

**CENTRAL IRON COUNTY
WATER CONSERVANCY DISTRICT**

**Reconnaissance Level Evaluation of Alternatives for
Management of the Water Resources in Cedar Valley, Utah**

Draft Report

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SECTION 1

**Executive Summary
And Introduction**

This report provides a reconnaissance level evaluation of the following:

- Updated cost of previously studied dams;
- Reconnaissance level cost estimate of a dam at Rock Canyon Damsite;
- Potential volume of additional groundwater withdrawals;
- Potential for irrigation systems improvements and secondary water systems;
- Potential for the purchase of water rights;
- Potential for a water conservation program; and
- Potential for wastewater recycling

In addition, a matrix (Tables I-2 through I-7) was developed to display the potential amounts of water, associated costs, and other pertinent information for the several different water development and/or water management options. Figure I-1 depicts graphically the range in costs. Also a graph of projected water needs and a cursory look at strategies to meet these needs is presented at the end of this section (see Figure I-2).

Cost of Dams

Table I-1 contains a summary of the reconnaissance level cost estimates of all the dams including the recently completed cost estimate for a dam located at Rock Canyon. From this, the dams with the most promise are dam sites located on Upper Urie Creek, Rock Canyon and Fiddlers Canyon. A summary of these three dams is also included in Table I-2. Urie Creek would cost approximately \$1.4 million with a storage capacity of 2,000 acre-feet. Dams located on Rock Canyon and Fiddlers Canyon would cost in the range of \$8.6 to \$10.6 million. The annualized cost of these three dams would range from \$81 per acre-foot to \$113 per acre-foot of water developed.

Table I-2 also presents a summary of the three dams with the lowest unit cost in providing for an importation of water into Cedar Valley.

Updated Cost of Previously Studied Dams

Dams have been previously studied by the State of Utah in 1985 and by Cedar City during 1992. These have been cost indexed up to the year 1999 using cost index values from the U.S. Bureau of Reclamation. Refer to Section 2 for details of cost.

Reconnaissance Level Cost Estimate for a Dam at Rock Canyon

A reconnaissance level cost estimate was made for the Rock Canyon Damsite. The storage capacity of this reservoir is approximately 6,000 acre-feet. The capital cost of the dam would range from \$8.6 million for a earth-filled dam to \$9.8 million for a roller compacted concrete dam. The annualized cost would range from \$100 to \$113 per acre-foot of water developed. Refer to Section 3 for the detail cost estimates associated with the Rock Canyon Damsite.



Potential Volume of Additional Groundwater Withdrawals

Groundwater volumes are a function of the storage coefficient, surface storage area of the groundwater basin, allowable draw-down of the groundwater aquifer, and the amount of recharge/discharge of the groundwater basin. A range of possible groundwater pumping scenarios were computed and presented in Section 4 of this report. Based on these results, total cumulative groundwater volumes could range from 86,000 acre-feet to 176,000 acre-feet for 20 feet of additional draw-down and 215,000 acre-feet to 440,000 acre-feet for 50 feet. This range is shown in Table I-3.

The annualized cost for groundwater development is approximately \$80 per acre-foot. Of this cost about \$10 per acre-foot is for the annualized capital cost of drilling and equipment for wells. The remaining annual cost of \$70 per acre-foot is for annual energy to pump the groundwater.

Potential for Irrigation Systems Improvements and Secondary Water Systems

A reconnaissance level cost estimate was made for the lining of canals for the Senior Irrigation Companies consisting of the Union Field Irrigation Company, the North Field Irrigation Company, and the East Extension Irrigation Company. These three companies have about 20 miles of concrete lined canals that need repair and about 6 miles of other unlined canals. The cost place these canals in pipe would be about \$3.6 million dollars and would save about 3,265 acre-feet.

A reconnaissance level cost estimate was made for a pressurized conveyance system (secondary system) was for both the Senior Irrigation Companies and the Junior Irrigation Companies. The Senior Irrigation Companies have a higher priority of water rights and irrigate about 2,470 acres in Cedar Valley (1985 data). The Junior Irrigation Companies irrigate about 10,500 acres of land in Cedar Valley (1985 data). A irrigation system to deliver pressurized water to the Senior Irrigation Companies would be about \$4.0 million. The cost for a pressurized water system for the Junior Irrigation Companies would be about \$14.0 million. The total for the two systems would be about \$18.0 million.

Table I-4 contains a summary of the reconnaissance level evaluation of irrigation systems improvements that could supply either irrigation water or M&I water. The details of the cost estimate are found in Section 5 of this report.

Potential for the Purchase of Water Rights

The basis for pursuing a water right purchase program is the growth of urbanization in Cedar Valley. During the time period of 1985 – 2000, the amount of irrigated land has been reduced from 13,000 acres to about 10,000 acres. This is equivalent to a reduction

in agriculture of about 200 acres per year. Based on a crop consumptive use of 2.0 acre-feet per acre this would mean that about 400 acre-feet of water becomes available for other uses. Most of this water goes toward meeting the needs of new residential developments in the unincorporated areas of Cedar Valley and the growth of M&I needs in Cedar City.

Section 6 contains a more detailed analysis of water rights purchase program to purchase 2,375 acre-feet of water over the time period of 2000 to 2030. Table I-5 contains a summary of the results.

Potential for A Water Conservation Program

Various levels of difficulty will be encountered in pursuing a water conservation program. A summary of the water savings and cost for water conservation is presented in Table I-6. Section VII contains more details on the various methods of water conservation, the expected cost and expected water savings in terms of dollars per acre-foot.

Potential for a Wastewater Recycling Program

Water recycling (sometimes referred to as water reclamation or water reuse) is a proven technology and can be an effective alternative supply for meeting urban, agricultural, and environmental water needs. When considered as an incremental cost to existing and future wastewater treatment facilities the concept of reusing wastewater becomes more competitive with other water management strategies. Section 8 contains a more descriptive discussion of the cost of conventional, tertiary, and advanced treatment for the reuse of water. Table I-7 contains a summary of these costs.

Projected Growth and Future M&I Water Demands

Table I – 8 contains population projections and projected M&I water needs for Cedar Valley using a low (1.8%), medium (2.5%), and high (3.25%) growth rate.

Water Management Strategies to Meet Future M&I Water Demands

Figure I-2 shows the graphically the projected water needs and how water conservation, conversion of agriculture water to M&I, and groundwater pumping can be used to meet the expected future growth of Cedar Valley.

Table I-1

**Reconnaissance Level Cost of Dams
Indexed to October 1999 Costs**

Damsite	Capital Cost of Dam (Indexed to October 1999)	Present Worth Cost per acre- foot	Annual Cost per acre-foot	Water Supply in acre-feet
Bulldog	Dam already constructed (about 400 acre-foot capacity)			
Urie Creek (upper)	\$1,416,576	\$1,313	\$81	2,000
Rock Canyon - Earth Filled Dam	\$8,570,680	\$1,545	\$100	6,540
Fiddlers Canyon	\$10,510,080	\$1,749	\$108	6,700
Rock Canyon - Roller Compacted Concrete Dam	\$9,851,746	\$1,741	\$113	6,540
Urie Creek (lower)	\$10,068,352	\$2,506	\$155	4,500
Right Hand Canyon - Urie Creek Reservoir with Crystal Creek Canal	\$17,295,491	\$2,951	\$182	6,270
Coal Creek	\$33,967,360	\$2,965	\$184	12,000
Pine Valley - Pinto Creek Diversion with New Castle Reservoir	\$8,472,286	\$3,000	\$186	3,630
Kolob Reservoir - Cedar City Diversion with Crystal Creek Canal	\$19,014,238	\$3,112	\$193	6,500
Right Hand Canyon - Urie Creek Reservoir with Crystal Creek Canal and Pipeline	\$17,865,000	\$3,290	\$203	5,800
Ashdown Creek	\$28,483,840	\$3,500	\$219	8,500
Right Hand Canyon - Urie Creek Reservoir with Crystal Creek Pipeline	\$20,354,464	\$3,850	\$238	5,600
Cross Hollow (upper)	\$13,526,016	\$3,878	\$240	3,800
Cross Hollow (lower)	\$41,278,720	\$4,124	\$255	10,400
Pine Valley - Pinto Creek Diversion	\$14,074,229	\$4,322	\$268	3,630
Quail Creek Reservoir Pumping	\$22,697,000	\$4,982	\$309	6,500
Right Hand Canyon - Urie Creek Reservoir	\$10,457,575	\$5,073	\$314	2,300
Ashdown Creek Reservoir - Groundwater Pumping	\$11,516,063	\$5,184	\$321	3,000
Last Chance Creek	\$6,168,960	\$5,271	\$327	1,400
Kolob Reservoir - Cedar City Diversion	\$15,145,670	\$5,452	\$338	3,000
City Reservoir	\$1,142,400	\$5,882	\$364	400
Maple Creek	\$13,861,120	\$6,280	\$389	2,400
Kolob Reservoir - Cedar City Diversion with Crystal Creek Tunnel	\$45,679,740	\$7,214	\$447	6,500
Upper Mammoth Creek - Castle Creek Reservoir	\$22,878,946	\$7,203	\$446	3,400
Deep Creek - Mill Creek Tunnel	\$78,565,238	\$23,191	\$1,437	3,440

Figure I - 1
Annual Cost of Water Management Options

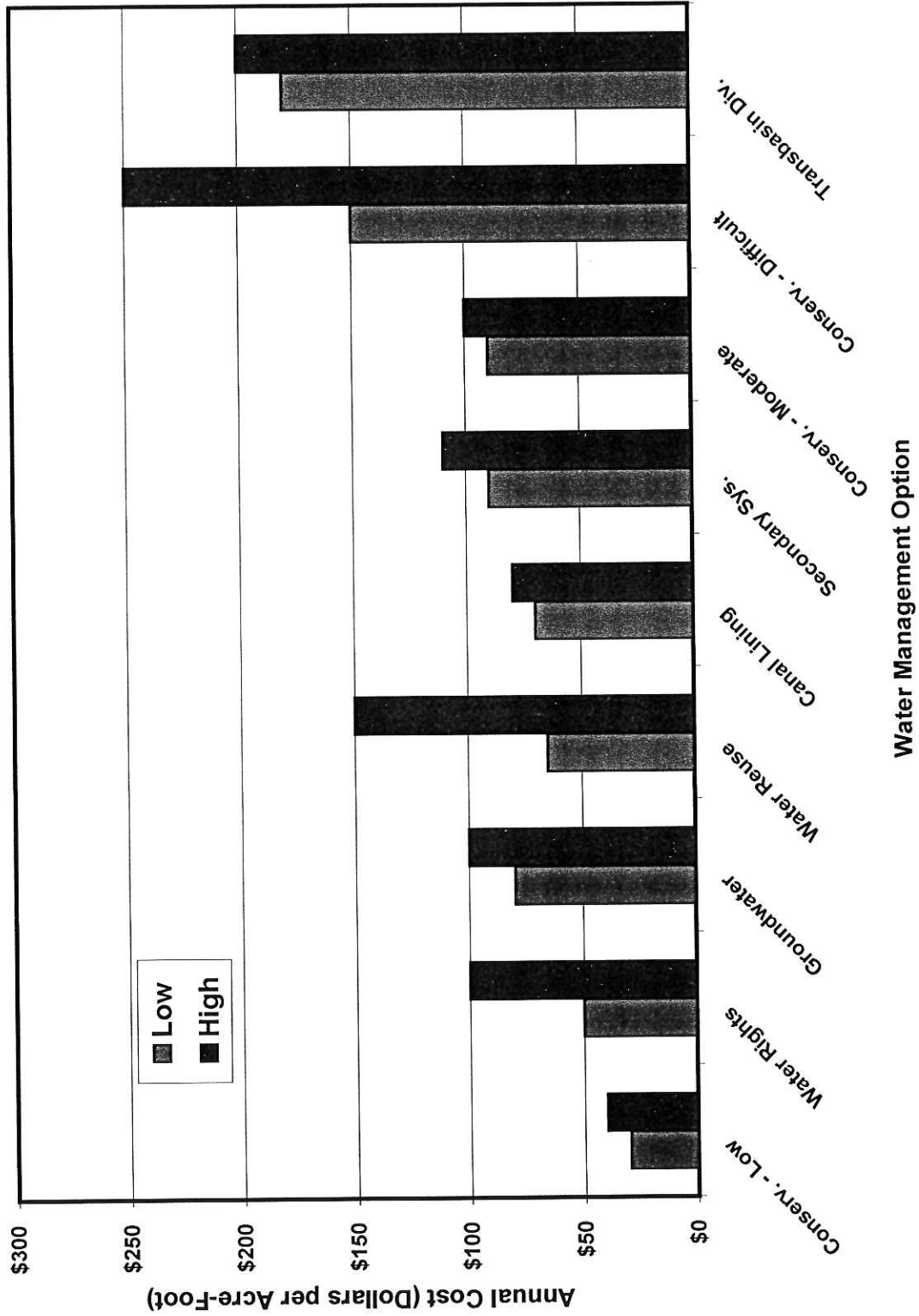


Table I - 2
Matrix of Alternatives for Management of Water Resources

	Storage Reservoirs			Transbasin Diversion Reservoirs		
	Urie Creek (upper)	Rock Canyon	Fiddlers Canyon	Right Hand Canyon-Urie Creek Reservoir with Crystal Creek Canal	Pine Valley - Pinto Creek Diversion with New Castle Reservoir	Kolob Reservoir - Cedar City Diversion with New Castle Reservoir
Potential Water Available for Exchange or Development	2,000 AF	6,540 AF	6,700 AF	6270 AF	3630 AF	6500 AF
Present Worth Cost of Features	\$ 1.4 million	\$ 8.6 million	\$10.5 million	\$ 17.3 million	\$ 8.5 million	\$ 19 million
Present Worth Cost per Acre-Foot	\$1,313	\$1,545	\$1,749	\$2,951	\$3,000	\$3,112
Annual Cost per Acre-Foot	\$81	\$100	\$108	\$182	\$186	\$193
Geotechnical Problems	Information not available	High Gypsum	Information not available	Information not available	Information not available	Information not available
Environmental	none significant	none significant	none significant	none significant	none significant	none significant
Agency Involvement	State of Utah	State of Utah	State of Utah	State of Utah and Washington Count	State of Utah and Washington County	State of Utah and Washington County
Reliability	Low because of location in watershed	High Gypsum	High	High if able to implement	High if able to implement	High if able to implement
Permitting Difficulty	no	no	no			
Multipurpose Potential	limited potential	limited potential	limited potential	limited potential	limited potential	limited potential
Comments	Water rights may have to be purchased to store water in the reservoir basin		Transbasin diversions bring additional water into Cedar Valley which is a positive from a water supply viewpoint			

Table I - 3
Matrix of Alternatives for Management of Water Resources

		Groundwater			
		(Note: Groundwater Amounts Are Cumulative Amounts Over a Period of Time)			
		(Assume a Drawdown of 20 additional feet is permissible)		(Assume a Drawdown of 50 additional feet is permissible)	
		Storage Coefficients		Storage Coefficients	
		S = 0.05	S = 0.075	S = 0.1023	S = 0.075
		S = 0.05	S = 0.075	S = 0.1023	S = 0.1023
Potential Water Available for Exchange or Development		86,000 AF	128,784 AF	175,661 AF	214,640 AF
Present Worth Cost of Features		Varies with groundwater depths and volumes			
Present Worth Cost per Acre-Foot		\$ 10 per acre - foot			
Annual Cost per Acre-Foot		Annualized cost including capital and O&M is \$ 80 per acre-foot with \$70 of the \$ 80 being for annual pumping costs			
Geotechnical Problems		no			
Environmental		Pumping over the years have reduced or eliminated some spring flows. Additional pumping could have some effect on existing designated wetland areas			
Agency Involvement		U. S. Geological Survey, Utah State Engineers Office, and Utah Geological Survey			
Reliability		High reliability from a storage coefficient standpoint. May be okay from additional depth of drawdown of groundwater reservoir	Medium to high reliability from a yield standpoint. May be okay from additional depth of drawdown of groundwater reservoir.	Low to medium reliability from a storage coefficient viewpoint. May be okay from additional depth of drawdown of groundwater reservoir	High reliability from a storage coefficient standpoint. Increasing concerns over depth of drawdown.
Permitting Difficulty		Additional depths of drawdown may be acceptable for ranges in the 20 to 30 feet area. Will need to coordinate with the State Engineers Office so that additional drawdown does not impact present users of the groundwater in an adverse way.			
Multipurpose Potential		no			
Comments		Water quality concerns will need to be addressed in more detailed modeling to determine the interrelationship between drawdown of the groundwater aquifer and the movement of water quality in the aquifer underlying Cedar Valley.			

Table 1 - 4
Matrix of Alternatives for Management of Water Resources

		Irrigation Systems Improvements and/or Secondary Water Systems	
		Canal Lining for Senior Irrigation Companies	Irrigation Water System for Pressurized Irrigation
Potential Water Available for Exchange or Development	3,265 AF	Junior Irrigation Companies (Coal Creek, Bulldog, & Old Fort/ Old Field for total of 10,500 acres)	Senior Irrigation Companies (North Field, East Extension, & Union Field for total of 2,470 acres)
Present Worth Cost of Features	\$3.6 million	Would deliver between 5,000 and 7,000 acre-feet per month or about 30,000 acre-feet during the irrigation season	Would deliver about 2,000 acre-feet per month or about 10,000 acre-feet during the irrigation season
Present Worth Cost per Acre-Foot or per Acre of land served	\$ 1,100 per AF	\$14.0 million	\$ 4.0 million
Annual Cost per Acre-Foot or per Acre of land served	\$ 72 per AF	\$1,300 per acre	\$ 1,600 per acre
Geotechnical Problems	no	\$ 87 per acre	\$ 105 per acre
Environmental	limited impacts	no	no
Agency involvement	limited impacts	limited impacts	limited impacts
Reliability	High if implemented	Utah Division of Water Resources, Local Irrigation Companies, and Agricultural Departments of the State of Utah and Federal Government	Utah Division of Water Resources, Local Irrigation Companies, and Agricultural Departments of the State of Utah and Federal Government
Permitting Difficulty	Local irrigation companies will need to participate	High if implemented	High if implemented
Multipurpose Potential	Local irrigation companies will need to participate	Local irrigation companies will need to participate	Local irrigation companies will need to participate
Comments	Needs acceptance by local irrigation companies	no	no
	Financial assistance is available from the State of Utah and the Agriculture Departments of the federal government		

Table 1 - 5
 Matrix of Alternatives for Management of Water Resources

	Water Rights Purchase		
	Inflation Rates		
	4%	5%	6%
Potential Water Available for Exchange or Development	2,325 AF	2,325 AF	2,325 AF
Present Worth Cost of Features	\$2,021,497	\$2,325,000	\$2,689,869
Present Worth Cost per Acre-Foot	\$869	\$1,000	\$1,157
Annual Cost per Acre-Foot	\$54	\$65	\$78
Geotechnical Problems	no	no	no
Environmental	no	no	no
Agency Involvement	Local irrigation companies and Utah Division of Water Rights		
Reliability	Purchase of water rights would be a reliable method of meeting future M&I needs of Central Iron County		
Permitting Difficulty	The Central County Water Conservancy District can purchase and hold water rights for the future use of the residents of Central Iron County. Others may have difficulty in purchasing and holding water rights		
Multipurpose Potential	No		
Comments	There is risk associated with the inflation of land/water right prices		

Table I - 6
Matrix of Alternatives for Management of Water Resources

	Water Conservation				
	Low Effort	Moderate Effort	Difficult Effort	Very Difficult Effort	Extremely Difficult Effort
Potential Water Available for Exchange or Development	1,222 AF	1,245 AF	3,621 AF	5,884 AF	391 AF
Present Worth Cost of Features	Not Available	Not Available	Not Available	Not Available	Not Available
Present Worth Cost per Acre-Foot	Not Available	Not Available	Not Available	Not Available	Not Available
Annual Cost per Acre-Foot	\$33	\$90	\$145 to \$158	\$177 to \$222	\$474
Geotechnical Problems	no	no	no	no	no
Environmental	none	none	none	none	none
Agency Involvement	Local public and citizens organizations	Local public and citizens organizations	Local public and citizens organizations	Local public and citizens organizations	Local public and citizens organizations
Reliability	High if implemented	High if implemented	High if implemented	High if implemented	High if implemented
Permitting Difficulty	Limited difficulty with ordinances to implement conversation	Difficulty with ordinances to implement conversation	May be difficult with ordinances to implemented conversation	Probable difficulty with ordinances requiring conversation	Probable difficulty with ordinances requiring conversation
Multipurpose Potential	no	no	no	no	no
Comments	Needs wide public acceptance				

