This report by engineers John Davis and Steve Harris was presented in January 2003, to analyze the best ways for PAWSD to address future drought situations by improving infrastructure by 2025.

The Dutton Ditch enclosure and the Stevens Reservoir enlargement have since been completed.

The discussion about Dry Gulch Reservoir project starts on page 45. It included an enlargement of the Snowball Treatment Plant, which is now scheduled to be completed in 2025. The projected size of the reservoir was 4,000 acre feet, of which perhaps 2,000 AF would likely be useable.

Starting on page 51, the engineers evaluated the seven alternatives, including Dry Gulch, and on page 52, they concluded :

Alternatives 1 (Snowball enlargement) and 7 (Dry Gulch Reservoir) are not recommended because their yield is more than double the amount needed in 2025. In the case of alternative 7, the existing rate payers are not able to finance the debt service to construct this large project and the existing water distribution system has insufficient capacity to utilize the large yield.

This report estimated that the PAWSD service area would have a population of 26,534 by the year 2025. (Page 9).

Actual full-time population in the PAWSD area in 2024 is estimated (by PAWSD) at about 10,800.

PRELIMINARY ENGINEERING STUDY

OF

WATER SUPPLY ALTERNATIVES
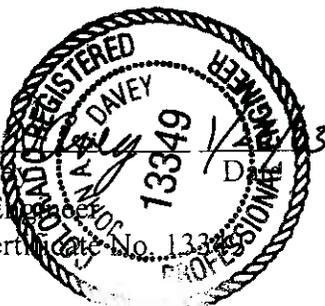
FOR

PAGOSA AREA WATER AND SANITATION DISTRICT

JANUARY 13, 2003
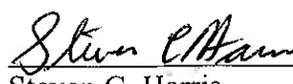
By

Davis Engineering Service, Inc.
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Appendix

1. STUDY OBJECTIVES

The Pagosa Area Water and Sanitation District (PAWSD) is developing plans to improve the existing Dutton Ditch and enlargement of Stevens Reservoir to provide additional water supplies to residents of PAWSD. The enlargement of the reservoir and perhaps improvement of the Dutton Ditch will require a 404 Permit from the Corp of Engineers. The purpose of this report is to provide information for use in the 404 Permit process addressing the need for additional water supplies and the alternatives that were considered to provide the water supply.

1.1. PURPOSE AND NEED

The PAWSD service area population and tap growth has increased by approximately 7% per year for the past ten years. Currently the population within PAWSD is estimated to be about 7,420 people based on the 2000 census, as described in Section 3.0. PAWSD is developing plans to supply water for the year 2025, at which time the population is estimated to be approximately 26,500 (refer to Table 3-2) requiring an estimated average annual water supply of 6,093 acre-feet.

In 2002, PAWSD completed raw and treated water facilities to utilize San Juan River water in order to meet the water demands for the remainder of the this decade. Additional facilities are projected to be required beginning in about 2010 in order to meet future demands.

The purpose of this study is to begin the process to develop new water supply facilities in order to meet the 2025 demand. Commonly, construction of water facilities requires more than 10 years, therefore, PAWSD is beginning the work to develop new facilities with the intent to have construction completed by 2010.

2. SERVICE AREA

The Pagosa Area Water and Sanitation District (PAWSD) encompasses approximately 64.7 square miles in the San Juan Mountains of southwestern Colorado. It includes within its boundaries the Town of Pagosa Springs and unincorporated portions of Archuleta County, including the Pagosa Lakes resort community. A map outlining the service area and PAWSD is included as Figure 2-1.

3. DESCRIPTION OF WATER SUPPLY NEEDS

The present population and water usage is described in this section, followed by the projected population and water usage in 5 year increments through the year 2025.

