and measurement, correlating and extending limited stream measurement records, or by using area/altitude methods and correlations to develop synthetic stream flow records. The methods used and the results of the water supply yield evaluation for the potential sources of water that might be developed is outlined in the following paragraphs.

It should be noted that two of the alternatives examined were deemed not to be feasible or in need of further investigation as noted below.

1. Upper Deep Creek Springs

   Meadow Spring, Williams Spring and Simpkins Spring were observed, measured and tested on July 15, 1992. Weir measurements of the flows were made using a 90 degree "V" Notch weir, the results are as follows:

   Meadow Spring - 0.30 ft = 0.1232 cfs = 55.33 gpm

   Williams Spring - 0.292 ft = 0.1147 cfs = 51.5 gpm

   Simpkins Spring - 0.16 ft = 0.0218 cfs = 9.8 gpm

   Measurements of turbidity (ntu) and total dissolved solids (TDS) based on specific conductivity were made on Simpkins Spring. These measurements are as follows:

   Turbidity - 0.51 ntu
   Total Dissolved solids based on Specific Conductivity - 180 ppm

   Based on the water quality of the springs, they would be an excellent source of drinking water. However, based on the above flow measurements and conflicting water rights, none of these sources of water were deemed to be feasible to develop. The flow from the springs was about 10% of that previously estimated.

2. Ash Creek Reservoir

   Ash Creek and Ash Creek Reservoir were examined on July 16 and again on August 12, 1992. On the first visit the reservoir was near full although the inflow to the reservoir was estimated to be less than 1 cfs on this wetter than normal year. On the second visit, the reservoir was estimated to be at less than half its capacity and the inflow was estimated to be less than 60 gpm. This inflow originated in springs a short distance upstream of the reservoir. There was no flow in Ash Creek above the springs. Historically Ash Creek reservoir fills once in about 4 or 5 years, and because of excessive seepage losses, it rapidly looses stored water. Some of this seepage water is believed to re-appear in Toquerville Springs and benefit downstream water users.

Stream flow measurements were made on Ash Creek from 1939 through 1947. The stream gage was located near the site of the existing Ash Creek Dam. Information recorded indicated the following annual discharge.

Year	Discharge Acre ft/yr
1939	1995
1940	2407
1941	16717
1942	7876
1943	5271
1944	9945
1945	7467
1946	1373
1947	10394
Avg.	7049

Within the scope of this study, it was not possible to determine if seepage losses from Ash Creek Reservoir could be sealed off through grouting of the damsite and/or lining of the reservoir, thereby permitting development of a reliable storage site. The inflow to the reservoir must also be gaged to determine its current adequacy and reliability. Development and depletions upstream may have severely reduced the inflow to the reservoir.

Assuming that a water supply could be developed at the site, an estimated cost of pumping the water from Ash Creek Reservoir and injecting it into the Cedar City Valley groundwater basin is provided in Chapter V of this report. This plan would need to be verified through updated streamflow measurements and further investigation.

Water Yield Evaluation

Of the potential water sources evaluated in this study, the following alternatives were deemed to have merit based on water quality and the measured or estimated supply that might be made available to meet future domestic needs by residents of Cedar City Valley.

1. Urie Creek Reservoir at head of Right Hand Canyon.

    Estimated mean annual yield - 2290 Acre feet
    (Based on area/altitude correlation with Summit Creek.)

Water quality based on sample taken in Right Hand Canyon near junction with Coal Creek.

Turbidity - 1.7 ntu

Total Dissolved Solids based on Specific Conductivity - 211 ppm

2a. Urie Creek Reservoir with Crystal Creek Diversion by Canal.

Estimated mean annual yield - 6270 Acre feet

(Based on area/altitude correlation with Summit Creek and extension of Crystal Creek stream gage measurements correlated with Virgin River at Springdale. Flow adjusted by percent of Crystal Creek drainage area not being captured for diversion.)

2b. Urie Creek Reservoir with Crystal Creek Diversion by Canal and Pipeline.

Estimated mean annual yield - 5720 Acre feet

(Basis of estimate is the same as for alternative 2a.)

2c. Urie Creek Reservoir with Crystal Creek Diversion by Pipeline.

Estimated mean annual yield - 5600 Acre feet

(Basis of estimate is the same as for alternative 2a.)

3a. Kolob Reservoir - Cedar City Diversion.

Estimated mean annual yield - 3000 Acre feet

(Based on yield developed by "Division of Water Resources, 1988 study")

3b. Kolob Reservoir - Cedar City Diversion - Crystal Creek Tunnel.

Estimated mean annual yield - 6500 Acre feet

(Basis of estimate is the same as for alternative 3a.)

3c. Kolob Reservoir - Cedar City Diversion - Crystal Creek Canal.

Estimated mean annual yield - 6500 Acre feet

(Basis of estimate is the same as for alternative 3a.)

4. Deep Creek Tunnel.

Estimated mean annual yield - 3440 Acre feet
(Based on Division of Water Resources correlation of Deep Creek to Virgin River U.S.G.S mean monthly flows. A bypass flow of 2 cfs and maximum flow of 30 cfs was used.)
Water Quality based on sample taken from East Fork of Deep Creek just below Shoppman hollow.

Turbidity - 0.86 ntu
Total Dissolved solids based on Specific Conductivity - 215ppm

5. Castle Creek/Upper Mammoth Creek via Navajo Lake.

Estimated mean annual yield - 3400 Acre feet
(Based on area altitude correlation of Summit Creek near Summit, Utah U.S.G.S mean monthly flows. Used spring runoff flows only.)

6a. Pine Valley - Pinto Creek Diversion - Newcastle Reservoir.

Estimated mean annual yield - 3630 Acre feet
(Based on correlation of Left Fork of Santa Clara and Water Canyon to Santa Clara River near Pine Valley, Utah U.S.G.S mean monthly flows. A bypass flow of 1 cfs and maximum flow of 30 cfs was used.)

6b. Pine Valley - Pinto Creek Diversion - Pinto Creek Reservoir.

Estimated mean annual yield - 3630 Acre feet
(Basis of estimate is the same as for alternative 6a.)
Water Quality based on sample taken from Little Pinto Creek just above Newcastle Reservoir.

Turbidity - 1.0 ntu
Total Dissolved solids based on Specific Conductivity - 228 ppm

7. Quail Creek Pumping.

Estimated mean annual yield - 6500 Acre feet
(Based on existing storage in Quail Creek Reservoir.)
Water Quality has presented some problems with plugging of filters for St. George Treatment Plant although the water is satisfactory for drinking water purposes.

8. Pumping from Ash Creek Reservoir.

No estimate of mean annual yield has been made. It is assumed that 3000 acre feet per year could be made available for pumping to Cedar City Valley if the reservoir were lined to prevent seepage losses.

Water Quality based on sample taken from Ash Creek just upstream of Ash Creek Reservoir.

Turbidity - 2.5 ntu

Total Dissolved solids based on Specific Conductivity - 200 ppm

Water Treatment Requirements and Cost

Current drinking water standards require that all surface waters, i.e., reservoirs, rivers, and surface springs, must have filtration along with disinfection. There are many ways to achieve filtration, but all of the different types are either conventional filtration or direct filtration. Water treatment filters can either be a standard design or they can be of a proprietary design.

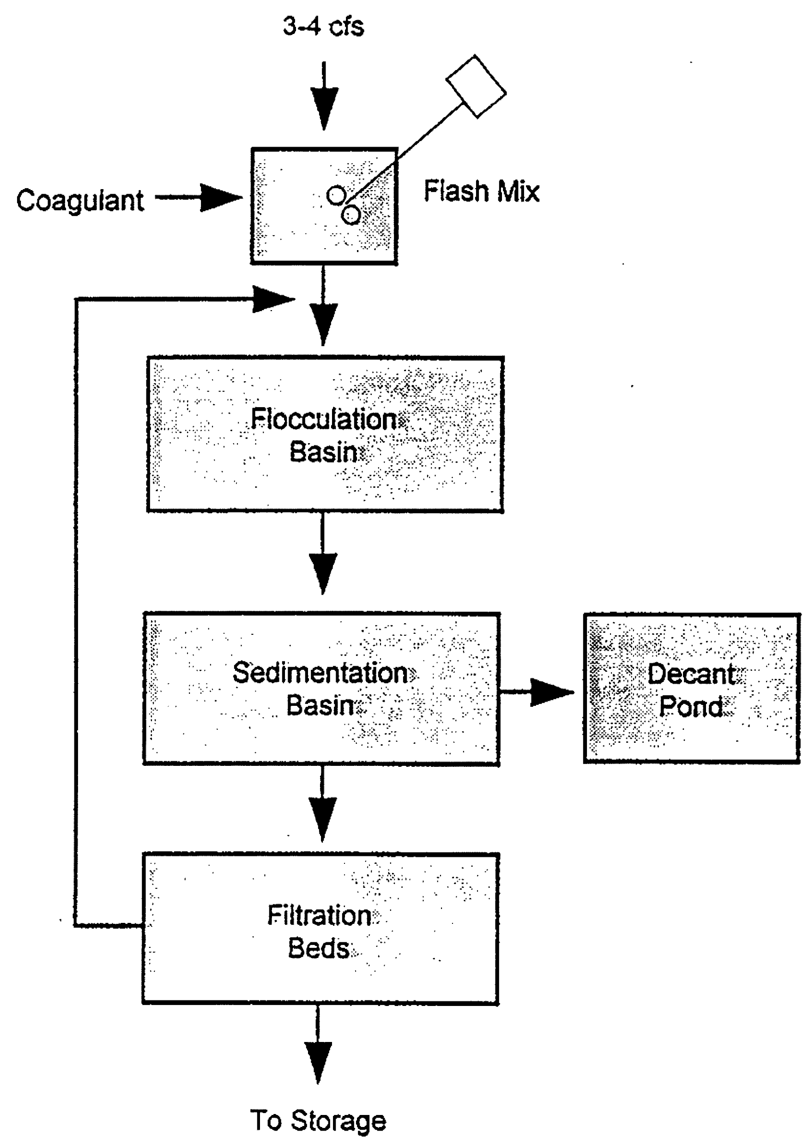
Figure 10 shows the flow diagrams of both a conventional filtration plant and a direct filtration plant. The State Department of Environmental Quality will not approve a direct filtration design if the surface water to be treated is susceptible to high turbidity such as during spring runoff. If the water has a relatively low turbidity, then direct filtration can be accepted but only with a pilot study being done before to see if treatment is possible.

Tables IV-1 and IV-2 show construction cost estimates for both conventional and direct filtration treatment plants. These estimates are based on a flow of 10 cfs and are conceptual. The costs can vary with many factors such as location, type of filter selected, and degree of treatment needed. In the water development alternatives outlined in the next Chapter, the treatment costs have been adjusted to reflect the amount of water to be treated.

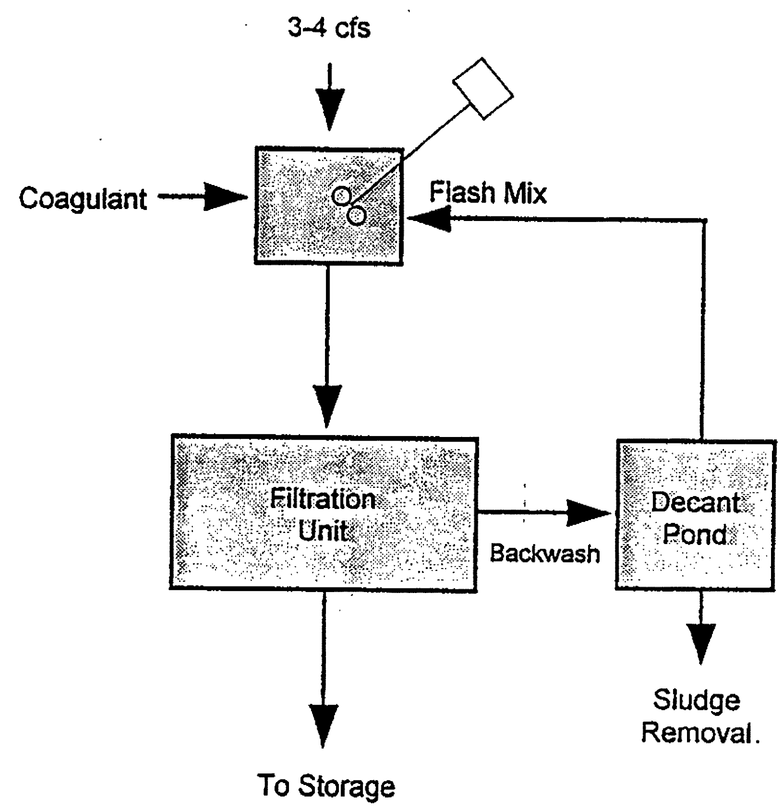
Table IV-1

COST ESTIMATE FOR CONVENTIONAL FILTRATION PLANT

ITEM	COST
1. Flocculation and Flash Mix	350,000
2. Sedimentation Basin	350,000
3. Filtration Units	700,000
4. Misc. Piping and Valves	400,000
5. Decant Ponds	200,000
6. Site Work	200,000
7. Electrical and Control	400,000
8. Buildings	600,000
9. HVAC	150,000
10. Disinfection	75,000
11. Pumping Stations	300,000
TOTAL	$3,725,000



CONVENTION FILTRATION TREATMENT PLANT



DIRECT FILTRATION TREATMENT PROCESS

FIGURE 10

Table IV-2

COST ESTIMATE FOR DIRECT FILTRATION PLANT

ITEM	COST
1. Flash Mix	40,000
2. Filtration Units	850,000
3. Misc. Piping and Valves	350,000
4. Decant Ponds	300,000
5. Site Work	150,000
6. Electrical and Control	250,000
7. Buildings	350,000
8. HVAC	150,000
9. Disinfection	75,000
10. Pumping Stations	300,000
TOTAL	$2,815,000

One type of direct filtration utilized for smaller plants is a slow sand filter. This type of plant requires very little service. It also requires that the water going into it is of a fairly good quality and is not susceptible to periods of high turbidity.

Operation and maintenance costs will vary depending on the quality of water to be treated. The O&M costs for this study were obtained from a "1991 Summary of Operations" for a conventional treatment plant located in the Salt Lake Valley. This "1991 Summary of Operations" is located in the Appendix. The following table lists the treatment plant operating costs for 1990 and 1991 with an average flow of 17 cfs.

Table IV-3

OPERATION AND MAINTENANCE COSTS FOR TREATMENT

Treatment Plant Costs	1990	1991
Personnel	116,961	157,354
Chemicals	28,748	63,696
Utilities	19,951	21,933
Other	54,636	44,535
Total Treatment Expenses	$220,296	$287,518
Cost per Acre-Foot	$28.16	$27.77

These numbers convert to approximately 9 or 10 cents per 1000 gallons for treatment.

Chapter V - Plan Formulation and Cost for Surface Water Development Alternatives

Purpose

This Chapter describes the various surface water development alternatives that have been considered and included as a part of this study. Each project is described along with variations that were evaluated. The quantity of each water source is considered together with the cost of developing the supply and delivering it into Cedar City Valley for use. The estimated annual cost of the water in terms of dollars per acre foot is presented in Chapter VI which includes an overall cost comparison for each alternative.

The advantages and disadvantages of each alternative is discussed. Consideration is also given to water rights that may conflict with development of the various water sources along with environmental issues that may impact the development and use of the source in the Cedar Valley area.

Water Development Alternatives

1. Urie Creek Reservoir at head of Right Hand Canyon.

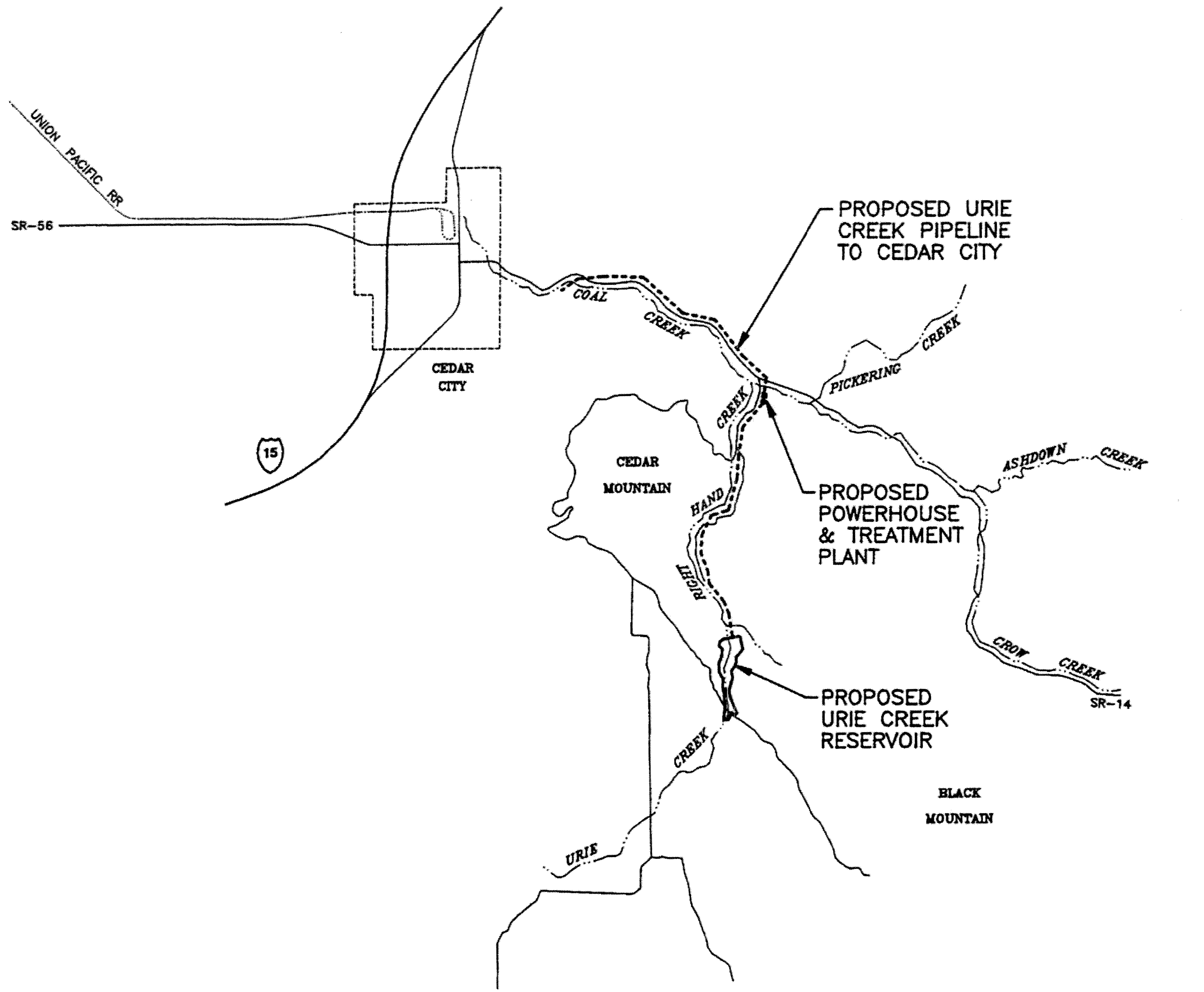
Project Description

Figure 11 is a map showing the proposed Urie Creek Reservoir development. Figure 12 is a topographic map of the reservoir site taken from USGS quadrangle maps. The Project would consist of a dam and reservoir on Urie Creek, a small perennial stream near the head of Right Hand Canyon which flows into Coal Creek. With development of the hydroelectric power potential, a penstock would be constructed from the reservoir to a proposed hydroelectric power plant located in Right Hand Canyon, just above Coal Creek. Water from the hydroelectric power plant would then be introduced into a water treatment plant, either conventional filtration or slow sand filter, and then conveyed in a gravity pipeline to existing storage tanks in Cedar City.

The proposed Urie Creek Reservoir has been studied previously by both the Division of Water Resources in 1986 and presumably by the Soil Conservation Service in the early 1950's, although no documentation of the latter studies has been found. This potential reservoir site was designated as the Lower Urie Creek Reservoir in the previously referenced study of 1986 by the Division of Water Resources.

Water Supply Yield and Development

The average annual yield was estimated to be about 2300 acre ft per year with an active reservoir storage capacity of about 5000 acre ft. Figures 13 and 14 show an Area-Capacity curve and Storage-Yield curve respectively for the site. This yield would require a dam approximately 170 ft high. The yield could likely be increased



APPROX. SCALE:
1" = 8,000 FEET

FIGURE 11 V-2

ALTERNATIVE 1A

CEDAR CITY

WATER SUPPLY EVALUATION

URIE CREEK–
CEDAR CITY OPTION

BINGHAM ENGINEERING
SALT LAKE CITY – (801) 532-2520

Design:
Drawn: STA
Checked:
Reviewed:

Date OCT. 1992 | Proj. # 1666-010 | Sht of

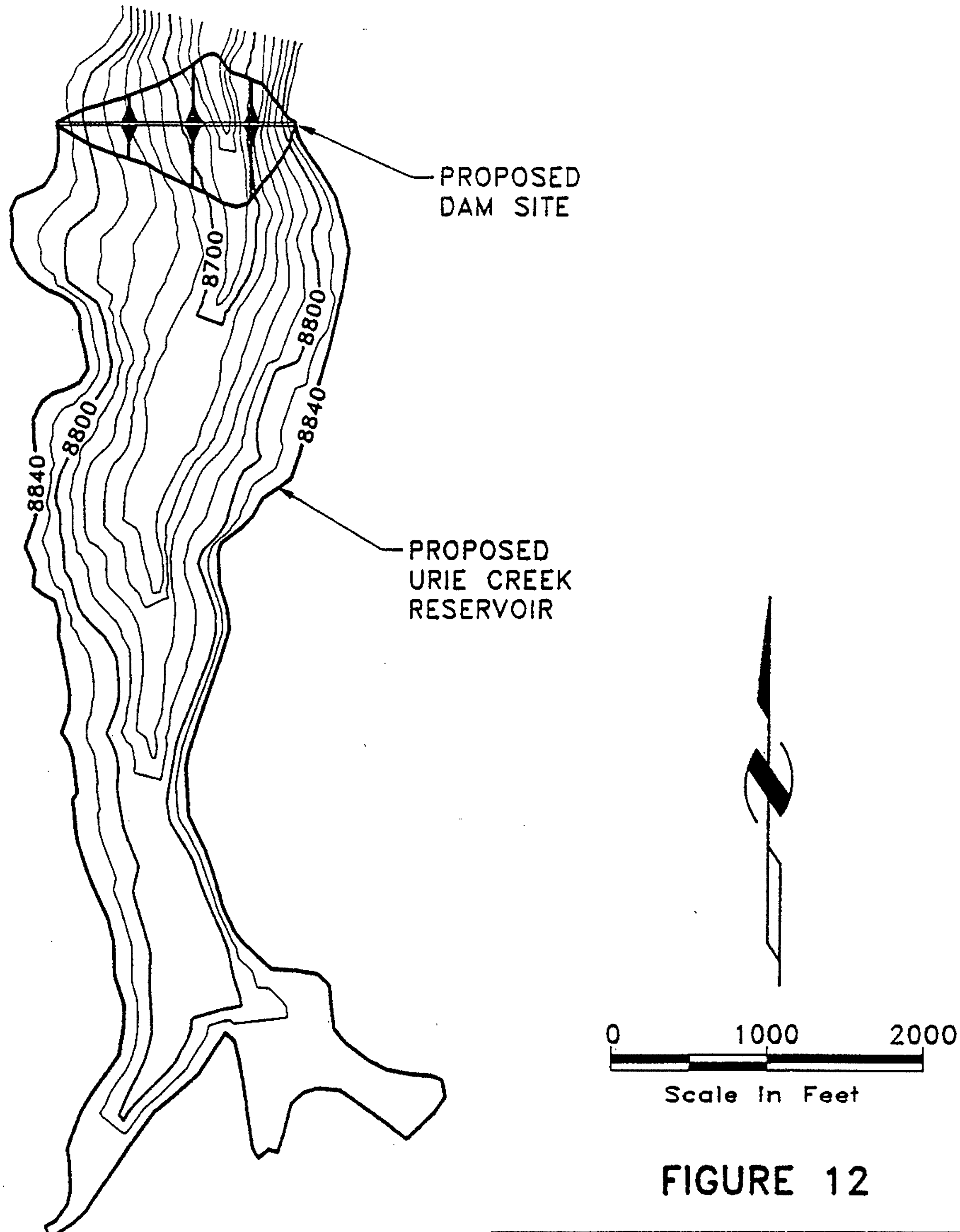


FIGURE 12

CEDAR CITY

WATER SUPPLY EVALUATION

URIE CREEK RESERVOIR

BINGHAM ENGINEERING
SALT LAKE CITY - (801) 532-2520

Design:
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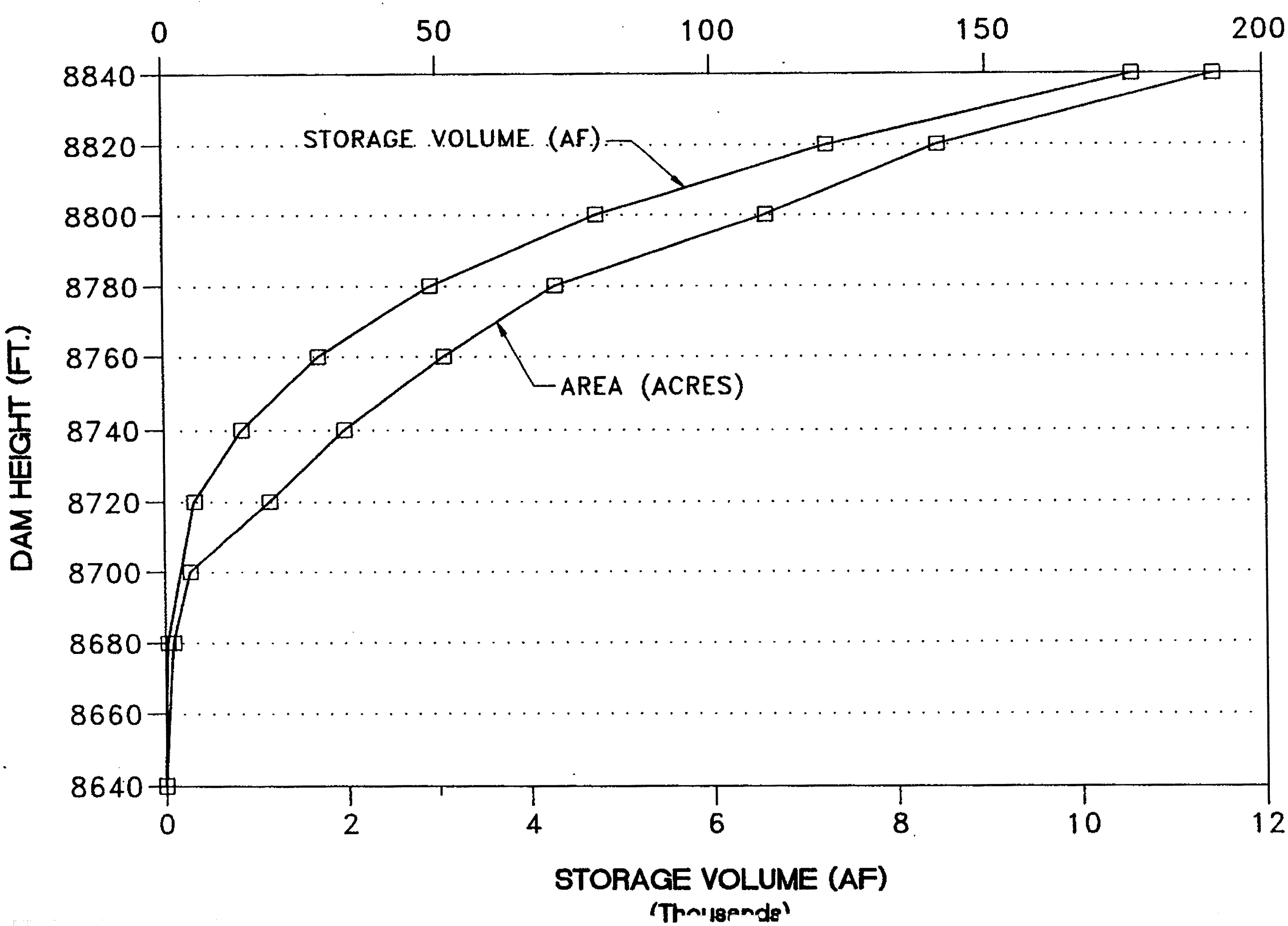
Urie Reservoir