Table I - 7
Matrix of Alternatives for Management of Water Resources

	Wastewater Reuse					
	Retrofit Tertiary Treatment To Existing Water Treatment Plant		New Tertiary Treatment Plant		Advanced Treatment Plant	
	with USBR 25% Cost Share	without USBR 25% Cost Share	with USBR 25% Cost Share	Without USBR 25% Cost Share	with USBR 25% Cost Share	without USBR Funding
Potential Water Available for Exchange or Development	4,000 AF	4,000 AF	4,000 AF	4,000 AF	4,000 AF	4,000 AF
Present Worth Cost of Features	\$ 2.6 million	\$ 3.5 million	\$ 10.6 million	\$ 14.1 million	\$ 15.9 million	\$ 21.2 million
Present Worth Cost per Acre-Foot	\$650	\$875	\$2,650	\$3,525	\$3,975	\$5,300
Annualized Cost of Present Worth per Acre-foot	\$42	\$57	\$172	\$229	\$258	\$345
Annual O & M per Acre-Foot	\$225	\$225	\$225	\$225	\$355	\$355
Subtotal for Annual Cost without any consideration of future cost of a conventional Wastewater Treatment Plant	\$267	\$282	\$397	\$454	\$613	\$700
Credit for O&M of Existing Plant	\$160	\$160	not applicable	not applicable	not applicable	not applicable
Credit for Cost of Conventional Wastewater Treatment Plant for both capital and O&M	not applicable	not applicable	\$332	\$332	\$332	\$332
Annual Cost per Acre-Foot	\$107	\$122	\$65	\$122	\$281	\$368
Geotechnical Problems	none significant	none significant	none significant	none significant	none significant	none significant
Environmental	High Acceptability from EPA					
Agency Involvement	State Division of Water Quality and the USBR					
Reliability	High					
Permitting Difficulty	Must meet State of Utah Water Quality Standards					
Multipurpose Potential	Yes, if wetlands can be created to assist in reducing the pollutants through aeration. This is being done in other areas to reduce the cost of treatment					
Comments	USBR may provide planning funds and will provide up to \$21,000,000 for construction					

Figure I - 2
Projected M&I Water Needs for Cedar Valley

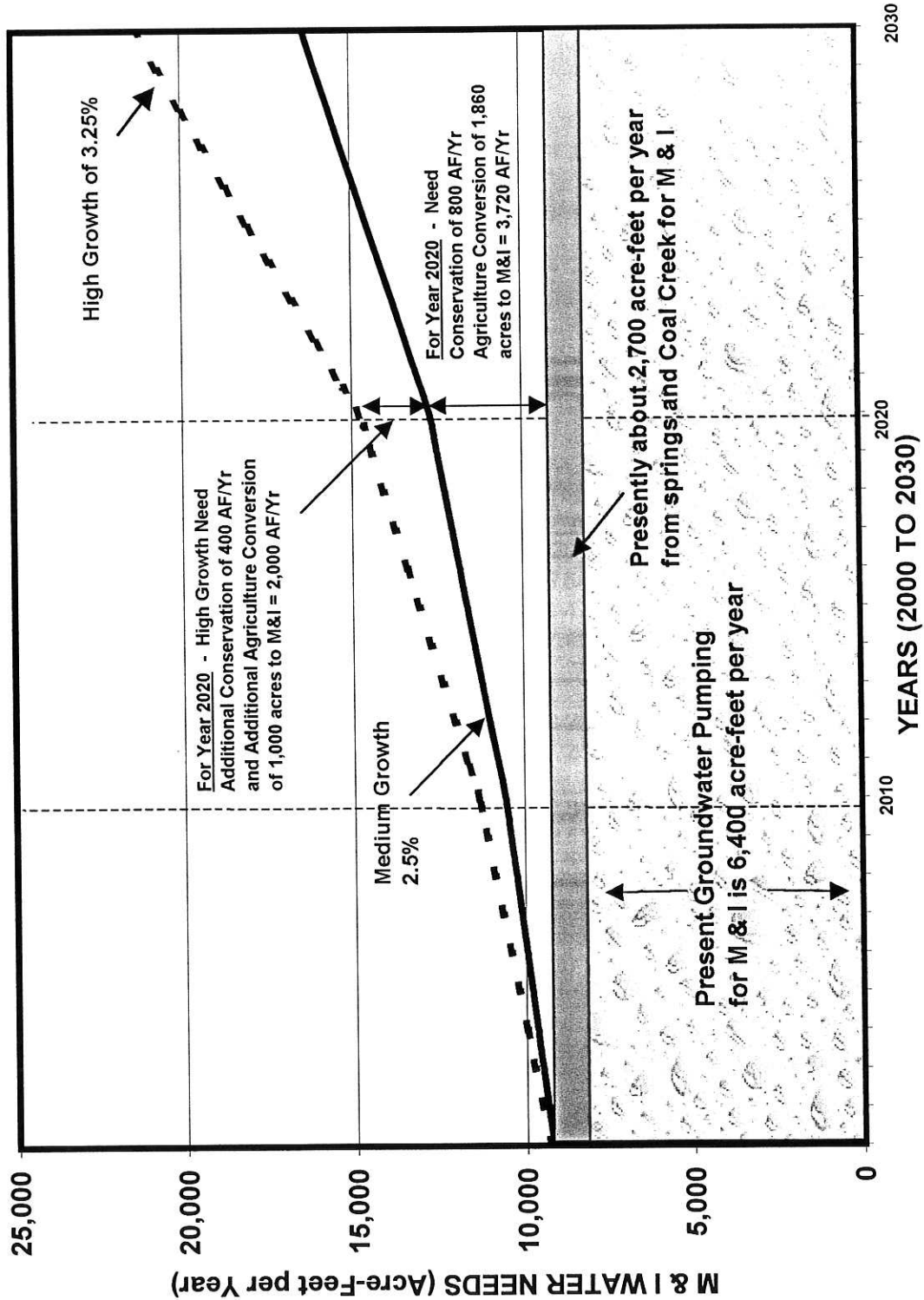


TABLE I - 8

CEDAR VALLEY

Projected Growth and Water Needs
From the Year 2000 to the Year 2100

	2000	2010	2020	2050	2100
Low Growth/Cedar Valley (1.8%)	30,836	36,858	44,057	75,240	183,584
Medium Growth/Cedar Valley (2.5%)	30,856	39,473	50,528	105,987	364,288
High Growth/Cedar Valley (3.25%)	30,836	42,458	58,460	152,602	755,204
<hr/>					
Water Use(AF/capita)	0.294	0.267	0.253	0.225	0.200
Water Use (gpcd)	250	236	224	200	180
<hr/>					
Water needs (1.8% growth)	9,066	9,841	11,146	16,929	36,717
Water needs (2.5% growth)	9,066	10,539	12,784	23,847	72,858
Water needs (3.25% growth)	9,066	11,336	14,790	34,335	151,041

SECTION 2

Updated Cost of Dams

A study of surface reservoirs to meet the water demands of Cedar Valley has been summarized in the report, "A Framework for Future Water Resource Planning and Policy Setting in Central Iron County, Utah", dated September 1999. The report summarized the previous cost estimates of dams from the following two reports:

1. Sprinkler Irrigation Project Alternatives for the Cedar Valley Water Users Association, Utah Division of Water Resources, 1986.
2. Evaluation of Water Supply, Water Demand, and Water Development Opportunities for Cedar City, Bingham Engineering, March 1993.

Basis for Updated Reconnaissance Level Cost Estimates to October 1999.

The basis for updated the previous cost estimates for dams are a set of cost indexes provided to the public by the U.S. Bureau of Reclamation. These cost indexes are been reproduced and presented at the end of this section of the report.

In addition there was a lack of continuity with previous cost estimates concerning the contingencies percentage that should be added to the cost estimate. The State of Utah used a contingency of 12% for their cost estimates and Bingham Engineering used a contingency of 25%. It is not uncommon for the U.S. Bureau of Reclamation to use a contingency of 40%. For the purposes of have a commensurate basis, a 25% contingency percentage was used for the indexing of the dams to October 1999 costs. This required no change in the contingency for the cost estimates made by Bingham Engineering. However the contingency used by the State of Utah was adjusted upward by a factor of 25% divided by 12%. It was felt that using a contingency of nearly 40% would be too high for a dam constructed by a local agency.

Updated Costs to October 1999 of Storage Reservoirs Studied by Utah Division of Water Resources in 1986

The Utah Division of Water Resources in 1985 and 1986 investigated a total of eleven dam sites. These updated costs are included in Table II - 1.

Updated Costs to October 1999 of Storage Reservoirs Studied by Bingham Engineering in 1993.

Bingham Engineers in their report, Evaluation of Water Supply, Water Demand, and Water Development Opportunities for Cedar City, March 1993, completed a study of reservoirs which focused principally on trans-basin diversions. In addition they included in some of their costs the cost of hydropower facilities and water treatment facilities. In order to make a

commensurate comparison of alternatives, the cost of dams without hydropower and without water treatment facilities were used as the cost of dams to be updated. This required that, to the degree possible, the annual operation and maintenance costs be subtracted from previous cost estimates. The results from indexing the cost to October 1999 levels are contained in Table II - 2.

Table II - 1
UPDATED COSTS
 Dams Investigated in 1985 by State of Utah

Damsite	Capital Cost (1985)	Contingency Adjustment from 12% to 25%	Present Worth Adjusted by Cost Index of 1.36 from 1985 to 1999	Assumed Operation & Maintenance	Present Worth of O&M	Reservoir Capacity in acre-feet	Present Worth Cost per acre-foot	Annual Cost per acre-foot
Bulldog						400		
			Reservoir already constructed					
Urie Creek (upper)	\$930,000	\$1,041,600	\$1,416,576	\$75,000	\$1,210,580	2,000	\$1,313	\$81
Fiddlers Canyon	\$6,900,000	\$7,728,000	\$10,510,080	\$75,000	\$1,210,580	6,700	\$1,749	\$108
Urie Creek (lower)	\$6,600,000	\$7,403,200	\$10,068,352	\$75,000	\$1,210,580	4,500	\$2,506	\$155
Coal Creek	\$22,300,000	\$24,976,000	\$33,967,360	\$100,000	\$1,614,000	12,000	\$2,965	\$184
Ashdown Creek	\$18,700,000	\$20,944,000	\$28,483,840	\$100,000	\$1,614,000	8,500	\$3,500	\$219
Cross Hollow (upper)	\$8,800,000	\$9,945,600	\$13,526,016	\$75,000	\$1,210,580	3,800	\$3,878	\$240
Cross Hollow (lower)	\$27,100,000	\$30,352,000	\$41,278,720	\$100,000	\$1,614,000	10,400	\$4,124	\$255
Last Chance Creek	\$4,050,000	\$4,536,000	\$6,168,960	\$75,000	\$1,210,580	1,400	\$5,271	\$327
City Reservoir	\$750,000	\$840,000	\$1,142,400	\$75,000	\$1,210,580	400	\$5,882	\$364
Maple Creek	\$9,100,000	\$10,192,000	\$13,861,120	\$75,000	\$1,210,580	2,400	\$6,280	\$389

TABLE II - 2
Updated Costs to October 1999
 Dams Investigated in 1992
 by Bingham Engineering

Dam/site	Adjusted Cost without hydro and without water treatment	Cost Index of 1.18 from 1992 to 1999	Indexed 1999 Capital Cost of Dams	Water Supply Yield in acre-feet	O&M w/o hydro and w/o water treatment	Present worth of O&M	Indexed Present Worth Cost per acre-foot	Annual cost per acre-foot
Right Hand Canyon - Urie Creek Reservoir with Crystal Creek Canal	\$14,657,196	1.18	\$17,295,491	6,270	\$75,000	\$1,210,580	\$2,951	\$182
Pine Valley - Pinto Creek Diversion with New Castle Reservoir	\$7,137,531	1.18	\$8,472,286	3,630	\$150,000	\$2,421,000	\$3,000	\$186
Kolob Reservoir - Cedar City Diversion with Crystal Creek Canal	\$15,334,063	1.24	\$19,014,238	6,500	\$75,000	\$1,214,580	\$3,112	\$193
Right Hand Canyon - Urie Creek Reservoir with Crystal Creek Canal and Pipeline	\$15,139,984	1.18	\$17,865,000	5,800	\$75,000	\$1,210,580	\$3,290	\$203
Right Hand Canyon - Urie Creek Reservoir with Crystal Creek Pipeline	\$17,249,546	1.18	\$20,354,464	5,600	\$75,000	\$1,210,580	\$3,850	\$238
Pine Valley - Pinto Creek Diversion	\$11,927,313	1.18	\$14,074,229	3,630	\$100,000	\$1,614,000	\$4,322	\$268
Quail Creek Reservoir Pumping	\$18,452,875	1.23	\$22,697,036	6,500	\$600,000	\$9,685,000	\$4,982	\$309
Right Hand Canyon - Urie Creek Reservoir	\$8,862,352	1.18	\$10,457,575	2,300	\$75,000	\$1,210,580	\$5,073	\$314
Ashdown Creek Reservoir - Groundwater Pumping	\$9,596,719	1.2	\$11,516,063	3,000	\$250,000	\$4,035,000	\$5,184	\$321
Kolob Reservoir - Cedar City Diversion	\$12,214,250	1.24	\$15,145,670	3,000	\$75,000	\$1,210,580	\$5,452	\$338
Kolob Reservoir - Cedar City Diversion with Crystal Creek Tunnel	\$36,838,500	1.24	\$45,679,740	6,500	\$75,000	\$1,210,580	\$7,214	\$447
Upper Mammoth Creek - Castle Creek Reservoir	\$19,388,938	1.18	\$22,878,946	3,400	\$100,000	\$1,614,000	\$7,203	\$446
Deep Creek - Mill Creek Tunnel	\$63,359,063	1.24	\$78,565,238	3,440	\$75,000	\$1,210,580	\$23,191	\$1,437

Bureau of Reclamation Construction Cost Trends

(Base: 1977 = 100 for Indexing Field Costs Only)

Item	1996				1997				1998				1999			
	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct
Construction Indexes																
Earth dams	175	180	174	176	177	178	179	179	179	180	182	182	183	185	188	191
Dam structure	160	167	157	159	162	163	162	162	163	162	161	161	161	161	168	172
Spillway	186	189	187	186	187	187	190	190	190	192	197	198	200	203	204	206
Outlet works	203	205	205	206	206	207	210	210	211	212	218	219	220	224	224	226
Concrete dams	200	202	202	203	200	205	208	208	208	210	215	217	218	222	223	225
Diversion dams	202	205	205	207	204	209	211	212	212	213	216	217	218	219	221	222
Pumping plants	207	211	213	215	214	216	217	218	219	219	221	222	223	223	225	226
Structures and improvements	195	202	205	209	205	207	209	210	211	211	213	214	215	216	218	218
Equipment	221	222	222	223	224	226	227	228	229	230	232	233	233	234	235	236
Pumps and prime movers	225	227	227	228	230	231	232	233	234	235	237	237	237	237	239	240
Accessory elect. & misc. equip.	213	214	214	216	216	217	220	221	221	222	225	226	226	227	228	229
Powerplants	215	216	217	219	217	220	222	224	224	225	226	227	228	229	231	231
Structures and improvements	196	202	205	209	205	208	209	210	211	211	213	214	215	216	218	219
Equipment	226	226	227	228	226	229	231	233	233	233	235	236	236	238	239	240
Turbines and accessories	228	229	230	231	228	230	233	235	235	236	238	238	239	241	241	242
Accessory elect. & misc. equip.	210	207	207	209	209	215	216	218	218	219	221	222	222	223	225	226
Steel pipelines	214	217	219	222	229	229	231	231	232	233	236	237	239	239	241	243
Concrete pipelines	191	194	193	196	197	200	201	203	205	206	209	211	212	213	215	216
Canals	186	196	194	199	198	198	198	199	200	200	201	202	203	203	207	210
Canal earthwork	178	189	177	181	185	185	184	184	185	183	183	182	182	182	190	195
Canal structures	197	203	208	213	209	211	212	214	215	216	218	220	221	221	223	224
Tunnels	221	224	223	226	226	231	233	233	235	236	239	240	241	241	243	245
Laterals and drains	186	195	197	202	214	215	216	216	218	218	219	220	221	220	224	226
Lateral earthwork	177	184	174	178	182	182	181	181	182	181	181	181	181	182	188	192
Lateral structures	193	203	209	215	231	233	234	235	238	239	240	241	242	241	243	245
Distribution pipelines	193	195	195	198	198	200	202	204	206	206	210	211	212	213	215	216
Switchyards and substations	204	186	188	190	189	211	212	213	213	215	216	218	218	220	223	226
Wood pole transmission lines	216	213	220	234	234	233	230	226	218	211	198	205	191	196	208	210
Poles and fixtures	217	217	231	255	262	254	245	238	224	212	192	209	186	198	216	217
Overhead conductors and devices	215	209	207	207	200	208	212	212	212	210	205	200	199	196	199	204
Steel tower transmission lines	218	216	216	217	214	219	221	222	222	223	224	222	222	222	223	225
Primary roads	208	209	214	219	217	222	224	224	223	219	221	225	224	226	229	231
Secondary roads	227	230	230	237	240	247	256	258	257	237	243	247	254	253	252	262
Bridges	211	218	221	226	224	227	230	232	233	229	232	234	237	237	239	242
General property	211	210	212	217	219	220	221	222	220	219	219	222	219	221	225	226
Composite trend	207	208	209	212	213	217	218	218	219	218	219	221	220	221	225	227
Land Indexes																
Arizona	245	251	257	263	270	277	284	291	298	303	310	315	322	329	334	338
California	301	307	313	319	325	331	335	339	343	346	350	355	359	359	359	359
Colorado	210	214	218	222	225	228	231	234	236	237	242	245	247	248	250	252
Idaho	190	193	196	199	202	205	208	211	214	216	220	224	227	230	233	236
Kansas	139	140	141	142	143	144	145	146	147	148	150	150	151	150	149	149
Montana	181	184	187	190	193	195	197	199	201	202	204	205	202	198	194	192
Nebraska	146	148	150	153	156	159	162	165	167	168	172	174	167	167	165	163
Nevada	282	287	292	297	302	307	312	317	322	325	330	335	340	346	350	354
New Mexico	244	250	256	262	267	272	277	282	287	290	292	295	296	298	296	294
North Dakota	139	141	143	145	147	149	151	153	155	156	156	156	154	152	150	148
Oklahoma	139	140	141	142	143	144	145	146	147	148	150	152	153	152	154	154
Oregon	242	249	256	263	270	277	284	291	298	301	304	307	306	303	300	297
South Dakota	157	158	160	162	164	166	168	170	171	171	174	178	183	183	184	185
Texas	187	190	193	195	199	202	204	206	207	208	213	217	213	208	204	202
Utah	240	247	255	260	266	272	278	280	282	283	285	288	290	290	292	294
Washington	204	206	209	212	217	223	229	235	241	244	250	255	250	246	242	238
Wyoming	181	183	185	188	192	195	198	200	203	205	207	208	206	204	203	202
Other Indicators																
Machinery and equipment (BLS)	221	221	225	225	226	227	229	230	231	232	234	234	235	237	239	239
Federal salary	207	207	207	207	212	212	212	212	217	217	217	217	225	225	225	225

Inquiries to: D-8170, Fax (303) 445-6475, lpedde@do.usbr.gov

Bureau of Reclamation Construction Cost Trends

(Base: 1977 = 100 For Indexing Field Costs Only)