FIGURE 2-1
MAP OF PAGOSA AREA WATER
AND SANITATION DISTRICT
SERVICE AREA

SCALE: 1" = 10,000'

DISTRICT BOUNDARY

3.1. PRESENT POPULATION AND WATER USAGE IN SERVICE AREA

PAWSD provides water to approximately 75% of the population of Archuleta County, including the Town of Pagosa Springs, the areas east and south of the Town, and the PAWSD service area west of the Town. The 2000 Census shows the population in Archuleta County increased: (1) from 3,664 in 1980 to 5,345 in 1990 to 9,898 in 2000; (2) the 1980 to 2000 annual growth rate was 5.1%; (3) the 1980 to 1990 growth rate was 4.0%; and (4) the 1990 to 2000 annual growth rate was 6.5%. The 1995 to 2000 PAWSD equivalent tap growth rate was 7.1%.

The year 2000 permanent population served by PAWSD is approximately 7,420; 75% of the Year 2000 Census estimate for Archuleta County of 9,898. Table 3.1 shows the per capita usage from 1995 through 2000 using estimated populations, interpolating between the 1990 and 2000 Census data. The average per capita usage for the 6 year period was 215 gallons per person per day.

TABLE 3.1

PER CAPITA WATER USAGE ESTIMATE

Year	Estimated Population	Total Water Treated (mg)	Average Yearly Per Capita Usage (g/p/d)
1995	5410	442.4257	212
1996	5815	461.994	209
1997	6215	486.3108	208
1998	6615	574.0772	233
1999	7020	547.90802	211
2000	7420	594.45835	220
	Six Year Average Usage		215

The population estimate does not include the significant transient population from tourism. There are 1,354 motel rooms, condos/time shares, cabins, and bed and breakfasts within the PAWSD service area. The per capita water usage is based on the permanent population in the PAWSD service area; the water used by the significant transient water usage is factored into the permanent population amount.

Typical daily per capita water usage is approximately 200 gallons for cities and towns in southwest Colorado. For instance, the City of Durango is approximately 200 gallons per person per day, which also has a significant transient population. The average of 215 gallons per person per day for PAWSD is reasonable for water systems that include lawn and garden watering and have a significant tourist economy.

Water conservation has been and will continue to be a component of the PAWSD water supply plan, refer to Section 3.5 below. The average per capita usage of 215 gallons per day is consistent with most cities and towns with significant summer lawn watering, and tourist economies; however, PAWSD has factored in a reduction of the per capita usage from 215 to 205 over the next 25 years through water conservation strategies.

3.2. FUTURE POPULATION and WATER USAGE PROJECTIONS

As described above, for the past 10 years Archuleta County has grown at a rate of 6.5% per year during a period of significant growth. The equivalent tap growth rate within PAWSD was 7.1% from 1995 to 2000. The County grew at a rate of 4.0% per year during the 1980's, a period of moderate growth. These growth rates would also apply to the PAWSD service area. The growth within PAWSD is projected to continue at 7.1% for the next 10 years, then after 2010, the growth rate is projected to decrease to a moderate value of 4% per year.

The estimated permanent population within PAWSD and the water usage based on: 215 gallons per person per day from 2000 to 2010; 210 gallons per person per day from 2010 to 2020; and 205 gallons per person per day from 2020 to 2025; are shown in Table 3.2 for each 5 year increment from 2000 to 2025. The population within the PAWSD in 2000 is estimated to be 75% of the Census data, or 7,420.

TABLE 3.2

ESTIMATED PAWSD FUTURE WATER DEMAND

Year	Annual Growth Rate	Estimated Permanent Population	Annual Use Per Capita (g/cap/day)	Total Annual Demand (acre-feet)	Total Annual Demand (million gallons)
2000		7,420	215	1,787	582
	7.10%				
2005		10,456	215	2,518	821
	7.10%				
2010		14,733	215	3,548	1,156
	4%				
2015		17,925	210	4,217	1,374
	4%				
2020		21,809	210	5,130	1,672
	4%				
2025		26,534	205	6,093	1,985

The population in the service area in 2025 is projected to be about 26,534. The associated annual water demand is 1,985 million gallons or 6,093 acre-feet.

The monthly water usage within the year varies as shown in Table 3.3, from a low of 6.1% in February to a high of 12.5% in June. The water supply facilities not only have to provide the annual water demand shown in Table 3.2 but also must be able to provide the monthly demand shown in Table 3.3.