FIGURE 13



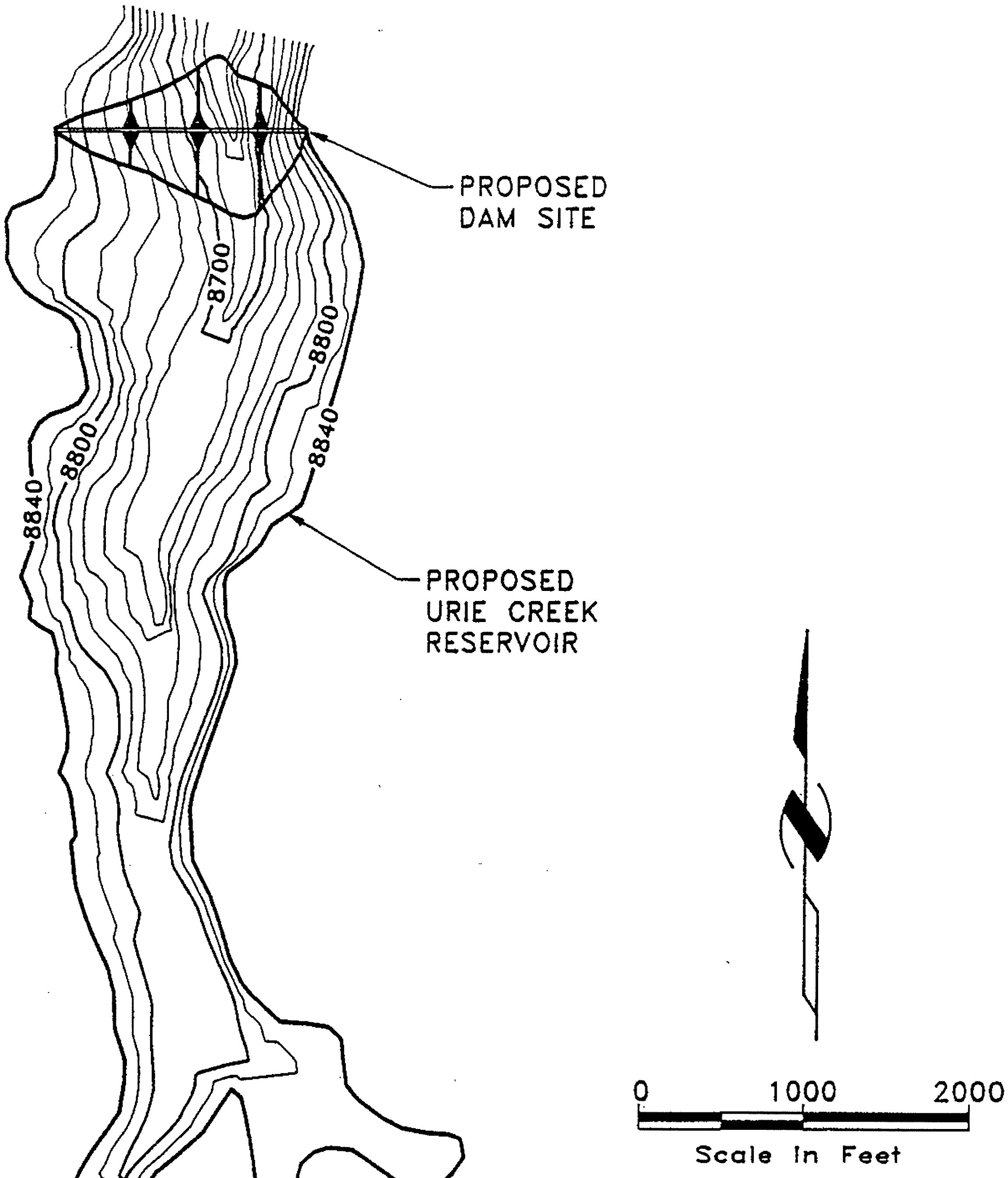


FIGURE 12

CEDAR CITY

WATER SUPPLY EVALUATION

URIE CREEK
RESERVOIR

BINGHAM ENGINEERING
SALT LAKE CITY - (801) 532-2520

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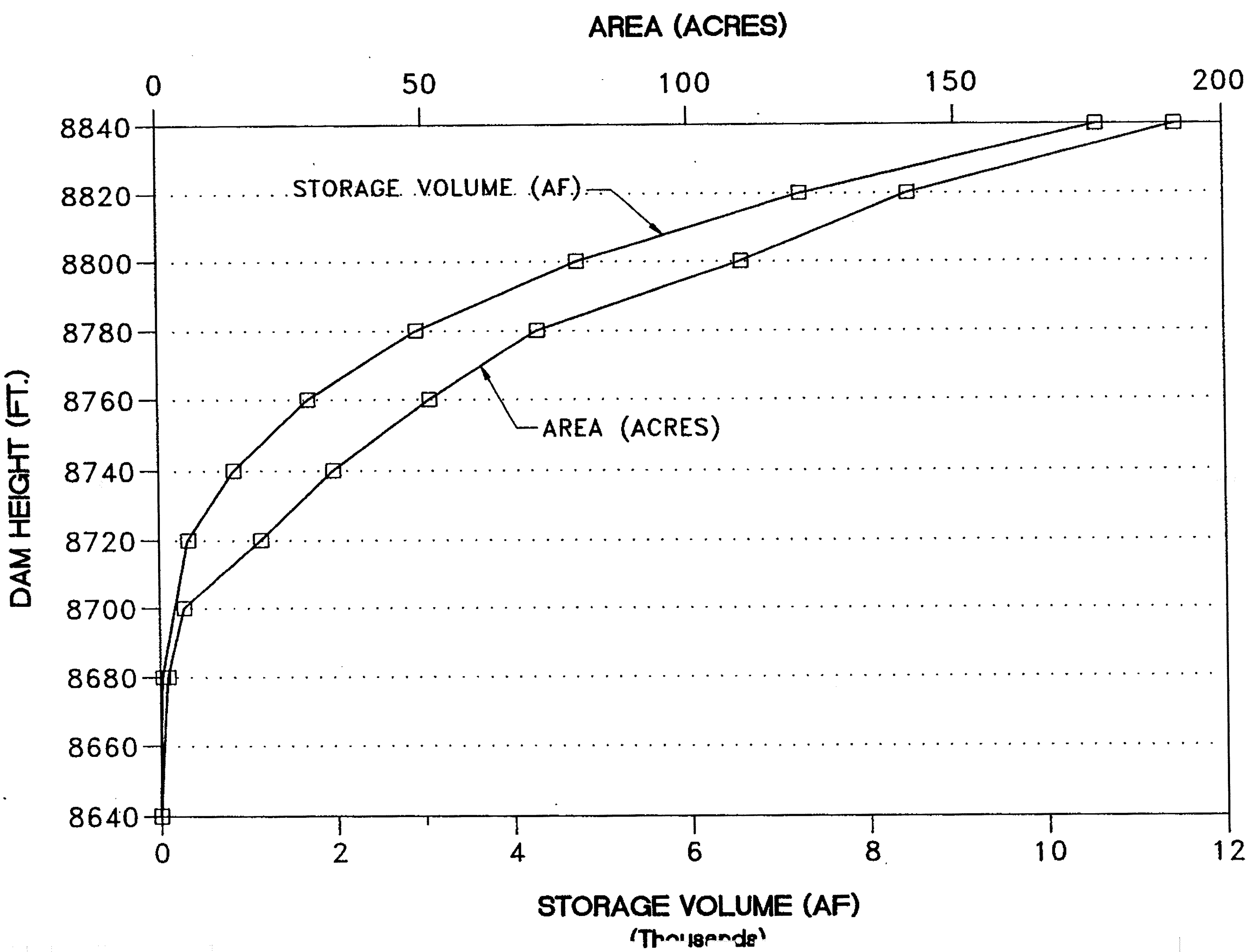
Reviewed: ______

Date	Proj. #	Sht	of
OCT. 1992	1666-010		

Urie Reservoir

FIGURE 13



to some extent by diverting some adjoining Urie Creek watershed areas into the reservoir drainage basin.

These adjoining watersheds now drain into Urie Creek just below the proposed dam site. It would likely be in the best interest of the community to provide some inactive storage in the reservoir for fishery and recreational purposes.

Environmental Considerations

The Urie Creek Drainage system is all on privately owned summer livestock range that is primarily devoted to sheep grazing. The vegetation consists of open grass/forb associations along with scattered aspen groves. The rangeland is maintained in its present condition under moderate to heavy seasonal grazing pressure. The largest plants along the stream course in the reservoir basin are willows. Approximately 1/2 mile of mountain roadway would have to be relocated.

There are no threatened or endangered plant or animal species known to occur in the area that would be impacted, nor would any be expected in such a highly utilized area. Since the water is already owned and utilized by users in Cedar City Valley, it would appear that a negative impact on lower Right Hand Canyon, Coal Creek, and Cedar City Valley would be minimal.

Advantages and Disadvantages

The proposed reservoir site is one of the few in the Coal Creek drainage basin which is not subjected to the high sediment loads of Coal Creek. It would probably control less than 15% of the Coal Creek flows but offers opportunity for development of a relatively high quality water source for domestic uses. Another advantage is that the reservoir may also provide some fishery, recreation and flood control benefits in both Right Hand Canyon and Coal Creek Canyons.

Cedar City Corporation currently owns 160 of 780 shares of stock in the South and West Fields Irrigation Company. Southern Utah University is also a significant stockholder and together with the City, controls more than 50% of the total shares of stock in the Irrigation Company which have a current value of $350.00 per share. Recent annual delivery of irrigation water under this stock has been 4.2 acre feet per share for a total of 3276 acre feet. Historically this water was used in Cedar City to irrigate large residential lots with garden areas, fields and pastures. In recent years, the land use has changed to reflect higher density residential areas, expansion of the University and commercial development. This has resulted in a decreasing demand for outside irrigation water.

Without considering other water rights the City may own in Coal Creek, it appears that with a joint effort between the City, the University and other share holders, the South and West Field Irrigation Company Rights could likely be transferred to the Urie Ceek Reservoir site for development of the proposed project. An immediate monitary benefit to the City would be a reduction in street and curb and gutter maintenance estimated to be $40,000 per year to handle the damage caused by irrigation water running in the street drainage system.

There are some minor water rights in the Urie Creek drainage that may be impacted; however, these are mostly stockwater rights that in large measure would still be served. The total flow rights for stockwater use is less than 1 cfs.

The main disadvantage of the Urie Creek development is that it will remove some high quality irrigation water from Coal Creek and it will not alleviate continued groundwater mining or possible deterioration of the groundwater quality by upstream removal of higher quality water supply.

Cost Estimate

The Estimated cost of developing the Urie Creek Reservoir project is shown on the following pages. The estimates include the project both with and without hydroelectric power generation.

PRELIMINARY COST ESTIMATE

CEDAR CITY

ALTERNATIVE 1

RIGHT HAND CANYON – URIE CREEK RESERVOIR

"WITHOUT HYDRO"

ITEM NO.	DESCRIPTION	UNIT	EST'D QUANTITY	UNIT PRICE	TOTAL COST
1	Mobilization	LS	JOB	LS	235,000
2	Pipeline Easement	LF	40200	0.75	30,150
3	Clearing, Stripping & Grubbing	AC	46	900.00	41,400
4	Reseeding	AC	46	100.00	4,600
5	Roadway Improvement & Relocation	LF	3000	20.00	60,000
6a	10" Pipeline	LF	21200	12.00	254,400
6b	12" Pipeline (Lower)	LF	19000	15.00	285,000
7	Valves	EA	8	1400.00	11,200
8	Water Treatment Plant	LS	JOB	LS	2,800,000
9	Water Right Share @ 4.2 AF/Share	AF	2300	83.33	191,659
	RESERVOIR				
10	Land	AC	142	1000.00	142,000
11	Clearing and Grubbing	AC	142	900.00	127,800
12	Dam Embankment	CY	1200000	4	4,800,000
13	Spillway	LS	JOB	LS	250,000
14	Outlet Works	LS	JOB	LS	250,000
		SUB TOTAL			$9,483,209
		ENGINEERING 10%			$948,321
		CONTINGENCY 15%			$1,422,481
		TOTAL			$11,854,011

2a. Urie Creek Reservoir with Crystal Creek Diversion by Canal.

Project Description

The proposed Urie Creek Reservoir Basin has a low saddle in the ridge where the road passes through the Coal Creek drainage divide into the upper Virgin River basin. As a part of this investigation, an examination was made of capturing and diverting Upper Virgin River water sources through the saddle and into the proposed Urie Creek Reservoir. It was determined that an interceptor canal and/or pipeline could be constructed southerly from the saddle, through a portion of the upper drainage of O'Neal Creek, and into the upper Crystal Creek drainage area. This interceptor canal/pipeline would have the potential of capturing most of the Crystal Creek flows that could be diverted to the Kolob Reservoir through the proposed Crystal Creek Tunnel for conveyance to Cedar City. The Proposed Crystal Creek/Urie Creek interceptor canal is shown in Figure 15.

In order to intercept, convey and store the waters of Crystal Creek in the proposed Urie Creek Reservoir, it would have to be enlarged to a capacity of about 9000 acre feet as shown in Figure 16 and the interceptor canal from the Crystal Creek drainage to the Urie Creek drainage would need to have a capacity of at least 50 cfs. This canal could intercept most of the spring snowmelt runoff and convey it to the reservoir for storage. It is anticipated that normal summertime flows of water in the Crystal Creek drainage would not be captured in the canal and that they would continue to serve the stockwatering rights and needs in the drainage basin.

Water Supply Yield and Development

The estimated mean annual yield of the enlarged Urie Creek reservoir with the Crystal Creek interceptor canal and diversion is 6270 acre feet. Urie Creek would supply 2300 acre feet of this yield and Crystal Creek plus the adjoining Virgin River drainage would supply an estimated 3970 acre feet per year. The yield estimate for Crystal Creek was made through correlation and extension of measured stream discharges on Crystal Creek taken near the entrance to the proposed Crystal Creek - Kolob Tunnel.

A review of the State Engineers water rights records in the Upper Crystal Creek Drainage revealed there are a number of summer stock water rights in the area, however, the total of these rights were less than 1 cfs. These rights would be preserved since the proposed diversion would only take spring runoff and high flows.

Environmental Considerations

The same general conditions for this expanded Urie Creek alternative exist as described under Alternative 1. The land is privately owned, open summer sheep range. There may be; however, some environmental concerns relating to the diversion into Cedar City Valley of water that would normally flow through Zion National Park. The proposed water capture canal is only a short distance above the

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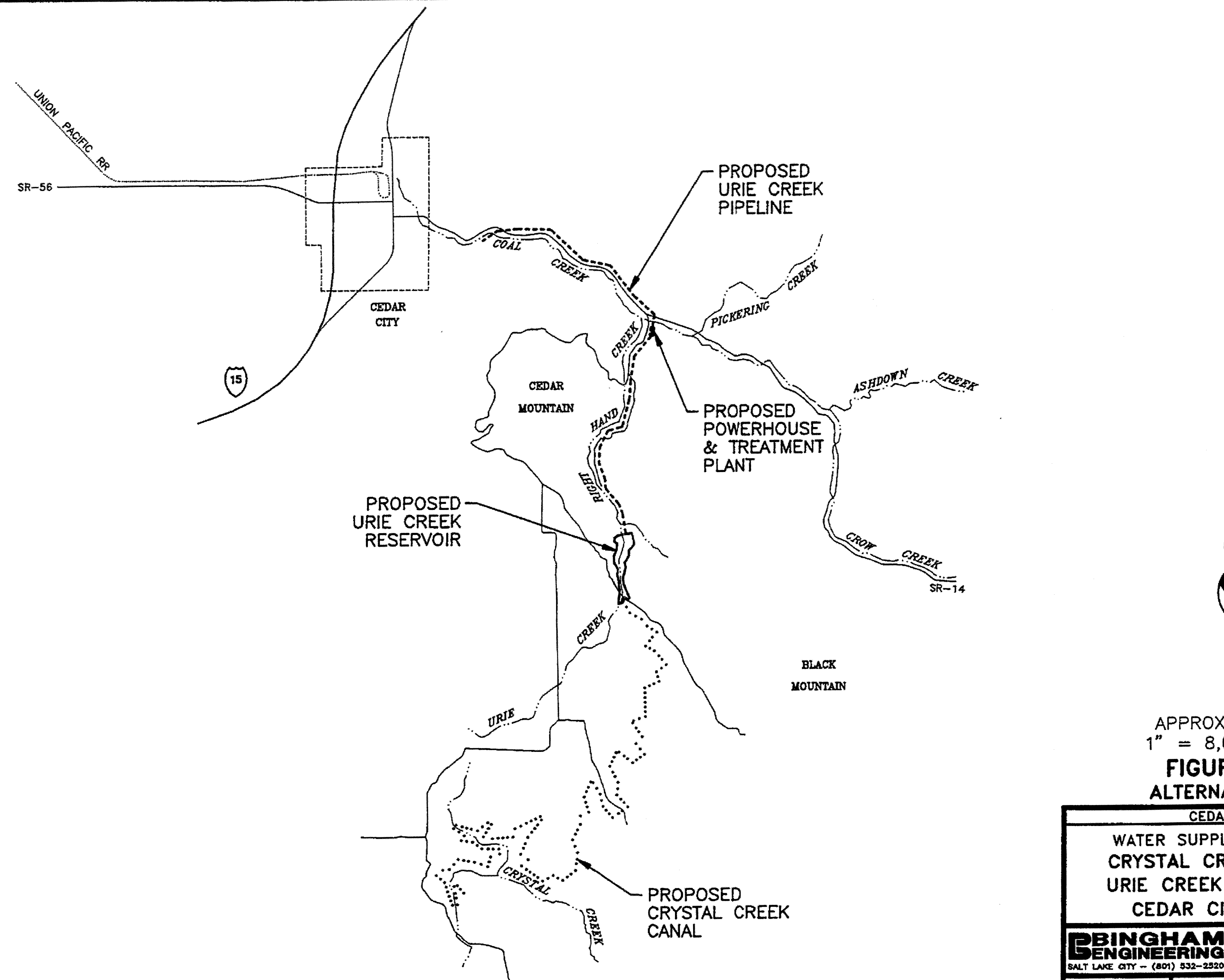

APPROX. SCALE:
1" = 8,000 FEET

FIGURE 15 V-11

ALTERNATIVE 2A

CEDAR CITY

WATER SUPPLY EVALUATION
CRYSTAL CREEK CANAL–
URIE CREEK RESERVOIR–
CEDAR CITY OPTION

BINGHAM ENGINEERING
SALT LAKE CITY – (801) 532-2520

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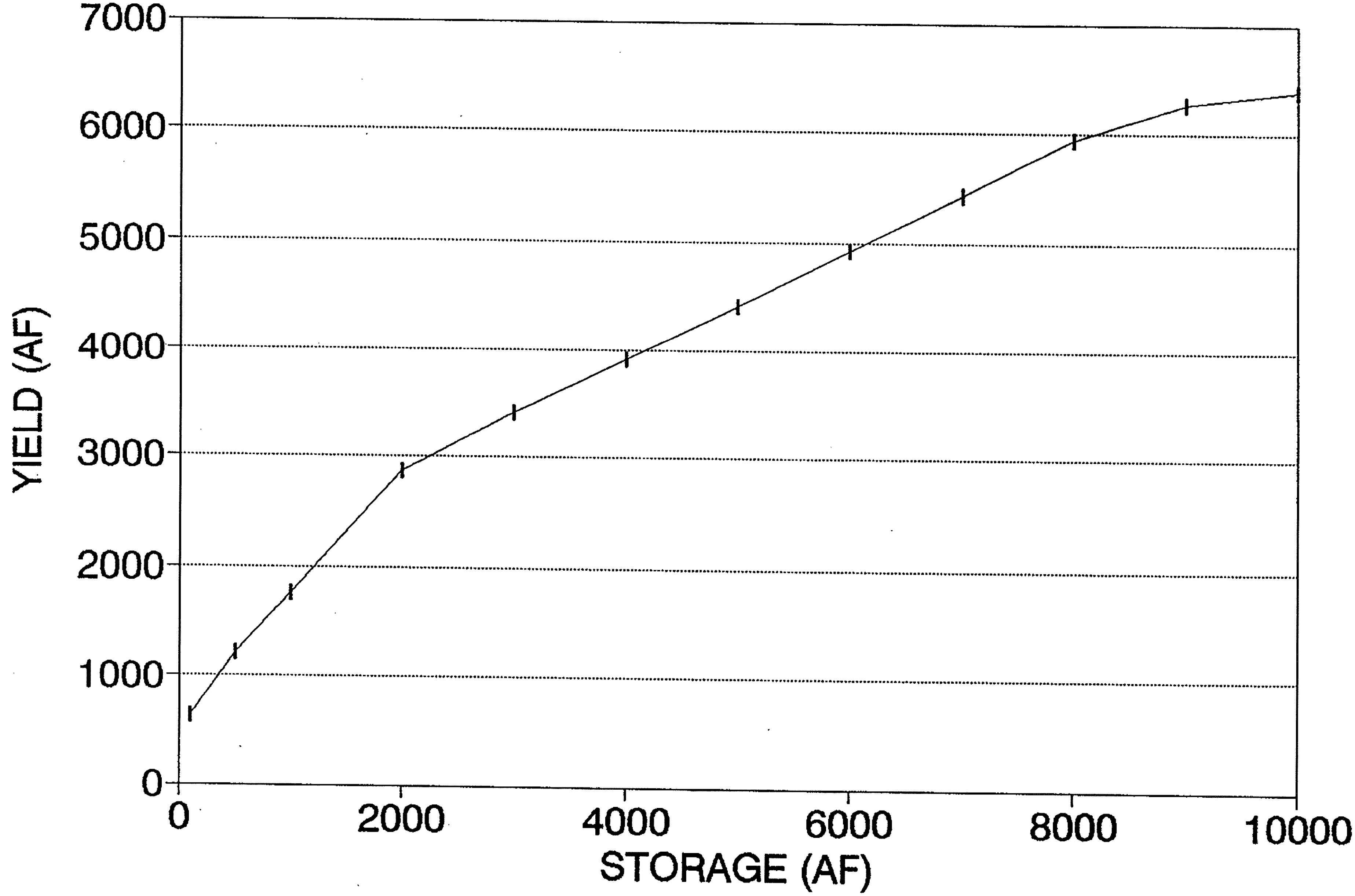
FIGURE 16

URIE RESERVOIR - ALT. 2A



top of the ledges carved from the Wahweap-Straight Cliffs Formation that forms the walls of O'Neal and Crystal Creek canyons. Because of the relatively low permeability of the strata, little of the spring runoff is absorbed. Therefore it is doubtful that diverting this runoff water would have much effect on springs and seeps in the bottom of these two canyons.