	1992				1993				1994				1995			
	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct
Construction Indexes																
Earth dams	162	160	161	162	164	165	165	166	168	163	167	168	173	175	178	178
Dam structure	147	145	146	148	150	151	152	152	154	145	155	156	162	163	165	163
Spillway	175	171	171	172	174	175	175	176	178	176	173	175	180	182	187	188
Outlet works	189	185	186	188	189	190	191	192	194	194	191	193	196	198	202	204
Concrete dams	186	184	184	186	188	189	189	190	193	192	188	190	193	196	199	201
Diversion dams	183	182	183	185	186	187	188	189	191	191	191	193	195	198	201	202
Pumping plants	185	185	187	188	189	190	191	192	193	195	195	197	200	202	204	206
Structures and improvements	172	171	173	174	175	176	177	178	181	183	182	184	188	191	194	197
Equipment	201	201	203	204	205	206	207	208	208	209	211	213	213	215	217	218
Pumps and prime movers	204	205	206	208	209	210	211	211	210	213	214	215	217	219	220	221
Accessory elect + misc. equip.	195	196	197	199	199	200	201	203	204	204	206	208	209	210	211	213
Powerplants	197	198	199	201	202	203	204	205	207	207	208	209	212	213	215	216
Structures and improvements	173	172	173	175	176	176	178	179	182	183	183	185	189	191	194	197
Equipment	212	213	215	217	218	219	220	221	222	222	223	224	226	227	228	228
Turbines and generators	216	217	218	220	221	222	223	224	226	225	225	227	228	229	230	231
Accessory elect + misc. equip.	191	191	192	194	195	195	197	198	199	200	202	204	205	206	207	208
Steel pipelines	195	195	196	198	199	200	201	202	203	204	204	206	209	211	212	213
Concrete pipelines	178	178	179	181	181	182	183	184	184	185	185	186	188	189	191	191
Canals	167	166	167	169	170	171	172	172	174	176	176	178	182	184	187	189
Canal earthwork	167	166	168	170	172	172	173	173	174	175	176	177	181	182	185	181
Canal structures	172	171	172	174	174	175	176	178	180	183	182	183	188	191	194	198
Tunnels	196	195	196	198	200	200	202	203	205	205	206	208	210	212	216	220
Laterals and drains	167	165	166	169	170	171	175	176	178	180	180	182	188	190	192	190
Lateral earthwork	167	166	167	170	171	172	173	173	174	175	176	177	181	181	185	182
Lateral structures	168	166	168	170	171	172	178	179	181	184	184	186	192	196	197	196
Distribution pipelines	178	178	179	181	181	182	183	184	184	185	185	187	188	190	192	193
Switchyards and substations	189	188	188	190	190	191	192	194	194	196	195	197	198	202	203	204
Wood pole transmission lines	172	171	173	175	177	180	185	198	195	201	208	210	209	217	214	214
Poles and fixtures	157	158	163	166	171	176	186	208	208	220	229	230	221	218	209	208
Overhead conductors and devices	191	188	187	186	185	185	184	186	180	179	182	185	195	218	222	222
Steel tower transmission lines	197	196	195	196	196	196	197	198	196	196	198	201	205	215	218	219
Primary roads	188	185	185	186	188	188	191	196	196	200	197	199	201	204	206	208
Secondary roads	216	211	209	210	212	209	214	215	217	211	216	217	224	229	230	231
Bridges	189	188	188	190	191	191	194	194	196	196	198	199	204	207	208	212
General property	185	185	187	189	190	191	194	198	201	203	205	208	208	209	209	210
Land Indexes																
Arizona	182	185	188	191	194	197	200	203	206	209	212	215	221	227	233	239
California	271	275	279	283	287	289	291	291	291	291	291	291	291	291	292	295
Colorado	162	164	166	168	168	168	171	174	178	182	186	190	194	198	202	206
Idaho	145	146	147	148	149	150	151	155	159	163	167	171	175	179	183	187
Kansas	113	114	115	116	118	120	122	124	126	128	130	132	134	136	137	138
Montana	139	139	139	142	145	148	151	154	157	160	163	166	169	172	175	178
Nebraska	123	123	123	123	123	123	124	126	128	130	134	136	138	140	142	144
Nevada	210	214	218	222	226	230	234	238	242	247	252	257	262	267	272	277
New Mexico	205	205	204	203	200	199	198	202	206	210	214	218	222	226	232	238
North Dakota	118	118	119	120	121	122	123	124	125	126	127	129	131	133	135	137
Oklahoma	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138
Oregon	151	155	159	163	168	173	178	183	188	193	200	207	214	221	228	235
South Dakota	148	146	144	144	143	143	144	145	146	148	150	152	153	154	155	156
Texas	165	164	163	163	163	163	164	167	169	171	173	176	178	181	183	185
Utah	160	163	165	169	173	176	180	185	190	195	200	207	212	219	225	233
Washington	166	166	166	166	167	168	169	176	183	190	197	198	199	200	201	202
Wyoming	140	142	143	145	147	149	151	153	155	160	164	168	171	173	175	178
Other Indicators																
Composite trend	186	185	186	188	189	190	190	194	195	196	197	199	201	204	206	207
Machinery and equipment (BLS)	204	206	207	209	211	214	213	213	214	215	215	216	216	218	219	220
Federal salary	187	187	187	187	194	194	194	194	200	200	200	200	202	202	202	202

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NOTE: The land indexes have been reinstated as part of the Construction Cost Trends. Because of a newly located source of land values from the U.S. Department of Agriculture, it was apparent that our previously published land index values lagged actual values significantly. Because of this it was necessary to recompute our values from 1985 forward.

Bureau of Reclamation Construction Cost Trends

(Base: 1977 = 100 For Indexing Field Costs Only)

	1988				1989				1990				1991			
	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct
Construction Indexes																
Earth dams	143	144	145	146	147	149	151	153	154	155	156	158	160	159	161	161
Dam structure	130	131	132	132	133	134	135	137	137	138	140	142	143	143	145	145
Spillway	152	153	154	158	158	160	164	165	167	167	170	172	173	172	174	174
Outlet works	164	165	167	171	171	173	177	179	181	181	183	185	186	186	188	188
Concrete dams	162	163	164	167	167	169	173	174	176	177	179	181	183	183	185	185
Diversion dams	162	163	164	166	167	169	171	173	174	175	176	178	180	180	182	182
Pumping plants	163	165	166	168	169	171	173	175	176	178	179	181	182	183	184	185
Structures and improvements	157	158	159	160	160	162	164	166	166	167	168	169	170	171	172	172
Equipment	172	173	175	178	179	181	184	187	188	190	192	194	196	197	199	200
Pumps and prime movers	171	172	175	177	179	182	186	189	191	193	194	197	200	200	203	204
Accessory elect + misc. equip.	174	175	177	179	180	181	182	184	186	187	188	190	191	191	194	195
Powerplants	170	171	172	173	175	177	180	182	183	184	187	190	192	193	195	196
Structures and improvements	157	158	159	160	161	163	164	166	166	167	168	169	171	171	172	172
Equipment	177	178	179	181	183	186	190	191	193	195	199	203	205	206	209	210
Turbines and generators	179	180	181	183	185	188	192	193	195	197	202	205	208	210	212	214
Accessory elect + misc. equip.	167	168	170	171	173	174	177	179	181	182	183	185	187	187	189	190
Steel pipelines	168	169	171	173	175	177	179	182	183	184	186	188	191	191	194	195
Concrete pipelines	165	165	165	166	166	167	167	168	168	169	169	171	173	174	176	177
Canals	153	154	154	155	155	157	158	160	161	161	162	163	165	165	167	167
Canal earthwork	152	153	153	154	155	157	157	160	161	161	162	163	165	166	168	167
Canal structures	156	157	158	159	160	161	163	164	165	165	167	168	169	170	171	171
Tunnels	174	175	176	178	179	181	183	185	186	187	189	191	192	192	194	195
Laterals and drains	151	152	153	154	155	156	158	159	160	160	161	163	165	165	166	166
Lateral earthwork	151	152	153	154	155	156	157	159	159	160	161	163	166	166	167	166
Lateral structures	151	153	154	155	156	157	159	160	161	161	162	164	165	166	167	167
Distribution pipelines	164	164	164	165	165	166	166	167	168	168	169	171	172	173	175	177
Switchyards and substations	165	168	169	170	171	173	177	180	181	181	183	185	187	187	188	189
Wood pole transmission lines	151	154	157	165	169	172	175	178	178	174	176	176	177	175	173	173
Poles and fixtures	139	139	141	144	146	147	152	158	161	158	162	160	159	155	153	157
Overhead conductors and devices	167	173	179	192	197	203	204	203	200	195	194	195	201	200	197	194
Steel tower transmission lines	175	179	182	189	192	195	197	198	198	196	197	198	201	200	200	198
Primary roads	167	168	169	172	171	174	177	179	180	181	183	185	186	185	186	186
Secondary roads	191	194	195	201	197	204	207	208	206	210	214	217	219	215	214	212
Bridges	170	171	172	174	174	176	179	180	180	182	184	186	187	187	188	188
General property	165	167	169	171	173	174	176	178	179	179	180	181	182	182	183	184
Land Indexes																
Arizona	152	153	154	155	157	159	161	163	165	167	169	171	173	175	177	179
California	207	211	215	219	223	227	231	235	239	243	247	251	255	259	263	267
Colorado	140	141	142	143	144	145	146	147	148	149	150	152	154	156	158	160
Idaho	122	123	124	125	126	127	128	129	132	135	138	141	144	144	144	144
Kansas	102	104	106	107	108	109	110	111	112	112	112	112	112	112	112	112
Montana	127	127	127	127	127	130	133	136	139	139	139	139	139	139	139	139
Nebraska	103	106	109	112	115	119	122	123	123	124	124	124	123	123	123	123
Nevada	152	154	156	158	162	166	170	174	178	182	186	190	194	198	202	206
New Mexico	156	160	164	168	172	176	180	184	188	192	196	200	201	202	203	204
North Dakota	113	113	114	114	115	115	116	116	117	117	117	118	118	119	119	119
Oklahoma	121	122	125	127	129	130	129	127	125	123	122	121	120	120	121	122
Oregon	125	125	126	127	128	129	131	133	135	137	139	141	143	145	147	149
South Dakota	130	132	136	137	138	139	141	144	148	150	151	151	151	151	151	150
Texas	181	180	179	178	177	176	175	174	173	172	171	170	169	168	167	166
Utah	134	135	136	137	138	140	142	144	145	146	148	150	152	154	155	157
Washington	137	136	136	138	140	142	144	146	148	150	152	154	157	160	163	166
Wyoming	128	128	127	127	127	126	126	127	128	130	131	133	134	136	137	139
Other Indicators																
Composite trend	163	165	166	168	169	171	174	176	177	177	179	181	183	183	184	185
Machinery and equipment (BLS)	178	179	180	181	186	187	190	191	193	194	197	198	199	200	201	203
Federal salary	160	160	160	160	166	166	166	166	172	172	172	172	179	179	179	179

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Bureau of Reclamation Construction Cost Trends

(Base: 1977 = 100 For Indexing Field Costs Only)

	1984				1985				1986				1987			
	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct
Construction Indexes																
Earth dams	139	138	139	139	139	139	139	140	140	140	140	141	141	141	142	142
Dam structure	131	131	130	129	129	129	128	128	128	128	128	128	127	128	129	130
Spillway	144	144	145	145	145	146	147	148	150	149	150	151	151	150	151	151
Outlet works	153	153	155	155	155	155	157	158	159	159	160	161	161	161	162	162
Concrete dams	154	154	155	156	155	156	157	158	159	159	160	160	160	160	161	161
Diversion dams	153	153	155	155	156	156	157	157	158	158	158	159	159	159	160	161
Pumping plants	154	154	156	157	157	157	158	159	160	160	160	161	161	161	162	163
Structures and improvements	148	149	150	151	152	152	153	154	154	154	154	154	154	154	155	156
Equipment	160	161	163	163	164	164	166	166	166	167	168	170	169	169	170	171
Pumps and prime movers	161	162	163	163	164	164	166	166	167	168	169	170	169	169	169	170
Accessory elect + misc. equip.	161	161	164	164	165	165	166	166	166	167	168	170	170	171	172	174
Powerplants	157	158	159	160	160	161	162	162	163	164	164	166	166	167	168	170
Structures and improvements	149	149	150	151	152	152	153	154	154	154	154	155	155	154	155	156
Equipment	161	162	164	164	164	164	166	166	168	169	169	171	172	173	175	176
Turbines and generators	163	163	165	165	166	166	167	168	169	170	171	173	174	175	178	179
Accessory elect + misc. equip.	156	156	158	158	159	159	160	160	160	161	161	163	163	163	164	166
Steel pipelines	161	161	163	162	163	162	163	162	163	163	164	165	165	165	166	167
Concrete pipelines	157	157	158	159	159	160	161	161	162	162	163	164	164	164	165	166
Canals	144	145	146	146	147	148	149	149	150	150	150	150	150	150	151	152
Canal earthwork	143	144	144	145	146	146	147	147	148	148	149	149	149	150	151	152
Canal structures	149	149	150	151	151	152	153	153	154	153	154	154	154	154	155	156
Tunnels	161	161	162	163	164	165	166	167	167	168	168	169	170	170	171	173
Laterals and drains	143	143	144	145	146	146	147	148	148	148	148	148	148	149	149	150
Lateral earthwork	141	142	143	143	144	145	145	146	147	147	148	148	148	149	149	150
Lateral structures	145	145	146	147	147	148	149	150	150	150	149	150	149	150	150	151
Distribution pipelines	155	155	156	157	157	158	158	159	160	160	160	162	162	162	163	164
Switchyards and substations	154	154	156	156	156	156	157	157	158	158	158	159	160	160	161	163
Wood pole transmission lines	146	146	148	149	148	147	148	150	148	146	145	146	147	145	146	148
Poles and fixtures	136	136	137	137	136	134	136	138	136	134	132	134	136	134	134	135
Overhead conductors and devices	159	161	164	164	164	163	164	165	163	162	161	163	162	161	162	164
Steel tower transmission lines	163	164	166	166	168	168	169	170	170	170	170	170	170	170	171	173
Primary roads	155	154	156	156	157	157	159	160	161	161	162	163	163	163	164	166
Secondary roads	160	160	161	161	162	164	165	168	171	174	175	178	181	182	186	189
Bridges	154	155	156	157	158	158	159	160	161	162	162	164	164	165	166	168
General property	155	155	158	158	158	159	159	159	159	159	160	161	162	161	162	164
Land Indexes																
Arizona	132	132	136	136	140	141	142	143	144	145	146	147	148	149	150	151
California	225	225	223	223	223	223	218	212	206	205	203	201	201	201	201	203
Colorado	160	160	166	166	166	166	140	138	136	136	136	136	136	137	138	139
Idaho	139	139	140	140	140	140	136	132	130	129	128	127	126	125	124	123
Kansas	125	125	122	122	122	122	115	110	105	100	96	96	96	96	98	100
Montana	145	145	149	149	147	145	143	141	139	137	135	133	131	129	127	127
Nebraska	128	128	114	114	113	112	111	107	103	99	96	95	95	95	97	100
Nevada	132	132	136	136	136	136	136	136	138	138	140	142	144	146	148	150
New Mexico	132	132	136	136	136	136	132	130	127	124	124	124	131	138	145	152
North Dakota	141	141	142	142	142	132	125	120	118	116	114	112	111	111	111	112
Oklahoma	155	155	156	156	156	152	146	135	133	131	129	127	125	122	121	121
Oregon	137	137	137	137	133	129	125	125	125	125	125	125	125	125	125	125
South Dakota	139	139	136	136	135	133	130	126	124	122	121	121	121	122	124	126
Texas	192	192	208	208	212	220	229	229	226	221	216	211	200	188	183	182
Utah	130	130	133	133	133	133	133	133	132	132	130	129	130	131	132	133
Washington	152	152	157	157	157	157	156	155	153	151	149	147	145	143	141	139
Wyoming	132	132	136	136	136	135	134	133	132	131	131	131	130	130	129	129
Other Indicators																
Composite trend	153	153	155	155	156	156	157	158	158	158	159	160	160	160	161	162
Machinery and equipment (BLS)	166	168	168	168	169	169	170	170	171	172	172	172	174	175	176	176
Federal salary	147	147	147	147	152	152	152	152	152	152	152	152	157	157	157	157

Inquiries to: D-8170 Fax: (303) 445-6475 or rbaumgarten@do.usbr.gov or lpedde@do.usbr.gov

NOTE: The land indexes have been reinstated as part of the Construction Cost Trends. Because of a newly located source of land values from the U.S. Department of Agriculture, it was apparent that our previously published land index values lagged actual values significantly. Because of this it was necessary to recompute our values from 1985 forward.

SECTION 3

**Rock Canyon Dam
Cost Estimate**

A reconnaissance level cost estimate was made for the Rock Canyon Damsite. This is an off-stream storage reservoir site that would divert flows from Coal Creek. Refer to Figure III-1 for location of the Damsite.

Reconnaissance level cost estimates were made for a roller compacted concrete dam for an earth-filled dam. The cost estimates are contained in Table III-1. Table III-2 presents information on the area-capacity of the reservoir site. The storage capacity of this reservoir site would be 6,000 acre-feet with a surface area of approximately 40 acres.

A general schematic of the profile of these two different dam types is shown in Figure III-2. Additional details of how the calculations for the cost estimates of the two dams are presented in Figure III-3 for Roller Compacted Concrete Dam and Figure III-4 for a Gravity Filled Dam.

The present worth cost per acre-foot and annual cost per acre-foot were computed based on an interest rate of 5% and a 30-year period.

Reconnaissance Level Cost estimate for a Roller Compacted Concrete Dam

The capital cost for a Roller Compacted Concrete Dam would be approximately \$9,851,746. The present worth cost per acre-foot, including operation and maintenance would be approximately \$1,741 per acre-foot. The annual cost per acre-foot would be about \$ 113 per acre-foot.

Reconnaissance Level Cost Estimate for an Earth Filled Dam

The capital cost for an earth filled dam would be approximately \$8,570,680. The present worth cost per acre-foot, including operation and maintenance would be approximately \$1,545 per AF. The annual cost would be about \$100 per acre-foot.

Geologic Concerns

Significant geologic concerns relating to gypsum occur at the Damsite. This could add considerably to the cost of each of the dams. A memorandum for the geology of the Damsite is discussion in a memorandum from the State of Utah and is presented in the attachment section found at the end of this report.



Figure III - 1

ROCK CANYON DAMSITE

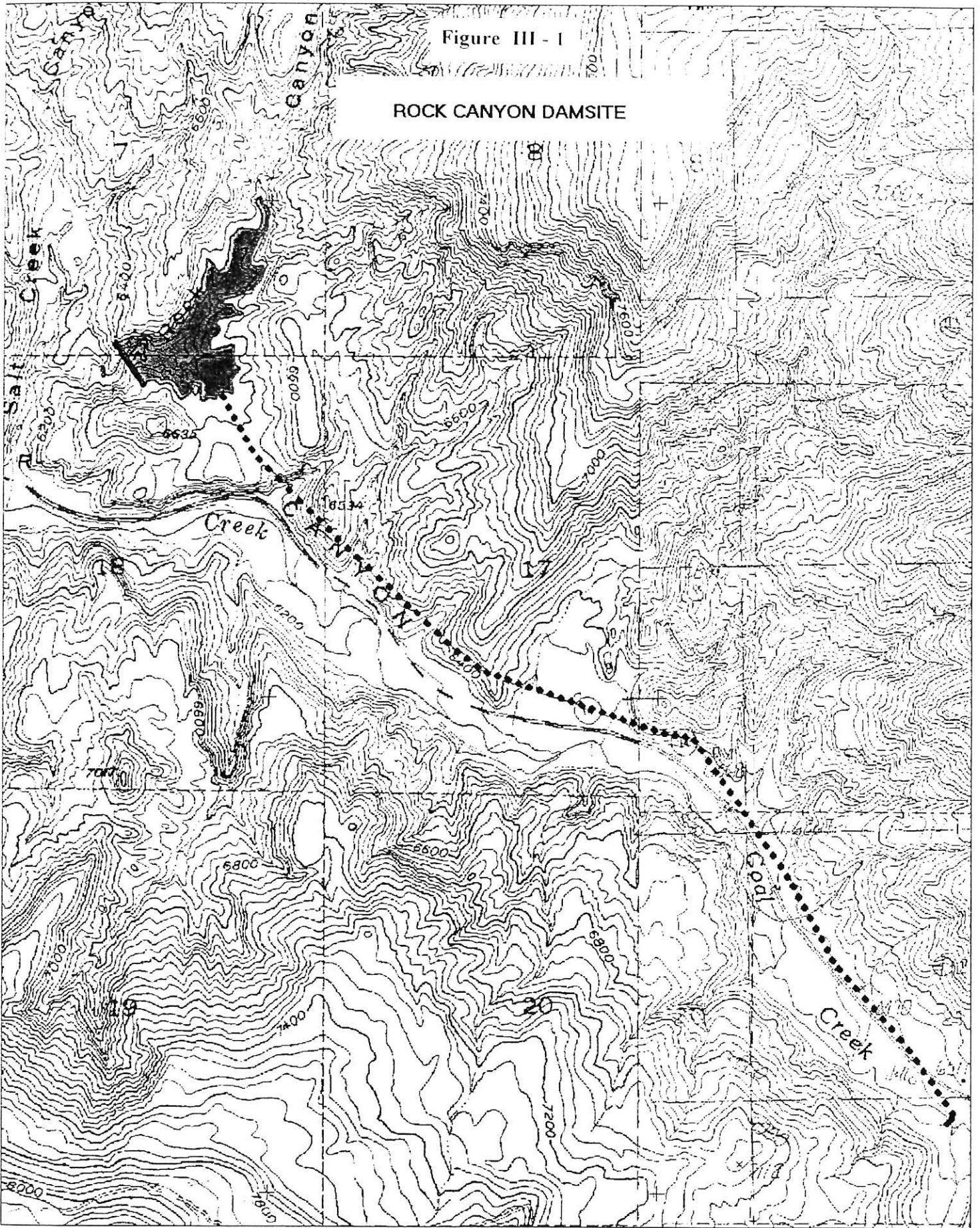


TABLE III - 1		
ROCK CANYON DAM SITE (NEAR CEDAR CITY, UTAH)		
RECONNAISSANCE LEVEL COST ESTIMATE		
Item	Gravity Dam	Roller Compacted Concrete (RCC) Dam
Height (above streambed)	180 feet	180 feet
Crest Length	600 feet	600 feet
Surface Area	40 acres	40 acres
Reservoir Capacity at Maximum Water Surface	6700 acre-feet	6,700 acre-feet
Reservoir Capacity at Minimum Water Surface	160 acre-feet	160 acre-feet
Active Capacity of Reservoir	6,540 acre-feet	6,450 acre-feet
Volume of Dam Embankment	845,429 cubic yards	149,446 cubic yards
Unit Price per Cubic Yard	\$5 per cubic yard	\$34 per cubic yard
Cost of Dam Embankment	\$4,227,145	\$5,081,164
Cost of Facilities to Fill Reservoir		
• 42 inch steel pipeline	2.5 miles	2.5 miles
- Length in linear feet	13,200 feet	13,200 feet
- Cost per foot	\$120 per foot	\$120 per foot
• Diversion dam/Desilting features	\$200,000	\$200,000
Cost of Features (dam and pipeline)	\$5,072,544	\$6,097,397
Add 20% for outlet works, spillway, roads and etc.	\$ 845,429	\$1,016,233
Subtotal	\$6,856,544	\$7,881,397
Add 25% for engineering, geology, and design	\$1,614,107	\$1,970,349
TOTAL CAPITAL COST	\$8,570,680	\$9,851,746
Present Worth of O&M assuming \$100,000 per year	\$1,537,245	\$1,537,245
Total Present Worth Cost of Dam including O&M	\$10,107,925	\$11,388,991
Annual Cost including O&M	\$657,535	\$740,870
Water Supply	6,540 AF	6,540 AF
Present worth cost of water per acre-foot	\$1,545 per AF	\$1,741 per AF
Annual cost of water per acre-foot	\$100 per AF	\$113 per AF