TABLE 3.3
MONTHLY WATER DEMAND IN 2025

Month	% Usage Each Month	Monthly Usage (million gallons)	Monthly Usage (acre-feet)
Jan	6.5%	129	396
Feb	6.0%	119	366
Mar	6.7%	133	409
Apr	6.4%	127	390
May	9.1%	181	555
June	12.5%	249	763
July	12.2%	243	745
Aug	10.2%	202	622
Sept	9.0%	179	549
Oct	7.5%	149	457
Nov	6.6%	131	402
Dec	7.2%	143	439
Total	100%	1,985	6,093

3.3 SUMMARY OF 2025 WATER DEMAND

PAWSD plans to have facilities constructed by 2010 that are adequate to supply the estimated 2025 annual and monthly water demand as shown in Table 3.3.

PAWSD is attempting to develop plans that will allow the construction of water supply facilities well ahead of the need for the estimated water demand because: (1) the 2025 water demand is based on long term population increases for Archuleta County, should the population growth of 7.1% per year continue for the next two decades, rather than one decade, the estimated 2025 water demand of 6,093 acre-feet will occur between 2015 and 2020 rather than 2025; and (2) the time to construct new water supply facilities is significant due to permitting, funding, and other issues which commonly delay construction of new facilities.

The alternatives presented in the following chapters, are evaluated relative to there ability to meet the 2025 water demand of 6,093 acre-feet.

3.4 WATER CONSERVATION MASTER PLAN

PAWSD developed and has implemented a "Water Conservation Master Plan" in January, 2000. The plan addresses water-efficient fixtures, low water use landscaping, and water efficient irrigation systems. PAWSD has constructed a water efficient demonstration site for use by residents and has implemented a rate structure conducive to water conservation. Reductions in the per capita usage have been factored into the future water use projections to reflect the implementation of the plan.

PAWSD has reduced the 1995 through 2000 average per capita usage of 215 gallons per day to 205 in 2025 to reflect water conservation measures; additional reductions were not included because: (1) a major reduction of water usage from implementation of the Water Conservation Master Plan may not occur and (2) the actual usage is consistent with cities and towns with significant summer lawn watering and tourist economies indicating that reduction in the water usage rate will be difficult.

PAWSD has implemented the Water Conservation Plan and will make every attempt to reduce water usage.

4.   EXISTING WATER SUPPLY SOURCES

4.1.   INTRODUCTION

This section describes the three existing raw water supply systems that are available to the PAWSD. In addition to the existing systems, the San Juan Water Treatment Plant, which is presently under construction, is included in this section. Knowledge of the raw water sources and systems has been derived from interviews with PAWSD personnel and through review of past water supply studies.

A surface water operations model has been used to predict water yield during drought conditions from two of the water supply sources. The two sources that were modeled included Hatcher and Stevens Reservoirs both of which obtain significant supplemental supplies from Fourmile creek. Camp, Dresser & McKee Inc. as part of a study entitled "Feasibility Study Hidden Valley Reservoir and Stevens Lake Dam Enlargement" developed the basic model. Some modifications have been made to the model as a result of new data. For purposes of this report, the model is referred to as the "CDM modified model." Since an extremely dry series of years has not occurred since the raw water systems have been operating at their present levels, water availability during a drought is not known. The model includes the very dry years of 1976, 1977 and 1978. Model runs are contained in Appendix A and a description of the model is included in Appendix B.

Water supply for the San Juan and Snowball water treatment plants were not modeled. Availability of supply for these sources was based on historical measurements of flow in the San Juan River that demonstrated water availability.

4.2. HATCHER RESERVOIR AND WATER TREATMENT PLANT

4.2.1. General Description

Hatcher Reservoir has a capacity of 1,729 acre-feet and is the source of supply for the Hatcher Water Treatment Plant (WTP). The reservoir stores water under its own decrees, runoff from Martinez Creek diverted under its J.B. Martinez and Perkins Ditch decrees and obtains water from Dutton Ditch through an extension pipeline. Dutton Ditch obtains its supply from Fourmile Creek. Hatcher WTP, with a capacity of 2 m.g.d., draws its supply from Hatcher Reservoir. A map showing the major components of the Hatcher Reservoir and water treatment plant is included as Figure 4-1.