If the spring runoff water is not diverted, it does have an impact on the sculpturing and deepening of Zion Canyon. Since the natural runoff is the reason for the formation of the canyon and the existence of Zion National Park, any upstream diversions that would further alter the natural course of the erosional process would meet with resistance from the Park Service. It should be pointed out though, that the major altering of the stream bottom and carving of the canyon is impacted more by floods resulting from summer thunderstorms than by spring runoff. While the total volume from spring runoff is undoubtedly higher, the peak discharge of a given summer flood can be many times higher, carrying a much heavier load of large boulders, trees, and other erosion enhancing debris, than the maximum discharge during even the highest spring runoff period.

Another consideration must be given to the impact of reducing spring runoff to the Virgin River below Zion National Park, including such factors as flow into the Quail Creek Reservoir, irrigation along the entire lower Virgin River, and changes in spring flooding of the lower valley.

There will be some visual impact in that much of the canal right-of-way will need to be kept clear of trees and debris for access and operation.

No threatened and endangered species are known to exist within the area directly impacted by the project. Several threatened or endangered species exist within Zion National Park, but none would likely be impacted through a minor reduction of high water during spring runoff.

Advantages and Disadvantages

The proposed diversion of Crystal Creek water to Urie Creek would eliminate the need for the Crystal Creek diversion to Kolob Reservoir and thereby eliminate the need for the costly Crystal Creek Tunnel. The vertical fall in elevation from the Urie Creek reservoir to the proposed power plant near the bottom of Right Hand Canyon is also somewhat greater than that in the Kolob/Cedar City pipeline, thus the potential for hydroelectric power generation is greater. The major disadvantages are that there would be less Crystal Creek water developed by the canal than by the proposed Crystal Creek tunnel to Kolob Reservoir. Also, regulating storage already exists in Kolob Reservoir and enlargement of the proposed Urie Creek Reservoir to regulate flows would not be necessary.

Cost Estimate

The Estimated cost of developing alternative 2a, Urie Creek Reservoir with Crystal Creek Diversion by Canal is shown on the following pages. The estimates show the cost of the alternative both with and without hydroelectric power generation.

PRELIMINARY COST ESTIMATE

CEDAR CITY

ALTERNATIVE 2a

RIGHT HAND CANYON – URIE CREEK RESERVOIR

WITH CRYSTAL CREEK CANAL

"WITH HYDRO"

ITEM NO.	DESCRIPTION	UNIT	EST'D QUANTITY	UNIT PRICE	TOTAL COST
1	Mobilization	LS	JOB	LS	367,000
2	Pipeline Easement	LF	40200	0.75	30,150
3	Clearing & Grubbing	AC	46	900.00	41,400
4	Reseeding	AC	46	100.00	4,600
5	Roadway Improvement & Relocation	LF	4000	20.00	80,000
6a	22" Pipeline (Penstock)	LF	21200	42.00	890,400
6b	18" Pipeline (Lower)	LF	19000	20.00	380,000
7	Valves	EA	8	4000.00	32,000
8	Power House	LS	JOB	LS	100,000
9	Turbine and Generator	LS	JOB	LS	1,600,000
10	Power Line Extension	LF	1500	25.00	37,500
11	Switchyard	LS	JOB	LS	100,000
12	Water Treatment Plant	LS	JOB	LS	5,300,000
13	Water Right Share @ 4.2 AF/Share	EA	2300	83.33	191,659
	RESERVOIR				
14	Land	AC	210	1000.00	210,000
15	Clearing and Grubbing	AC	210	900.00	189,000
16	Dam Embankment	CY	1800000	4	7,200,000
17	Spillway	LS	JOB	LS	250,000
18	Outlet Works	LS	JOB	LS	250,000
	CANAL				
19	Canal Easement	LF	80900	0.75	60,675
20	Clearing, & Grubbing	AC	93	900.00	83,700
21	Canal	LF	80900	7.00	566,300
22	Canal Liner	LF	80900	6.00	485,400
23	Control Structures	EA	14	4000.00	56,000
24	Diversion Structure	LS	JOB	LS	50,000
		SUB TOTAL			$18,555,784
		ENGINEERING 10%			$1,855,578
		CONTINGENCY 15%			$2,783,368
		TOTAL			$23,194,730

PRELIMINARY COST ESTIMATE

CEDAR CITY

ALTERNATIVE 2a

RIGHT HAND CANYON – URIE CREEK RESERVOIR

WITH CRYSTAL CREEK CANAL

"WITHOUT HYDRO"

ITEM NO.	DESCRIPTION	UNIT	EST'D QUANTITY	UNIT PRICE	TOTAL COST
1	Mobilization	LS	JOB	LS	319,000
2	Pipeline Easement	LF	40200	0.75	30,150
3	Clearing & Grubbing	AC	46	900.00	41,400
4	Reseeding	AC	46	100.00	4,600
5	Roadway Improvement & Relocation	LF	4000	20.00	80,000
6a	14" Pipeline	LF	21200	16.00	339,200
6b	18" Pipeline (Lower)	LF	19000	20.00	380,000
7	Valves	EA	8	4000.00	32,000
8	Water Treatment Plant	LS	JOB	LS	5,300,000
9	Water Right Share @ 4.2 AF/Share	AF	2300	83.33	191,659
	RESERVOIR				
10	Land	AC	210	1000.00	210,000
11	Clearing and Grubbing	AC	210	900.00	189,000
12	Dam Embankment	CY	1800000	4	7,200,000
13	Spillway	LS	JOB	LS	250,000
14	Outlet Works	LS	JOB	LS	250,000
	CANAL				
15	Canal Easement	LF	80900	0.75	60,675
16	Clearing, & Grubbing	AC	93	900.00	83,700
17	Canal	LF	80900	7.00	566,300
18	Canal Liner	LF	80900	6.00	485,400
19	Control Structures	EA	14	4000.00	56,000
20	Diversion Structure	LS	JOB	LS	50,000
		SUB TOTAL			$16,119,084
		ENGINEERING 10%			$1,611,908
		CONTINGENCY 15%			$2,417,863
		TOTAL			$20,148,855

2b. Urie Creek Reservoir with Crystal Creek Diversion by Canal and Pipeline.

Project Description

This alternative is a modification to that previously described under 2a. The modification is to construct an interceptor system of pipelines to intercept the headwater drainages of Crystal Creek as shown in Figure 17. These interceptor pipelines would act as inverted siphons to convey intercepted water down into Crystal Creek Canyon and then back up out of the Canyon and over the drainage divide into the O'Neal Creek drainage. From there, the water would be conveyed in a canal to the proposed Urie Creek reservoir site for storage.

Water Supply Yield and Development

The estimated water supply yield of this alternative as shown in Figure 18 is 5800 acre feet per year which is slightly less than that estimated for alternative 2a. This reduction is due to the less efficient pipeline collection system.

Environmental Considerations

The environmental considerations for this alternative are basically the same as those described under Alternative 2a.

Advantages and Disadvantages

The advantage of this alternative over 2a. is that the pipeline collection system in the upper Crystal Creek drainage would be somewhat shorter than the Canal route and that operation and maintenance costs inherent in canal cleaning and repairs would be reduced. Visual impact in terms of clearing and right-of-way maintenance would also be reduced. The primary disadvantage would be the relatively minor decrease in water supply development.

Cost Estimate

The Estimated cost of developing alternative 2b, Urie Creek Reservoir with Crystal Creek Diversion by Canal and Pipeline is shown following Figures 17 and 18. The estimates show the cost of the alternative both with and without hydroelectric power generation.

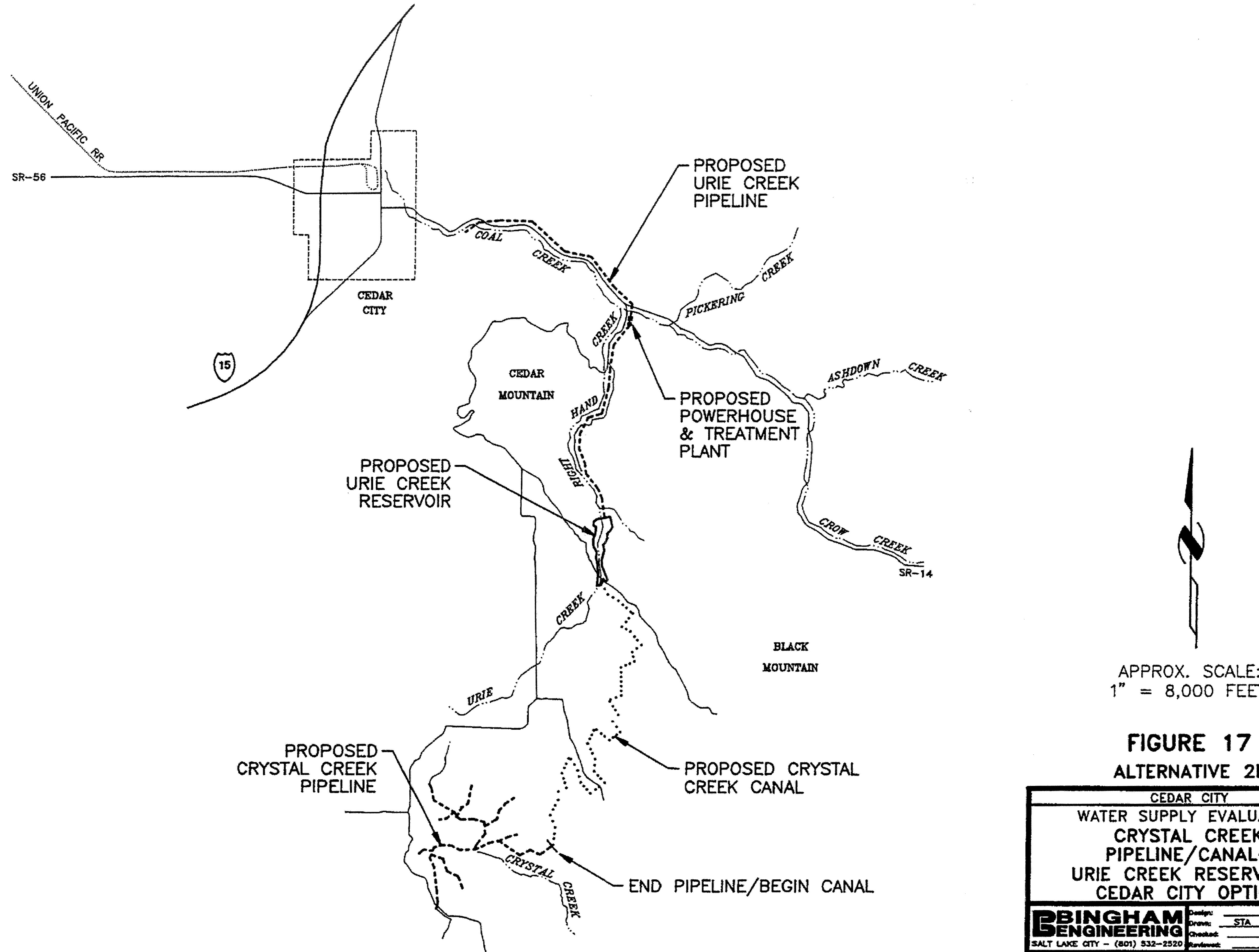


FIGURE 17 V-18

ALTERNATIVE 2B

CEDAR CITY
WATER SUPPLY EVALUATION
CRYSTAL CREEK PIPELINE/CANAL– URIE CREEK RESERVOIR– CEDAR CITY OPTION

BINGHAM ENGINEERING
SALT LAKE CITY – (801) 532-2520

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CEDAR CITY

ALTERNATIVE 2b "WITH HYDRO"

RIGHT HAND CANYON – URIE CREEK RESERVOIR

WITH CRYSTAL CREEK CANAL AND PIPELINE

ITEM NO.	DESCRIPTION	UNIT	EST'D QUANTITY	UNIT PRICE	TOTAL COST
1	Mobilization	LS	JOB	LS	367,000
2	Pipeline Easement	LF	77200	0.75	57,900
3	Clearing & Grubbing	AC	89	900.00	80,100
4	Reseeding	AC	89	100.00	8,900
5	Roadway Improvement	LF	4000	20.00	80,000
6a	20" Pipeline (Penstock)	LF	21200	38.00	805,600
6b	16" Pipeline (Lower)	LF	19000	18.00	342,000
6c	4" Pipeline (Collection)	LF	1300	6.00	7,800
6d	10" Pipeline (Collection)	LF	4150	15.00	62,250
6e	12" Pipeline (Collection)	LF	8470	18.00	152,460
6f	14" Pipeline (Collection)	LF	1260	21.00	26,460
6g	16" Pipeline (Collection)	LF	2580	24.00	61,920
6h	18" Pipeline (Collection)	LF	5920	27.00	159,840
6i	20" Pipeline (Collection)	LF	4020	30.00	120,600
6j	22" Pipeline (Collection)	LF	3180	33.00	104,940
6k	24" Pipeline (Collection)	LF	4110	36.00	147,960
6l	30" Pipeline (Collection)	LF	2000	45.00	90,000
7a	Valves	EA	15	3300.00	49,500
8	Power House	LS	JOB	LS	100,000
9	Turbine and Generator	LS	JOB	LS	1,500,000
10	Power Line Extension	LF	1500	25.00	37,500
11	Switchyard	LS	JOB	LS	100,000
12	Water Treatment Plant	LS	JOB	LS	5,000,000
13	Water Right Share @ 4.2 AF/Share	EA	2300	83.33	191,659
	RESERVOIR				
14	Land	AC	210	1000.00	210,000
15	Clearing and Grubbing	AC	210	900.00	189,000
16	Dam Embankment	CY	1800000	4	7,200,000
17	Spillway	LS	JOB	LS	250,000
18	Outlet Works	LS	JOB	LS	250,000
	CANAL				
19	Canal Easement	LF	45900	0.75	34,425
20	Clearing & Grubbing	AC	53	900.00	47,700
21	Canal	LF	45900	7.00	321,300
22	Canal Liner	LF	45900	6.00	275,400
23	Control Structures	EA	8	4000.00	32,000
24	Diversion Structure	LS	JOB	LS	50,000
		SUB TOTAL			$18,514,214
		ENGINEERING 10%			$1,851,421
		CONTINGENCY 15%			$2,777,132

PRELIMINARY COST ESTIMATE

CEDAR CITY

ALTERNATIVE 2b

RIGHT HAND CANYON – URIE CREEK RESERVOIR

WITH CRYSTAL CREEK CANAL AND PIPELINE

"WITHOUT HYDRO"

ITEM NO.	DESCRIPTION	UNIT	EST'D QUANTITY	UNIT PRICE	TOTAL COST
1	Mobilization	LS	JOB	LS	322,000
2	Pipeline Easement	LF	77200	0.75	57,900
3	Clearing & Grubbing	AC	89	900.00	80,100
4	Reseeding	AC	89	100.00	8,900
5	Roadway Improvement	LF	4000	20.00	80,000
6a	14" Pipeline	LF	21200	16.00	339,200
6b	16" Pipeline (Lower)	LF	19000	18.00	342,000
6c	4" Pipeline (Collection)	LF	1300	6.00	7,800
6d	10" Pipeline (Collection)	LF	4150	15.00	62,250
6e	12" Pipeline (Collection)	LF	8470	18.00	152,460
6f	14" Pipeline (Collection)	LF	1260	21.00	26,460
6g	16" Pipeline (Collection)	LF	2580	24.00	61,920
6h	18" Pipeline (Collection)	LF	5920	27.00	159,840
6i	20" Pipeline (Collection)	LF	4020	30.00	120,600
6j	22" Pipeline (Collection)	LF	3180	33.00	104,940
6k	24" Pipeline (Collection)	LF	4110	36.00	147,960
6l	30" Pipeline (Collection)	LF	2000	45.00	90,000
7a	Valves	EA	15	3300.00	49,500
8	Water Treatment Plant	LS	JOB	LS	5,000,000
9	Water Right Share @ 4.4 AF/Share	AF	2300	83.33	191,659
	RESERVOIR				
10	Land	AC	210	1000.00	210,000
11	Clearing and Grubbing	AC	210	900.00	189,000
12	Dam Embankment	CY	1800000	4	7,200,000
13	Spillway	LS	JOB	LS	250,000
14	Outlet Works	LS	JOB	LS	250,000
	CANAL				
15	Canal Easement	LF	45900	0.75	34,425
16	Clearing & Grubbing	AC	53	900.00	47,700
17	Canal	LF	45900	7.00	321,300
18	Canal Liner	LF	45900	6.00	275,400
19	Control Structures	EA	8	4000.00	32,000
20	Diversion Structure	LS	JOB	LS	50,000
		SUB TOTAL			$16,265,314
		ENGINEERING 10%			$1,626,531
		CONTINGENCY 15%			$2,439,797
		TOTAL			$20,331,643

CEDAR CITY

ALTERNATIVE 2b "WITH HYDRO"

RIGHT HAND CANYON – URIE CREEK RESERVOIR

WITH CRYSTAL CREEK CANAL AND PIPELINE

ITEM NO.	DESCRIPTION	UNIT	EST'D QUANTITY	UNIT PRICE	TOTAL COST
1	Mobilization	LS	JOB	LS	367,000
2	Pipeline Easement	LF	77200	0.75	57,900
3	Clearing & Grubbing	AC	89	900.00	80,100
4	Reseeding	AC	89	100.00	8,900
5	Roadway Improvement	LF	4000	20.00	80,000
6a	20" Pipeline (Penstock)	LF	21200	38.00	805,600
6b	16" Pipeline (Lower)	LF	19000	18.00	342,000
6c	4" Pipeline (Collection)	LF	1300	6.00	7,800
6d	10" Pipeline (Collection)	LF	4150	15.00	62,250
6e	12" Pipeline (Collection)	LF	8470	18.00	152,460
6f	14" Pipeline (Collection)	LF	1260	21.00	26,460
6g	16" Pipeline (Collection)	LF	2580	24.00	61,920
6h	18" Pipeline (Collection)	LF	5920	27.00	159,840
6i	20" Pipeline (Collection)	LF	4020	30.00	120,600
6j	22" Pipeline (Collection)	LF	3180	33.00	104,940
6k	24" Pipeline (Collection)	LF	4110	36.00	147,960
6l	30" Pipeline (Collection)	LF	2000	45.00	90,000
7a	Valves	EA	15	3300.00	49,500
8	Power House	LS	JOB	LS	100,000
9	Turbine and Generator	LS	JOB	LS	1,500,000
10	Power Line Extension	LF	1500	25.00	37,500
11	Switchyard	LS	JOB	LS	100,000
12	Water Treatment Plant	LS	JOB	LS	5,000,000
13	Water Right Share @ 4.2 AF/Share	EA	2300	83.33	191,659
	RESERVOIR				
14	Land	AC	210	1000.00	210,000
15	Clearing and Grubbing	AC	210	900.00	189,000
16	Dam Embankment	CY	1800000	4	7,200,000
17	Spillway	LS	JOB	LS	250,000
18	Outlet Works	LS	JOB	LS	250,000
	CANAL				
19	Canal Easement	LF	45900	0.75	34,425
20	Clearing & Grubbing	AC	53	900.00	47,700
21	Canal	LF	45900	7.00	321,300
22	Canal Liner	LF	45900	6.00	275,400
23	Control Structures	EA	8	4000.00	32,000
24	Diversion Structure	LS	JOB	LS	50,000
		SUB TOTAL			$18,514,214
		ENGINEERING 10%			$1,851,421
		CONTINGENCY 15%			$2,777,132

PRELIMINARY COST ESTIMATE

CEDAR CITY

ALTERNATIVE 2b

RIGHT HAND CANYON – URIE CREEK RESERVOIR

WITH CRYSTAL CREEK CANAL AND PIPELINE

"WITHOUT HYDRO"

ITEM NO.	DESCRIPTION	UNIT	EST'D QUANTITY	UNIT PRICE	TOTAL COST
1	Mobilization	LS	JOB	LS	322,000
2	Pipeline Easement	LF	77200	0.75	57,900
3	Clearing & Grubbing	AC	89	900.00	80,100
4	Reseeding	AC	89	100.00	8,900
5	Roadway Improvement	LF	4000	20.00	80,000
6a	14" Pipeline	LF	21200	16.00	339,200
6b	16" Pipeline (Lower)	LF	19000	18.00	342,000
6c	4" Pipeline (Collection)	LF	1300	6.00	7,800
6d	10" Pipeline (Collection)	LF	4150	15.00	62,250
6e	12" Pipeline (Collection)	LF	8470	18.00	152,460
6f	14" Pipeline (Collection)	LF	1260	21.00	26,460
6g	16" Pipeline (Collection)	LF	2580	24.00	61,920
6h	18" Pipeline (Collection)	LF	5920	27.00	159,840
6i	20" Pipeline (Collection)	LF	4020	30.00	120,600
6j	22" Pipeline (Collection)	LF	3180	33.00	104,940
6k	24" Pipeline (Collection)	LF	4110	36.00	147,960
6l	30" Pipeline (Collection)	LF	2000	45.00	90,000
7a	Valves	EA	15	3300.00	49,500
8	Water Treatment Plant	LS	JOB	LS	5,000,000
9	Water Right Share @ 4.4 AF/Share	AF	2300	83.33	191,659
	RESERVOIR				
10	Land	AC	210	1000.00	210,000
11	Clearing and Grubbing	AC	210	900.00	189,000
12	Dam Embankment	CY	1800000	4	7,200,000
13	Spillway	LS	JOB	LS	250,000
14	Outlet Works	LS	JOB	LS	250,000
	CANAL				
15	Canal Easement	LF	45900	0.75	34,425
16	Clearing & Grubbing	AC	53	900.00	47,700
17	Canal	LF	45900	7.00	321,300
18	Canal Liner	LF	45900	6.00	275,400
19	Control Structures	EA	8	4000.00	32,000
20	Diversion Structure	LS	JOB	LS	50,000
		SUB TOTAL			$16,265,314
		ENGINEERING 10%			$1,626,531
		CONTINGENCY 15%			$2,439,797
		TOTAL			$20,331,643

2c. Urie Creek Reservoir with Crystal Creek Diversion by Pipeline.

Project Description

This alternative is a modification to Alternatives 2b. The modification is to construct an interceptor system of pipelines to intercept the headwater drainages of Crystal Creek as described in Alternative 2b; however, instead of conveying the water from the Crystal Creek drainage in a canal, it would be conveyed in a pipeline to the Urie Creek drainage. See Figure 19. Additional interceptor facilities would be placed along the Urie Creek conveyance pipeline to capture runoff from the upper O'Neal Creek drainage and convey it to the proposed Urie Creek reservoir site for storage.

Water Supply Yield and Development

The estimated water supply yield of this alternative as shown in Figure 20 is 5600 acre feet per year which is slightly less than that estimated for alternative 2b. This reduction is again due to the less efficient pipeline collection and conveyance system.

Environmental Considerations

The environmental considerations for this alternative are basically the same as those described under Alternative 2a.

Advantages and Disadvantages

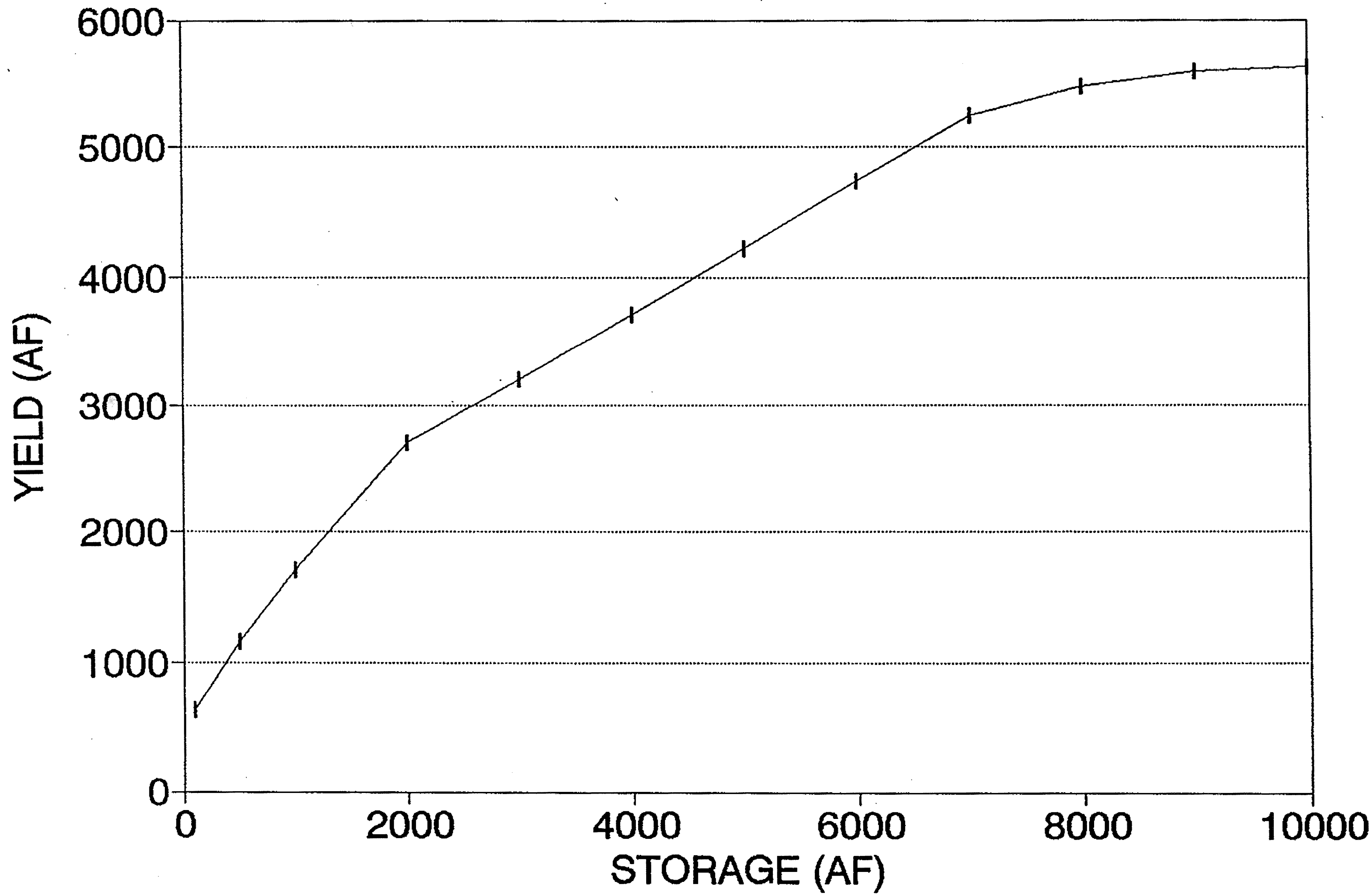
The advantage of this alternative over 2a and 2b is that the pipeline route from Urie Creek to Crystal Creek would be somewhat shorter than the Canal route and that operation and maintenance costs inherent in canal cleaning and repairs would be further reduced. Visual impact in terms of clearing and right-of-way maintenance would also be further reduced. The primary disadvantage would be the relatively minor decrease in water supply development as compared to Alternatives 2a and 2b.