Table III - 2

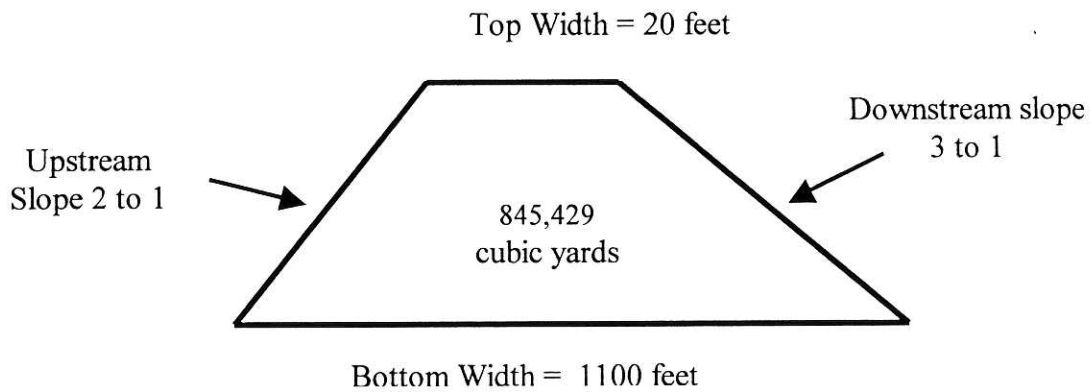
ROCK CANYON DAMSITE

Elevation - Area - Capacity

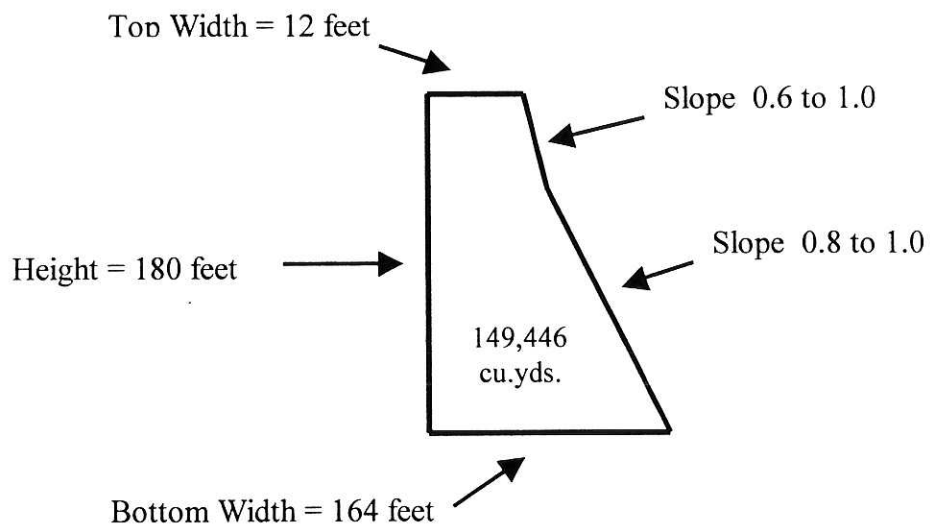
Elevation	Depth	Area (acres)	Average Area (acres)	Volume (acre-feet)
6180	0	0	0	0
6200	20	0.6	0.3	6
6400	60	3.7	2.7	160
6280	100	8	5.9	586
6320	16.8	16.8	12.4	1,734
6360	35	40	28.4	6,700

**ROCK CANYON DAM SITE
(Near Cedar City)**

GRAVITY DAM



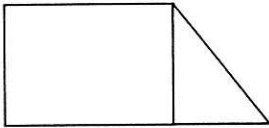
**Roller Compacted Concrete Dam
(RCC)**



**Figure III - 2
Profile of Dam Cross-Section**

FIGURE III - 3
Roller Compacted Concrete Dam
Computation of Areas and Volumes
Of Dam Embankment Materials
Rock Canyon Damsite

First 15 feet of dam height as measured from top of dam

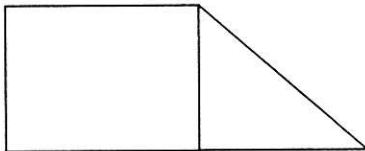


Note: Sketches of profiles are not drawn in portion to their relative height or width. They are merely shown to demonstrate how computations were made of each section of the dam.

$$\text{Area} = 15 \times 12 + \frac{1}{2} \times 10.5 \times 15 = 180 + 78.75 = 258.75 \text{ square feet}$$

$$\text{Volume} = \text{Length} \times \text{Area} = 600 \times 258.75 = 155,250 \text{ cubic feet or } 5,750 \text{ cubic yards}$$

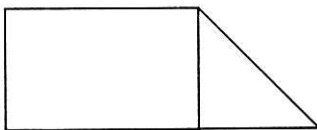
Between 15 feet and 55 feet of dam height as measured from top of dam



$$\text{Area} = 22.5 \times 40 + \frac{1}{2} \times 16.0 \times 40 = 900 + 320 = 1,220 \text{ square feet}$$

$$\text{Volume} = \text{Length} \times \text{Area} = 505 \times 1,220 = 616,100 \text{ cubic feet or } 22,819 \text{ cubic yards}$$

Between 55 feet and 95 feet of dam height as measured from top of dam



$$\text{Area} = 38.5 \times 40 + 1.2 \times 40.0 \times 40.0 = 1540 + 800 = 2,340 \text{ square feet}$$

$$\text{Volume} = \text{Length} \times \text{Area} = 2,340 \times 335 = 783,900 \text{ cubic feet or } 29,033 \text{ cubic yards}$$

FIGURE III- 3 (continued)

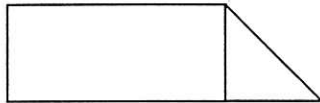
Between 95 feet and 135 feet of dam height as measured from top of dam



$$\text{Area} = 78.5 \times 40 + \frac{1}{2} \times 28 \times 40 = 3,140 + 560 = 3,700 \text{ square yards}$$

$$\text{Volume} = \text{Length} \times \text{Area} = 3,700 \times 215 = 795,500 \text{ cubic feet or } 29,463 \text{ cubic yards}$$

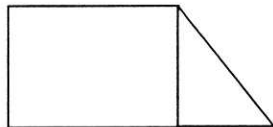
Between 135 feet and 180 feet of dam height as measured from top of dam



$$\text{Area} = 106.5 \times 55 + 1.2 \times 31.5 \times 55 = 5857.5 + 866.25 = 6,723.75$$

$$\text{Volume} = \text{Length} \times \text{Area} = 6,723.75 \times 125 = 840,468.75 \text{ cubic feet or } 31,128 \text{ cubic yards}$$

Between 180 feet and 200 feet of dam height as measured from top of dam



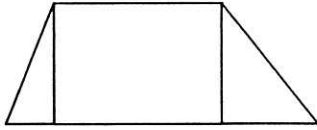
$$\text{Area} = 152 \times 20 + \frac{1}{2} \times 1.2 \times 12 \times 20 = 3,040 + 120 = 3,160 \text{ square feet}$$

$$\text{Volume} = \text{Length} \times \text{Area} = 3,160 \times 40 = 126,400 \text{ cubic feet or } 31,253 \text{ cubic yards}$$

Roller Compacted Concrete Dam Summary of Cubic Yards of Dam Embankment	
Section of Dam	Volume of Dam Material
0 to 15 feet depth	5,750 cubic yards
15 feet to 55 feet depth	22,819 cubic yards
55 feet to 95 feet depth	29,033 cubic yards
95 feet to 135 feet depth	29,463 cubic yards
135 feet to 180 feet depth	31,128 cubic yards
180 feet to 200 feet depth	31,253 cubic yards
Total	149,446 cubic yards

FIGURE III - 4
Earth-Filled Dam
Computation of Areas and Volumes
Of Dam Embankment Materials
Rock Canyon Damsite

First 15 feet of dam height as measured from top of dam



Note: Sketches of profiles are not drawn in portion to their relative height or width. They are merely shown to demonstrate how computations were made of each section of the dam.

$$\text{Area} = 20 \times 20 + \frac{1}{2} \times 40 \times 15 + \frac{1}{2} \times 15 \times 60 = 1150 \text{ square feet}$$

$$\text{Volume} = \text{Length} \times \text{Area} = 600 \times 1150 = 690,000 \text{ cubic feet or } 25,600 \text{ cubic yards}$$

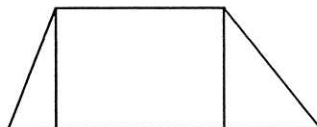
Between 15 feet and 55 feet of dam height as measured from top of dam



$$\text{Area} = \frac{1}{2} \times 80 \times 40 + 120 \times 40 + \frac{1}{2} \times 40 \times 20 = 8,800 \text{ square feet}$$

$$\text{Volume} = \text{Length} \times \text{Area} = 505 \times 8,800 = 4,444,000 \text{ cubic feet or } 164,595 \text{ cubic yards}$$

Between 55 feet and 95 feet of dam height as measured from top of dam

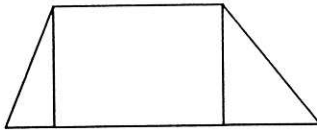


$$\text{Area} = \frac{1}{2} \times 80 \times 40 + 320 \times 40 + 1.2 \times 40 \times 120 = 16,800 \text{ square feet}$$

$$\text{Volume} = \text{Length} \times \text{Area} = 16,800 \times 335 = 5,628,000 \text{ cubic feet or } 208,444 \text{ cubic yards}$$

Figure III - 4 (continued)

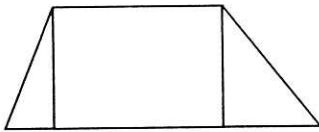
Between 95 feet and 135 feet of dam height as measured from top of dam



$$\text{Area} = \frac{1}{2} \times 80 \times 40 + 520 \times 40 + \frac{1}{2} \times 40 \times 120 = 24,800 \text{ square feet}$$

$$\text{Volume} = \text{Length} \times \text{Area} = 215 \times 24,800 = 5,332,000 \text{ cubic feet or } 197,481 \text{ cubic yards}$$

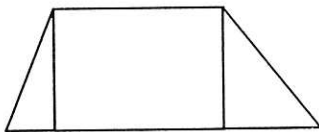
Between 135 feet and 180 feet of dam height as measured from top of dam



$$\text{Area} = \frac{1}{2} \times 110 \times 55 + 55 \times 720 + \frac{1}{2} \times 55 \times 165 = 47,163 \text{ square feet}$$

$$\text{Volume} = \text{Length} \times \text{Area} = 125 \times 47,163 = 5,895,375 \text{ cubic feet or } 218,347 \text{ cubic yards}$$

Between 180 feet and 200 feet of dam height as measured from top of dam



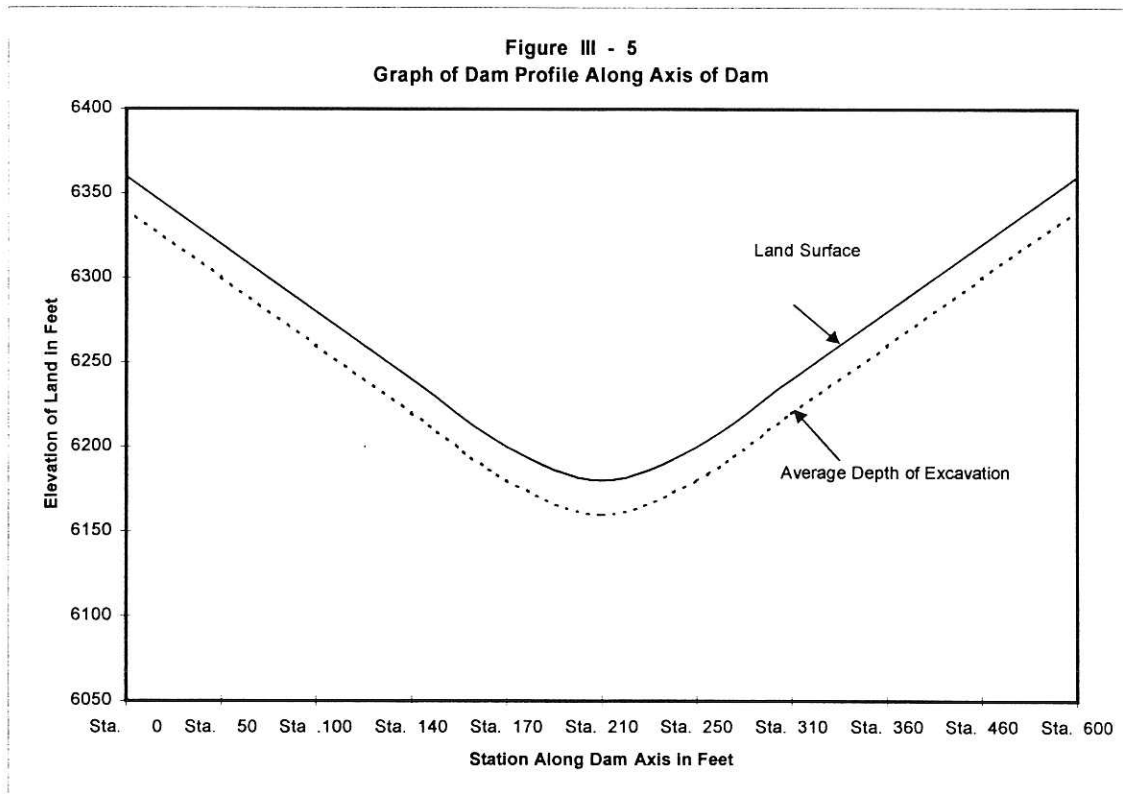
$$\text{Area} = \frac{1}{2} \times 40 \times 20 + 995 \times 20 + \frac{1}{2} \times 20 \times 60 = 20,900 \text{ square feet}$$

$$\text{Volume} = \text{Length} \times \text{Area} = 40 \times 20,900 = 836,000 \text{ cubic feet or } 30,962 \text{ cubic yards}$$

Figure III - 4 (continued)

Earth Filled Dam Summary of Cubic Yards of Dam Embankment	
Section of Dam	Volume of Dam Material (Cubic Yards)
0 to 15 feet depth	25,600
15 feet to 55 feet depth	164,595
55 feet to 95 feet depth	208,444
95 feet to 135 feet depth	197,481
135 feet to 180 feet depth	218,347
180 feet to 200 feet depth	30,962
Total	845, 429

Table III - 3			
Station	Elevation	Assumed Depth (ft.) of Excavation to bedrock	Elevation at bedrock
Sta. 0	6360	20	6340
Sta. 50	6320	20	6300
Sta. 100	6280	20	6260
Sta. 140	6240	20	6220
Sta. 170	6200	20	6180
Sta. 210	6180	20	6160
Sta. 250	6200	20	6180
Sta. 310	6240	20	6220
Sta. 360	6280	20	6260
Sta. 460	6320	20	6300
Sta. 600	6360	20	6340



SECTION 4

Groundwater

Groundwater withdrawals are based upon a very simplified approach to yield results that are within the accuracy of reconnaissance level estimates. For this approach information is required on the storage coefficient, surface area of the groundwater basin, and the allowable depth of additional groundwater withdrawals.

Reconnaissance levels estimates of groundwater withdrawals are based upon the equation:

$$\text{Change in Groundwater Storage} = \text{Surface Area} \times \text{Storage Coefficient} \times \text{Change in Depth}$$

Groundwater volumes (withdrawal/recharge) and storage coefficient are based upon information from the report, Groundwater Resources of the Parowan-Cedar City Drainage Basin, Iron County, Utah, Technical Publication No. 60, State of Utah and U.S. Geological Survey, 1978.

Determination of Storage Coefficient from Previous Studies

Information on the storage coefficient is available from Technical Publication No. 60 as shown in Table IV – 1. The storage coefficient (S) of an aquifer is the volume of water it releases from or takes into storage per unit of surface area of the aquifer per unit change in head. S is a dimensionless number. Under confined conditions, S is typically small, generally between 0.00001 and 0.0001. Under unconfined conditions, S is much larger, typically ranging from 0.05 to 0.30.

Pumped Well	Observation Well	Storage Coefficient
(C-35-10)18cca-1	(C-35-10)18cbd-1	0.2 _{estimate}
“	(C-35-10)18ccb-1	0.2 _{estimate}
“	(C-35-11)13ada-1	0.2 _{estimate}
“	(C-35-11)13ddb-1	0.2 _{estimate}
“	(C-35-11)24aab-1	0.2 _{estimate}
(C-35-10)18cca-1	(C-35-10)18cca-1	0.2 _{estimate}
(C-36-12)32ccb	(C-36-12)32ccc-1	0.0013
“	(C-37-12) 5bbb-1	0.01
“	(C-37-12) 5bcb-1	0.0015
(C-36-12)32ccc-1	(C-36-12)32ccc-1	0.0015
(C-37-12)23acb-1	(C-37-12)23aca-1	0.0005
“	(C-37-12)23cbd-1	0.013
Average of Numbers for Storage Coefficient		0.1023

The U.S. Geological Survey is presently developing a groundwater model for Cedar Valley. This model will be available in the year 2002 and will be the tool to be used in predicting the storage coefficient and impacts of additional groundwater withdrawals on the water table.

Determination of Surface Area of Groundwater Basin from Previous Studies

From information contained in Technical Publication No. 60, the approximate surface area affected by groundwater withdrawals was 150 square miles which is approximately 100,000 acres. The surface area of Cedar Valley that is affected by different depths of groundwater withdrawal are shown in Table IV -2. The affected surface area of 100,000 acres in Technical Publication No. 60 could have included the fringe areas of the groundwater basin. It is possible that these fringe areas could have shallow depths and therefore contribute little to overall groundwater budget. To be conservative a range of values from 75,000 to 95,000 acres was used for the surface area in predicting the potential for additional groundwater withdrawals. These results are presented in Table IV - 3.