4.2.2. Water Supply

The water supply for this facility is largely dependent on the natural runoff characteristics of the reservoir basin, Martinez and Fourmile Creeks. During years when precipitation is average and above, experience has indicated that a nearly full water supply is available to this water treatment plant. Since municipal water use does not decrease during dry periods, continued water supply availability is critical.

To prepare for these dry periods, the CDM modified model was operated for Hatcher Reservoir and WTP to estimate available water supplies during drought conditions. The model output is included as Case 4, page A-8, in Appendix A.

The referenced model indicates that a production rate from the Hatcher WTP of 90 acre-feet per month during the period May through September and 20 acre-feet per month during the remaining portion of the year could be maintained during drought conditions. The 90 and 20 acre-feet per month are equal to 0.96 m.g.d and 0.21 m.g.d. respectively. Production at the maximum rate is equal to less than one-half of the capacity of the water treatment plant. Therefore, the model indicates that drought conditions will significantly reduce the water supply available from Hatcher WTP.

It is important to recognize that all modeled assumptions do not replicate past operation of the Hatcher WTP source. Significant assumptions used in the model include:
  - ➢ Diversion of 21.25 c.f.s. under the JB Martinez and Perkins Ditch rights through the Perkins Ditch when water is available in Martinez Creek. At the present time, the ditch is of insufficient size to carry the full water right.
  - ➢ The present ability to draw Hatcher Reservoir down to a storage level of only 850 acre-feet was maintained in the model. The WTP supply pump inlet channel is set at an elevation that permits withdrawal of water only from the upper portion of the reservoir.

Descriptions of all model assumptions are contained in Appendix B.

Labels on map: DUTTON PIPELINE EXTENSION, DUTTON PIPELINE EXTENSION, PERKINS DITCH DIVERSION, MARTINEZ CREEK, PERKINS DITCH, HATCHER WTP