Cost Estimate

The Estimated cost of developing alternative 2c, Urie Creek Reservoir with Crystal Creek Diversion by Pipeline is shown following Figures 19 and 20. The estimated costs include development both with and without hydroelectric power generation.

FIGURE 20

URIE RESERVOIR - ALT. 2C



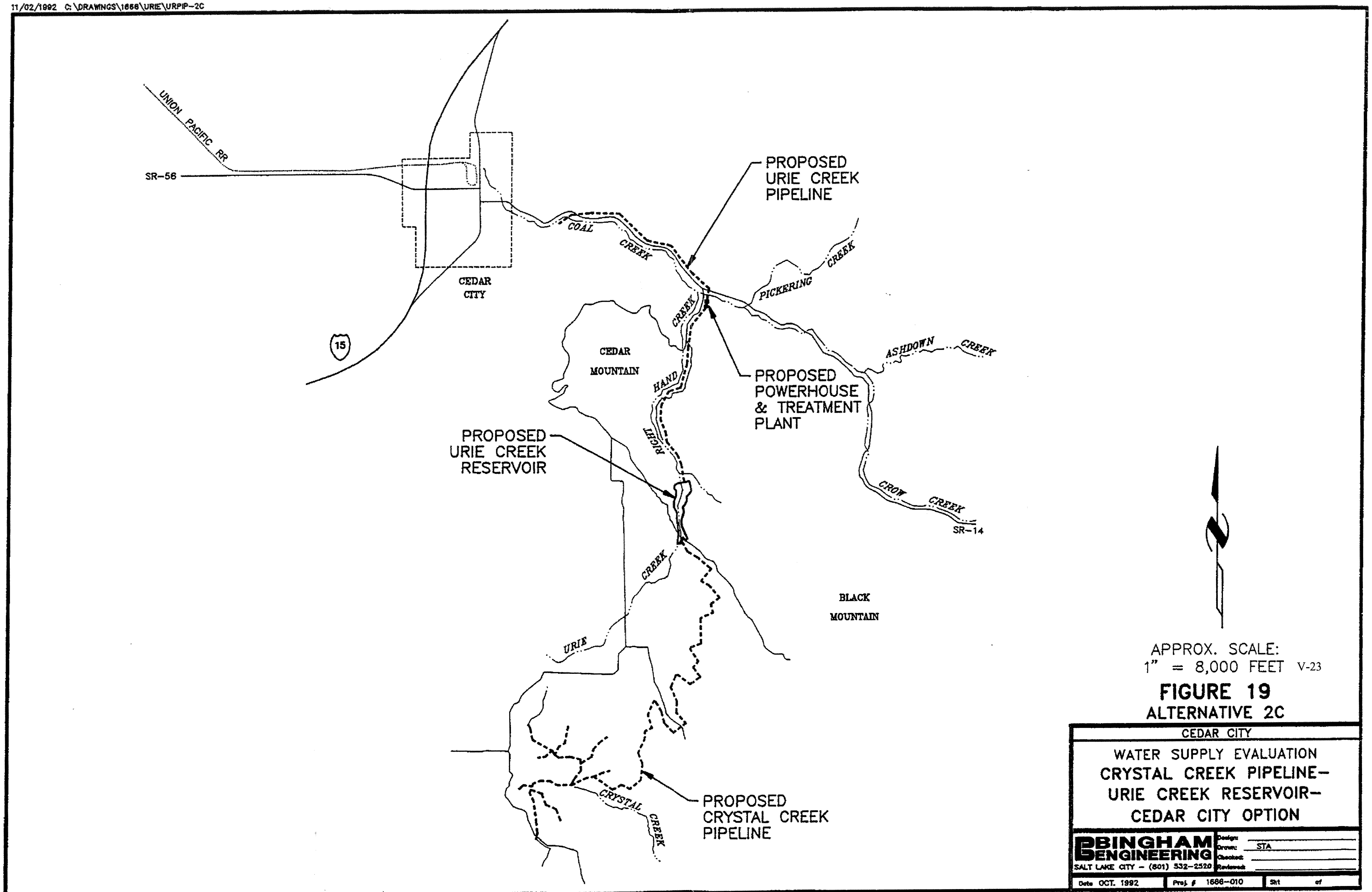


FIGURE 19
ALTERNATIVE 2C

PRELIMINARY COST ESTIMATE

CEDAR CITY

ALTERNATIVE 2c

RIGHT HAND CANYON – URIE CREEK RESERVOIR

WITH CRYSTAL CREEK PIPELINE

"WITH HYDRO"

ITEM NO.	DESCRIPTION	UNIT	EST'D QUANTITY	UNIT PRICE	TOTAL COST
1	Mobilization	LS	JOB	LS	395,000
2	Pipeline Easement	LF	123100	0.75	92,325
3	Clearing, & Grubbing	AC	150	900.00	135,000
4	Reseeding	AC	150	100.00	15,000
5	Roadway Improvement & Relocation	LF	4000	20.00	80,000
6a	20 " Pipeline (Penstock)	LF	21200	38.00	805,600
6b	16" Pipeline (Lower)	LF	19000	18.00	342,000
6c	6" Pipeline (Collection)	LF	1300	9.00	11,700
6d	10" Pipeline (Collection)	LF	4160	15.00	62,400
6e	12" Pipeline (Collection)	LF	8470	18.00	152,460
6f	14" Pipeline (Collection)	LF	1260	21.00	26,460
6g	18" Pipeline (Collection)	LF	2580	27.00	69,660
6h	20" Pipeline (Collection)	LF	5920	30.00	177,600
6i	22" Pipeline (Collection)	LF	4020	33.00	132,660
6j	26" Pipeline (Collection)	LF	3180	39.00	124,020
6k	28" Pipeline (Collection)	LF	4110	42.00	172,620
6l	38" Pipeline (Collection)	LF	47900	48.00	2,299,200
7a	Valves	EA	24	5800.00	139,200
8	Power House	LS	JOB	LS	100,000
9	Turbine and Generator	LS	JOB	LS	1,400,000
10	Power Line Extension	LF	1500	25.00	37,500
11	Switchyard	LS	JOB	LS	100,000
12	Water Treatment Plant	LS	JOB	LS	4,800,000
13	Water Right Share @ 4.2 AF/Share	EA	2300	83.33	191,659
	RESERVOIR				
14	Land	AC	210	1000.00	210,000
15	Clearing and Grubbing	AC	210	900.00	189,000
16	Dam Embankment	CY	1800000	4	7,200,000
17	Spillway	LS	JOB	LS	250,000
18	Outlet Works	LS	JOB	LS	250,000
		SUB TOTAL			$19,961,064
		ENGINEERING 10%			$1,996,106
		CONTINGENCY 15%			$2,994,160
		TOTAL			$24,951,330

PRELIMINARY COST ESTIMATE

CEDAR CITY

ALTERNATIVE 2c

RIGHT HAND CANYON – URIE CREEK RESERVOIR

WITH CRYSTAL CREEK PIPELINE

"WITHOUT HYDRO"

ITEM NO.	DESCRIPTION	UNIT	EST'D QUANTITY	UNIT PRICE	TOTAL COST
1	Mobilization	LS	JOB	LS	352,000
2	Pipeline Easement	LF	123100	0.75	92,325
3	Clearing, & Grubbing	AC	150	900.00	135,000
4	Reseeding	AC	150	100.00	15,000
5	Roadway Improvement & Relocation	LF	4000	20.00	80,000
6a	12" Pipeline	LF	21200	15.00	318,000
6b	16" Pipeline (Lower)	LF	19000	18.00	342,000
6c	6" Pipeline (Collection)	LF	1300	9.00	11,700
6d	10" Pipeline (Collection)	LF	4160	15.00	62,400
6e	12" Pipeline (Collection)	LF	8470	18.00	152,460
6f	14" Pipeline (Collection)	LF	1260	21.00	26,460
6g	18" Pipeline (Collection)	LF	2580	27.00	69,660
6h	20" Pipeline (Collection)	LF	5920	30.00	177,600
6i	22" Pipeline (Collection)	LF	4020	33.00	132,660
6j	26" Pipeline (Collection)	LF	3180	39.00	124,020
6k	28" Pipeline (Collection)	LF	4110	42.00	172,620
6l	38" Pipeline (Collection)	LF	47900	48.00	2,299,200
7	Valves	EA	24	5800.00	139,200
8	Water Treatment Plant	LS	JOB	LS	4,800,000
9	Water Share @ 4.2 AF/Share	AF	2300	83.33	191,659
	RESERVOIR				
10	Land	AC	210	1000.00	210,000
11	Clearing and Grubbing	AC	210	900.00	189,000
12	Dam Embankment	CY	1800000	4	7,200,000
13	Spillway	LS	JOB	LS	250,000
14	Outlet Works	LS	JOB	LS	250,000
		SUB TOTAL			$17,792,964
		ENGINEERING 10%			$1,779,296
		CONTINGENCY 15%			$2,668,945
		TOTAL			$22,241,205

3a. Kolob Reservoir - Cedar City Diversion.

Project Description

Figure 21 shows the proposed diversion of water from Kolob Reservoir to Cedar City. The concept for this water development project was originally studied in the early 1950's and included diversion of water to Kolob Reservoir from Crystal Creek. This evaluation includes 3 atlernatives, 3a, 3b, and 3c.

Alternative 3a considers the diversion of water from Kolob Reservoir to Cedar City without any transbasin diversion of water from Crystal Creek. A 6700 foot tunnel would convey the water through a hill next to the reservoir. Following the tunnel, the water would enter a 6.9 mile pipeline. After this pipeline, there would be 6.4 miles of penstock to take the water off Kanarra Mountain. A hydroelectric generating plant would be constructed at the end of the penstock which is at the base of the Hurricane Cliffs. This would also be the location of the water treatment plant. Following the water treatment plant, the water would flow by pipeline to the existing storage tanks southwest of Cedar City. The entire system would flow by gravity, no pumping would be required.

Water Supply Yield and Development

Kolob Reservoir with its existing capacity will provide a mean annual yield of 3000 acre feet to Cedar City.

Environmental Considerations

The environmental considerations for this alternative are essentially the same as those considered in alternative 2.

Advantages and Disadvantages

One advantage to this project is that it will operate by gravity. No pumping is required which will keep operation and maintenance costs down. However the over all construction cost is relatively high because of the length of pipelines and limited supply of water without the diversion of Crystal Creek.

Cost Estimate

The Estimated cost of developing Alternative 3a, Kolob Reservoir - Cedar City Diversion is shown following Figure 21. The cost estimates show the cost both with and without hydroelectric power generation.

PRELIMINARY COST ESTIMATE

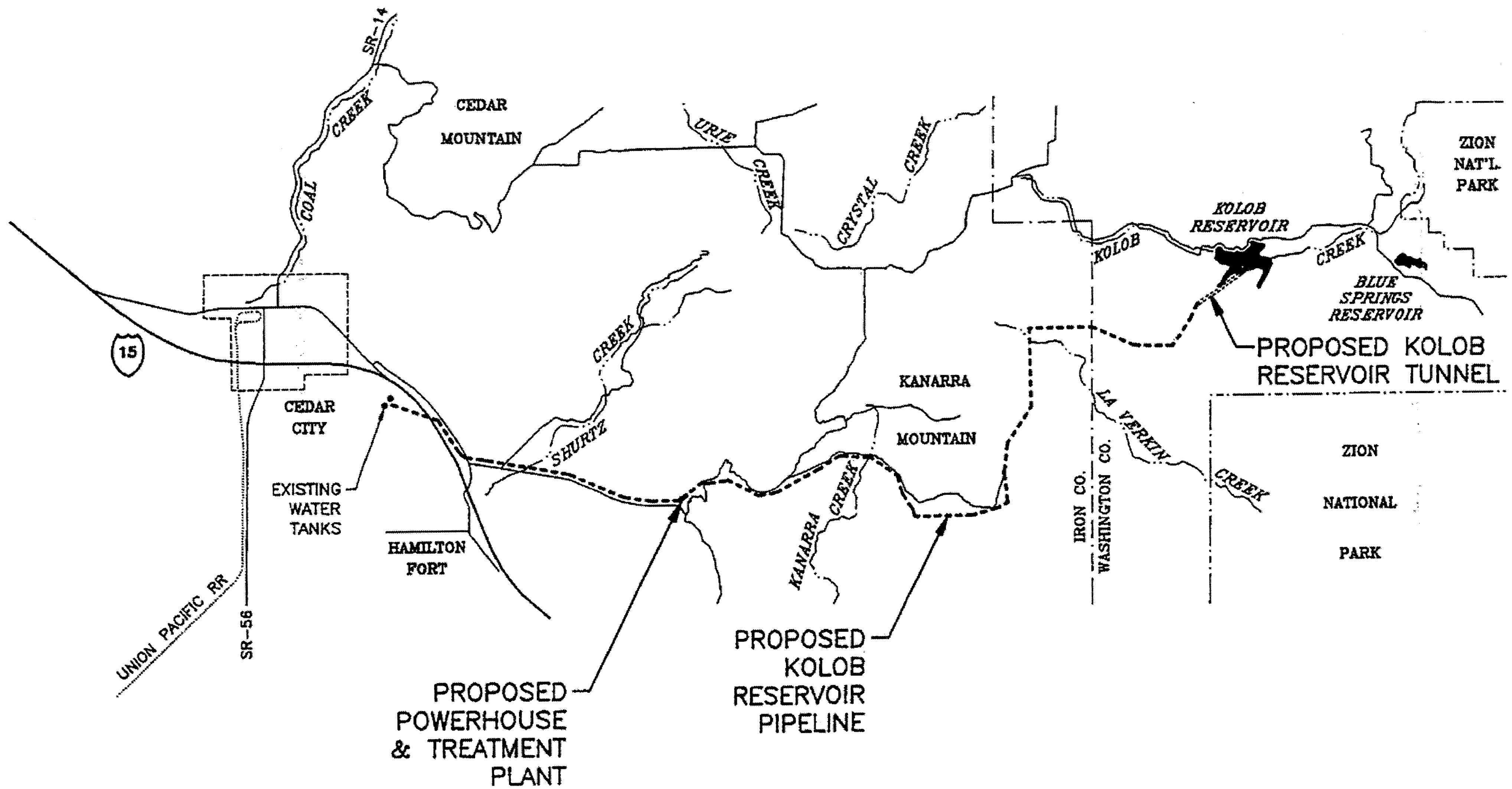
CEDAR CITY

ALTERNATIVE 3A

KOLOB RESERVOIR - CEDAR CITY DIVERSION

"WITH HYDRO"

ITEM NO.	DESCRIPTION	UNIT	EST'D QUANTITY	UNIT PRICE	TOTAL COST
1	Mobilization	LS	JOB	LS	309,000
2	Pipeline Easement	LF	98400	0.75	73,800
3	Clearing & Grubbing	AC	113	900.00	101,700
4	Reseeding	AC	113	100.00	11,300
5	Roadway Improvement	LF	20000	10.00	200,000
6a	20" Pipeline (Upper)	LF	36200	22.00	796,400
6b	20" Pipeline (Penstock)	LF	33800	39.00	1,318,200
6c	16" Pipeline (Lower)	LF	28400	18.00	511,200
7	Tunnel at Kolob Reservoir	LF	6700	900.00	6,030,000
8	Valves	EA	20	4000.00	80,000
9	Diversion Structure at Kolob Reservoir	LS	JOB	LS	200,000
10	Kolob Dam Improvement	LS	JOB	LS	200,000
11	Power House	LS	JOB	LS	100,000
12	Turbine and Generator	LS	JOB	LS	900,000
13	Power Line Extension	LF	20000	25.00	500,000
14	Switchyard	LS	JOB	LS	100,000
15	Water Treatment Plant	LS	JOB	LS	4,000,000
		SUB TOTAL			$15,431,600
		ENGINEERING 10%			$1,543,160
		CONTINGENCY 15%			$2,314,740
		TOTAL			$19,289,500



APPROX. SCALE:
1" = 12,000 FEET

V-28

FIGURE 21
ALTERNATIVE 3A

CEDAR CITY
WATER SUPPLY EVALUATION

KOLOB RESERVOIR–
CEDAR CITY OPTION

BINGHAM ENGINEERING
SALT LAKE CITY – (801) 532-2520

Design:
Drawn: STA
Checked:
Reviewed:

Date OCT. 1992 | Proj. # 1666-004 | Sht of

PRELIMINARY COST ESTIMATE

CEDAR CITY

ALTERNATIVE 3A

KOLOB RESERVOIR – CEDAR CITY DIVERSION

"WITHOUT HYDRO"

ITEM NO.	DESCRIPTION	UNIT	EST'D QUANTITY	UNIT PRICE	TOTAL COST
1	Mobilization	LS	JOB	LS	260,000
2	Pipeline Easement	LF	98400	0.75	73,800
3	Clearing & Grubbing	AC	113	900.00	101,700
4	Reseeding	AC	113	100.00	11,300
5	Roadway Improvement	LF	20000	10.00	200,000
6a	20" Pipeline (Upper)	LF	36200	22.00	796,400
6b	12" Pipeline	LF	33800	15.00	507,000
6c	16" Pipeline (Lower)	LF	28400	18.00	511,200
7	Tunnel at Kolob Reservoir	LF	6700	900.00	6,030,000
8	Valves	EA	20	4000.00	80,000
9	Diversion Structure at Kolob Reservoir	LS	JOB	LS	200,000
10	Kolob Dam Improvement	LS	JOB	LS	200,000
11	Water Treatment Plant	LS	JOB	LS	4,000,000
		SUB TOTAL			$12,971,400
		ENGINEERING 10%			$1,297,140
		CONTINGENCY 15%			$1,945,710
		TOTAL			$16,214,250

3b. Kolob Reservoir - Cedar City Diversion - Crystal Creek Tunnel.

Project Description

This project is shown in Figure 22 and is similar to Alternative 3a but includes the diversion of Crystal Creek water by a 3.8 mile tunnel 9 feet in diameter. Judging from previous geologic investigations, the tunnel would likely need to be supported and concrete lined. It would convey water from Crystal Creek at its entrance which is at elevation 8389. The outlet would be approximately 2 miles northeast of Kolob Reservoir at elevation 8320. At this point the water would flow into Hornet Creek and then into the reservoir.

Water Supply Yield and Development

Kolob Reservoir with its existing capacity and the additional water from the transbasin tunnel diversion will provide a mean annual yield of 6500 acre feet to Cedar City.

Environmental Considerations

The environmental considerations for this alternative are essentially the same as those considered in alternative 2.

Advantages and Disadvantages

The advantage to this alternative is the additional water available from the transbasin diversion of Crystal Creek. The entire system would flow by gravity. The project utilizes the existing Kolob Reservoir for storage and regulation, but costs are still high due to the length of the Crystal Creek Tunnel and expensive tunneling costs.

Cost Estimate

The Estimated cost of developing Alternative 3b, Kolob Reservoir -Cedar City Diversion - Crystal Creek Tunnel is shown following Figure 22. The cost estimates are based on development of the project both with and without hydroelectric power generation.

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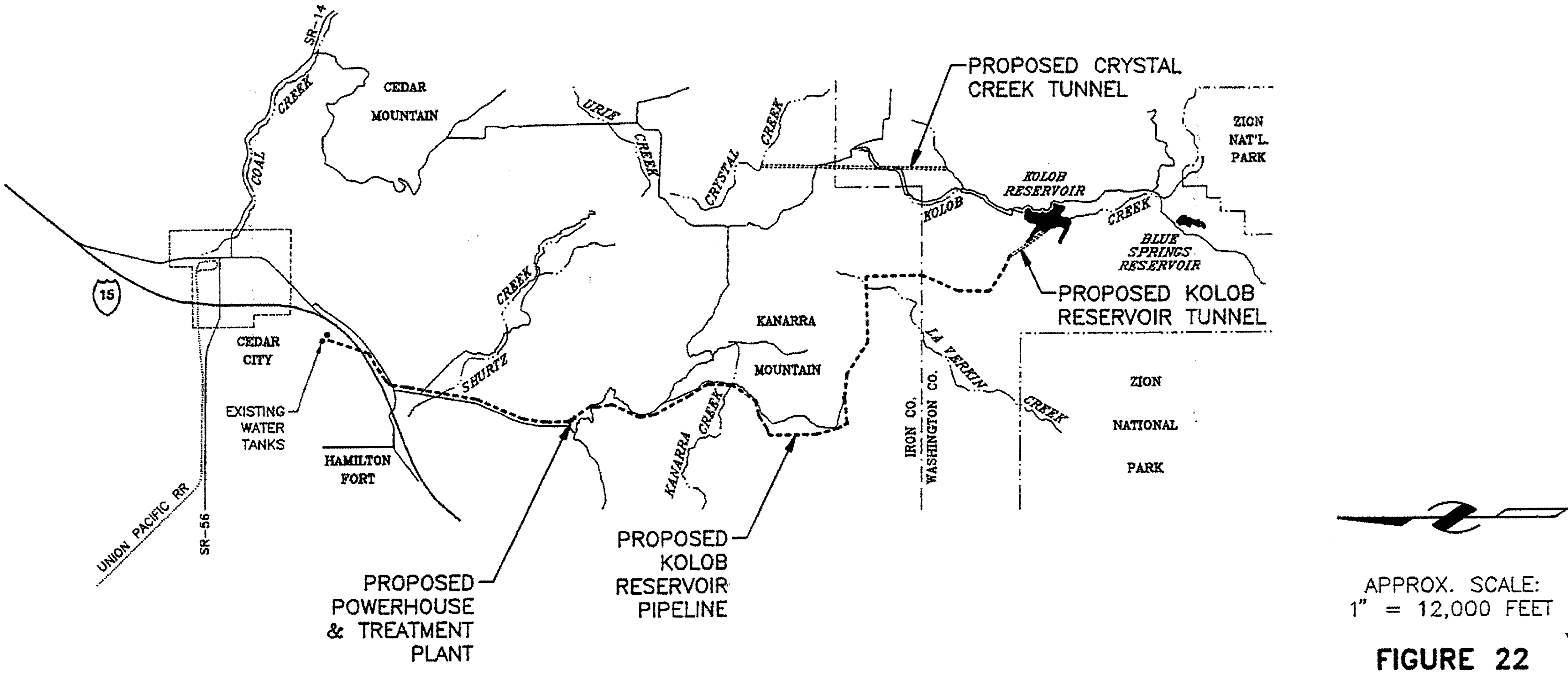


V-32

FIGURE 22
ALTERNATIVE 3B

CEDAR CITY
WATER SUPPLY EVALUATION
CRYSTAL CREEK TUNNEL-KOLOB RESERVOIR-CEDAR CITY OPTION

BINGHAM ENGINEERING
SALT LAKE CITY - (801) 532-2520
Design:
Drawn: STA
Checked:
Reviewed:
Date OCT. 1992 | Proj # 1666-004 | Sht of

PRELIMINARY COST ESTIMATE

CEDAR CITY

ALTERNATIVE 3B

KOLOB RESERVOIR – CEDAR CITY DIVERSION

WITH CRYSTAL CREEK TUNNEL

"WITH HYDRO"

ITEM NO.	DESCRIPTION	UNIT	EST'D QUANTITY	UNIT PRICE	TOTAL COST
1	Mobilization	LS	JOB	LS	744,000
2	Pipeline Easement	LF	98400	0.75	73,800
3	Clearing & Grubbing	AC	113	900.00	101,700
4	Reseeding	AC	113	100.00	11,300
5	Roadway Improvement	LF	30000	10.00	300,000
6a	28" Pipeline (Upper)	LF	36200	35.00	1,267,000
6b	26" Pipeline (Penstock)	LF	33800	57.00	1,926,600
6c	22" Pipeline (Lower)	LF	28400	24.00	681,600
7	Tunnel at Kolob Reservoir	LF	6700	900.00	6,030,000
8	Valves	EA	20	5800.00	116,000
9	Diversion Structure at Kolob Reservoir	LS	JOB	LS	200,000
10	Kolob Dam Improvement	LS	JOB	LS	300,000
11	Power Line Extension	LF	2000	25.00	50,000
12	Power Plant Building	LS	JOB	LS	100,000
13	Turbine and Generator	LS	JOB	LS	1,400,000
14	Water Treatment Plant	LS	JOB	LS	6,000,000
15	Tunnel from Crystal Creek	LF	19800	900.00	17,820,000
16	Diversion Structure at Crystal Creek	LS	JOB	LS	75000
		SUB TOTAL			$37,197,000
		ENGINEERING 10%			$3,719,700
		CONTINGENCY 15%			$5,579,550
		TOTAL			$46,496,250

PRELIMINARY COST ESTIMATE

CEDAR CITY

ALTERNATIVE 3B

KOLOB RESERVOIR – CEDAR CITY DIVERSION

WITH CRYSTAL CREEK TUNNEL

"WITHOUT HYDRO"

ITEM NO.	DESCRIPTION	UNIT	EST'D QUANTITY	UNIT PRICE	TOTAL COST
1	Mobilization	LS	JOB	LS	686,000
2	Pipeline Easement	LF	98400	0.75	73,800
3	Clearing & Grubbing	AC	113	900.00	101,700
4	Reseeding	AC	113	100.00	11,300
5	Roadway Improvement	LF	30000	10.00	300,000
6a	28" Pipeline (Upper)	LF	36200	35.00	1,267,000
6b	16" Pipeline	LF	33800	18.00	608,400
6c	22" Pipeline (Lower)	LF	28400	24.00	681,600
7	Tunnel at Kolob Reservoir	LF	6700	900.00	6,030,000
8	Valves	EA	20	5800.00	116,000
9	Diversion Structure at Kolob Reservoir	LS	JOB	LS	200,000
10	Kolob Dam Improvement	LS	JOB	LS	300,000
11	Water Treatment Plant	LS	JOB	LS	6,000,000
12	Tunnel from Crystal Creek	LF	19800	900.00	17,820,000
13	Diversion Structure at Crystal Creek	LS	JOB	LS	75,000
		SUB TOTAL			$34,270,800
		ENGINEERING 10%			$3,427,080
		CONTINGENCY 15%			$5,140,620
		TOTAL			$42,838,500

3c. Kolob Reservoir - Cedar City Diversion - Crystal Creek Canal.