TABLE IV - 2			
SURFACE AREA OF GROUNDWATER BASIN AND WEIGHTED AVERAGE DEPTH OF GROUNDWATER LEVEL DRAWDOWN FOR THE PERIOD OF 1940 - 1974			
(SOURCE: STATE OF UTAH, TECHNICAL PUBLICATION NO. 60, 1978)			
Decline of ground-water level 1940-74	Size of Area Affected	Percent of area affected	Weighted Depth Of Groundwater
More than 30 feet	8 square miles	5%	1.5 feet
20 to 30 feet	18 square miles	12%	3.0 feet
10 to 20 feet	49 square miles	33%	5.0 feet
0 to 10 feet	75 square miles	50%	2.5 feet
Total Surface Area	150 square miles		
Weighted Average Depth of Decline			12.0 feet

Results from Reconnaissance Level Evaluation of Potential for Additional Groundwater Pumping

A range of possible groundwater pumping scenarios was computed utilizing various assumed allowable changes in groundwater depths, a range of storage coefficients and several different assumptions for the surface area of the groundwater aquifer.

These results are presented in Table IV – 3 and graphically in Figure IV – 1. As shown in Table IV – 3, the surface area, change in groundwater depth, and the storage coefficient each have a significant impact on the amount of groundwater that is eventually available for use. In absence of the availability of data to determine the exact nature of each of these parameters, a professional judgment was made concerning a possible groundwater pumping scenario. Based upon the information to date, it appears reasonable that for planning purposes in assessing how groundwater pumping could meet the future needs of Cedar Valley - a storage coefficient of 0.075, additional increase in groundwater depths of 20 feet, and a surface area of 85,000 acres can be used.

Based upon Table IV – 3, a total volume in the range of 86,000 to 176,000 acre-feet is used as a reasonable estimate of the additional water that could be pumped from the aquifer underlying Cedar Valley. Over a 30 year period of 2000 to 2030 this volume would represent an average of 3,000 to 6,000 acre-feet per year.

Cost Estimate of Groundwater Pumping

The cost of groundwater pumping consists of two components. One is the capital cost of installing wells and the second is the annual operating and maintenance costs.

Calculation of Costs in Terms of Present Worth Cost per Acre-Foot

From a study by Montgomery-Watson, Cedar City Water System Master Plan, October 1998, the capital cost of installing 12 wells, each producing 1000 gallons per minute, would be a total of \$2,760,000. One thousand gallons per minute is equivalent to 1,600 acre-feet per year. Therefore the total of 12 wells would have the capacity for approximately 19,000 acre-feet. The capital component would have a present value in terms of dollars per acre-foot of \$145.

From information provided by Cedar City's engineering department the annual operating and maintenance costs of their existing wells is 21 cents per 1000 gallons. This is equivalent to approximately \$70 per acre-foot. The present value of this annual cost based upon a well field capacity of 19,000 acre-feet, an interest rate of 5 percent and a 30-year period would \$ 20,445,360 or \$ 1,076 per acre-foot.

The total present worth cost per acre-foot would then be \$145 per acre-foot plus \$1,076 per acre-foot, which would be a total present worth cost of \$1,221 per acre-foot.

Calculation of Cost in Terms of Annual Cost per Acre-Foot

The annualized present worth cost of based upon an interest rate of 5 percent and a 30 - year period of time would be \$179,542. Based upon a well field capacity of 19,000 acre-feet, the annual cost of the capital would then be \$ 10 per acre-feet.

As stated previously the annual operating cost would be \$70 per acre-foot.

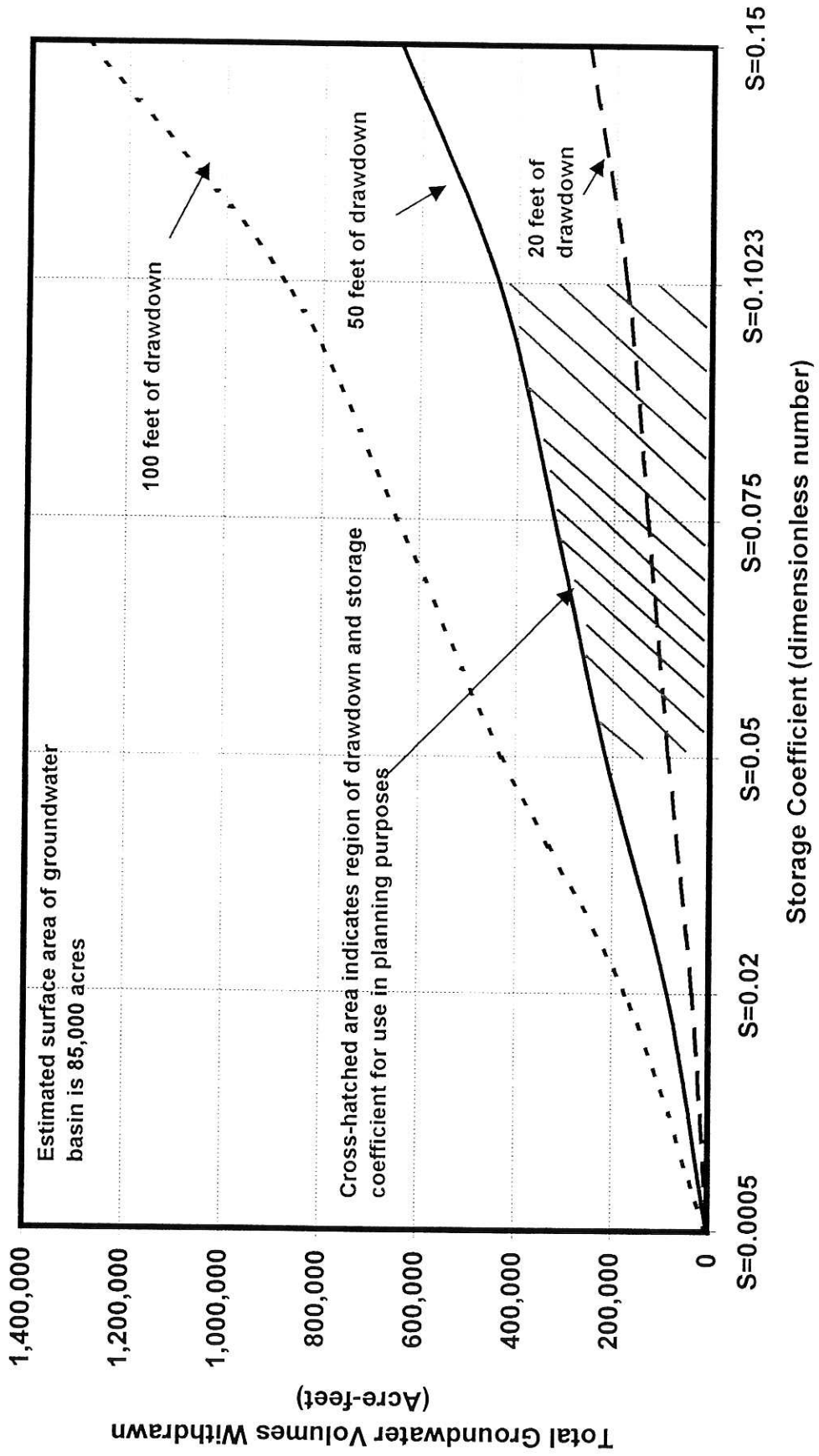
Calculation of Total Annual Cost

Total annual cost per acre-foot for production of water from wells would be:

Annualized capital cost	=	\$ 10/AF
Annual operating/maintenance cost	=	\$ 70/AF
Total	=	\$ 80 per acre-foot

Additional costs to convey water to points of use and additional facilities such as storage tanks to meet peak daily and hourly demands have not been included.

FIGURE IV - 1
Comparison of Groundwater Volumes as a Function
of Drawdown and Storage Coefficient



SECTION 5

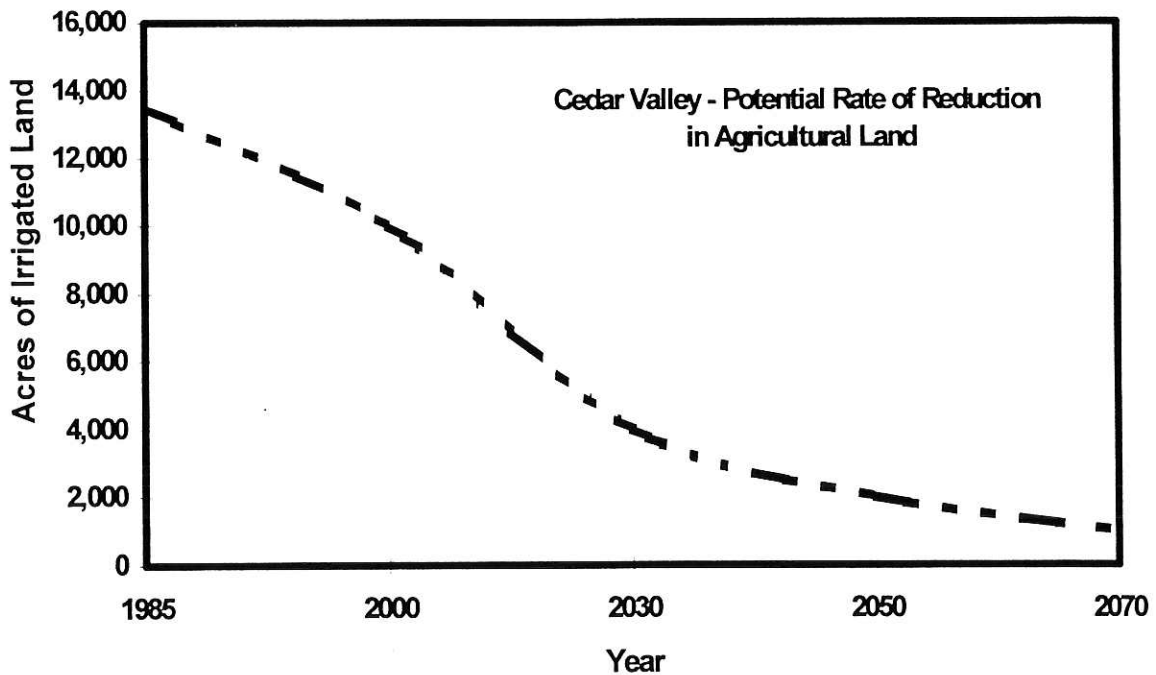
Irrigation Systems

Possible Rate of Change in Irrigated Land As An Agricultural Economy

The amount of irrigated land in Cedar Valley has been declining. The amount of irrigated land in 1985 was 13,500 acres, while in 1999 the amount of irrigated land was estimated at 10,000 acres. This represents a reduction of 3,500 acres over the last 15 years which is approximately 200 acres per year. Assuming this same trend continues in future years, the amount of irrigated land would be reduced to about 4,000 acres in 2030 and would approach zero between 2050 and 2075. This rate of change decreases the likelihood of irrigators investing heavily in equipment or conveyance facilities to increase overall irrigation system efficiency.

**Cedar Valley
Possible Rate of Agricultural Land Decrease**

	Years				
	1985	2000	2030	2050	2070
Irrigated Land	13,500	10,000	4,000	2,000	1,000



Evaluation of Opportunities for Water Savings from Lining Main Canals

The Senior Water Users consisting of the Union Field Irrigation Company, the North Field Irrigation Company, and the East Extension Irrigation Company divert approximately 44% of the primary flow of Coal Creek. In addition to their primary flow they divert a large amount of high water. These three irrigation companies have about 20 miles of concrete lined canals and about 6 miles of other unlined canals. Based on 1985 prices the cost to either line or replace with concrete pipe would cost \$1,810,000. The cost index from 1985 to 1999 is about 1.6. Therefore the cost in 1999 dollars would be \$2,896,000. Adding 25% for engineering and contingencies would bring this cost to a total of \$3,620,000. As a "rule of thumb" in irrigation projects that use unlined canals/ditches to convey water, the water loss is approximately as follows:

- 10 to 15% in transport by main canals from rivers to major farm laterals;
- 10 to 15% loss in major and minor farm laterals;
- 10 to 15 % loss in on-farm irrigation efficiencies;
- 5 to 10 % loss due to poor timing of arriving or applying irrigation water

Using information from Table V-1, the amount diverted by direct flow rights is approximately 21,765 acre-feet on the average. Using a loss of 15% for the main canals, a water savings of approximately 3,265 acre-feet could be achieved if the 26 miles of main canals were placed in a piping network.

Evaluation of Opportunities for Secondary Systems in the Agricultural and Sparsely Developed Areas

One option that offers promise for the changing role of agriculture in Cedar Valley would be the installation of secondary water systems in the partially and newly developed areas of Cedar Valley provide the potential for overall water system efficiency. A secondary water system consists of a water delivery network, completely separate from the drinking water distribution system and intended solely for the delivery of untreated or partially treated water for outdoor irrigation such as irrigated farmland, golf courses, and residential gardens and lots. A pressurized system is preferable to a non-pressurized system.

Table V - 1
Determination of the Approximate Amount of Water
That Could be Delivered by Direct Flow From Coal Creek by a Pressurized Irrigation System

	April	May	June	July	Aug.	Sept.	Oct.	Total
AVAILABLE SURFACE WATER								
Coal Creek Flows	3,479	9,288	4,555	1,560	1,205	874	804	21,765
Effective Precipitation	868	562	446	793	1,008	595	736	5,008
Total Surface Water for Irrigation Crop Needs	4,347	9,850	5,001	2,353	2,213	1,469	1,540	26,773
IRRIGATION REQUIREMENTS								
Crop Consumptive Use	0.04	0.35	0.51	0.59	0.51	0.25	0.04	2.29
Crop Water Requirements for Irrigation Companies (based on a total of 10,000 acres)								
Senior City & South/West Field Irrigation	21	184	268	310	268	131	21	1,204
Senior North (Union Field, North Field, & East Extension)	72	631	920	1,064	920	451	72	4,129
Junior Water Users (Coal Creek, Bulldog, & Old Fort/Old Field)	307	2,684	3,911	4,525	3,911	1,917	307	17,561
Total Crop Water Requirements	400	3,499	5,099	5,898	5,099	2,499	400	22,894
Overall Irrigation System Efficiency	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total Required Diversions for Agricultural Water	800	6,998	10,197	11,797	10,197	4,999	800	45,788
HOW DEMANDS ARE MET								
Amount Met by Surface Diversions/Precipitation ^{1/}	800	6,998	5,001	2,353	2,213	1,469	800	26,773
Amount Met by Groundwater Pumping ^{2/}	0	0	5,196	9,444	7,984	3,530	0	19,015

^{1/} Also the approximate amount that could be delivered by direct flow diversions from Coal Creek through a pressurized network of pipelines.

^{2/} Also the approximate amount that could be delivered from storage reservoirs or recycled water.

Secondary water systems provide several advantages over the use of culinary water for outdoor uses. These include:

- Reducing pumping on the groundwater aquifer underlying Cedar Valley;
- Monetary savings by not treating water for irrigation to meet drinking water standards;
- Removal of peak demands on the culinary water supply system due to outdoor watering;
- Reduction of the need to develop new treatment plants or expand culinary transmission line capacity;
- Ability to utilize lower quality waters which otherwise could not be used; and
- The potential for recycling of treated wastewater.

Significant opportunities exist in Cedar Valley for implementing a secondary water systems that could serve both agriculture and future and municipal growth. These opportunities include:

1. Secondary system to serve the agricultural lands for the junior and senior irrigation companies in Cedar Valley.
2. Secondary systems to serve future M&I growth in Cedar Valley.
3. Secondary systems to utilize water treated by tertiary treatment for outdoor landscape and agricultural irrigation.

Costs for a pressurized secondary water system that serve either agricultural or municipal users has been estimated on a reconnaissance level using the data provided by the State of Utah in their report on evaluation of sprinkler systems for Cedar Valley, dated 1985. This data is presented in Tables V-2 and V-3. These unit costs are based on 1985 costs and have cost indexed to 1999 using a cost inflation factor of 1.6.

The amount of irrigated land in 1985 was approximately 10,500 acres for the Junior Irrigation Companies. The total irrigated land in 1985 was about 13,500 acres for all irrigation companies. By 1999 the amount of irrigated land in Cedar Valley was estimated at 10,000 acres by Utah Division of Water Resources. Therefore a percentage reduction of $10,000/13,500$ or 73% was applied to the 10,500 acres to arrive at an approximate acreage in the year 2000. Table V-2 determined that a reconnaissance level cost for a pressurized network of pipelines to provide pressure for the Junior Irrigation Companies would be about \$14,000,000. To include a pressurized system for the Senior Irrigation Companies would add another \$4,000,000 for a total of \$18,000,000 to serve the approximately 10,000 acres of presently irrigated lands.

SECTION 5

IRRIGATION SYSTEM EFFICIENCY
AND SECONDARY WATER SYSTEM

Table V-2 Cost Estimate For Delivery System for Pressurized Irrigation Junior Irrigation Companies (Bulldog, Coal Creek, and Old Fort/Old Field)				
System Would Cover 10,500 acres of land (Data below is reproduced from Sprinkler Irrigation Study, Utah Division of Water Resources, 1985)				
Item	Description	Quantity (Linear Feet)	Unit Price (1985 cost)	Total
1	3" PVC Pipe 125 psi	10,000	\$1.50	\$15,000
2	4" PVC Pipe 125 psi	30,000	\$1.90	\$57,000
3	6" PVC Pipe 1000 psi	20,000	\$2.70	\$54,000
4	8" PVC pipe 100 psi	14,000	\$3.40	\$47,600
5	10" PVC Pipe 100 psi	22,000	\$4.80	\$105,600
6	12 " PVC Pipe 100 psi	21,500	\$5.60	\$120,400
7	15" PVC Pipe 100 psi	44,300	\$7.50	\$332,250
8	18" PVC Pipe 100 psi	41,000	\$11.30	\$463,300
9	21 " PVC Pipe 100 psi	23,700	\$15.10	\$357,870
10	24 " PVC Pipe 100 psi	57,800	\$17.60	\$1,017,280
11	27" PVC Pipe 100psi	8,900	\$24.00	\$213,600
12	42" Steel Pipe	15,900	\$79.00	\$1,256,100
13	48 " Steel Pipe	8,300	\$91.00	\$755,300
14	54" Steel Pipe	5,000	\$121.00	\$605,000
Subtotal Cost for PVC Pipe				\$5,400,300
15	Fittings, valves, etc. @10%			\$540,030
16	Wells, electric motors, pumps, pump houses	State of Utah included the cost for 50 wells @ \$80,000 per well for a total of \$4,000,000		
17	Diversion structure	lump sum		\$100,000
18	Desilting structures	2	\$50,000	\$100,000
19	State road crossings	lump sum		\$5,000
20	County road crossings	20 each	\$1,000	\$20,000
21	Regulation pond 400 af	lump sum		\$800,000
22	Bulldog pond renovation	lump sum		\$20,000
Subtotal of other features				\$1,585,030
TOTAL (1985 cost)				\$6,985,330
Total 1999 cost using Cost Index of 1.6				\$11,176,528
Add engineering and contingencies of 25%				\$2,794,132
TOTAL COST				\$13,970,660
TOTAL COST (ROUNDED)				\$14,000,000

SECTION 5

IRRIGATION SYSTEM EFFICIENCY
AND SECONDARY WATER SYSTEM

Table V - 3				
Cost Estimate For Delivery System for Pressurized Irrigation Senior Irrigation Companies (North Field, East Extension, and Union Field)				
System would cover 2470 acres of land (Data below is reproduced from Sprinkler Irrigation Study, Utah Division of Water Resources, 1985)				
Item	Description	Quantity (Linear Feet)	Unit Price (1985 cost)	Total
1	4" PVC Pipe 125 psi	20,000	\$1.90	\$38,000
2	6" PVC Pipe 100 psi	35,000	\$2.70	\$94,500
3	8" PVC pipe 100 psi	39,000	\$3.40	\$132,600
4	10" PVC Pipe 100 psi	21,700	\$4.80	\$104,160
5	12 " PVC Pipe 100 psi	7,600	\$5.60	\$42,560
6	15" PVC Pipe 100 psi	2,400	\$7.50	\$18,000
7	18" PVC Pipe 100 psi	4,200	\$11.30	\$47,460
8	21 " PVC Pipe 100 psi	9,600	\$15.10	\$144,960
9	24 " PVC Pipe 100 psi	12,000	\$17.60	\$211,200
10	27" PVC Pipe 100psi	29,800	\$24.00	\$715,200
Subtotal Cost for PVC Pipe				\$1,548,640
11	Fittings, valves, etc. @10%			\$154,864
12	Pressure reducing station (large)	lump sum		\$15,000
13	Pressure reducing station (small)	lump sum		\$5,000
14	Install pump on Union well	lump sum		\$50,000
15	Wells, electric motors, pumps, pump houses	State of Utah included the cost for 3 wells @ \$80,000 per well for a total of \$240,000		
16	Diversion structure	lump sum		\$100,000
17	Desilting structures	1	\$50,000	\$50,000
18	State road crossings	3 each	\$5,000	\$5,000
19	County road crossings	15 each	\$1,000	\$15,000
20	Regulation pond 70 af	lump sum		\$170,000
21	Bulldog pond renovation	lump sum		\$20,000
Subtotal of other features				\$584,864
TOTAL (1985 cost)				\$2,133,504
Total 1999 cost using Cost Index of 1.6				\$3,413,606
Add engineering and contingencies of 25%				\$853,402
TOTAL COST				\$4,267,008
TOTAL COST (ROUNDED)				\$4,000,000

SECTION 6

**Cost for Purchase
Of Water Rights**

The basis for pursuing a water right purchase program is the growth of urbanization in Cedar Valley which is witnessing a reduction in the agricultural land base. In 1985 the amount of irrigated land was 13,000 acres and by the year 2000 the amount of irrigated land had been reduced to 10,000 acres. This reduction of 3,000 acres over this 15 year period amounts to an average of approximately 200 acres of land each year that is either converted to urban use or is no longer irrigated. Based on the usual manner for adjudication of water rights, an acre of irrigated land was allotted about 4.0 acre-feet per acre as a diversion right. The amount that is consumptively used is limited to the crop consumptive use which for the major crop of alfalfa in Cedar Valley amounts to approximately 2.0 acre-feet per acre. This is the amount that can usually be transferred to another use.