FIGURE 4-1
MAP OF HATCHER RESERVOIR
AND WATER TREATMENT PLANT
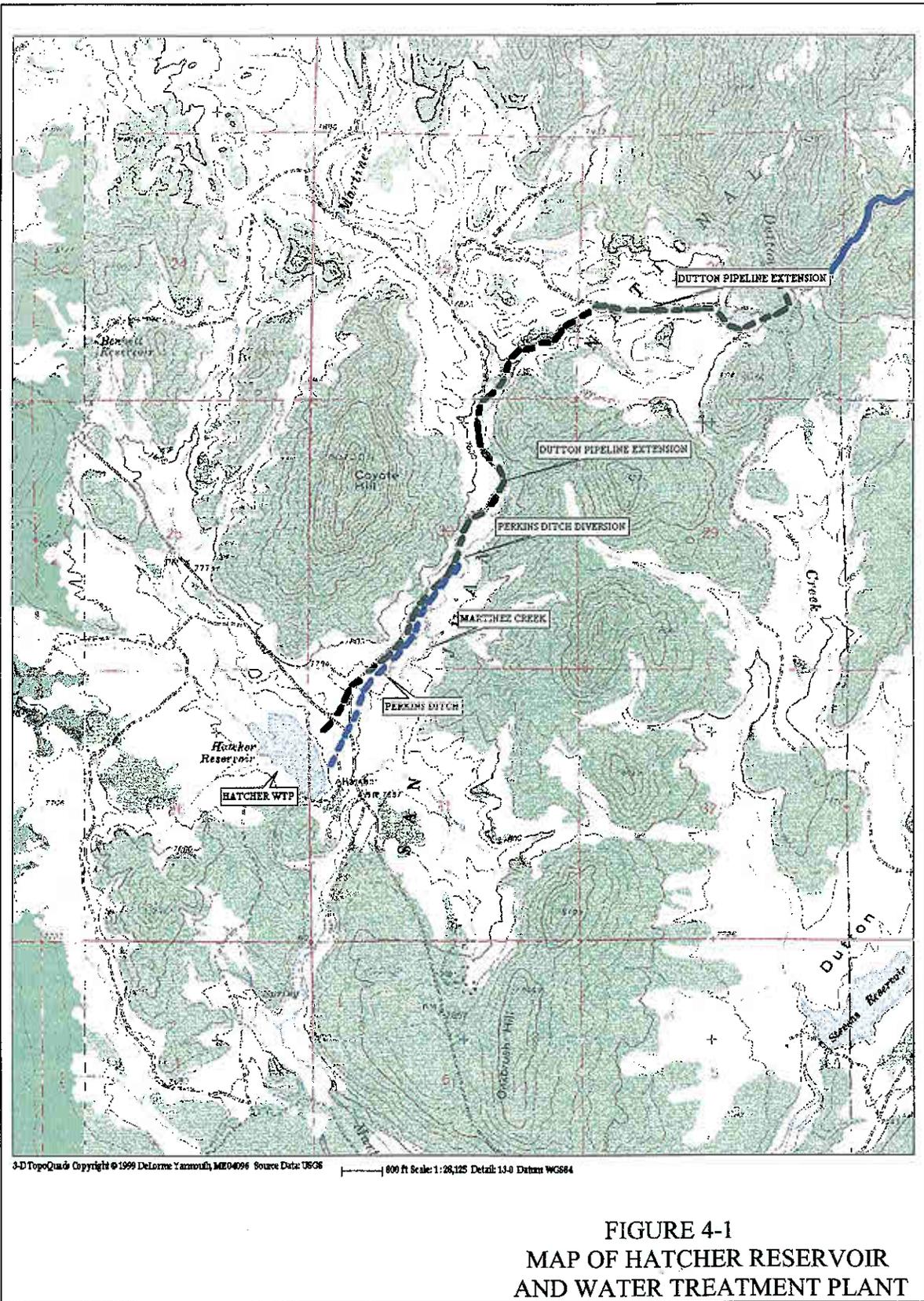
4.3. SNOWBALL WATER TREATMENT PLANT

4.3.1. General Description

The existing water supply facilities at Snowball WTP include a 2 m.g.d. water treatment plant, 8 million gallon raw water reservoir, 250,000 gallon treated water storage tank, and a water transmission pipeline. The transmission pipeline carries water by gravity from the intake on the West Fork of the San Juan River 8 miles to a raw water reservoir. At a site immediately below the reservoir, water from the reservoir passes through a water treatment plant, storage tank and then flows through a three-mile pipeline to its connection with the distribution system in the Town of Pagosa Springs. A sketch showing the location and major components is included as Figure 4-2.

4.3.2. Water Supply

The transmission pipeline above the treatment plant has a design capacity of 2.0 m.g.d. using the planned pipe sizes and grades. A soil slide along the pipeline route is 4.1 miles downstream from the diversion from the West Fork of the San Juan at Jackson Mountain. As a result of numerous repairs to the pipeline that has raised the elevation of the pipeline where it crosses the soil slide, the capacity of the pipe has been reduced from the design of 2.0 m.g.d. to approximately 1.5 m.g.d. The soil slide moves continuously with the most rapid movement occurring during periods of high precipitation. A catastrophic event along the active slide area is very likely. Such an event would result in complete loss of the pipeline over a length of approximately ¼ of a mile. The treated water transmission pipeline below the plant has a design capacity of 4.0 m.g.d.

Experience during the record dry years of 1976, 1977 and 1978 indicate that water availability and water rights in the West Fork are adequate even during dry years to maintain this supply.

4.4. STEVENS RESERVOIR AND WATER TREATMENT PLANT

4.4.1. General Description

With a storage capacity of 635 acre-feet, Stevens Reservoir is located in Dutton Creek drainage approximately 4½ miles northwesterly of Pagosa Springs, Colorado. The reservoir stores water under its own decree and from Dutton Ditch which diverts from Fourmile Creek and discharges in Dutton Creek. The 0.5 m.g.d. Stevens (WTP) is located immediately below the reservoir and draws its supply from the reservoir. A map showing the location of the Reservoir is included as Figure 4-3.