Project Description

This alternative is similar to alternative 3b, however, water from the Crystal Creek drainage would be captured in an interceptor canal extending from Hornet Creek above Kolob Reservoir and into the upper Crystal Creek drainage area. This interceptor canal would have the potential of capturing most of the Crystal Creek flows that could be diverted to the Kolob Reservoir through the proposed Crystal Creek Tunnel. The proposed Crystal Creek interceptor canal is shown in Figure 23. The Canal would require a liner and have a capacity of 50 cfs. The total length is approximately 12 miles

Water Supply Yield and Development

Kolob Reservoir with its existing capacity and the additional water from the upper Crystal Creek canal will provide a mean annual yield of 6500 acre feet to Cedar City.

Environmental Considerations

The environmental considerations for this alternative are essentially the same as those considered in alternative 2a.

Advantages and Disadvantages

The major disadvantage of this alternative is that there may be a little less Crystal Creek water developed by the canal than by the proposed Crystal Creek Tunnel to Kolob Reservoir. The operation and maintenance costs would also likely be higher. The advantage is that this alternative is considerably less expensive than alternative 3b.

Cost Estimate

The Estimated costs of developing Alternative 3c, Kolob Reservoir - Cedar City Diversion - Crystal Creek Canal is shown on the pages following Figure 23. The cost estimates show the cost both with and without hydroelectric powrer generation.

PRELIMINARY COST ESTIMATE

CEDAR CITY

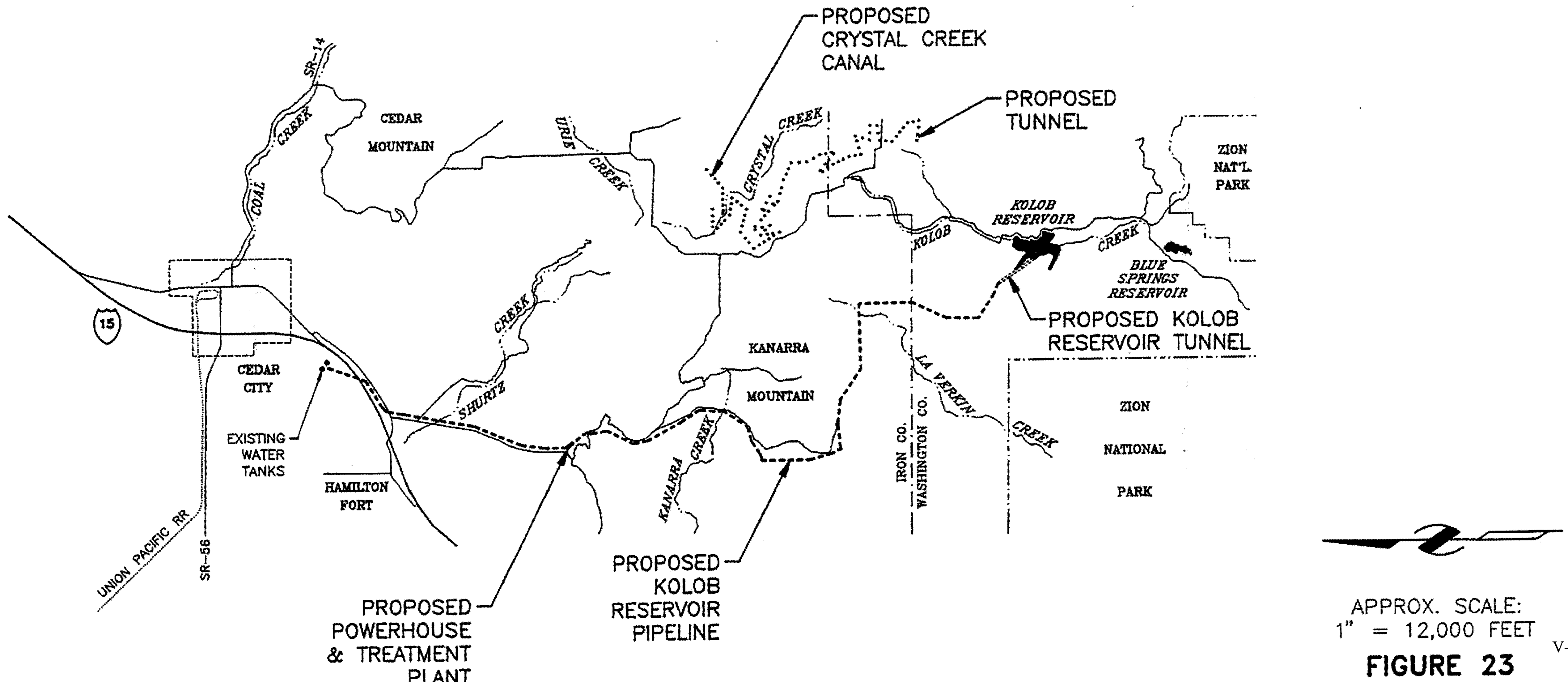
ALTERNATIVE 3c

KOLOB RESERVOIR – CEDAR CITY DIVERSION

WITH CRYSTAL CREEK CANAL

"WITH HYDRO"

ITEM NO.	DESCRIPTION	UNIT	EST'D QUANTITY	UNIT PRICE	TOTAL COST
1	Mobilization	LS	JOB	LS	400,000
2	Pipeline Easement	LF	98400	0.75	73,800
3	Clearing & Grubbing	AC	113	900.00	101,700
4	Reseeding	AC	113	100.00	11,300
5	Roadway Improvement	LF	30000	10.00	300,000
6a	28" Pipeline (Upper)	LF	36200	35.00	1,267,000
6b	26" Pipeline (Penstock)	LF	33800	57.00	1,926,600
6c	22" Pipeline (Lower)	LF	28400	24.00	681,600
7	Tunnel at Kolob Reservoir	LF	6700	900.00	6,030,000
8	Valves	EA	20	5800.00	116,000
9	Diversion Structure at Kolob Reservoir	LS	JOB	LS	200,000
10	Kolob Dam Improvement	LS	JOB	LS	300,000
11	Power Line Extension	LF	2000	25.00	50,000
12	Power Plant Building	LS	JOB	LS	100,000
13	Turbine and Generator	LS	JOB	LS	1,400,000
14	Water Treatment Plant	LS	JOB	LS	6,000,000
	CANAL				
15	Canal Easement	LF	63400	0.75	47,550
16	Clearing and Grubbing	AC	73	900.00	65,700
17	Canal	LF	63400	7.00	443,800
18	Canal Liner	LF	63400	6.00	380,400
19	Control Structure Along Canal	EA	12	4000.00	48,000
20	Diversion Structure	LS	JOB	LS	50,000
		SUB TOTAL			$19,993,450
		ENGINEERING 10%			$1,999,345
		CONTINGENCY 15%			$2,999,018
		TOTAL			$24,991,813



V-36

FIGURE 23
ALTERNATIVE 3C

CEDAR CITY

WATER SUPPLY EVALUATION
CRYSTAL CREEK CANAL–
KOLOB RESERVOIR–
CEDAR CITY OPTION

BINGHAM ENGINEERING
SALT LAKE CITY – (801) 532-2520

Design:
Drawn: STA
Checked:
Reviewed:

Date OCT. 1992 | Proj. # 1666-004 | Sht of

PRELIMINARY COST ESTIMATE

CEDAR CITY

ALTERNATIVE 3c

KOLOB RESERVOIR – CEDAR CITY DIVERSION

WITH CRYSTAL CREEK CANAL

"WITHOUT HYDRO"

ITEM NO.	DESCRIPTION	UNIT	EST'D QUANTITY	UNIT PRICE	TOTAL COST
1	Mobilization	LS	JOB	LS	342,000
2	Pipeline Easement	LF	98400	0.75	73,800
3	Clearing & Grubbing	AC	113	900.00	101,700
4	Reseeding	AC	113	100.00	11,300
5	Roadway Improvement	LF	30000	10.00	300,000
6a	28" Pipeline (Upper)	LF	36200	35.00	1,267,000
6b	16" Pipeline	LF	33800	18.00	608,400
6c	22" Pipeline (Lower)	LF	28400	24.00	681,600
7	Tunnel at Kolob Reservoir	LF	6700	900.00	6,030,000
8	Valves	EA	20	5800.00	116,000
9	Diversion Structure at Kolob Reservoir	LS	JOB	LS	200,000
10	Kolob Dam Improvement	LS	JOB	LS	300,000
11	Water Treatment Plant	LS	JOB	LS	6,000,000
	CANAL				
12	Canal Easement	LF	63400	0.75	47,550
13	Clearing and Grubbing	AC	73	900.00	65,700
14	Canal	LF	63400	7.00	443,800
15	Canal Liner	LF	63400	6.00	380,400
16	Control Structure Along Canal	EA	12	4000.00	48,000
17	Diversion Structure	LS	JOB	LS	50,000
		SUB TOTAL			$17,067,250
		ENGINEERING 10%			$1,706,725
		CONTINGENCY 15%			$2,560,088
		TOTAL			$21,334,063

4. Deep Creek Tunnel.

Project Description

This project is the same as that investigated by the Division of Water Resources in the 1988 Investigation of Transbasin Diversion From Upper Virgin River Basin to Cedar City. It was then identified as alternate C3 - Upper Virgin Springs/Cedar City Pipeline - Low Collection. A diagram of the Project is shown in Figure 24.

The project would require tunneling from immediately below the confluence of Deep Creek and East Fork of Deep Creek into Coal Creek Canyon above Right Hand Canyon. A diversion structure would be built on Deep Creek to control the diversion into the tunnel. Because of downstream fishery requirements, it was determined that diversions would likely only be permitted when the flows downstream from the diversion were in excess of 2 cfs. In other words only that portion of the Deep Creek streamflow greater than 2 cfs would be diverted through the tunnel. Flows greater than 30 cfs would also be excluded, although they are quite rare.

Because of the high variability of flow through the Tunnel and the non-availability of natural storage sites to control the discharge, the flow through the tunnel would discharge into Coal Creek and be conveyed to Cedar City where it would be diverted for irrigation and/or recharge to the Cedar City Valley Groundwater Reservoir.

Water Supply Yield and Development

Prior to 1988, there were no stream gage records to validate the proposed diversion. Following the recommendations of the 1988 study however, Cedar City and the Division of Water Resources jointly installed stream gages on both Deep Creek and the East Fork of Deep Creek. The 4 years of flow records from these gages were combined and then correlated and extended using the long term records of the Virgin River near Springdale. These extended records indicate the watershed yield at the proposed diversion point averages about 5200 acre feet per year which is somewhat less than prior estimates. If the flows greater than 2 cfs and less than 30 cfs are diverted through the tunnel, the diverted flow would average about 3440 acre feet per year.

There are numerous irrigation and stockwater rights in both Deep Creek and East Fork drainages above the proposed diversion tunnel. However, the diversion should not affect these rights since the water proposed for diversion already reflects upstream uses.

Environmental Considerations

The environmental concerns for this project would be very nearly the same as those outlined in Alternative 2a, namely concern for flow maintenance through Zion National Park and the Lower Virgin River. One other environmental concern that will need to be considered is the possible impact of high flow diversion through the

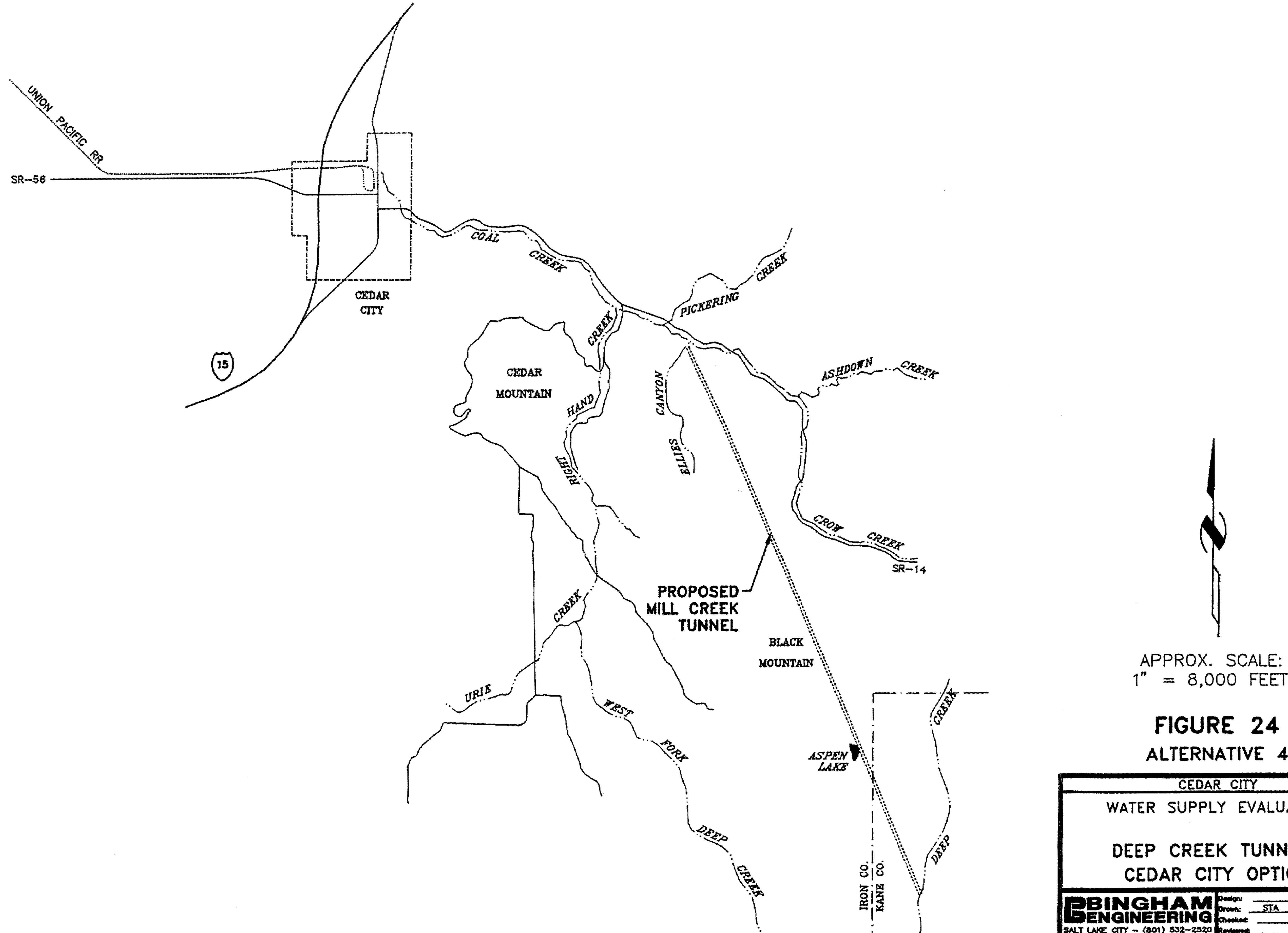


FIGURE 24

ALTERNATIVE 4

CEDAR CITY

WATER SUPPLY EVALUATION

DEEP CREEK TUNNEL–
CEDAR CITY OPTION

BINGHAM ENGINEERING
SALT LAKE CITY – (801) 532-2520

Design:
Drawn: STA
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Date OCT. 1992 | Proj. # 1666-005 | Sht of

Tunnel to the Deep Creek channel downstream from the Tunnel entrance to O'Neal Creek. At times, these high flows may need to be released downstream to scour out the channel of Deep Creek sufficient to prevent vegetative overgrowth and maintain the riffle/pool environment for the natural fishery habitat.

Advantages and Disadvantages

The major advantage of this project would be that it is relatively simple to operate and operational costs would be minimal. The tunnel may also intercept some groundwater during construction which would add to the water supply. The major disadvantage of this alternative is that the initial cost for water development is extremely high.

Cost Estimate

The Estimated cost of developing Alternative 4, Deep Creek Tunnel is shown on the following page.

PRELIMINARY COST ESTIMATE

CEDAR CITY

ALTERNATIVE 4

DEEP CREEK – MILL CREEK TUNNEL

ITEM NO.	DESCRIPTION	UNIT	EST'D QUANTITY	UNIT PRICE	TOTAL COST
1	Mobilization	LS	JOB	LS	500,000
2	Easement	LF	15000	0.75	11,250
3	Roadway Improvement	LF	15000	10.00	150,000
4	Mill Creek Tunnel	LF	55440	900.00	49,896,000
5	Diversion Structure	LS	JOB	LS	30,000
6	Coal Creek Bank Protection	LS	JOB	LS	100,000
		SUB TOTAL			$50,687,250
		ENGINEERING 10%			$5,068,725
		CONTINGENCY 15%			$7,603,088
		TOTAL			$63,359,063

5. Castle Creek/Upper Mammoth Creek via Navajo Lake.

Project Description

In the late 1960's, a very preliminary investigation was made by the Division of Water Resources to determine the possibility of diverting water from the upper Mammoth Creek drainage into Cedar City Valley. This preliminary investigation, conducted as a part of the State Water Planning effort, focused on diverting spring runoff water from the Upper Mammoth Creek through a pipeline to Navajo Lake where it would be stored and then pumped from the Lake over the low divide west of the Lake and conveyed to Cedar City. The investigation was not completed at that time because the Central Utah Water Conservancy District (CUWCD) was being organized and it was recognized that until water was imported into the lower Sevier River Basin such that water rights could be exchanged upstream, the project had little chance for implementation. It was also believed that this project alternative could be further investigated for feasibility after formation of the CUWCD and perhaps could be made a part of the Central Utah Project.

The Upper Mammoth Creek/Cedar City transbasin diversion plan has been included as a part of this evaluation in order to gain a comparative appraisal of this potential alternative with others that have been proposed.

Figure 25 shows the proposed alternative to transport water from the upper Mammoth Creek (upper Sevier River) to Cedar City. The project would require construction of a reservoir on Castle Creek, a tributary to the upper Mammoth Creek drainage, to capture and regulate runoff from spring snowmelt. Runoff waters from Mammoth Creek and Lowder Creeks would have to be diverted in either lined canals or pipelines from these drainages and conveyed to the proposed reservoir on Castle Creek.

Water released from Castle Creek Reservoir would be conveyed southerly in a pipeline through Tippits Valley to Highway U-24 and then westerly around the south side of Navajo Lake to the drainage divide west of the Lake. From this point, the pipeline would be routed across the upper Deep Creek and O'Neal Creek drainage areas and conveyed to the Urie Creek drainage near the head of Right Hand Canyon. The water would then be conveyed in a penstock down through Right Hand Canyon to a hydroelectric power plant located near Coal Creek. Water leaving the power plant would then be treated, and conveyed in a pipeline to Cedar City for storage and use.

Much of the upper Mammoth Creek/Castle Creek watershed area consists of Tertiary age volcanic deposits. These lava flows are extremely permeable and much of the natural runoff seeps into the formations only to emerge further downstream in sometimes very visible springs such as Mammoth Springs and Blue Springs. Because of these predominant formations, lining of the collection and diversion canals would be necessary and lining of the proposed Castle Creek Reservoir with either earth or a membrane would also be necessary.

Providing storage and regulation in the proposed Castle Creek Reservoir and routing the pipeline around Navajo Lake would eliminate the need for using Navajo Lake as an uncertain storage reservoir and also eliminate the need for pumping from the Lake. The pipeline in this area would act as an inverted siphon and would be under sufficient pressure to enable the water to bypass the Lake by gravity.

Water Supply Yield and Development

The estimated yield of the proposed Castle Creek Reservoir is 3400 acre ft per year based on a reservoir of 8000 acre feet. A topographic map of the reservoir basin and damsite is shown in Figure 26 and the area-capacity curves for the reservoir are shown in Figure 27. A storage/yield curve for the reservoir is shown in Figure 28.

The Castle Creek Dam would have to be about 100 feet high in order to develop a reservoir that would store 8000 acre feet and yield 3400 acre feet per year. The estimated volume of the Dam required would be slightly more than 1,000,000 cubic yards. It appears that on-site materials are available for construction of a properly designed and zoned earth fill dam. Suitable native materials for reservoir lining may not be available on site and therefore a membrane lining material has been included in the cost estimate for the project.

Environmental Considerations

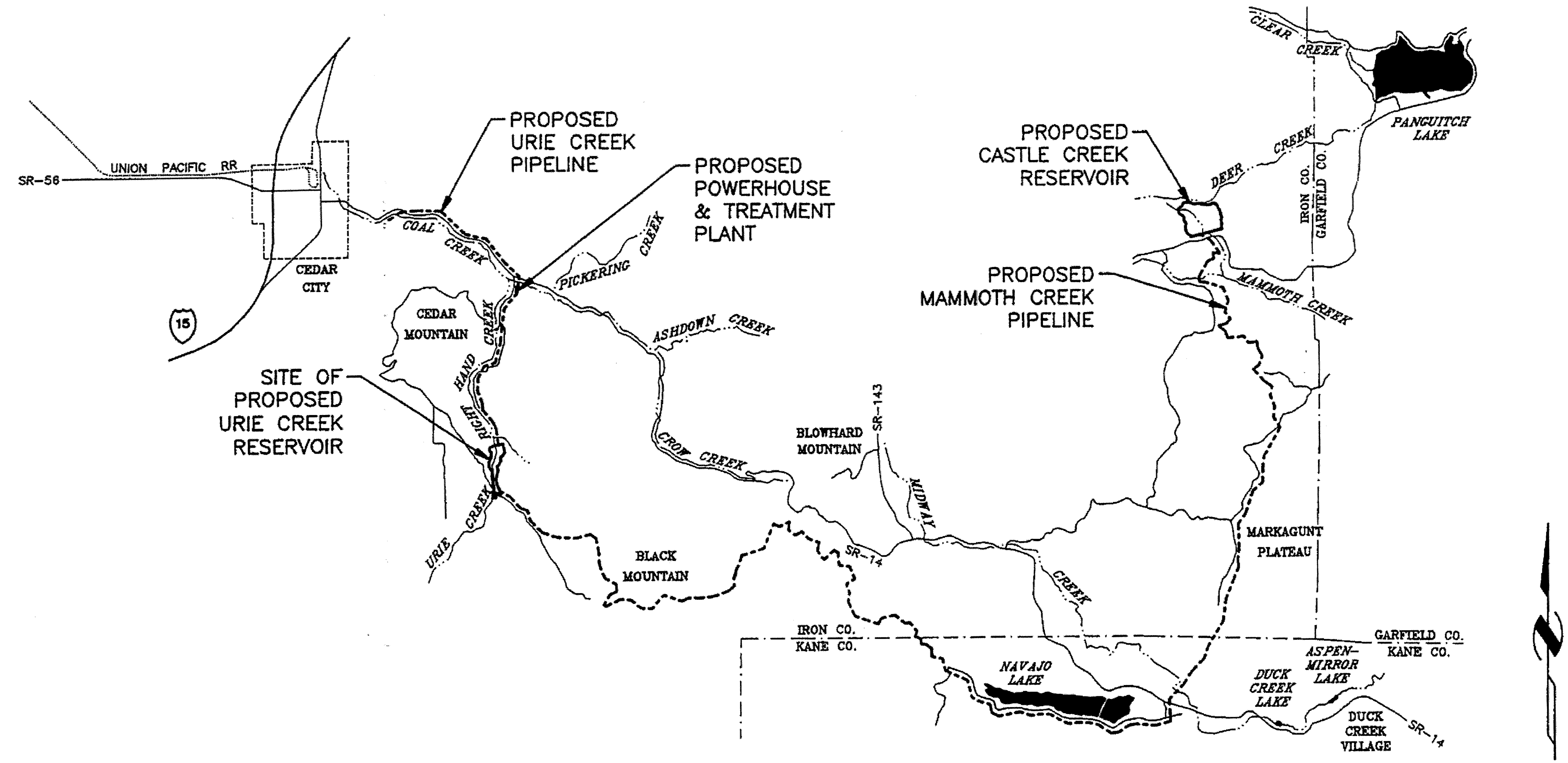
The Castle Creek/Upper Mammoth Creek via Navajo Lake transbasin diversion alternative presents a greater potential for environmental concerns than any of the other proposed alternatives for the following reasons:

1. The volcanic substrate that covers most of the area of concern between a proposed dam site on Castle Creek and Navajo Lake which impacts seepage losses and subsurface flow to downstream springs.