Assumptions of a Water Right Purchase Program to Purchase 75 acre-feet of Water Rights per Year

As land goes out of production a significant portion is developed as residential areas. For purposes of analyzing a water right purchase program the following assumptions are used.

- Assume the long-term average yearly reduction in agricultural = 200 acres
- Assume a Conservative Estimate of the amount of water potential available for M&I = $150 \times 2.0 \text{ AF/acre} = 300 \text{ AF}$
- Assume that others will acquire utilize three-fourths of the 300 acre-feet of water rights over the time period of 2000 to 2030. This will leave 75 acre-feet to be either purchased or left in the ground for storage.
- Assume the Central Iron County Water Conservancy District may choose to pursue a program of purchasing 75 acre-feet per year of water rights that are then held for the future use of the residents of Central Iron County.

Calculation of Costs to Purchase Water Rights

Both present worth and annual costs per acre-foot of water right purchase have been computed for a water rights purchase program. Table VI - 1 is a summary of these costs with additional details provided in Table VI - 2 through Table VI - 11.

For reconnaissance level planning purposes, an inflation rate in the 6% to 8% range is considered to be within the level of accuracy required to evaluate the cost of a water right purchase program.

Risks of Water Rights Purchase Program

There are several risks associated with a water rights purchase program. A brief listing of these risks is provided.

- Risk of Availability of Lands with Senior Water Rights.
- Risks Associated with Estimating Rate of Inflation of Land and Associated Water Rights
- Risks Associated with the Assumption There Would Be No Disruption to Market Prices of Land.
- Risk of Encountering Higher Costs Resulting from A Longer Procurement Period for Water Right Purchases.

Assumed Rate of Inflation for Land/Water Prices	Present Worth Cost	Present Worth Cost in Dollars per Acre-Foot	Annual Cost in Dollars per Acre - Foot
1%	\$1,378,162	\$593	\$32
2%	\$1,556,274	\$669	\$38
3%	\$1,768,267	\$761	\$45
4%	\$2,021,497	\$869	\$54
5%	\$2,325,000	\$1,000	\$65
6%	\$2,689,869	\$1,157	\$78
7%	\$3,129,733	\$1,346	\$95
8%	\$3,661,334	\$1,575	\$115
9%	\$4,305,239	\$1,852	\$140
10%	\$5,086,707	\$2,188	\$171

Table VI - 2
Cost to Purchase Water Rights

(Total of 2,375 acre-feet over 30 year period)

Rate of Increase in Land/Water Rights	Years	Volume each Year of Water Right Purchase in acre-feet	Present Cost of Water Rights (year 2000)	Future Value at end of each year to purchase water rights	Present Value of Water Right Purchase
1%	0	75	\$1,000.00	\$75,000	\$75,000
1%	1	75	\$1,000.00	\$75,750	\$72,143
1%	2	75	\$1,000.00	\$76,508	\$69,395
1%	3	75	\$1,000.00	\$77,273	\$66,751
1%	4	75	\$1,000.00	\$78,045	\$64,208
1%	5	75	\$1,000.00	\$78,826	\$61,762
1%	6	75	\$1,000.00	\$79,614	\$59,409
1%	7	75	\$1,000.00	\$80,410	\$57,146
1%	8	75	\$1,000.00	\$81,214	\$54,969
1%	9	75	\$1,000.00	\$82,026	\$52,875
1%	10	75	\$1,000.00	\$82,847	\$50,861
1%	11	75	\$1,000.00	\$83,675	\$48,923
1%	12	75	\$1,000.00	\$84,512	\$47,059
1%	13	75	\$1,000.00	\$85,357	\$45,267
1%	14	75	\$1,000.00	\$86,211	\$43,542
1%	15	75	\$1,000.00	\$87,073	\$41,883
1%	16	75	\$1,000.00	\$87,943	\$40,288
1%	17	75	\$1,000.00	\$88,823	\$38,753
1%	18	75	\$1,000.00	\$89,711	\$37,277
1%	19	75	\$1,000.00	\$90,608	\$35,857
1%	20	75	\$1,000.00	\$91,514	\$34,491
1%	21	75	\$1,000.00	\$92,429	\$33,177
1%	22	75	\$1,000.00	\$93,354	\$31,913
1%	23	75	\$1,000.00	\$94,287	\$30,697
1%	24	75	\$1,000.00	\$95,230	\$29,528
1%	25	75	\$1,000.00	\$96,182	\$28,403
1%	26	75	\$1,000.00	\$97,144	\$27,321
1%	27	75	\$1,000.00	\$98,116	\$26,280
1%	28	75	\$1,000.00	\$99,097	\$25,279
1%	29	75	\$1,000.00	\$100,088	\$24,316
1%	30	75	\$1,000.00	\$101,089	\$23,390
Total Acre-feet		2325			
Assume an interest rate of 5%					
Total Cost				\$2,709,956	
				Total Present Worth	\$1,378,162
				Present worth/acre-foot	\$593
				Annual cost	\$119,359
				Annual Cost/acre-foot	\$32

Table VI - 3
Cost to Purchase Water Rights

(Total of 2,325 acre-feet over 30 year period)

Rate of Increase in Land/Water Rights	Years	Volume eachYear of Water Right Purchase in acre-feet	Present Cost of Water Rights (year 2000)	Future Value at end of each year to purchase water rights	Present Value of Water Right Purchase
2%	0	75	\$1,000.00	\$75,000	\$75,000
2%	1	75	\$1,000.00	\$76,500	\$72,857
2%	2	75	\$1,000.00	\$78,030	\$70,776
2%	3	75	\$1,000.00	\$79,591	\$68,753
2%	4	75	\$1,000.00	\$81,182	\$66,789
2%	5	75	\$1,000.00	\$82,806	\$64,881
2%	6	75	\$1,000.00	\$84,462	\$63,027
2%	7	75	\$1,000.00	\$86,151	\$61,226
2%	8	75	\$1,000.00	\$87,874	\$59,477
2%	9	75	\$1,000.00	\$89,632	\$57,778
2%	10	75	\$1,000.00	\$91,425	\$56,127
2%	11	75	\$1,000.00	\$93,253	\$54,523
2%	12	75	\$1,000.00	\$95,118	\$52,965
2%	13	75	\$1,000.00	\$97,020	\$51,452
2%	14	75	\$1,000.00	\$98,961	\$49,982
2%	15	75	\$1,000.00	\$100,940	\$48,554
2%	16	75	\$1,000.00	\$102,959	\$47,167
2%	17	75	\$1,000.00	\$105,018	\$45,819
2%	18	75	\$1,000.00	\$107,118	\$44,510
2%	19	75	\$1,000.00	\$109,261	\$43,238
2%	20	75	\$1,000.00	\$111,446	\$42,003
2%	21	75	\$1,000.00	\$113,675	\$40,803
2%	22	75	\$1,000.00	\$115,948	\$39,637
2%	23	75	\$1,000.00	\$118,267	\$38,504
2%	24	75	\$1,000.00	\$120,633	\$37,404
2%	25	75	\$1,000.00	\$123,045	\$36,336
2%	26	75	\$1,000.00	\$125,506	\$35,298
2%	27	75	\$1,000.00	\$126,016	\$34,289
2%	28	75	\$1,000.00	\$130,577	\$33,309
2%	29	75	\$1,000.00	\$133,188	\$32,358
2%	30	75	\$1,000.00	\$135,852	\$31,433
Total Acre-feet		2325			
Assume an interest rate of 5%					
Total Cost				\$3,178,458	
				Total Present Worth	\$1,556,274
				Present worth/acre-foot	\$669
				Annual cost	\$141,150
				Annual Cost/acre-foot	\$38

Table VI - 4
Cost to Purchase Water Rights

(Total of 2,325 acre-feet over 30 year period)

Rate of Increase in Land/Water Rights	Years	Volume each Year of Water Right Purchase in acre-feet	Present Cost of Water Rights (year 2000)	Future Value at end of each year to purchase water rights	Present Value of Water Right Purchase
3%	0	75	\$1,000.00	\$75,000	\$75,000
3%	1	75	\$1,000.00	\$77,250	\$73,571
3%	2	75	\$1,000.00	\$79,568	\$72,170
3%	3	75	\$1,000.00	\$81,955	\$70,795
3%	4	75	\$1,000.00	\$84,413	\$69,447
3%	5	75	\$1,000.00	\$86,946	\$68,124
3%	6	75	\$1,000.00	\$89,554	\$66,827
3%	7	75	\$1,000.00	\$92,241	\$65,554
3%	8	75	\$1,000.00	\$95,008	\$64,305
3%	9	75	\$1,000.00	\$97,858	\$63,080
3%	10	75	\$1,000.00	\$100,794	\$61,879
3%	11	75	\$1,000.00	\$103,818	\$60,700
3%	12	75	\$1,000.00	\$106,932	\$59,544
3%	13	75	\$1,000.00	\$110,140	\$58,410
3%	14	75	\$1,000.00	\$113,444	\$57,297
3%	15	75	\$1,000.00	\$116,848	\$56,206
3%	16	75	\$1,000.00	\$120,353	\$55,135
3%	17	75	\$1,000.00	\$123,964	\$54,085
3%	18	75	\$1,000.00	\$127,682	\$53,055
3%	19	75	\$1,000.00	\$131,513	\$52,044
3%	20	75	\$1,000.00	\$135,458	\$51,053
3%	21	75	\$1,000.00	\$139,522	\$50,080
3%	22	75	\$1,000.00	\$143,708	\$49,126
3%	23	75	\$1,000.00	\$148,019	\$48,191
3%	24	75	\$1,000.00	\$152,460	\$47,273
3%	25	75	\$1,000.00	\$157,033	\$46,372
3%	26	75	\$1,000.00	\$161,744	\$45,489
3%	27	75	\$1,000.00	\$166,597	\$44,623
3%	28	75	\$1,000.00	\$171,595	\$43,773
3%	29	75	\$1,000.00	\$176,742	\$42,939
3%	30	75	\$1,000.00	\$182,045	\$42,121
Total Acre-feet		2325			
Assume an interest rate of 5%					
				Total Cost	\$3,750,201
				Total Present Worth	\$1,768,267
				Present worth/acre-foot	\$761
				Annual cost	\$167,821
				Annual Cost/acre-foot	\$45

Table VI - 5
Cost to Purchase Water Right

(Total of 2,325 acre-feet over 30 year period)

Rate of Increase in Land/Water Rights	Years	Volume each Year of Water Right Purchase in acre feet	Present Cost of Water Rights (year 2000)	Future Value at end of each year to purchase 50 acre-feet	Present Value of Water Right Purchase
4%	0	75	\$1,000.00	\$75,000	\$75,000
4%	1	75	\$1,000.00	\$78,000	\$74,286
4%	2	75	\$1,000.00	\$81,120	\$73,578
4%	3	75	\$1,000.00	\$84,365	\$72,877
4%	4	75	\$1,000.00	\$87,739	\$72,183
4%	5	75	\$1,000.00	\$91,249	\$71,496
4%	6	75	\$1,000.00	\$94,899	\$70,815
4%	7	75	\$1,000.00	\$98,695	\$70,141
4%	8	75	\$1,000.00	\$102,643	\$69,473
4%	9	75	\$1,000.00	\$106,748	\$68,811
4%	10	75	\$1,000.00	\$111,018	\$68,156
4%	11	75	\$1,000.00	\$115,459	\$67,507
4%	12	75	\$1,000.00	\$120,077	\$66,864
4%	13	75	\$1,000.00	\$124,881	\$66,227
4%	14	75	\$1,000.00	\$129,876	\$65,596
4%	15	75	\$1,000.00	\$135,071	\$64,971
4%	16	75	\$1,000.00	\$140,474	\$64,353
4%	17	75	\$1,000.00	\$146,093	\$63,740
4%	18	75	\$1,000.00	\$151,936	\$63,133
4%	19	75	\$1,000.00	\$158,014	\$62,531
4%	20	75	\$1,000.00	\$164,334	\$61,936
4%	21	75	\$1,000.00	\$170,908	\$61,346
4%	22	75	\$1,000.00	\$177,744	\$60,762
4%	23	75	\$1,000.00	\$184,854	\$60,183
4%	24	75	\$1,000.00	\$192,248	\$59,610
4%	25	75	\$1,000.00	\$199,938	\$59,042
4%	26	75	\$1,000.00	\$207,935	\$58,480
4%	27	75	\$1,000.00	\$216,253	\$57,923
4%	28	75	\$1,000.00	\$224,903	\$57,371
4%	29	75	\$1,000.00	\$233,899	\$56,825
4%	30	75	\$1,000.00	\$243,255	\$56,284
Total Acre-feet		2325			
Assume an interest rate of 5%					
Total Cost				\$4,449,625	
				Total Present Worth	\$2,021,497
				Present worth/acre-foot	\$869
				Annual cost	\$200,525
				Annual Cost/acre-foot	\$54

Table VI - 6
Cost to Purchase Water Rights

(Total of 2,325 acre-feet over 30 year period)

Rate of Increase in Land/Water Rights	Years	Volume eachYear of Water Right Purchase in acre-feet	Present Cost of Water Rights (year 2000)	Future Value at end of each year to purchase water rights	Present Value of Water Right Purchase
5%	0	75	\$1,000.00	\$75,000	\$75,000
5%	1	75	\$1,000.00	\$78,750	\$75,000
5%	2	75	\$1,000.00	\$82,688	\$75,000
5%	3	75	\$1,000.00	\$86,822	\$75,000
5%	4	75	\$1,000.00	\$91,163	\$75,000
5%	5	75	\$1,000.00	\$95,721	\$75,000
5%	6	75	\$1,000.00	\$100,507	\$75,000
5%	7	75	\$1,000.00	\$105,533	\$75,000
5%	8	75	\$1,000.00	\$110,809	\$75,000
5%	9	75	\$1,000.00	\$116,350	\$75,000
5%	10	75	\$1,000.00	\$122,167	\$75,000
5%	11	75	\$1,000.00	\$128,275	\$75,000
5%	12	75	\$1,000.00	\$134,689	\$75,000
5%	13	75	\$1,000.00	\$141,424	\$75,000
5%	14	75	\$1,000.00	\$148,495	\$75,000
5%	15	75	\$1,000.00	\$155,920	\$75,000
5%	16	75	\$1,000.00	\$163,716	\$75,000
5%	17	75	\$1,000.00	\$171,901	\$75,000
5%	18	75	\$1,000.00	\$180,496	\$75,000
5%	19	75	\$1,000.00	\$189,521	\$75,000
5%	20	75	\$1,000.00	\$198,997	\$75,000
5%	21	75	\$1,000.00	\$208,947	\$75,000
5%	22	75	\$1,000.00	\$219,395	\$75,000
5%	23	75	\$1,000.00	\$230,364	\$75,000
5%	24	75	\$1,000.00	\$241,882	\$75,000
5%	25	75	\$1,000.00	\$253,977	\$75,000
5%	26	75	\$1,000.00	\$266,675	\$75,000
5%	27	75	\$1,000.00	\$280,009	\$75,000
5%	28	75	\$1,000.00	\$294,010	\$75,000
5%	29	75	\$1,000.00	\$308,710	\$75,000
5%	30	75	\$1,000.00	\$324,146	\$75,000
Total Acre-feet		2325			
Assume an interest rate of 5%					
Total Cost				\$5,307,059	
				Total Present Worth	\$2,325,000
				Present worth/acre-foot	\$1,000
				Annual cost	\$240,690
				Annual Cost/acre-foot	\$65

Table VI - 7
Cost to Purchase Water Rights

(Total of 2,325 acre-feet over 30 year period)

Rate of Increase in Land/Water Rights	Years	Volume eachYear of Water Right Purchase in acre-feet	Present Cost of Water Rights (year 2000)	Future Value at end of each year to purchase 50 acre-feet	Present Value of Water Right Purchase
6%	0	75	\$1,000.00	\$75,000	\$75,000
6%	1	75	\$1,000.00	\$79,500	\$75,714
6%	2	75	\$1,000.00	\$84,270	\$76,435
6%	3	75	\$1,000.00	\$89,326	\$77,163
6%	4	75	\$1,000.00	\$94,686	\$77,898
6%	5	75	\$1,000.00	\$100,367	\$78,640
6%	6	75	\$1,000.00	\$106,389	\$79,389
6%	7	75	\$1,000.00	\$112,772	\$80,145
6%	8	75	\$1,000.00	\$119,539	\$80,908
6%	9	75	\$1,000.00	\$126,711	\$81,679
6%	10	75	\$1,000.00	\$134,314	\$82,457
6%	11	75	\$1,000.00	\$142,372	\$83,242
6%	12	75	\$1,000.00	\$150,915	\$84,035
6%	13	75	\$1,000.00	\$159,970	\$84,835
6%	14	75	\$1,000.00	\$169,568	\$85,643
6%	15	75	\$1,000.00	\$179,742	\$86,459
6%	16	75	\$1,000.00	\$190,526	\$87,282
6%	17	75	\$1,000.00	\$201,958	\$88,114
6%	18	75	\$1,000.00	\$214,075	\$88,953
6%	19	75	\$1,000.00	\$226,920	\$89,800
6%	20	75	\$1,000.00	\$240,535	\$90,655
6%	21	75	\$1,000.00	\$254,967	\$91,519
6%	22	75	\$1,000.00	\$270,265	\$92,390
6%	23	75	\$1,000.00	\$286,481	\$93,270
6%	24	75	\$1,000.00	\$303,670	\$94,158
6%	25	75	\$1,000.00	\$321,890	\$95,055
6%	26	75	\$1,000.00	\$341,204	\$95,960
6%	27	75	\$1,000.00	\$361,676	\$96,874
6%	28	75	\$1,000.00	\$383,377	\$97,797
6%	29	75	\$1,000.00	\$406,379	\$98,728
6%	30	75	\$1,000.00	\$430,762	\$99,669
Total Acre-feet		2325			
Assume an interest rate of 5%					
Total Cost				\$6,360,126	
				Total Present Worth	\$2,689,869
				Present worth/acre-foot	\$1,157
				Annual cost	\$290,082
				Annual Cost/acre-foot	\$78

Table VI - 8
Cost to Purchase Water Rights
 (Total of 2,325 acre-feet over 30 year period)

Rate of Increase in Land/Water Rights	Years	Volume eachYear of Water Right Purchase in acre-feet	Present Cost of Water Rights (year 2000)	Future Value at end of each year to purchase 50 acre-feet	Present Value of Water Right Purchase
7%	0	75	\$1,000.00	\$75,000	\$75,000
7%	1	75	\$1,000.00	\$80,250	\$76,429
7%	2	75	\$1,000.00	\$85,868	\$77,884
7%	3	75	\$1,000.00	\$91,878	\$79,368
7%	4	75	\$1,000.00	\$98,310	\$80,880
7%	5	75	\$1,000.00	\$105,191	\$82,420
7%	6	75	\$1,000.00	\$112,555	\$83,990
7%	7	75	\$1,000.00	\$120,434	\$85,590
7%	8	75	\$1,000.00	\$128,864	\$87,220
7%	9	75	\$1,000.00	\$137,884	\$88,882
7%	10	75	\$1,000.00	\$147,536	\$90,575
7%	11	75	\$1,000.00	\$157,864	\$92,300
7%	12	75	\$1,000.00	\$168,914	\$94,058
7%	13	75	\$1,000.00	\$180,738	\$95,849
7%	14	75	\$1,000.00	\$193,390	\$97,675
7%	15	75	\$1,000.00	\$206,927	\$99,536
7%	16	75	\$1,000.00	\$221,412	\$101,432
7%	17	75	\$1,000.00	\$236,911	\$103,364
7%	18	75	\$1,000.00	\$253,495	\$105,332
7%	19	75	\$1,000.00	\$271,240	\$107,339
7%	20	75	\$1,000.00	\$290,226	\$109,383
7%	21	75	\$1,000.00	\$310,542	\$111,467
7%	22	75	\$1,000.00	\$332,280	\$113,590
7%	23	75	\$1,000.00	\$355,540	\$115,754
7%	24	75	\$1,000.00	\$380,428	\$117,958
7%	25	75	\$1,000.00	\$407,057	\$120,205
7%	26	75	\$1,000.00	\$435,551	\$122,495
7%	27	75	\$1,000.00	\$466,040	\$124,828
7%	28	75	\$1,000.00	\$498,663	\$127,206
7%	29	75	\$1,000.00	\$533,569	\$129,629
7%	30	75	\$1,000.00	\$570,919	\$132,098
Total Acre-feet		2325			
Assume an interest rate of 5%					
Total Cost				\$7,655,478	
				Total Present Worth	\$3,129,733
				Present worth/acre-foot	\$1,346
				Annual cost	\$350,889
				Annual Cost/acre-foot	\$95