4.4.2. Water Supply

The water supply for Stevens Reservoir and water treatment plant is largely dependent on the natural runoff characteristics of the reservoir basin and water diverted through Dutton Ditch from Fourmile Creek. There is a nearly full water supply for this water treatment

FIGURE 4-2
MAP OF
SNOWBALL WATER SUPPLY
FACILITIES

SCALE: 1" = ±7,540'
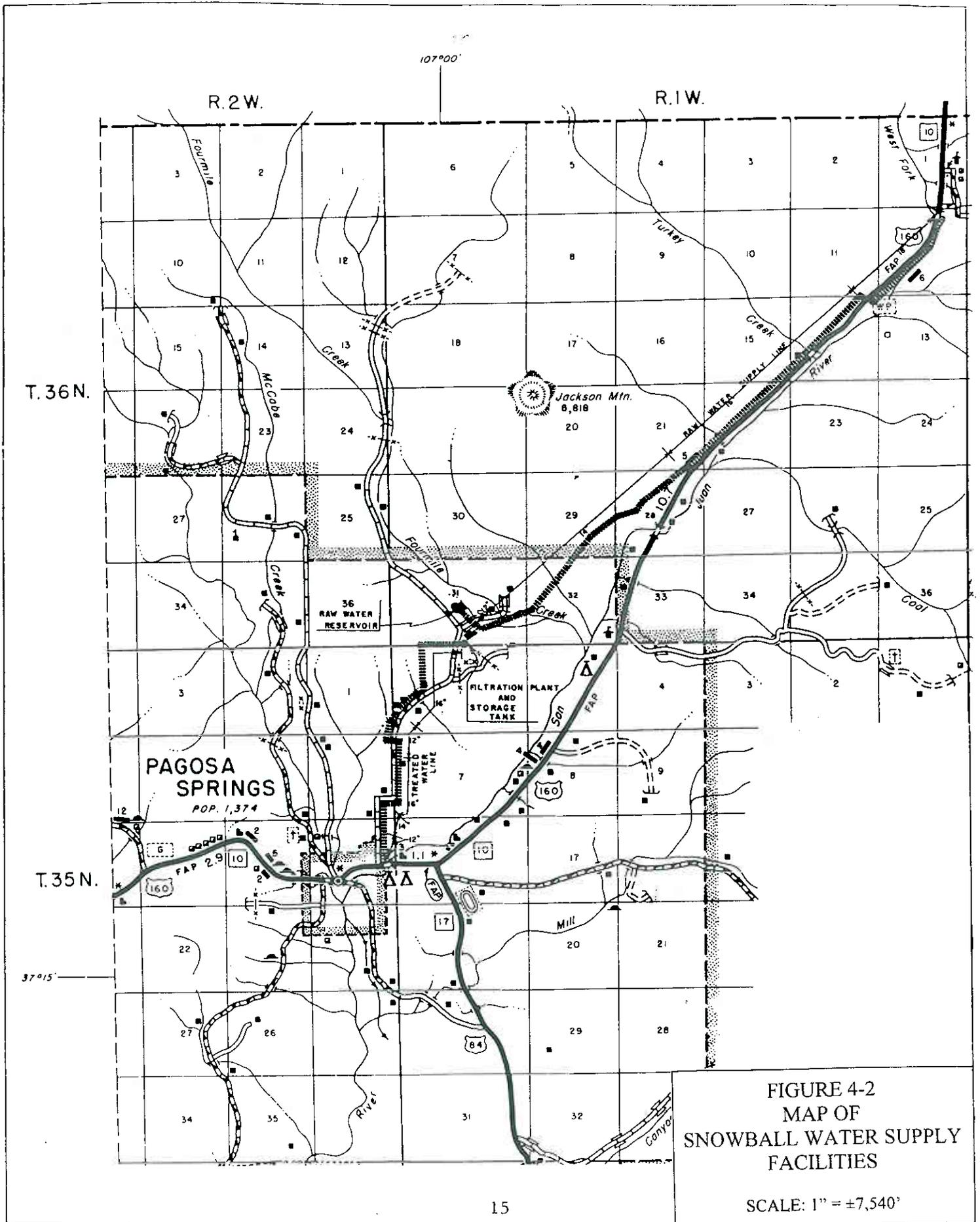
plant during years when precipitation is average and above. Since a series of extremely dry years has not occurred since this water treatment plant has been operating at its present level, water availability is not known.