2. A major portion of the project would be on public (Forest Service) land that has a higher aesthetic value than any of the other proposed projects. Therefore objection from environmental groups would be expected to be greater.

3. The much greater length of the pipeline and the attendant problems of site restoration would increase the level of environmental concern.

Major concerns center on item number one. They are all related to the ability of the ground to absorb spring snow melt with only a minimum of direct runoff. The impact of the diversion on springs such as Mammoth Spring as well as others must be addressed. The drying up of some springs, the emergence of new springs, or changes in discharge volume, both up and down, are all possibilities given the nature of the area. In addition, the ability of the proposed reservoir to hold water must be considered.



APPROX. SCALE:
1" = 12,000 FEET

FIGURE 25

ALTERNATIVE 5

CEDAR CITY

WATER SUPPLY EVALUATION
CASTLE CREEK/UPPER MAMMOTH RESERVOIR–CEDAR CITY OPTION

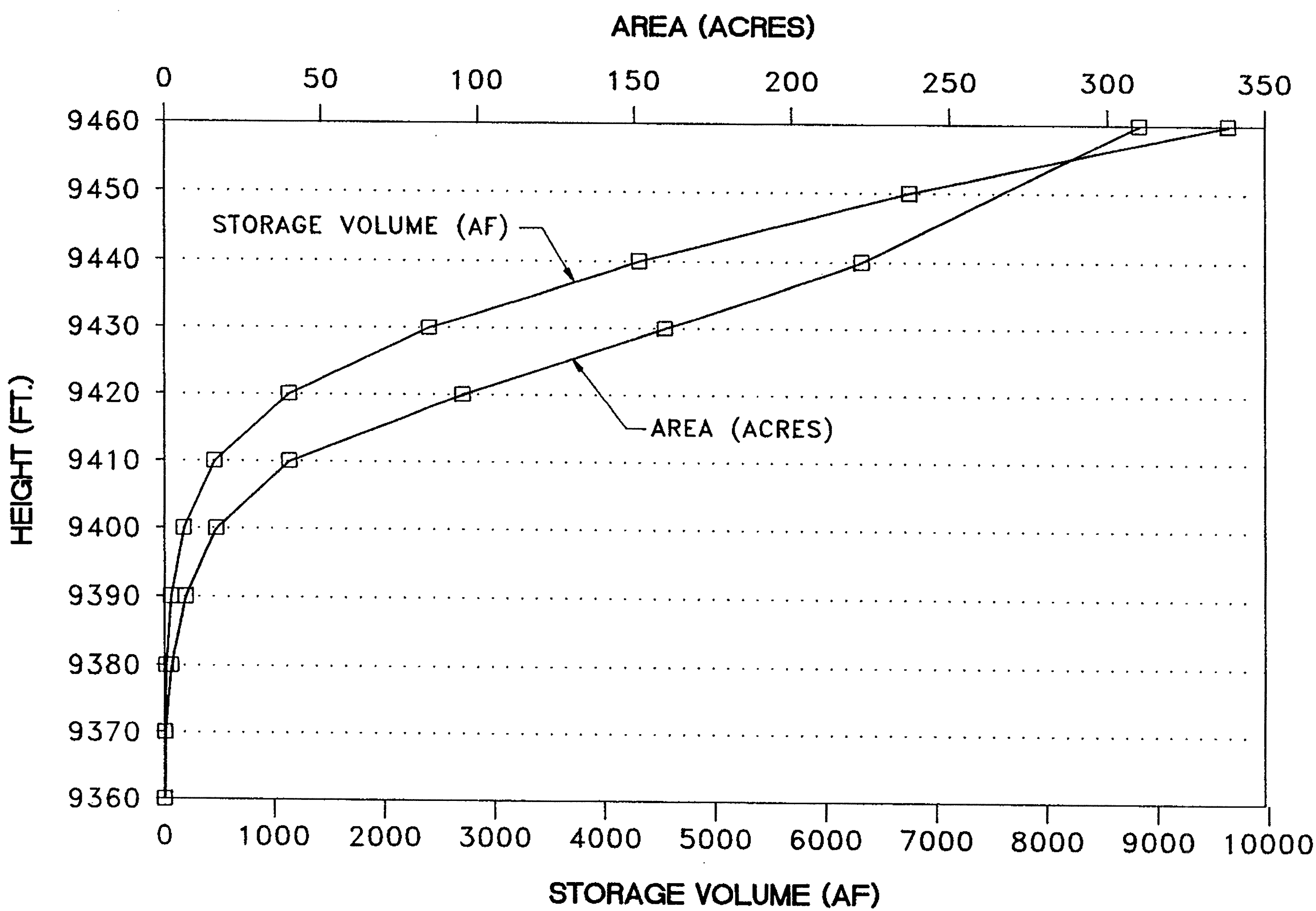
BINGHAM ENGINEERING
SALT LAKE CITY – (801) 532-2520

Design:
Drawn: STA
Checked:
Reviewed:

Date OCT. 1992 | Proj. # 1666-008 | Sht of

Castle Creek / Upper Mammoth Reservoir

FIGURE 27



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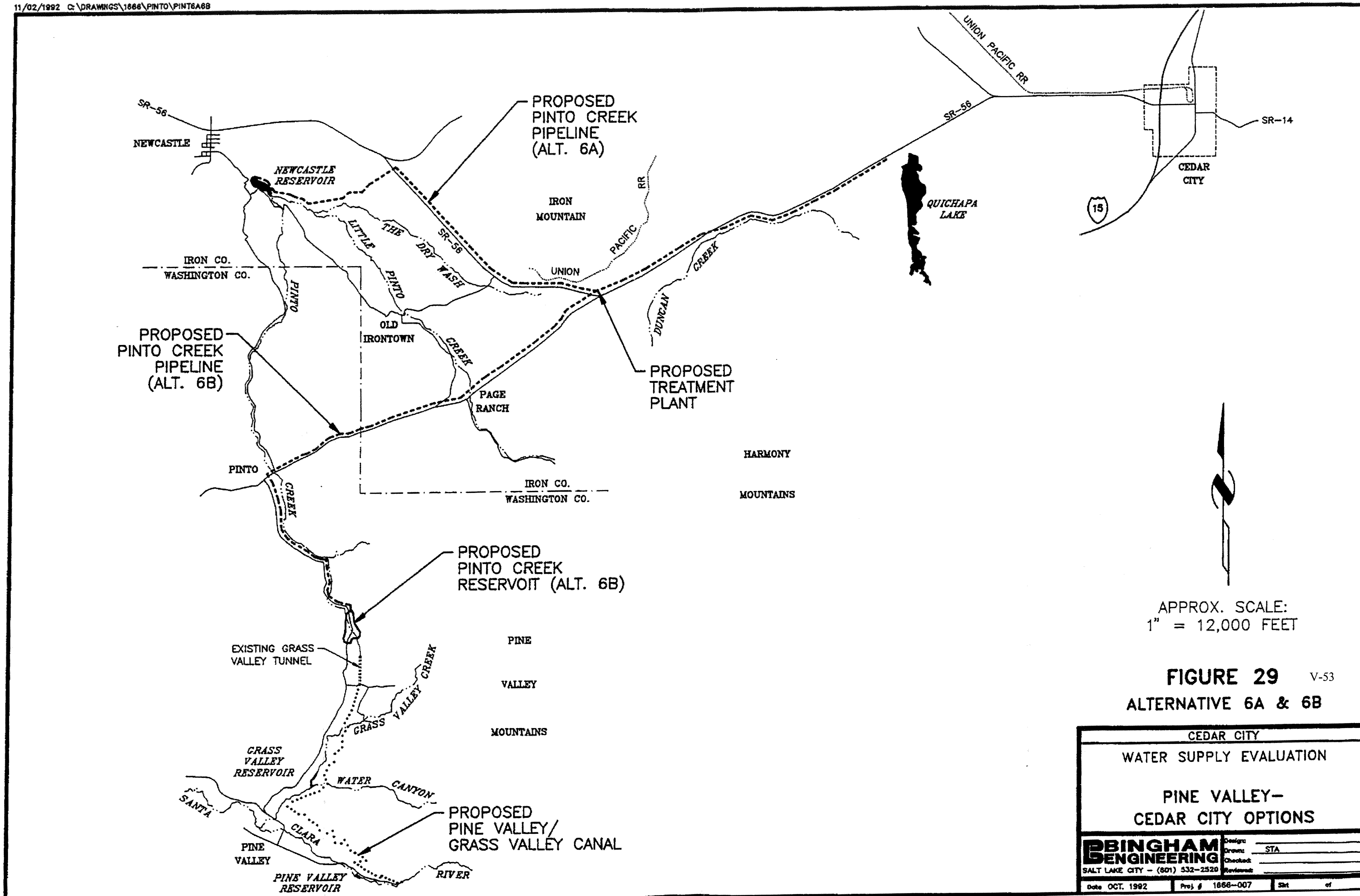


FIGURE 29

ALTERNATIVE 6A & 6B

PRELIMINARY COST ESTIMATE

CEDAR CITY

ALTERNATIVE 5

UPPER MAMMOTH CREEK – CASTLE CREEK RESERVOIR

"WITHOUT HYDRO"

ITEM NO.	DESCRIPTION	UNIT	EST'D QUANTITY	UNIT PRICE	TOTAL COST
1	Mobilization	LS	JOB	LS	363,000
2	Pipeline Easement	LF	238200	0.75	178,650
3	Clearing, & Grubbing	AC	273	900.00	245,700
4	Reseeding	AC	273	100.00	27,300
5	Roadway Improvement	LF	6000	10.00	60,000
6a	12" Pipeline	LF	29300	15.00	439,500
6b	12" Pipeline (Lower)	LF	19000	15.00	285,000
6c	20" Pipeline (Upper)	LF	174200	24.00	4,180,800
6d	22" Pipeline (Diversion)	LF	15700	25.00	392,500
7	Valves	EA	45	2200.00	99,000
8	Water Treatment Plant	LS	JOB	LS	3,300,000
	RESERVOIR				
9	Land	AC	363	1000.00	363,000
10	Clearing and Grubbing	AC	363	900.00	326,700
11	Reservoir Liner	AC	290	11000.00	3,190,000
12	Dam Embankment	CY	1050000	4	4,200,000
13	Spillway	LS	JOB	LS	250,000
14	Outlet Works	LS	JOB	LS	250,000
		SUB TOTAL			$18,151,150
		ENGINEERING 10%			$1,815,115
		CONTINGENCY 15%			$2,722,673
		TOTAL			$22,688,938

Historical Excerpts - Pine Valley/Grass Valley Tunnel

"In the year 1911, the Newcastle Reclamation Company began construction of the Grass Valley Creek Dam, which is referred to in the court decrees as the Newcastle Irrigation Co. Dam. The structure is situated on the Grass Valley Creek below the confluence with Water Canyon Creek and about two miles upstream from the confluence with Pine Valley Creek. The dam crest is 3,200 feet long and the dam has a maximum height of 95 feet. The storage capacity of the reservoir is about 26,650 acre feet. A drain canal 6,500 feet long with a maximum depth of 40 feet, was constructed upstream through the central portion of the reservoir basin and thence, a tunnel, bearing N. 23° 48′ W; 4,135 feet in length was constructed through the mountain to Pinto Creek."[13]

This drain canal reversed the natural drainage of the Grass Valley Basin from the south to the north, and consequently, was one of the first projects to take water from the Colorado drainage and put it into the Great Basin area. To supply water to the dam site and on to the tunnel entrance, a feeder canal, about 3½ miles long, was constructed up to the north and middle forks of the Pine Valley Creek. This Pine Valley "feeder" contour canal was built in 1914 with Japanese hand labor. It had an approximate capacity of 100 second feet of water and was constructed at an expense of about 65 thousand dollars.[14] The overall plan was to transfer water from the Santa Clara River drainage, where there is very little usable flat land, to the Grass Valley Reservoir for storage, and then through the tunnel to the Pinto Creek drainage. They planned to generate power by means of hydro-electric turbines, after which the water would continue to a location near the valley east of Newcastle (herdhouse). Plans included building another reservoir there to help control the spring run-off.

The Grass Valley Reservoir was completed and filled and water flowed over the spillway on the wetter years in 1919, 1920 and 1928; however, problems began to build up on every side. There were three major causes of the "downfall" of the Newcastle Reclamation Project.

1. There was not adequate funds and financing for such an extensive project. 2. There were many time-consuming law suits involving water rights. Moreover, "the general Land Office made an adverse report on the New Castle Reclamation Co. in the matter of approving the water supply for desert entry." (Jan. 1920 Report to Federal Land Bank State. Engineers from Engineer Appraisal) 3. The reservoir failed, due to leakage, which developed in the storage basin making it possible to store water only a short period of time in excessively wet years.[15] The volcanic formation would not stand the tremendous weight of the water.[16]

Many people never did give up the New Castle Project plan in general, or fighting for water rights. An example of this is the statement made in 1937 by J. X. Gardner — "the Grass Valley Reservoir leaks approximately 8 to 10 second feet of water, but, the leakage could be stopped with a $10,000 expenditure."

Water Supply Yield and Development

Based on area/altitude correlations with the stream gage on the Santa Clara River near Pine Valley, the proposed Pine Valley - Pinto Creek Diversion could develop a mean annual flow estimated to be 5000 acre feet. This quantity would be reduced however if minimal downstream flows will need to be maintained in the East Fork of the Santa Clara River. Visual observation of the stream flows indicate that the base flow is likely less than 1 cfs during much of the summer. If it is assumed that flows greater than 30 cfs would not be diverted and that any time minimum flows of 1 cfs or less were in the stream, they would be allowed to pass on downstream, the mean annual yield to the Grass Valley Tunnel is estimated to be 3630 acre feet. If minimum flows of 2 cfs and smaller were allowed to pass on downstream, then the mean annual yield to the Tunnel is estimated to be 3070 acre feet.

The waters of the Santa Clara River are fully appropriated with storage and regulation in Baker and Gunlock Reservoirs. In order for the proposed Pine Valley - Pinto Creek Diversion to materialize, water use exchanges would need to be made in the St. George/Lower Santa Clara River areas between the waters stored in Quail Creek and the waters stored in Gunlock Reservoir.

Environmental Considerations

The Pine Valley - Pinto Creek Diversion would entail taking spring runoff water from the head of the Santa Clara River just above the Pine Valley camp ground and diverting it around the hill into Grass Valley via the route of the old canal built by the Newcastle Reclamation Company to also divert water from the Colorado River system into the Great Basin. The water would be channeled along the east side of Grass Valley and then fed into Pinto Creek via the tunnel that runs through the hill on the north end of the valley. The canal from upper Pine Valley to Grass Valley Reservoir is in remarkably good condition and would require a minimum of work to at least bring it into a state of repair where a pipeline could be laid in it. There is also an existing canal running from Mill Canyon near Rencher's Ranch south along the east side of the valley at approximately the same elevation as the one coming from Pine Valley. With some connecting work and some change in grades along the Mill Creek canal there could be a system developed that would create the minimum amount of disturbance for such a project, especially if the water were to be conducted in a pipeline. Consequently the main environmental concern would lie in the fact that the scar left along the hill where the canal runs would be more visible than at present, where it is nearly obscured by a regrowth of mahogany and oak. It would likely remain visible for a lengthy period of time.

Allowing the water to flow down Pinto Creek into Newcastle Reservoir and then pumping the water from the Reservoir into Cedar City Valley would minimize environmental concerns because the pipeline would follow existing rights of way. The alternative plan calls for constructing a reservoir on Pinto Creek just below Grass Valley and then using a pressure pipeline to conduct the water to Cedar City via Pages Ranch and along the road between there and Cedar City. Environmental concerns would mainly be directed to the reservoir construction and pipeline installation down Pinto Creek between the reservoir and Page's Ranch.

The major environmental concerns are related to the impact of diverting the spring runoff out of the Santa Clara River. This water is captured in the reservoirs along the Santa Clara, including Pine Valley, Baker, and Gunlock. Water lost from the system would have an impact from Pine Valley to St. George and perhaps beyond.

Threatened and Endangered Species

The milkvetch Astragalus oophorus var. lonchocalyx occurs in northwestern Iron County in a habitat similar to that which would be encountered along the pipeline route between Pinto Creek and Page's Ranch. This plant is not known to occur in Washington County but a search should be made if the project is pursued.

Advantages and Disadvantages

The advantage of alternative 6a is that flows diverted through the Grass Valley Tunnel would be stored and regulated in the existing Newcastle Reservoir thus minimizing the initial cost of the project. The primary disadvantage is the potentially high pumping cost associated with lifting the water some 640 feet in elevation to get it from Newcastle Reservoir into Cedar City Valley.

Cost Estimate

The Estimated cost of developing Alternative 6a, Pine Valley - Pinto Creek Diversion - Newcastle Reservoir is shown on the following page. It should be noted that these costs do not include possible costs associated with exchanging existing water uses between Quail Creek and Gunlock Reservoirs.

PRELIMINARY COST ESTIMATE

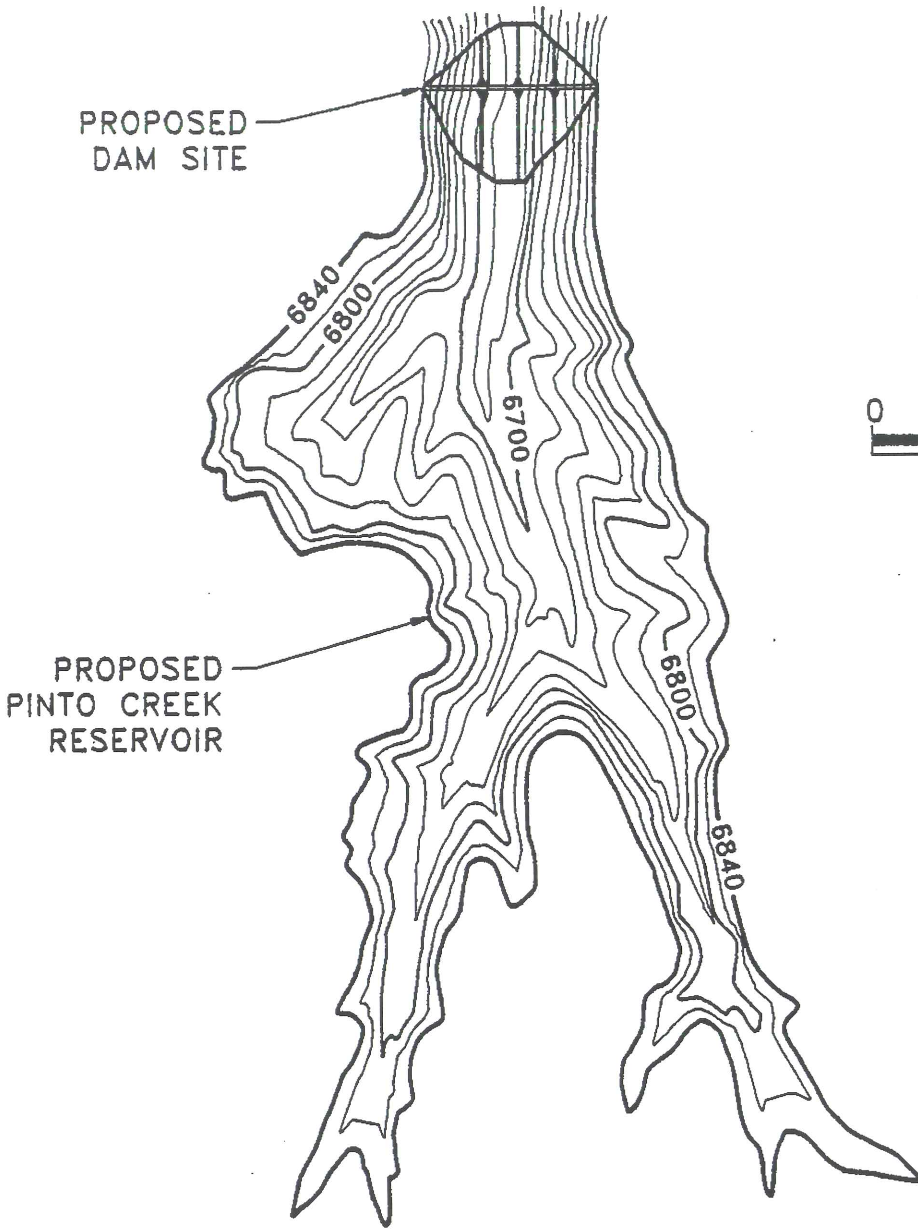
CEDAR CITY

ALTERNATIVE 6a

PINE VALLEY – PINTO CREEK DIVERSION

WITH NEW CASTLE RESERVOIR

ITEM NO.	DESCRIPTION	UNIT	EST'D QUANTITY	UNIT PRICE	TOTAL COST
1	Mobilization	LS	JOB	LS	170,000
2	Pipeline Easement	LF	105900	0.75	79,425
3a	20″ Pipeline (Lower)	LF	59400	35.00	2,079,000
3b	18″ Pipeline (Upper)	LF	46500	24.00	1,116,000
4	Valves	EA	21	4000.00	84,000
5	Water Treatment Plant	LS	JOB	LS	3,500,000
6	Pumping Stations	EA	2	150000.00	300,000
7	Electrical	EA	2	100000.00	200,000
8	Intake Structure at New Castle Reservoir	LS	JOB	LS	300,000
	CANAL				
9	Canal Easement	LF	8800	0.75	6,600
10	Clearing & Grubbing	AC	10	900.00	9,000
11	New Canal	LF	8800	4.00	35,200
12	Improve Existing Canal	LF	53500	2.00	107,000
13	Canal Liner	LF	62300	6.00	373,800
14	Diversion Structure Improvement	EA	2	75000.00	150,000
		SUB TOTAL			$8,510,025
		ENGINEERING 10%			$851,003
		CONTINGENCY 15%			$1,276,504
		TOTAL			$10,637,531



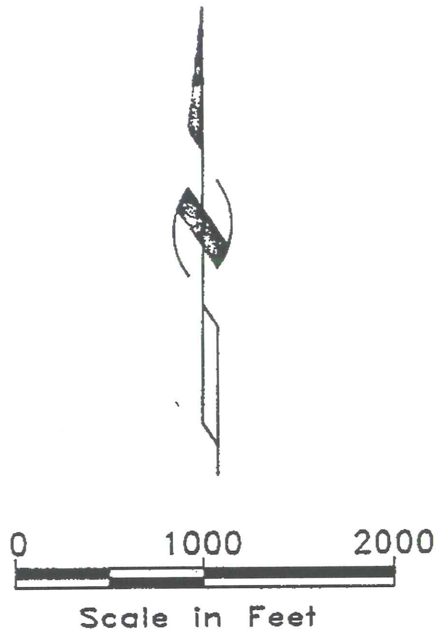


FIGURE 30

CEDAR CITY

WATER SUPPLY EVALUATION

PINTO CREEK
RESERVOIR

BINGHAM ENGINEERING
SALT LAKE CITY - (801) 532-2520

Design:
Drawn: STA
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Reviewed:

Date OCT. 1992 | Proj. # 1666-007 | Sht of

Pinto Reservoir

FIGURE 31

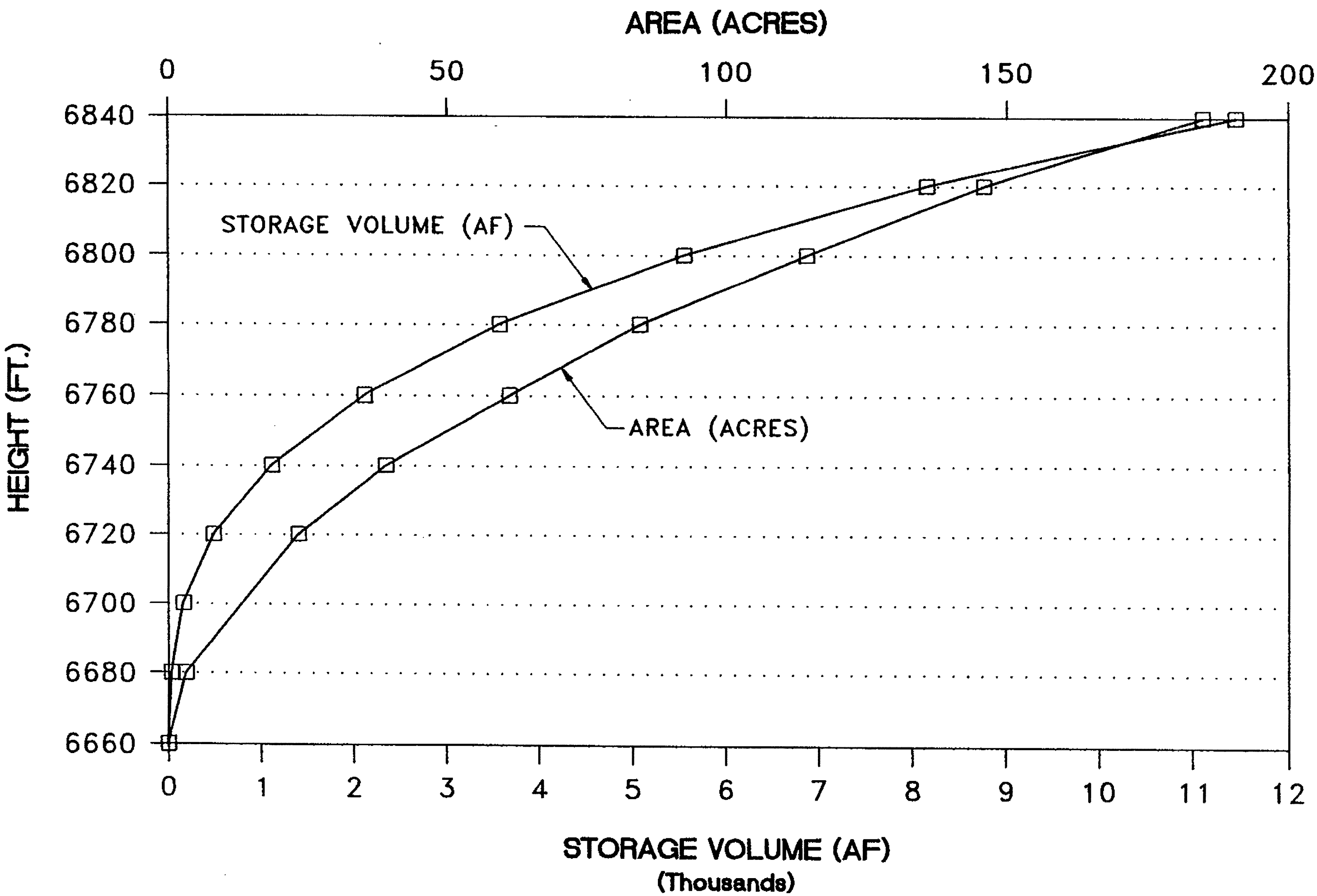
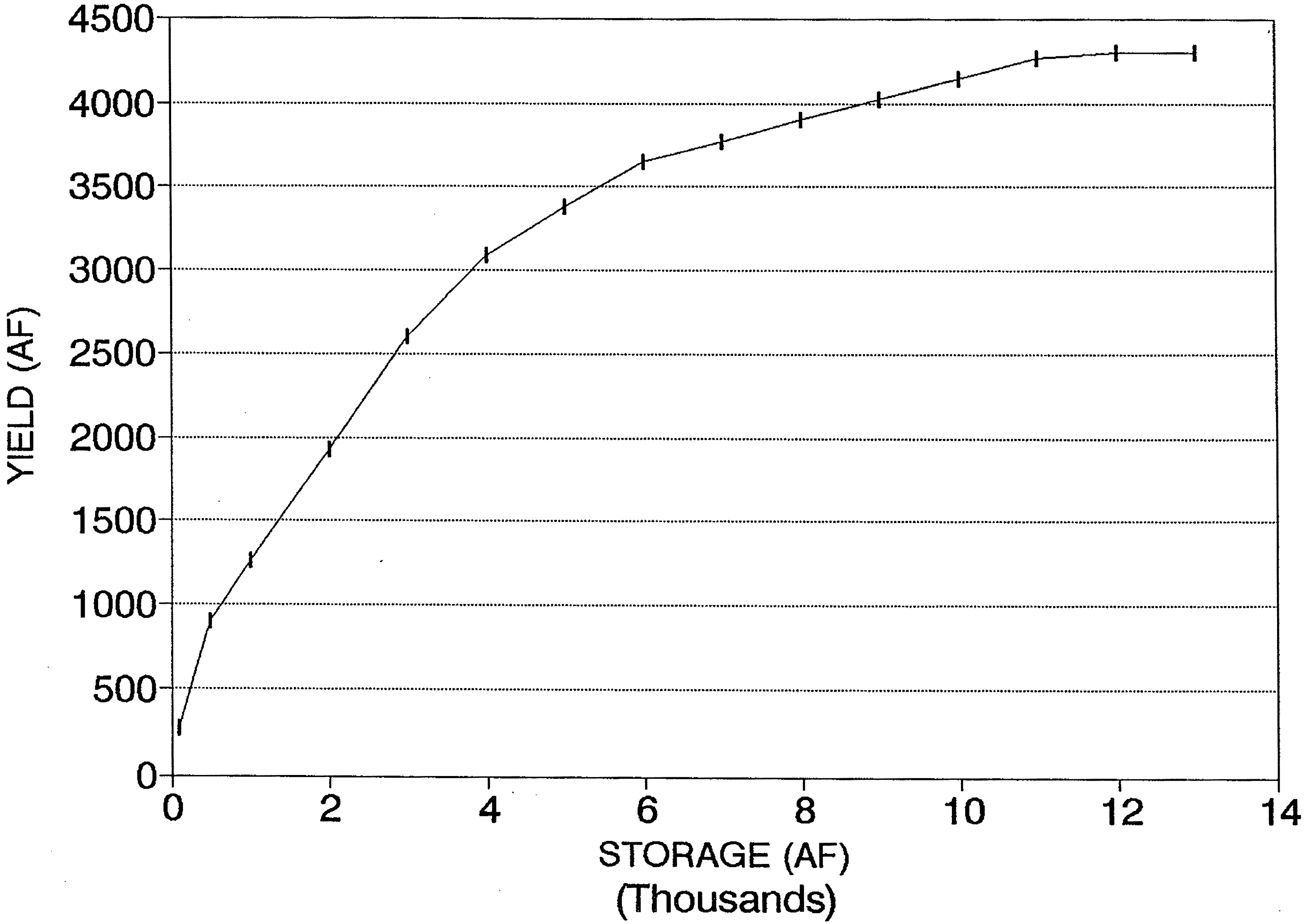


FIGURE 32
PINTO RESERVOIR



PRELIMINARY COST ESTIMATE

CEDAR CITY

ALTERNATIVE 6b

PINE VALLEY – PINTO CREEK DIVERSION

WITH PINTO CREEK RESERVOIR

ITEM NO.	DESCRIPTION	UNIT	EST'D QUANTITY	UNIT PRICE	TOTAL COST
1	Mobilization	LS	JOB	LS	247,000
2	Pipeline Easement	LF	127800	0.75	95,850
3	Roadway Relocation	LF	9000	20.00	180,000
4a	18″ Pipeline (Lower)	LF	46500	24.00	1,116,000
4b	22″ Pipeline (Upper)	LF	81300	28.00	2,276,400
5	Valves	EA	25	4000.00	100,000
6	Water Treatment Plant	LS	JOB	LS	3,500,000
	RESERVOIR				
7	Land	AC	150	1000.00	150,000
8	Clearing and Grubbing	AC	150	900.00	135,000
9	Dam Embankment	CY	840000	4.00	3,360,000
10	Spillway	LS	JOB	LS	250,000
11	Outlet Works	LS	JOB	LS	250,000
	CANAL				
12	Canal Easement	LF	8800	0.75	6,600
13	Clearing & Grubbing	AC	10	900.00	9,000
14	New Canal	LF	8800	4.00	35,200
15	Improve Existing Canal	LF	53500	2.00	107,000
16	Canal Liner	LF	62300	6.00	373,800
17	Diversion Structure Improvement	EA	2	75000.00	150,000
		SUB TOTAL			$12,341,850
		ENGINEERING 10%			$1,234,185
		CONTINGENCY 15%			$1,851,278
		TOTAL			$15,427,313

7. Quail Creek Pumping.

Project Description

The Quail Creek Pumping Alternative is shown in Figure 33. The project would entail construction of a water treatment plant near the southwest shore of Quail Creek Reservoir in the vicinity of St. George City's existing treatment plant. Water would be diverted through the treatment plant and then into the initial stage of an 8 stage pumping and pipeline conveyance system which would deliver water to Cedar City. The pipeline conveyance system would extend from Quail Creek Reservoir, along existing roadway or utility easements parallel to Interstate Highway 15 and thence to Cedar City's existing water tanks located on the hill southwest of the City.

The 41 mile pipeline would ascend about 3300 feet in elevation to the water storage tanks. Figure 34 shows a vertical profile of the pipeline would be 22 inch diameter steel pipe. The pumping stations would house 3 pumps, each capable of pumping 5 cfs.

Water Supply Yield and Development

For preliminary design and cost estimating purposes, the pumping and pipeline systems were designed to handle a flow discharge capacity of 15 cfs and an annual supply of 6500 acre feet. Since pumping costs are of prime importance in a project such as this, it was desirable to arrive at the most economical pipeline sizing and pumping options. Other discharge capacities and annual supply options were evaluated to determine the most economical pumping and delevery scheme. These evaluations are graphically summarized in Figures 35 through 38.

Environmental Considerations

Environmental concerns would be fewer for this proposed project than for any of the others. The Quail Creek Reservoir is already in place and operating. It is located below Zion National Park so that the major environmental issues have already been dealt with. The construction of the pipeline from Quail Creek to Cedar City is expected to be almost entirely within road or utility rights-of-way, where environmental concerns should be minimal. No threatened or endangered species are known to exist along the proposed pipeline route.

Advantages and Disadvantages

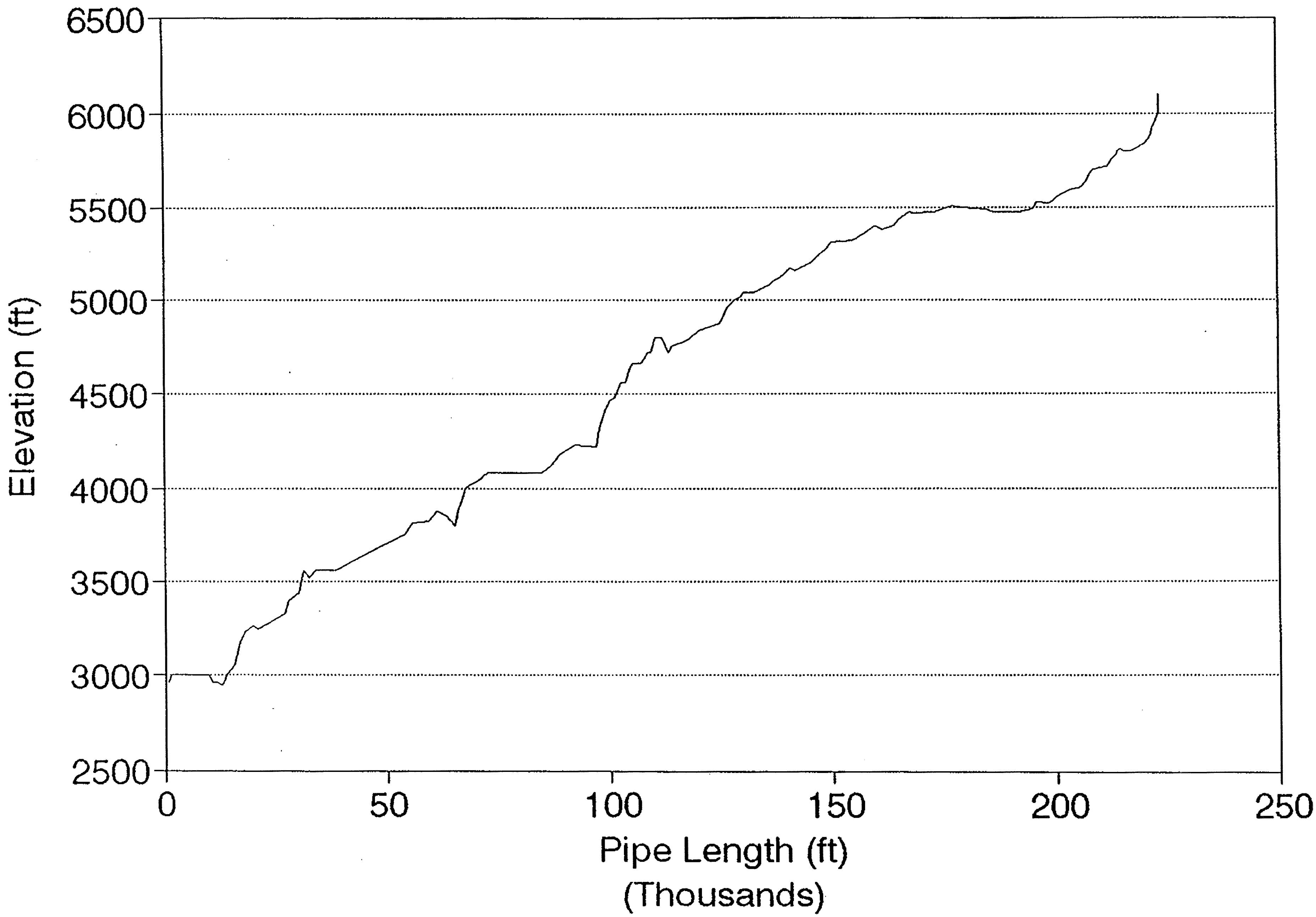
The principal advantage to this alternative is that Quail Creek Reservoir with its storage capability is already existing. Environmental issues have already been addressed.

The obvious disadvantage to the Quail Creek Pumping alternative is the high energy demand of this project. The cost of energy can also be expected to increase. The project is vulnerable to any future energy crisis and the project would require fairly high annual maintenace because it is mechanically dependant.

Cost Estimate

The Estimated cost of developing Alternative 7, Quail Creek Pumping, is shown on the page following Figure 38.

FIGURE 34
Vertical Alignment



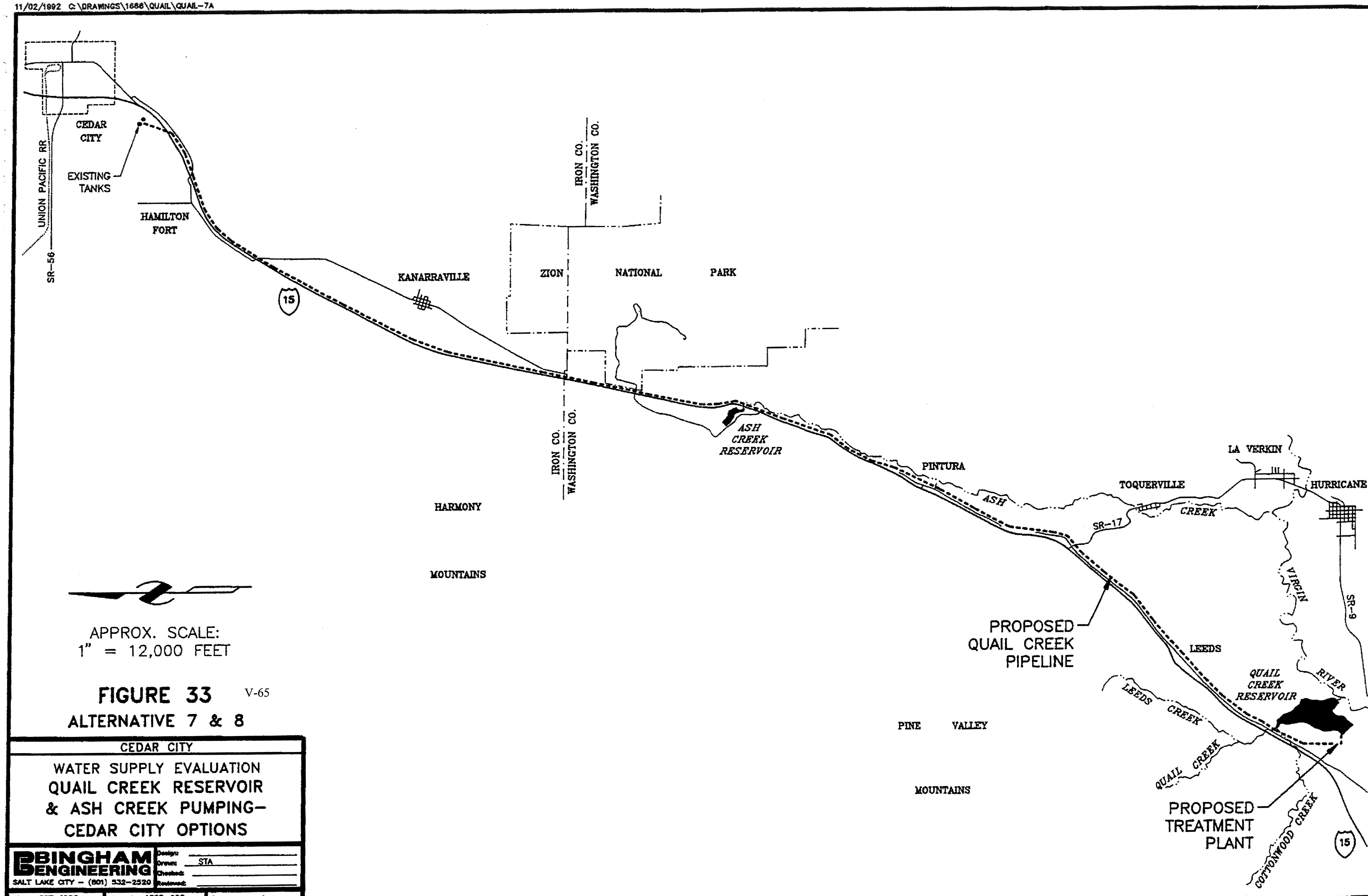


FIGURE 33

V-65

ALTERNATIVE 7 & 8

CEDAR CITY

WATER SUPPLY EVALUATION
QUAIL CREEK RESERVOIR
& ASH CREEK PUMPING–
CEDAR CITY OPTIONS

BINGHAM ENGINEERING
SALT LAKE CITY – (801) 532-2520

Design:
Drawn: STA
Checked:
Reviewed:

Date OCT. 1992 | Proj. # 1686-006 | Sht of

The project is largely on Forest land and would require necessary permits and easements as well as detailed Environmental evaluation.

Water Rights would be dependent on water supply/service agreement with Central Utah Water Conservancy District.

6a. Pine Valley - Pinto Creek Diversion - New Castle Reservoir

This alternative would reconstruct at least portions of the "Newcastle Reclamation Project" of the early 1900's which diverted water from Pine Valley Creek, a part of the Upper Santa Clara River, through the Grass Valley Tunnel and into Pinto Creek which flows into the Great Basin. Only high water flows in excess of 2 cfs would be diverted.

Diverted water would be stored and regulated in Newcastle Reservoir and pumped into Cedar City Valley.

There could possibly be some threatened and endangered plant species along the pipeline routes. This would need further investigation.

Water rights and water exchange problems would need to be resolved. Some water rights and uses on lower Santa Clara River (Gunlock Reservoir) would need to be exchanged with Virgin River Water (Quail Creek Reservoir). This exchange may be politically or legally difficult to accomplish.

6b. Pine Valley - Pinto Creek Diversion - Pinto Creek Reservoir

This alternative is the same as alternative 6a above except that a reservoir would be built on Pinto Creek just below the Grass Valley Tunnel exit for water storage and regulation. Water would then be diverted by gravity through a pipeline to Cedar City Valley.

Water Rights problems would be the same as those described under Alternative 6a.

7. <u>Quail Creek Reservoir Pumping</u>

This alternative would require construction of a water treatment plant at Quail Creek Reservoir, a pipeline extending from the treatment plant to Cedar City and a series of pumping stations to lift the treated water to Cedar City.

The project would largely follow existing developed routes therefore environmental conflicts would appear to be non-existent.

Water rights for the project would be in accordance with the 5/16/84 agreement with WCWCD.

8. <u>Ash Creek Reservoir Pumping - Groundwater Recharge</u>

This project envisions lining Ash Creek Reservoir with an impermeable membrane to prevent subsurface seepage from the reservoir, installing a pumping plant at the reservoir and then pumping the water northward into Cedar City Valley and injecting the water into the Cedar City Valley groundwater basin in the vicinity of the City's wells west if Quichapa Lake.

The amount of water that could be developed under this project alternative is assumed but appears to be in the range of possibility.

The Project would largely follow existing developed routes therefore environmental conflicts would appear to be non-existent.

This alternative would require an exchange agreement and/or modification to the 5/16/84 agreement with WCWCD.

<u>Cost Comparisons</u>

For each of the alternative water development projects evaluated, a preliminary estimate of the cost of developing the water supply for use in the Valley was prepared along with an economic appraisal of the project. This economic appraisal included determining the present worth value of the Construction cost, present worth value of estimated Operation and Maintenance cost and present worth value of potential Hydroelectric Power revenues for those projects that have a potential for generation of Hydroelectric Power. These values were then combined to show the total project present worth value. For comparative purposes, the present worth values for each project was determined using a project life expectancy of 50 years and amortizing the costs over this time period at an interest rate of 5%.

The Tables on the following two pages compare the costs of each of the alternative water development projects evaluated. The last two columns in each Table show the estimated average annual water supply that could be developed from outside the Cedar City Valley

CEDAR CITY WATER STUDY

FINANCIAL COMPARISON OF ALTERNATIVES WITH HYDRO POWER

NOTE: Present Values are costs over 50 years at 5.00% interest.

	ALTERNATIVE	CONSTRUCTION COST ($)	PRESENT VALUE O&M COST ($)	PRESENT VALUE HYDRO REVENUE ($)	PRESENT VALUE COST TOTAL ($)	PRESENT VALUE COST PER ACRE-FOOT ($/AF)	TRANS-BASIN AVERAGE ANNUAL SUPPLY (AF/YR)	TOTAL AVERAGE ANNUAL SUPPLY (AF/YR)
		ALTERNATIVES WITH APPROXIMATELY 6500 AF TRANSBASIN DIVERSION						
3b	Kolob Reservoir – Cedar City Diversion Crystal Creek Tunnel	46,496,250	3,299,218	5,874,392	43,921,076	6,757	6500	6,500
3c	Kolob Reservoir – Cedar City Diversion Crystal Creek Canal	24,991,813	3,442,170	5,874,392	22,559,591	3,471	6500	6,500
7	Quail Creek Reservoir Pumping	18,452,875	10,377,734	0	28,830,609	4,435	6500	6500
		ALTERNATIVES WITH APPROXIMATELY 3000 TO 4000 AF TRANSBASIN DIVERSION						
2a	Right Hand Canyon – Urie Creek Reservoir Crystal Creek Diversion by Canal	23,194,730	3,586,116	7,771,239	19,009,607	3,032	3970	6,270
2b	Right Hand Canyon – Urie Creek Reservoir Crystal Creek Diversion by Canal & Pipeline	23,142,768	3,406,936	7,188,706	19,360,998	3,338	3500	5,800
2c	Right Hand Canyon – Urie Creek Reservoir Crystal Creek Diversion by Pipeline	24,951,330	3,192,949	6,940,820	21,203,459	3,786	3300	5,600
3a	Kolob Reservoir – Cedar City Diversion	19,289,500	2,468,807	2,711,258	19,047,049	6,349	3000	3,000
4	Deep Creek – Mill Creek Tunnel	63,359,063	1,253,358	0	64,612,421	18,783	3440	3,440
6a	Pine Valley – Pinto Creek Diversion New Castle Reservoir	10,637,531	5,230,580	0	15,868,111	4,371	3630	3,630
6b	Pine Valley – Pinto Creek Diversion Pinto Creek Reservoir	15,427,313	2,726,766	0	18,154,079	5,001	3630	3,630
8	Ash Creek Reservoir Pumping Groundwater Recharge	9,596,719	4,316,833	0	13,913,552	4,638	3000	3000
		ALTERNATIVES WITH NO TRANSBASIN DIVERSION						
0	Cedar City Valley Groundwater Development	15,356,375	6,905,788	0	22,262,163	3,425	0	6500
1	Right Hand Canyon – Urie Creek Reservoir	13,375,636	1,998,719	2,850,694	12,523,661	5,445	0	2,300
		SEVIER RIVER WATER						
5	Upper Mammoth Creek – Castle Creek Reservoir Navajo Lake	24,753,188	4,043,862	4,718,879	24,078,171	7,082	3400	3,400

CEDAR CITY WATER STUDY

FINANCIAL COMPARISON OF ALTERNATIVES WITHOUT HYDRO POWER

NOTE: Present Values are costs over 50 years at 5.00% interest.