Table VI - 9
Cost to Purchase Water Rights

(Total of 2,325 acre-feet over 30 year period)

Rate of Increase in Land/Water Rights	Years	Volume eachYear of Water Right Purchase in acre-feet	Present Cost of Water Rights (year 2000)	Future Value at end of each year to purchase 50 acre-feet	Present Value of Water Right Purchase
8%	0	75	\$1,000.00	\$75,000	\$75,000
8%	1	75	\$1,000.00	\$81,000	\$77,143
8%	2	75	\$1,000.00	\$87,480	\$79,347
8%	3	75	\$1,000.00	\$94,478	\$81,614
8%	4	75	\$1,000.00	\$102,037	\$83,946
8%	5	75	\$1,000.00	\$110,200	\$86,344
8%	6	75	\$1,000.00	\$119,016	\$88,811
8%	7	75	\$1,000.00	\$128,537	\$91,349
8%	8	75	\$1,000.00	\$138,820	\$93,959
8%	9	75	\$1,000.00	\$149,925	\$96,643
8%	10	75	\$1,000.00	\$161,919	\$99,404
8%	11	75	\$1,000.00	\$174,873	\$102,245
8%	12	75	\$1,000.00	\$188,863	\$105,166
8%	13	75	\$1,000.00	\$203,972	\$108,171
8%	14	75	\$1,000.00	\$220,290	\$111,261
8%	15	75	\$1,000.00	\$237,913	\$114,440
8%	16	75	\$1,000.00	\$256,946	\$117,710
8%	17	75	\$1,000.00	\$277,501	\$121,073
8%	18	75	\$1,000.00	\$299,701	\$124,532
8%	19	75	\$1,000.00	\$323,678	\$128,090
8%	20	75	\$1,000.00	\$349,572	\$131,750
8%	21	75	\$1,000.00	\$377,538	\$135,514
8%	22	75	\$1,000.00	\$407,741	\$139,386
8%	23	75	\$1,000.00	\$440,360	\$143,369
8%	24	75	\$1,000.00	\$475,589	\$147,465
8%	25	75	\$1,000.00	\$513,636	\$151,678
8%	26	75	\$1,000.00	\$554,726	\$156,012
8%	27	75	\$1,000.00	\$599,105	\$160,469
8%	28	75	\$1,000.00	\$647,033	\$165,054
8%	29	75	\$1,000.00	\$698,796	\$169,770
8%	30	75	\$1,000.00	\$754,699	\$174,620
Total Acre-feet		2325			
Assume an interest rate of 5%					
Total Cost				\$9,250,940	
				Total Present Worth	\$3,661,334
				Present worth/acre-foot	\$1,575
				Annual cost	\$425,813
				Annual Cost/acre-foot	\$115

Table VI - 10
Cost to Purchase Water Rights
 (Total of 2,325 acre-feet over 30 year period)

Rate of Increase in Land/Water Rights	Years	Volume each Year of Water Right Purchase in acre-feet	Present Cost of Water Rights (year 2000)	Future Value at end of each year to purchase water rights	Present Value of Water Right Purchase
9%	0	75	\$1,000.00	\$75,000	\$75,000
9%	1	75	\$1,000.00	\$81,750	\$77,857
9%	2	75	\$1,000.00	\$89,108	\$80,823
9%	3	75	\$1,000.00	\$97,127	\$83,902
9%	4	75	\$1,000.00	\$105,869	\$87,098
9%	5	75	\$1,000.00	\$115,397	\$90,416
9%	6	75	\$1,000.00	\$125,783	\$93,861
9%	7	75	\$1,000.00	\$137,103	\$97,436
9%	8	75	\$1,000.00	\$149,442	\$101,148
9%	9	75	\$1,000.00	\$162,892	\$105,002
9%	10	75	\$1,000.00	\$177,552	\$109,002
9%	11	75	\$1,000.00	\$193,532	\$113,154
9%	12	75	\$1,000.00	\$210,950	\$117,465
9%	13	75	\$1,000.00	\$229,935	\$121,940
9%	14	75	\$1,000.00	\$250,630	\$126,585
9%	15	75	\$1,000.00	\$273,186	\$131,407
9%	16	75	\$1,000.00	\$297,773	\$136,413
9%	17	75	\$1,000.00	\$324,573	\$141,610
9%	18	75	\$1,000.00	\$353,784	\$147,005
9%	19	75	\$1,000.00	\$385,625	\$152,605
9%	20	75	\$1,000.00	\$420,331	\$158,418
9%	21	75	\$1,000.00	\$458,161	\$164,453
9%	22	75	\$1,000.00	\$499,395	\$170,718
9%	23	75	\$1,000.00	\$544,341	\$177,222
9%	24	75	\$1,000.00	\$593,331	\$183,973
9%	25	75	\$1,000.00	\$646,731	\$190,981
9%	26	75	\$1,000.00	\$704,937	\$198,257
9%	27	75	\$1,000.00	\$768,381	\$205,810
9%	28	75	\$1,000.00	\$837,535	\$213,650
9%	29	75	\$1,000.00	\$912,914	\$221,789
9%	30	75	\$1,000.00	\$995,076	\$230,238
Total Acre-feet		2325			
Assume an interest rate of 5%					
Total Cost				\$11,218,141	
				Total Present Worth	\$4,305,239
				Present worth/acre-foot	\$1,852
				Annual cost	\$518,197
				Annual Cost/acre-foot	\$140

Table VI - 11
Cost to Purchase Water Rights

(Total of 2,325 acre-feet over 30 year period)

Rate of Increase in Land/Water Rights	Years	Volume eachYear of Water Right Purchase in acre-feet	Present Cost of Water Rights (year 2000)	Future Value at end of each year to purchase water rights	Present Value of Water Right Purchase
10%	0	75	\$1,000.00	\$75,000	\$75,000
10%	1	75	\$1,000.00	\$82,500	\$78,571
10%	2	75	\$1,000.00	\$90,750	\$82,313
10%	3	75	\$1,000.00	\$99,825	\$86,233
10%	4	75	\$1,000.00	\$109,808	\$90,339
10%	5	75	\$1,000.00	\$120,788	\$94,641
10%	6	75	\$1,000.00	\$132,867	\$99,147
10%	7	75	\$1,000.00	\$146,154	\$103,869
10%	8	75	\$1,000.00	\$160,769	\$108,815
10%	9	75	\$1,000.00	\$176,846	\$113,997
10%	10	75	\$1,000.00	\$194,531	\$119,425
10%	11	75	\$1,000.00	\$213,984	\$125,112
10%	12	75	\$1,000.00	\$235,382	\$131,070
10%	13	75	\$1,000.00	\$258,920	\$137,311
10%	14	75	\$1,000.00	\$284,812	\$143,850
10%	15	75	\$1,000.00	\$313,294	\$150,700
10%	16	75	\$1,000.00	\$344,623	\$157,876
10%	17	75	\$1,000.00	\$379,085	\$165,394
10%	18	75	\$1,000.00	\$416,994	\$173,270
10%	19	75	\$1,000.00	\$458,693	\$181,520
10%	20	75	\$1,000.00	\$504,562	\$190,164
10%	21	75	\$1,000.00	\$555,019	\$199,220
10%	22	75	\$1,000.00	\$610,521	\$208,706
10%	23	75	\$1,000.00	\$671,573	\$218,645
10%	24	75	\$1,000.00	\$738,730	\$229,056
10%	25	75	\$1,000.00	\$812,603	\$239,964
10%	26	75	\$1,000.00	\$893,863	\$251,391
10%	27	75	\$1,000.00	\$983,250	\$263,362
10%	28	75	\$1,000.00	\$1,081,575	\$275,903
10%	29	75	\$1,000.00	\$1,189,732	\$289,041
10%	30	75	\$1,000.00	\$1,308,705	\$302,805
Total Acre-feet		2325			
Assume an interest rate of 5%					
			Total Cost	\$13,645,757	
				Total Present Worth	\$5,086,707
				Present worth/acre-foot	\$2,188
				Annual cost	\$632,170
				Annual Cost/acre-foot	\$171

SECTION 7

Water Conservation

To better facilitate how these measures could fit into a long-range water conservation program, the conservation measures are grouped into categories according to expected level of difficulty for implementation. These are presented below in Table VII - 1. The source for cost and potential water savings are taken from the report, "Cedar City Water Master Plan, Montgomery-Watson, October 1998. These conservation measures are presented in more detail in Table VII - 2.

Level of Difficulty	Conservation Measures	Expected Water Savings	Unit Cost of Water Saved (\$/acre-foot)
Low	System water audits, public information, non-promotional pricing and water saving fixtures	1,222 AF	\$ 33
Moderate	Non-residential land ordinances	1,245 AF	\$ 90
Difficult	Residential retrofit, non-residential ultra low flow flush toilet replacement	3,621 AF	\$ 145 to \$ 158
Very Difficult	High efficiency appliances, residential water audits, residential ultra low flush toilet replacement.	5,884 AF	\$ 177 to \$ 222
Extremely Difficult	Large landscape conservation	391 AF	\$ 474

Water Conservation Measure	Water Savings In MGD to Year 2022	Water Savings in Acre-feet	Unit Cost of Water Saved (\$/1000 gallon)	Unit Cost of Water Saved (\$/acre-foot)
System water audits, public information, non-promotional pricing and water saving fixtures	1.08 mgd	1,222	\$ 0.10	\$ 33
Non-residential land ordinances	1.1 mgd	1,245	\$ 0.28	\$ 90
Residential retrofit	2.6 mgd	2,942	\$ 0.45	\$ 145
Non-residential ultra low flow flush toilet replacement	0.6 mgd	679	\$ 0.49	\$ 158
High efficiency appliances	0.4 mgd	4,526	\$ 0.55	\$ 177
Residential water audits	0.2 mgd	226	\$ 0.60	\$ 194
Residential ultra low flush toilet replacement	1.0 mgd	1,132	\$ 0.69	\$ 222
Large Landscape conservation	0.7 mgd	391	\$ 1.47	\$ 474

SECTION 8

Wastewater Reuse

Water recycling (sometimes referred to as water reclamation or water reuse) is a proven technology and can be an effective alternative supply for meeting urban, agricultural, and environmental water needs. All water supplies are actually "re-used". Nature provides the ultimate reuse system in the hydrologic cycle by constantly purifying and delivering the same water over and over again. The only difference in modern wastewater reuse is that man provides the intermediate treatment.

Potential Benefits from Water Reuse

Recycled water from municipal waste treatment plants can provide the following potential benefits:

- Supply water for secondary water systems which can offset annual and peak demands on the culinary system;
- Supply water for agricultural and environmental wetland enhancement;
- Provide a source of water which is lower in TDS to blend with the lower quality groundwater zones of Cedar Valley;
- Provide a source of water that be used to recharge the groundwater aquifer;

Another benefit is that recycled water can be developed in phased project expansions, which offers flexibility as to the timing of water supply investments.

Description of Wastewater Treatment Processes

Definition for types of wastewater treatment plant include:

Conventional (or secondary) wastewater treatment - Generally, a level or treatment of wastewater that produces removal efficiencies for biochemical oxygen demand (BOD) and suspended solids (SS) of greater or equal than 85%. Cedar City's present wastewater plant is an example of this type of wastewater treatment.

Tertiary wastewater treatment - The treatment of wastewater beyond the conventional or secondary stage. This process includes filtration or the removal of nutrients, such as phosphorous and nitrogen, and a high percentage of suspended solids. A potential use of this water would be treatment of water to the point that is could be used for irrigation of golf courses and secondary water systems in which human contact could occur.

Advanced wastewater treatment - Any physical, chemical, or biological treatment process used to accomplish a degree of treatment greater than achieved by secondary treatment. A potential use of this water would be the recharge of

the groundwater reservoir in Cedar Valley that could then be pumped and treated for public consumption.

State of Utah – Water Reuse Regulations

A potential issue is who has legal rights to direct wastewater reuse. The Utah Legislature approved House Bill 105 on January 10, 1995, entitled Water Reuse – Sewage Effluent.

Section 73-3c-2 of the Bill reads as follows:

- (1) Any municipality or other governmental entity owning and operating a POTW (publicly owned treatment works) that treats sewage and other pollutants contained in water collected from water supplied under the governmental entity's water rights may apply the resulting sewage effluent to a beneficial use consistent with, and without enlargement of, those water rights.
- (2) The governmental entity must file a change application with the state engineer if it proposes to use sewage effluent: (a) outside the defined place of use for purposes other than those authorized in the underlying water rights; or (b) in a manner otherwise consistent with the underlying water rights.

The Utah Administrative Code, Section R317-1-4, contains two separate provisions for the reuse of domestic wastewater, one in which human exposure to the treated wastewater is likely (designated as Type I) and the second, where human exposure is unlikely (designated as Type II).

Use of Treated Domestic Wastewater Effluent Where Human Exposure is Likely (Type I)

Uses of Type I water include residential irrigation at individual houses, irrigation of non-residential landscape irrigation including parks and golf courses, toilet flushing, fire protection and other uses with similar potential for human exposure. Also included is irrigation of food crops where the applied reclaimed water is likely to have direct contact with the edible part of the crop or irrigation of pasture to be used by milking animals. Type I treatment is also required where wastewater is to be applied using sprinklers.

Required treatment includes secondary treatment, filtration, and disinfection. Effluent must not exceed 10 mg/l biological oxygen demand (BOD), 5 mg/l total suspended solids (TSS) and 2 nephelometer turbidity units (NTU). The weekly median fecal coliform concentration shall be non-detect as determined from daily grab samples; no sample shall exceed 14 organisms/100 ml. The total residual chlorine shall be 1.0 mg/l after 30 minutes contact time.

Use of Treated Domestic Wastewater Effluent Where Human Exposure is Unlikely (Type II)

Uses of Type II water include irrigation of sod farms, irrigation of limited access highway rights-of-way, and irrigation of food crops where the applied reclaimed water is not likely to have direct contact with the edible portion (spray irrigation not allowed) and for industrial cooling water.

Required treatment includes secondary treatment and disinfection. Reused effluent must not exceed 25 mg/l BOD, and TSS as a monthly mean. No NTU requirement is specified. The weekly median fecal coliform concentration shall not exceed 200 organisms/100 mg/l, with no sample exceeding 800 organisms/100 ml. An alternate disposal option or diversion must be available in case water quality requirements are not met. Filtration is not required.

Expected Wastewater Availability

Municipal water use, particularly the indoor use, is largely a non-consumptive use of water. This results in a significant portion of the water metered into the municipal system returning as wastewater flows. Table VIII – 1 contains on a monthly basis the diversions and uses of municipal water by the residents in Cedar Valley. As presented in Figure VIII-1, the annual return flow is 67% (or 3,614 acre-feet) of the annual water diverted. During the winter months, this return flow percentage is approximately 90%, indicating that indoor consumptive use is only about 10% of the water diverted. A significant use of municipal water as demonstrated by Figure VIII-2 where the outdoor use is 56% of the annual M&I demand.

Construction and Operation/Maintenance Costs from Existing Water Recycling Plants

The reconnaissance level costs for a water recycling plant are based upon the costs of water recycling plants that has been constructed and are presently under operation. This information was obtained from plants in present operation in the Phoenix, Arizona area. This information is presented in Table VIII – 2.

In addition the cost of the conventional (or secondary) wastewater plant in Cedar City is presented in Table VIII-2.

Potential Assistance with Financing

The U.S. Bureau of Reclamation has a program that provides 25% of the construction cost of a recycled project up to \$20,000,000. Figure VIII – 3 is a schematic of this process.

Table VIII - 1
Cedar Valley
Monthly and Annual M&I Water Uses and Return Flows

	Jan	Feb	Mar.	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Municipal Surface Diversions	64	64	64	124	195	266	372	266	124	104	64	64	1,771
Groundwater Pumped	168	168	168	324	509	694	971	694	324	271	168	168	4,627
Total M&I Diversions/Groundwater Pumping	232	232	232	448	704	960	1343	960	448	375	232	232	6,398
Consumptive Use	23	23	23	132	260	388	580	388	132	95	23	23	2,090
Return Flow	209	209	209	316	444	572	763	572	316	280	209	209	4,308
Return Flow as A Percent of Diversions	0.90	0.90	0.90	0.71	0.63	0.60	0.57	0.60	0.71	0.75	0.90	0.90	0.67
Amount Consumptively Used as A Percent of Diversions	0.10	0.10	0.10	0.29	0.37	0.40	0.43	0.40	0.29	0.25	0.10	0.10	0.33
Base Indoor Demand	232	232	232	232	232	232	232	232	232	232	232	232	2784
Outdoor Demand	0	0	0	216	472	728	1111	728	216	143	0	0	3614