	ALTERNATIVE	CONSTRUCTION COST ($)	PRESENT VALUE O&M COST ($)	PRESENT VALUE HYDRO REVENUE ($)	PRESENT VALUE COST TOTAL ($)	PRESENT VALUE COST PER ACRE FOOT ($/AF)	TRANS-BASIN AVERAGE ANNUAL SUPPLY (AF/YR)	TOTAL AVERAGE ANNUAL SUPPLY (AF/YR)
	ALTERNATIVES WITH APPROXIMATELY 6500 AF TRANSBASIN DIVERSION							
3b	Kolob Reservoir – Cedar City Diversion Crystal Creek Tunnel	42,838,500	2,795,576	0	45,634,076	7,021	6,500	6,500
3c	Kolob Reservoir – Cedar City Diversion Crystal Creek Canal	21,334,063	2,938,529	0	24,272,592	3,734	6,500	6,500
7	Quail Creek Reservoir Pumping	18,452,875	10,377,734	0	28,830,609	4,435	6,500	6,500
	ALTERNATIVES WITH APPROXIMATELY 3000 TO 4000 AF TRANSBASIN DIVERSION							
2a	Right Hand Canyon – Urie Creek Reservoir Crystal Creek Diversion by Canal	20,148,855	3,083,496	0	23,232,351	3,705	3,970	6,270
2b	Right Hand Canyon – Urie Creek Reservoir Crystal Creek Diversion by Canal & Pipeline	20,331,643	2,940,651	0	23,272,294	4,012	3,500	5,800
2c	Right Hand Canyon – Urie Creek Reservoir Crystal Creek Diversion by Pipeline	22,241,205	2,745,992	0	24,987,197	4,462	3,300	5,600
3a	Kolob Reservoir – Cedar City Diversion	16,214,250	2,219,268	0	18,433,518	6,145	3,000	3,000
4	Deep Creek – Mill Creek Tunnel	63,359,063	1,253,358	0	64,612,421	18,783	3,440	3,440
6a	Pine Valley – Pinto Creek Diversion New Castle Reservoir	10,637,531	5,230,580	0	15,868,111	4,371	3,630	3,630
6b	Pine Valley – Pinto Creek Diversion Pinto Creek Reservoir	15,427,313	2,726,766	0	18,154,079	5,001	3,630	3,630
8	Ash Creek Reservoir Pumping Groundwater Recharge	9,596,719	4,316,833	0	13,913,552	4,638	3,000	3,000
	ALTERNATIVES WITH NO TRANSBASIN DIVERSION							
0	Cedar City Valley Groundwater Development	15,356,375	6,905,788	0	22,262,163	3,425	0	6,500
1	Right Hand Canyon – Urie Creek Reservoir	11,854,011	1,805,049	0	13,659,060	5,939	0	2,300
	SEVIER RIVER WATER							
5	Upper Mammoth Creek – Castle Creek Reservoir Navajo Lake	22,688,938	3,759,493	0	26,448,431	7,779	3,400	3,400

drainage basin and the estimated total average annual water supply that could be developed under each project, including in-basin supply where applicable.

The first Table compares the present worth value of each alternative project based on the assumption that hydroelectric power will be generated at each project that has the potential for hydroelectric power generation and that the revenues derived from the power generation will be an economic benefit to the project. Utah Power and Light Company's current Avoided Cost Schedule was used as the basis for determining the present value of hydroelectric power generation. Utah Power and Light Co. did not have a power cost schedule for pumping rates, therefore a rate of 1.5 times the Avoided Cost Schedule was used.

The second Table compares the present worth value of each project assuming that the hydroelectric power generation potential would not be developed as a part of the project.

Identification and Comparison of Other Issues

In addition to the cost and economic comparisons of each of the alternatives as shown on the previous two pages, there are additional permit requirements, issues and concerns of various regulatory and approving agencies or organizations. The table on the following page lists each of the project alternatives, identifies the present value cost, the water supply that would be developed and permits that would likely be required. It also identifies potential levels of concern for various environmental and water right issues. The Table provides a reference for an over-all comparison of the alternatives evaluated in this study.

Conclusions

Cedar City has made a long standing commitment to augment their existing water supplies through importation of water from the Virgin River drainage basin. This commitment is demonstrated by their past participation in the Kolob and Quail Creek Reservoir Projects. One goal of this evaluation was to compare the alternatives on an equal basis to assist the City in making a decision on the correct alternative water development plan to pursue and bring to realization.

It is apparent from the foregoing Tables that development of hydroelectric power plays an important role in the over-all cost of a transbasin importation plan for water development to serve Cedar City Valley. Similarly, the expected future increase in power costs casts some doubt on the value of the alternatives which rely heavily on pumping for their development. It appears that one decision the City must make is whether or not the City wishes to include hydroelectric power generation, with its potential for cost reduction, as a part of the water development plan.

With hydroelectric power generation the most inexpensive (cost per acre foot) transbasin importation alternative is Alternative 2a, Urie Creek Reservoir - Crystal Creek Canal. Following closely behind this alternative is the Kolob Reservoir - Crystal Creek Canal (Alternative 3c) which has been studied for many years on different occasions.

In order to maximize the development of water for Cedar City Valley, assuming the estimates of available water supply are correct, the following combination of alternatives is suggested.

With hydroelectric power generation.

Alternative 1. Right Hand Canyon - Urie Creek Reservoir plus Alternative 3c. Kolob Reservoir-Crystal Creek Diversion by Canal.
Present value total cost = $35,083,252.

This combination would be closely followed by Alternative 2a. Right Hand Canyon-Urie Creek Reservoir with Crystal Creek Diversion by canal plus Alternative 3a. Kolob Reservoir-Cedar City Diversion.
Present value total cost = $38,056,656.

Without hydroelectric power generation.

The same combinations above also appear to maximize the water development for Cedar City Valley with the least present value total cost without hydroelectric power generation. These costs are as follows:

Alternative 1 plus Alternative 3c.
Present value total cost = $37,931,652

Alternative 2a plus Alternative 3a.
Present value total cost = $41,665,869

Recommendations

1. Stream Gage Installation

The water supply that might be developed in each of the transbasin importation alternatives in many cases has been estimated using correlation techniques. It is believed that these estimates are conservative, but they need to be verified. It is recommended that stream gages be installed at appropriate locations in the Urie Creek and Crystal Creek drainages to verify the water supply estimates. These gages should be installed as follows:

a. On Urie Creek near the proposed dam site.
b. Upper Crystal Creek Drainages on Crystal Creek, Shiver Creek, Co-op Spring Creek and possibly on Horse Hollow. These gages should be installed at about the 9000 ft to 9200 ft elevation level.
c. If Cedar City wishes to further pursue the Ash Creek Pumping alternative, a stream gage should also be installed to measure inflow to Ash Creek Reservoir.

The gages should be operated for a sufficient period of time to verify a correlation with existing long term stream gages in the area.

2. Additional Studies of Alternatives

It is recommended that transbasin importation alternatives, other than Urie Creek, Crystal Creek, Kolob Reservoir and possibly Ash Creek, be excluded from further study at this time.

3. Additional Studies

We suggest that Cedar City continue to pursue the following alternatives for water importation with more detailed preliminary design/feasibility studies to verify the water supply and to re-evaluate or verify the plan alternatives and modifications, including hydroelectric power generation. These studies should also examine in more depth the permitting requirements and environmental issues that could possibly place undue restrictions on the proposed water development and importation into the Valley.

<u>Alternative 2a</u>	Importation of water from upper Crystal Creek via Urie Creek.
<u>Alternative 3c</u>	Importation of water via Kolob Reservoir and Crystal Creek Canal.

This work should include confirmation or necessary modification of the preliminary design and cost estimates presented in this report. It should also examine the possibility of developing additional in-basin water at the proposed Urie Creek Reservoir site.

Further studies should also examine the types of water conveyance facilities, namely pipelines or canals, which would best serve the needs of the development as well as related easements and rights of way. More detailed examination of other project features will also be needed to determine the most cost effective final design.

4. Water Conservation

Implementation of water conservation practices can reduce the demand for high quality municipal water. It is suggested that Cedar City consider the following to help delay the increasing demand for this water.

a. Restrict the time of day and/or days during the week when outside use of culinary water for irrigation can be used.

b. In new development which relies solely on culinary water supplies for outdoor irrigation, restrict the area of land which can be irrigated or the amount of water that can be used for outside irrigation.

c. Adopt an agressive water use rate structure which has a minimal charge rate for a certain amount of water used, then a progressively higher rate for each 1000 gallons of water used thereafter. In other words, the more water a customer uses the more he pays for that use. This would reduce water waste.

APPENDIX A

1984 Agreement between Cedar City and Washington County Water Conservancy District

A G R E E M E N T

This AGREEMENT entered into this 16 day of May, 1984, by and between WASHINGTON COUNTY WATER CONSERVANCY DISTRICT, a water conservancy district organized pursuant to the laws of the State of Utah, and hereinafter referred to as "WCWCD", CEDAR CITY CORPORATION, a municipal corporation of the State of Utah, hereinafter referred to as "Cedar", KOLOB RESERVOIR AND STORAGE ASSOCIATION, INC., a Corporation of the State of Utah, hereinafter referred to as "Kolob", HURRICANE CANAL COMPANY, a Corporation of the State of Utah, hereinafter referred to as "Hurricane", and ST. GEORGE AND WASHINGTON CANAL COMPANY, a Utah Corporation, hereinafter referred to as "St. George."

W I T N E S S E T H

WHEREAS, the following agreements have been entered into for the development of water resources in Iron County, Utah, and Washington County, Utah, to wit:

> Agreement dated August 26, 1953 between Cedar, Iron County, Kolob, and Washington County; Agreement dated January 19, 1955 between Kolob and Owen B. Wright, Floyd Wright, Clarence Lamoreaux, Robert A. Thorley, and Ervil Saunders, or their successors; Agreement dated June 25, 1956 between Utah Board of Water Resources (hereinafter "Water Resources"), Hurricane and St. George; and

WHEREAS, Kolob and Cedar recognize that Owen B. Wright, Floyd Wright, Clarence Lamoreaux, Robert A. Thorley and Ervil Saunders, or their successors, are entitled to the use of the first six hundred (600) acre feet of water annually stored in Kolob Reservoir pursuant to the above Agreement dated January 19, 1955; and

WHEREAS, WCWCD is the sponsor of the water storage project in the Virgin River drainage known as the Quail Creek Project, construction of which has commenced and is scheduled for completion in the winter of the year 1984-1985, comprising the Quail Creek Reservoir with a storage capacity of approximately forty thousand (40,000) acre feet created by a dam to be constructed on Quail Creek in the Virgin River Drainage and related works and facilities and the water rights therefor and including a diversion facility on the Virgin River situated upstream from the Hurricane diversion and the St. George diversion and a feeder pipeline therefrom to the Quail Creek Reservoir; and

WHEREAS, Cedar anticipates future population growth and future demands on its present sources of water supply and desires to provide for additional sources of water supply including those provided for in this Agreement; and

WHEREAS, it will be for the mutual benefit of the parties hereto for Cedar to participate in the repayment of a portion of the costs of construction of the Quail Creek Project in exchange for the right of Cedar to divert water from the upper Virgin River drainage for transbasin conveyance to Cedar in the manner provided for in this Agreement; and

WHEREAS, in the event Cedar determines not to construct the facilities necessary to divert water from the upper Virgin River drainage for transmountain diversion to Cedar, it is intended that WCWCD will reimburse Cedar for the amount then paid by Cedar towards the cost of construction of the Quail Creek Project with interest and WCWCD will purchase Cedar's two-fifths (2/5) interest in Kolob Reservoir, the water rights therefor and Reservoir Real Property hereinabove described; and

WHEREAS, the parties hereto desire to cooperate and mutually agree upon certain water resource developments within the Virgin River drainage and to define their respective rights, all as are more particularly set forth in this Agreement.

NOW, THEREFORE, in consideration of the mutual covenants and promises contained herein the parties agree as follows:

1. Cedar shall purchase from WCWCD the right to use of three thousand three hundred forty (3,340) acre feet annually of the waters stored in Quail Creek Reservoir as developed by the Quail Creek Project for delivery to Kolob, Hurricane and

St. George, as their interests appear, in exchange for the rights of Cedar to divert waters from sources in the upper Virgin River drainage for transbasin conveyance to Cedar for its own use, in accordance with the terms and provisions of this Agreement.

2. In exchange for the 3,340 acre feet of storage water delivered to Kolob, Hurricane and St. George as provided for in the preceding paragraph 1 Cedar shall have the right to divert annually one thousand six hundred (1,600) acre feet of the primary waters from Crystal Creek in addition to any high water rights Cedar may own or hereafter acquire, and in addition thereto, all of the waters developed by and stored in Kolob Reservoir for transbasin conveyance from both Crystal Creek and Kolob Reservoir to Cedar for its own use. Diversions under the foregoing high water rights shall be subordinated to the rights of WCWCD to divert the waters of the Virgin River up to the three hundred fifteen (315) c.f.s. diversion capacity of the Quail Creek Project feeder pipeline.

3. In the event Cedar shall determine in its sole discretion that it is economically or environmentally infeasible to divert and convey to Cedar both the waters of Crystal Creek and Kolob Reservoir, as provided for in the preceding paragraph, then and in that event Cedar shall have the right to develop any and all of those springs within the Virgin

River drainage situated in the upper Mill Creek and Three Creeks drainages and to divert collectively therefrom up to six thousand one hundred (6,100) acre feet of water annually for transbasin conveyance to Cedar for its own use, provided however, that during the months of July, August and September of each year, Cedar shall not divert more than 533-1/3 acre feet per month during each of those months from the said springs.

4. Cedar shall pay to WCWCD the sum of One Hundred Forty-Two Thousand Five Hundred Dollars ($142,500.00) each year for a period of fifty (50) years which sum is the agreed upon pro-rata share of all costs of construction of the Quail Creek Project apportioned to the annual storage and delivery of the said 3,340 acre feet and to all costs and expenses of administration, operation and maintenance relating thereto. The first payment shall be due and payable on December 1 of the year in which the 3,340 acre feet of water is made available to Kolob, Hurricane and St. George and the successive payments shall be due and payable on December 1 of each year thereafter until a total fifty (50) annual payments have been made unless terminated earlier pursuant to the provisions of paragraph 10 hereinafter.

5. Cedar shall have nine (9) years from the date hereof within which to make a final decision of whether it is eco-

nomically and environmentally feasible to divert and convey to Cedar both the waters of Crystal Creek and Kolob Reservoir as provided for in paragraph 2 hereinabove and Cedar shall so notify WCWCD in writing within sixty (60) days after such final decision is made by Cedar.

6. In the event Cedar shall notify WCWCD pursuant to the preceding paragraph 5 that it is economically and environmentally feasible to divert and convey to Cedar both the waters of Crystal Creek and Kolob Reservoir,

(a) Cedar shall be entitled to immediately commence the construction of the necessary works to accomplish those puposes and to divert the waters of Crystal Creek and Kolob Reservoir for Cedar's own use provided that until such time as the Quail Creek Project is sufficiently completed for WCWCD to make available the 3,340 acre feet of storage water in Quail Creek Reservoir to Kolob, Hurricane and St. George, then

(i) Cedar shall not divert the waters of Crystal Creek nor its share of the waters from Kolob Reservoir and

(ii) WCWCD shall be entitled to use Cedar's existing share of the waters stored in Kolob Reservoir and WCWCD shall pay to Cedar the sum of Three Thousand Three Hundred Seventy-Five Dollars

($3,375.00) each year which shall be due and payable on or before the first day of January of the year in which WCWCD shall use such waters.

(b) Kolob shall convey its entire three-fifths (3/5) interest in Kolob Reservoir, the water rights therefor and the Reservoir Real Property as hereinabove described, to Cedar by good and sufficient deed with marketable title and free and clear of all encumbrances at the time Cedar makes payment in full to WCWCD of all payments required under paragraph 4 hereinabove.

(c) Cedar shall have an option for a period of ten (10) years from the date hereof to purchase from Kolob all of the "Above Reservoir Real Property" as described hereinabove in accordance with the terms and provisions of the next succeeding paragraph 7.

7. The option provided in the next preceding subparagraph 6(c) shall be exercised by Cedar serving written notice thereof on WCWCD on or before ten (10) years from the date hereof. In that event the purchase price shall be the fair market value as of the date of the exercise of said option determined as follows:

(a) Cedar shall employ two qualified real estate appraisers and Kolob shall employ two equally qualified real estate appraisers and those four shall jointly select a fifth equally qualified real estate appraiser.

(b) Each of the five real estate appraisers shall prepare a written appraisal report stating his opinion of the fair market value of the "Above Reservoir Real Property", the basis therefor and supporting data using standard appraisal methods and practices and each shall deliver a copy of his appraisal report to Cedar, Kolob and to WCWCD.

(c) The fair market value as the purchase price shall be determined by the arithmetical average of the three remaining appraisals after discarding the highest and the lowest appraisal.

The purchase price shall be paid by Cedar to Kolob in cash within ninety (90) days after the delivery of the last of the above five (5) appraisal reports. Kolob shall convey to Cedar good and marketable title to the "Above Reservoir Real Property" by Warranty Deed and free and clear of all liens and encumbrances and shall furnish to Cedar a policy of title insurance in the face amount of the purchase price insuring title in the name of Cedar and issued by a title insurance company authorized to transact business in the State of Utah. Cedar and Kolob shall pay each of the two real estate appraisers employed by them, respectively, and Cedar and Kolob each shall pay one-half of the fees and expenses of the fifth real estate appraiser. Kolob shall pay all recording fees and the costs of the title insurance policy.

8. In the event that Cedar shall notify WCWCD pursuant to paragraph 5 hereinabove that it is economically or environmentally infeasible to divert and convey to Cedar both the waters of Crystal Creek and Kolob reservoir, Cedar shall have one (1) year from the date thereof within which to make the final decision on whether it is economically and environmentally feasible to develop the springs situated in the upper Mill Creek and Three Creeks drainages as provided for in paragraph 3 hereinabove and Cedar shall so notify WCWCD within sixty (60) days after such final decision is made by Cedar.

9. In the event that Cedar shall notify WCWCD pursuant to the preceding paragraph 8 that it is economically and environmentally feasible to develop the springs in the upper Mill Creek and Three Creeks drainages

(a) Cedar shall be entitled to immediately commence the construction of the necessary works and facilities to accomplish those purposes and to divert the waters from the springs in the upper Mill Creek and Three Creeks drainages for Cedar's own use as provided for in paragraph 3 hereinabove, and provided however, that until such time as the Quail Creek Project is sufficiently completed for WCWCD to make available the 3,340 acre feet of storage water in Quail Creek Reservoir to Kolob, Hurricane and St. George, Cedar shall not divert the waters of springs in the Upper Mill Creek and Three Creeks drainages for its own use, and

(b) Cedar shall relinquish all of its claims to the waters of Crystal Creek and Kolob Reservoir and upon the completion of its development of said springs and diversion and conveyance facilities relating thereto, Cedar shall convey its entire two-fifths (2/5) interest in Kolob Reservoir, the water rights therefor and the Reservoir Real Property as hereinabove described to WCWCD by good and sufficient deed with marketable title and free and clear of all encumbrances and Cedar shall quitclaim all of its remaining right, title and interest in and to the waters of Crystal Creek to WCWCD.

10. Cedar shall have the right, notwithstanding any other provison herein, at its election to terminate its obligations to continue making the payments required of it under paragraph 4 hereinabove upon and after the occurrence of all of the following events and conditions, to wit:

(a) upon the expiration of ten (10) years after the date of the first annual payment required under paragraph 4 hereinabove, and

(b) at such time as the maximum mill levy authorized by law (presently five mills) to be assessed by WCWCD on all taxable property situated within WCWCD would yield the sum of Seven Hundred Ninety Thousand Dollars ($790,000.00) or more, annually and

(c) upon serving written notice on WCWCD that Cedar has made a final determination that it is economically or environmentally infeasible for Cedar to develop water in the upper Virgin River drainage for transbasin conveyance to Cedar.

On or before the first day of August of each year, WCWCD shall furnish to Cedar a copy of the statement showing the aggregate valuation of all taxable property within WCWCD as transmitted to WCWCD by the auditor of Washington County pursuant to Section 59-5-6 U.C.A. 1953 (1982 Supp.) together with the rate of levy certified by WCWCD to the Board of Commissioners of Washington County pursuant to the provisions of Section 73-9-16 U.C.A 1953 (1982 Supp.)

11. In the event that the conditions set forth in the preceding subparagraphs 10(a) and 10(b) have been fulfilled and satisfied and in the further event that Cedar shall serve the written notice provided for in the preceding paragraph 10(c) on WCWCD, then and in those events:

(a) WCWCD shall repay to Cedar all of the monies theretofore paid by Cedar pursuant to paragraph 4 hereinabove together with simple interest thereon at the rate of five percent (5%) per annum as hereinafter determined over a period of twenty-five (25) years. Payment shall be made to Cedar in twenty (20) equal annual installments with the first annual payment due and payable in five (5) years from the date of the written notice herein provided for and like payments shall be due and payable on the same date of each successive year until all twenty (20) payments shall have been made. The amount of interest at the rate of five percent (5%) per annum for each of the first five years shall be added to the amount of the monies previously paid by Cedar and the total amount thereof shall be capitalized at the end of the first five (5) year period and shall be paid together with simple interest on the remaining balance over the remaining twenty (20) year period. [e.g., if Cedar had paid WCWCD $1,000,000 then the $1,000,000 plus 5% interest per year, or $50,000 each year over the first five-year period will be capitalized ($1,000,000 plus $250,000). Over the next twenty (20) year period, $1,250,000 plus 5% interest per annum would be paid to Cedar in equal annual installments of $100,303.23.]

(b) Cedar shall sell to WCWCD and WCWCD shall purchase Cedar's entire two-fifths (2/5) interest in and to Kolob Reservoir, the water rights therefor and the Reservoir Real Property as hereinabove described, by paying to Cedar Forty-Nine Thousand Four Hundred Sixty Dollars Thirty-Two Cents ($49,460.32) each year for fifty (50) consecutive years, it being understood that such payment is calculated by amortizing Nine Hundred Two Thousand Nine Hundred Forty-Four Dollars ($902,944) at five percent (5%) simple interest over a period of fifty (50) years. The first payment shall be due and payable one (1) year after the date of the written notice herein provided for and like payments shall be due and payable on the same date of each successive year until all fifty (50) payments shall have been made at which time Cedar shall convey its entire two-fifths (2/5) interest in Kolob Reservoir, the water rights therefor and the Reservoir Real Property as hereinabove described to WCWCD by good and sufficient deed with marketable title free and clear of all encumbrances.

(c) WCWCD shall continue to store and deliver the 3,340 acre feet of water annually provided for in paragraph 1 hereinabove to Kolob, Hurricane and St. George.

12. Cedar shall have the obligation to prepare and file the necessary change applications on the applicable water rights owned or to be acquired by Cedar and to obtain the approvals thereof by the Utah State Engineer to authorize the diversion and use by Cedar of 1,600 acre feet annually of the primary waters of Crystal Creek (and additional high water rights) and the three-fifths (3/5) of the waters of Kolob

Reservoir or in the alternative 6,100 acre feet of the waters from the springs in the upper Mill Creek and Three Creeks drainages, all as hereinabove provided, and the parties hereto shall not oppose or protest such applications as are filed to carry out the provisions of this Agreement.

13. None of the provisions of this Agreement are intended to be and shall not be construed to be in violation of Article XI, Section 6 of the Constitution of Utah, it being understood that

(a) the provisions of paragraph 6(a)(ii) hereinabove are intended and shall be construed as a temporary sale of surplus water pursuant to Section 10-8-14 UCA 1953, as amended; and

(b) the provisions of paragraphs 1, 2 and 3 hereinabove are intended and shall be construed as an exchange of water rights and sources of water supply of equal value; and

(c) the provisions of paragraph 11 hereinabove are intended and shall be construed to apply to inchoate water rights and sources of water supply which have not been developed or used by Cedar and cannot be developed either with economical or physical feasibility or in the best interests of Cedar and its inhabitants.

14. The obligations of Cedar under this Agreement are intended and shall be construed as a special fund obligation paid solely by the revenues of the Cedar City Water Fund and shall not be construed as a general obligation under Article XIV, Section 3 of the Utah Constitution, nor is the full faith and credit of Cedar City pledged for repayment of the debt. It is understood that water revenue funds have been pledged by Cedar to obtain a revenue bond issued by Cedar on November 1, 1983. This obligation is subordinated to that prior indebtedness.

15. All of the parties recognize that Owen B. Wright, Floyd Wright, Clarence Lamoreaux, Robert A. Thorley and Ervil Saunders, or their successors, are entitled to the use of the first six hundred (600) acre feet of water annually stored in Kolob Reservoir pursuant to the above Agreement dated January 19, 1955.

16. This Agreement is in addition to any existing contracts between the parties regarding the above-mentioned subject matter. Should there be a conflict between any provisions of this agreement and any earlier agreement, the provisions of this agreement shall take precedence and the conflicting portion of any prior agreement shall be void.

17. This agreement shall be binding upon any assignees or successors in interest and no assignment shall be made without approval and written consent of all other parties.

18. In the event of default or a need for judicial interpretation hereof the defaulting party shall pay or the prevailing party shall be entitled to all costs of enforceing this agreement, including costs of court and a reasonable attorney's fee.

19. This agreement constitutes the total agreement and understanding of the parties and merges any prior oral representations. Any modifications or changes hereto must be in writing and signed by all the parties hereto.

WASHINGTON COUNTY WATER
WATER CONSERVANCY DISTRICT

Attest:

Secretary

By

Its:

Approved as to form
and content:

By

Its Attorney

CEDAR CITY-CORPORATION

Attest:

Clerk

By

Its:

Approved as to form
and content:

Cedar City Attorney

KOLOB RESERVOIR AND STORAGE
ASSOCIATION, INC.

Attest:

Secretary

By

Its:

HURRICANE CANAL COMPANY

Attest:

Secretary

By

Its:

ST. GEORGE AND WASHINGTON
CANAL COMPANY

Attest:

Secretary

By Evan J. Woodbury
Its: President

FIGURE 18

URIE RESERVOIR - ALT. 2B