**Figure VIII-1
Cedar Valley
Comparison of Consumptive Use with Return Flow**

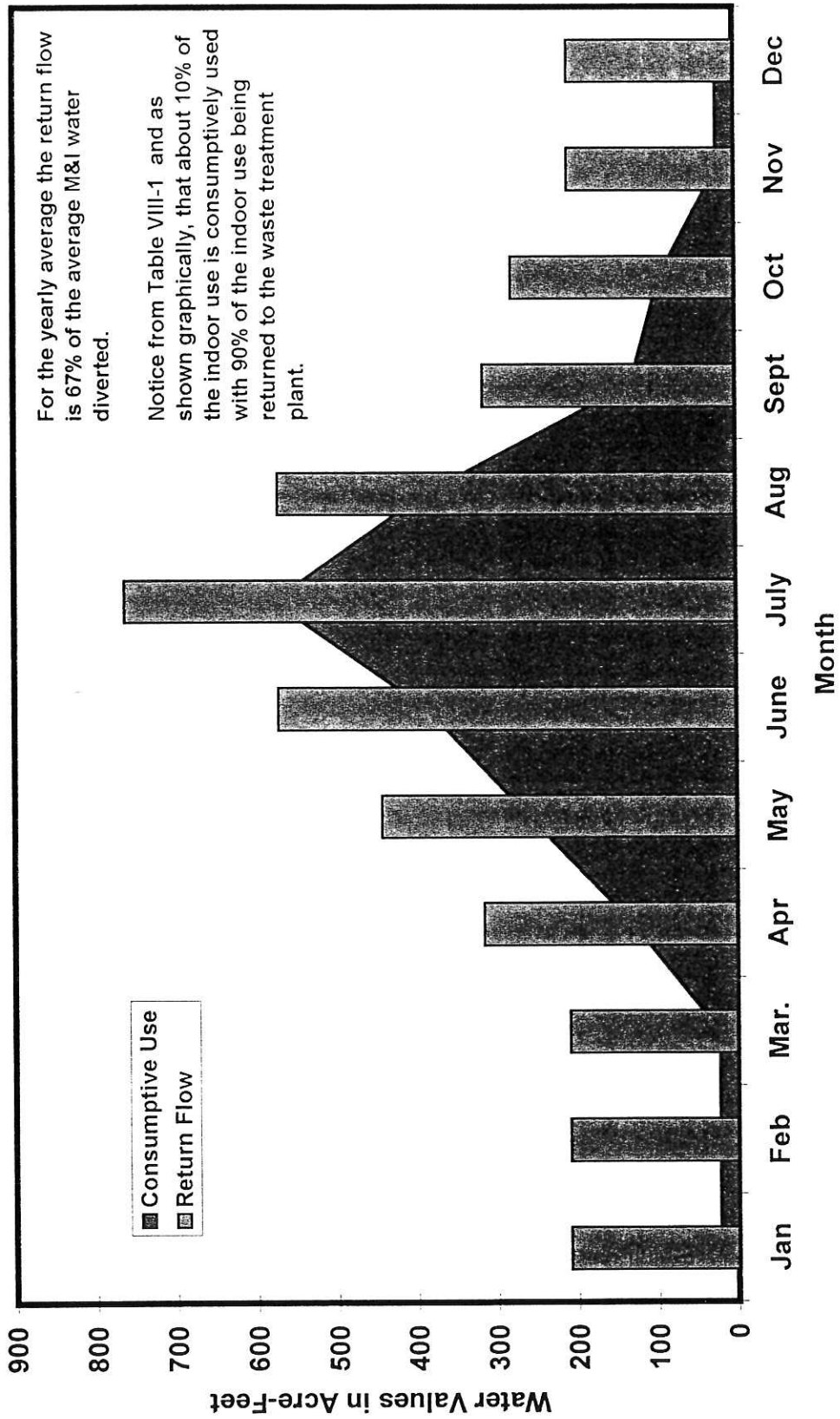
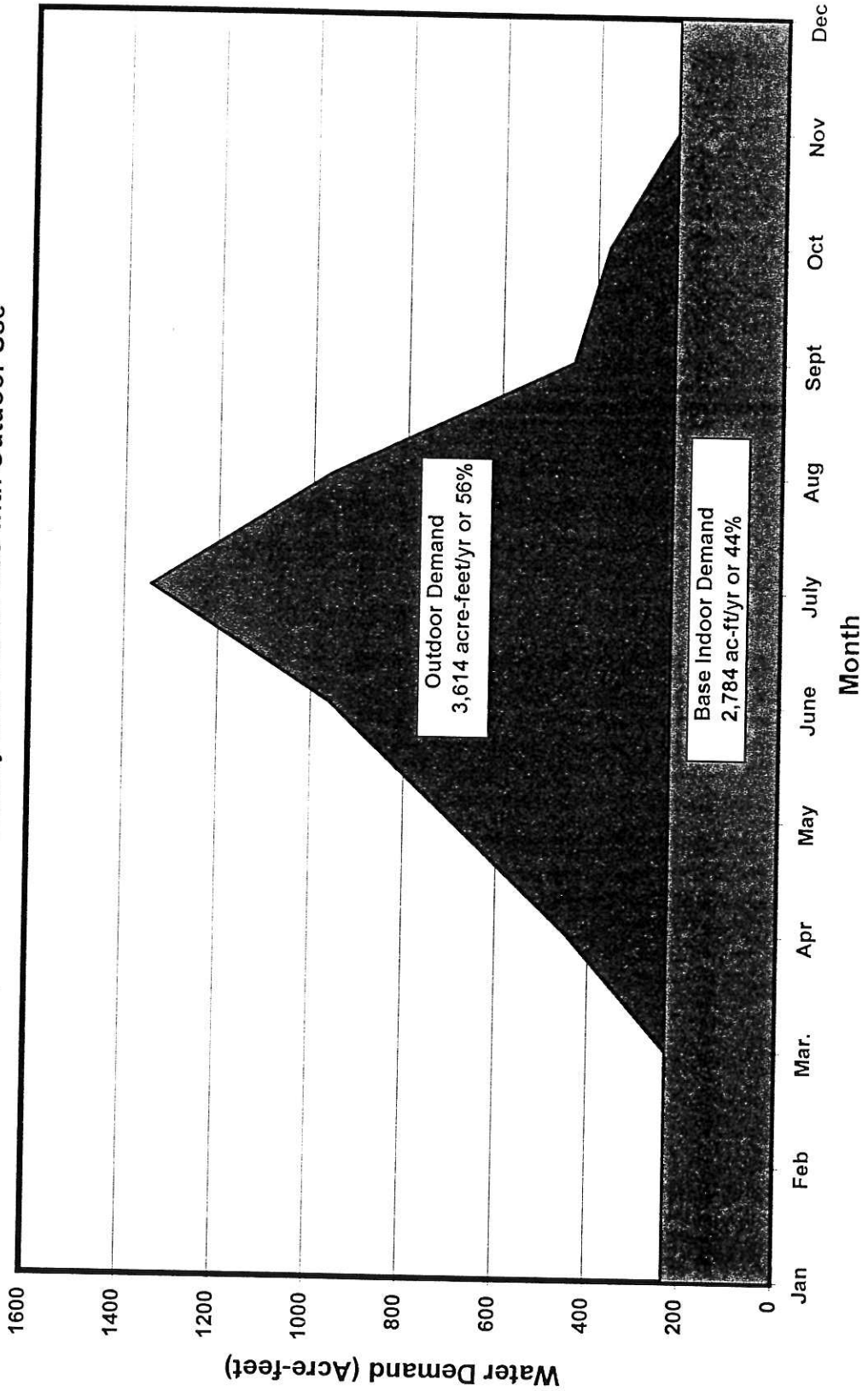


Figure VIII - 2
Cedar Valley
Comparison of Monthly M&I Indoor Use with Outdoor Use



**TABLE VIII - 2
COST OF EXISTING WASTEWATER TREATMENT PLANTS**

Location of Plant	Type of Treatment	Capital Cost	Size of Plant	Cost per million gallon per day
Cedar City	Conventional	\$12,000,000	4 mgd	\$3,000,000 per mgd
Phoenix	Tertiary	\$32,000,000	8 mgd	\$4,000,000 per mgd
Scottsdale	Tertiary	\$50,000,000	12 mgd	\$4,200,000 per mgd
Scottsdale	Advanced	\$70,000,000	12 mgd	\$5,800,000 per mgd

In comparison of alternatives, it is critical to present costs in either terms of a net present worth or on an annual cost basis. The annual operating and maintenance costs of water recycling are significant and therefore must be accounted for the analysis of alternatives. Table VIII - 3 presents the operation and maintenance costs of existing plants.

**TABLE VIII - 3
ANNUAL OPERATING AND MAINTENANCE COSTS
OF EXISTING WASTEWATER TREATMENT PLANTS**

Location of Plant	Type of Treatment	Size of Plant	Annual O&M per 1000 gallon	Annual O&M per Million gallon per day	Annual O & M per Acre-foot
Cedar City	Conventional	4 mgd	\$0.80	\$800	\$258
Scottsdale	Conventional	Not available	\$0.50	\$500	\$160
Scottsdale	Tertiary	12 mgd	\$0.70	\$700	\$225
Scottsdale	Tertiary	12 mgd	\$1.10	\$1100	\$355

Reconnaissance Level Cost Estimates for Potential Water Recycling in Cedar Valley

The cost estimates in Tables VIII-4 and VIII-5 are based upon actual costs of water recycling plants in operation in Scottsdale, Arizona and Phoenix, Arizona.

TABLE VIII - 4

**RECONNAISSANCE LEVEL COST ESTIMATES
BASED ON EXISTING TREATMENT PLANTS IN ARIZONA**

(NOTE: STANDARDS FOR UTAH WILL NEED TO BE CHECKED)

Type of Waste Water Treatment	Approved Use of Water	Capital Cost Per Acre-Foot	Incremental Capital Cost per Acre-foot between Treatment Processes	O & M Per Acre-Foot	Incremental O&M Cost between Treatments
Conventional Waste Treatment	For discharge to areas of non-public contact	\$2650/AF		\$160 / AF	
Increments from Conventional to Tertiary			\$833/AF		\$65/AF
Tertiary Treatment	For discharge to areas of public contact such as golf courses or agricultural use near public areas	\$3533/AF		\$225/AF	
Increment from Tertiary to Advanced			\$1,767/AF		\$130/AF
Advanced Treatment	For discharge to groundwater to be pumped for public consumption	\$5,300/AF		\$355/AF	

TABLE VIII - 5

EXAMPLE
ASSUME A PLANT OF 4,000 ACRE-FEET PER YEAR CAPACITY
(THIS IS ABOUT THE SIZE OF CEDAR CITY'S EXISTING
WASTEWATER TREATMENT PLANT)

(NOTE: STANDARDS FOR STATE OF UTAH NEED TO BE CHECKED)

Cost Item	Type of Wastewater Treatment		
	Conventional	Tertiary	Advanced
Assumed Plant Yearly Production	4,000 AF	4,000 AF	4,000 AF
Capital Cost	\$10,600,000	\$14,132,000	\$21,200,000
Annual Cost of Capital Cost / AF	\$172 / AF	\$229 / AF	\$345 / AF
Annual Cost of O&M / AF	\$160 / AF	\$225 / AF	\$355 / AF
Total Annual Cost per AF	\$332 / AF	\$454 / AF	\$700 / AF
Incremental cost of going from Conventional Treatment to Tertiary		\$ 122 / AF	
Incremental cost of going from Conventional to Advanced			\$368 / AF
Effect of credit from Public Law 102 – 175 which authorizes the Bureau of Reclamation to fund 25% of the construction cost for facilities which recycle water			
Capital Cost	\$10,600,000	\$10,599,000	\$15,900,000
Annual Cost of Capital Cost/AF	\$172 / AF	\$172 / AF	\$258 / AF
Annual Cost of O&M / AF	\$160 / AF	\$225 / AF	\$355 / AF
Total Annual Cost per AF	\$342 / AF	\$397 / AF	\$613 / AF
Incremental cost of going from conventional treatment to tertiary with 25% U.S. Bureau of Reclamation		\$55 / AF	
Incremental cost of going from Conventional to Advancement Treatment with 25% U.S. Bureau of Reclamation cost share			\$271 / AF

**US BUREAU OF RECLAMATION
Title XVI Water Recycling Grants
P.L. 102-575**

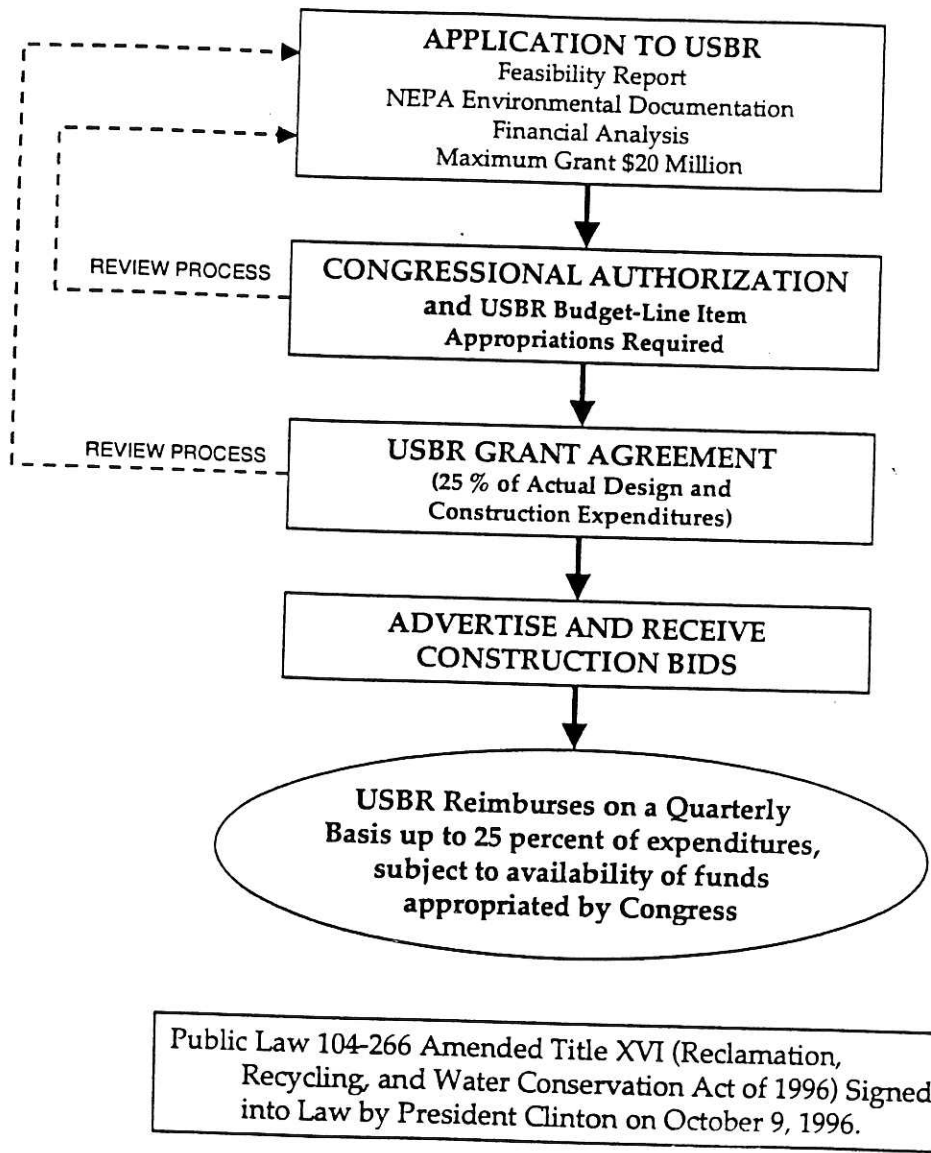


Figure VIII - 1

ATTACHMENTS

DIVISION OF WATER RESOURCES

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M E M O R A N D U M

March 16, 2000

TO: Dennis Strong
FROM: Ben Everitt 
SUBJECT: Proposed off-stream reservoir in Salt Creek, Cedar City

Introduction

Monday, March 6, Dan Aubrey and I met in Cedar City with the Central Iron County Water Conservancy District to look at a new proposal for a dam site which would store water from Coal Creek. Present were Scott Wilson, Chairman of the Central Iron County WCD, and Leon Hyatt, board member; Ed Ginouves, geologist, Ervin Larsen, realty specialist, and Eric Mullins, surveyor, all with the BLM Cedar City field office; Joe Melling, Cedar City manager; Bill Lund, geologist for the UGS; Gary Player and York Jones, project proponents; and Frank Nichols, land developer, who has an interest in adjoining property.

Location

There are two proposed dam sites, both in Salt Creek, tributary to Coal Creek just above the old power plant (map attached). The lower (Salt Creek) site would store 16,000 acre-feet behind a 300-foot high dam, and the second, upstream, would store some 6,000 acre-feet behind a 150-foot high dam in a tributary (Rock Canyon) which is within the reservoir basin of the lower dam. Both dam sites and the reservoir basin are underlain by the Carmel Formation of Jurassic age.

Stratigraphy

Locally, the USGS (Geologic map of the Cedar City Quadrangle, GQ-1120, by Paul Averitt and Richard Threet, 1973) has divided the Carmel Formation into 4 members, as follows:

- Winsor Member - gray to brown sandstone and mudstone
- Gypsiferous Member - massive white gypsum (Curtis Formation of other workers)
- Banded Member - Red-brown sandstone, siltstone, and mudstone with thin beds and fracture-fillings of gypsum (Entrada Formation of others)
- Limestone Member - gray thin-bedded fissile shaly limestone (=Homestake Limestone of the iron district)

Structure

The rock layers at the site are folded into a series of anticlines and synclines which strike north-south. The weaker gypsum and shale have responded to tectonic stresses by folding,

whereas the adjacent limestone and sandstone (the Navajo Sandstone at the Red Hill) have responded by fracturing and faulting. It is likely therefore that the folds expressed in soft rock at the surface turn into faults at depth. The combination of faulted rock adjacent to gypsum provides a strong potential for the existence of subsurface pathways for water to escape the reservoir.

Lower site

The lower site is mostly underlain by the gypsiferous member of the Carmel Formation, which is mostly massive white and banded gypsum, about 50 feet thick. Gypsum is the sulfate salt of calcium (CaSO_4) and is moderately water soluble. The consensus at the site inspection was that a safe dam would require removal of this layer from beneath the entire footprint. The dam would then be keyed into the Banded Member, which contains minor gypsum in the form of thin beds and fracture-fillings. Because of the steep slopes, gypsum outcropping within the reservoir basin would continue to erode and dissolve for many years, affecting water quality. The fault adjacent to the right abutment and dipping beneath the dam is possibly related to the Hurricane Fault, and would need to be evaluated carefully, both for its earthquake potential and as a potential seepage conduit. Although this fault does not intersect the reservoir basin, it does contact and offset the gypsiferous member adjacent to where the gypsum dips beneath the reservoir. I regard the combination of gypsum and faulting extending below the high water level as a fatal flaw, a foundation condition for which engineering mitigation is probably not possible.

Upper site

The upper (Rock Canyon) site is on the Banded Member which contains only thin beds and fracture fills of gypsum up to ½ inch thick. Bedding dips steeply downstream. The upper site may provide an adequate foundation for either a zoned earth-fill dam or a roller compacted concrete dam, if construction can avoid the overlying massive gypsum which caps both abutments. The reservoir basin is upstream of the massive gypsum, but is separated from it by only a few hundred feet of the Banded Member. The reservoir basin is partly underlain by the Limestone Member. The opportunity for end-run seepage through the fractured limestone should be evaluated.

Borrow

Residual soils formed on the Winsor and Banded members are moderately plastic. Laboratory analyses will be needed to determine their suitability for core material. Soils are thin, however, and it is unlikely that sufficient core borrow can be obtained for either dam within the reservoir basin.

Alluvial gravels within the reservoir basin are thin, and contain abundant pebbles and cobbles of gypsum, constituting 10 to 20% of the deposits and rendering them unsuitable for shell material. The alluvium of nearby Coal Creek also contains gypsum, and would need to be evaluated carefully for suitability. Possibly a dam could be designed as a rockfill, using rock of the Banded or Limestone members quarried within the reservoir basin.

Reservoir Basin

Slopes of the reservoir basin and both dam sites are steep, as shown on the attached map. Access for exploratory drilling will be difficult, and may require winching or flying in portable skid rigs, particularly to the high abutment areas of the upper site. The steep slopes on the soft rock of the Carmel Formation will be subject to continual erosion and possible instability, shortening reservoir life.

Recreation potential

I don't think either reservoir has much recreation potential. Because of steep shorelines, reservoir storage changes will create relatively large drawdowns. Shorelines will be of mud or shelving rock, with little sand. Undercutting of dip slopes by wave action may create unstable banks and possible hazardous conditions.

Recommendations

At first glance the economics look doubtful as a water development project. The site is difficult, and if a dam is feasible, would be expensive. I recommend that before money is spent on a foundation evaluation, a preliminary cost analysis be conducted to test economic feasibility. Foundation conditions can be assumed from drilling conducted on similar soft rock sites elsewhere. The Banded Member, with its thin beds and fracture-fillings of gypsum, is similar to the Upper Red Member of the Moenkopi Formation upon which the Quail Creek main dam is partly founded. The Quail Creek experience could serve as a model for construction and maintenance of a high dam on gypsiferous shale. Extensive foundation grouting was required, and remedial grouting may be necessary as seepage dissolves away gypsum fracture-fillings. Subsequent to construction, blanketing of the right abutment was required to reduce seepage and foundation pressure.

Since most undiverted Coal Creek water presently recharges the Cedar City Valley groundwater basin, water developed by the proposed reservoir would be diverted from the groundwater basin. Therefore the cost of developing surface storage of Coal Creek water can be easily compared to the cost of further management and development of the same water from the groundwater basin.

A preliminary foundation evaluation would include both surface geologic mapping and subsurface exploration. Geologic mapping of the dam site should be prepared at a scale sufficient to show geologic contacts, attitude of bedding, jointing, and possible faults. Mapping of the reservoir basin should show contacts in sufficient detail to allow calculation of the exposure of the different rock types to the reservoir, attitude of bedding, and faults and joints which might provide conduits for seepage. Special attention should be given to the fault just west of Salt Creek, which dips eastward beneath the site, and its relationship to the potentially active Hurricane Fault, and its relationship to the folds which underlie the basin. Mapping should be extended south to Coal Creek and north to Dry Canyon to include potential avenues for escape of reservoir water along faults, fractured limestone, or gypsum beds.

A program of subsurface exploration would include test pits to determine the thickness and properties of residual and alluvial soils. Rock of the Limestone Member is probably suitable for concrete aggregate, but would need to be tested.

Preliminary core drilling would include a hole at the maximum section and each abutment of the proposed dam. Holes should be angled to best intersect zones of potential seepage, such as bedding planes and joints. Hole depth would be roughly equal to dam height, and should provide stratigraphic overlap so that a complete section of foundation rock is recovered. In addition, a hole should be drilled on the ridge between the reservoir basin and Coal Creek to test the seepage potential of the underlying Limestone Member.

Care is needed in coring the gypsiferous rock in order to recover representative samples. Exposure of the keyway of Quail Creek main dam revealed considerably more gypsum than had been anticipated from the core recovered during the design drilling, suggesting that some of the fragile gypsum fracture fillings had been eroded by the drilling fluid.

cc: Bill Lund
Ed Ginouves
✓ Scott Wilson
Dallas Wall
Joe Melling
Gary Player