To prepare for these dry periods, the CDM modified model was operated for Stevens Reservoir and WTP to estimate available water supplies during drought conditions. The model output is included as Case 4, page A-9, in Appendix A. Descriptions of operational assumptions are contained in Appendix B.

The referenced model indicates that a production rate from the Stevens Reservoir of 92 acre-feet per month during the period May through September could be maintained during drought years. No production would be available during the remaining portion of the year. 92 acre-feet per month is equal to 0.99 m.g.d. which exceeds the present capacity of the water treatment plant. Therefore, it was assumed the maximum production rate during a drought would be 0.5 m.g.d. during May through September. The remaining storage would be divided throughout the other seven months of the year and produce 0.35 m.g.d. Due to water quality limitations, it was assumed the lower 150 acre-feet of the reservoir could not be used to supply the WTP.

4.5. SAN JUAN RIVER DIVERSION AND SAN JUAN WATER TREATMENT PLANT

4.5.1. General Description

The 3 m.g.d. San Juan WTP is located approximately six miles westerly of Pagosa Springs, Colorado. Water is supplied to the water treatment plant through a 6.1 mile transmission pipeline that diverts from the San Juan River approximately four miles south of Pagosa Springs. This project is presently under construction with completion of the first stage expected late 2001. The project is being built in stages with the first stage providing a capacity of 2 m.g.d. A map of the major components of this water supply system is included as Figure 4-4.

4.5.2. Water Supply

Although there has been no experience concerning the physical availability of water at the river diversion or the reliability of the water rights, historical records indicate that a full water supply will be available from the San Juan River at this point of diversion.

4.6. SUMMARY OF ESTIMATES OF AVAILABLE WATER SUPPLY DURING DRY PERIODS

The present maximum treatment plant production capacity during the peak usage time including the San Juan WTP, when entirely completed, is approximately 5.96 m.g.d. A tabulation of the maximum yield from each source is presented in Table 4-1.

Table 4-1
Summary of Water Availability
During Dry Periods

Water Source	Maximum Yield During May – September Period (m.g.d.)	Maximum Yield During October – April Period (m.g.d.)
Hatcher Water Treatment Plant	0.96	0.21
Snowball Water Treatment Plant	1.50*	1.50*
Stevens Water Treatment Plant	0.50	0.35
San Juan Water Treatment Plant	3.00**	3.00**
Total	5.96	5.06

* Limited by transmission pipeline capacity.
** First stage construction will be 2.0 m.g.d. with the additional 1 m.g.d. to be installed when needed.

These estimated supply amounts are the maximum possible during assumed dry year conditions. A safety factor for unforeseen events has not been included.

The monthly water supply from existing sources based on the CDM modified model during May through September is 179 million gallons and the monthly water supply during October through April is 152 million gallons. A comparison of the monthly water demand as shown in Table 3-3 and the supply from current facilities is shown in Table 4-2.

Table 4-2
Monthly Water Demand in 2025
Compared to Current Supply

Month	Monthly Usage (million gallons)	Monthly Supply (million gallon)	Shortage (million gallon)
Jan	138	152	None
Feb	130	152	None
Mar	143	152	None
Apr	139	152	None
May	203	179	24
June	273	179	94
July	263	179	84
Aug	215	179	36
Sept	194	179	15
Oct	154	152	2
Nov	137	152	None
Dec	151	152	None
Total	2,141	1,959	255

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The maximum monthly water shortage is in June with a projected shortfall of 94 million gallons (289 acre-feet). The summer shortfall volume is 255 million gallons or 782 acre-feet.

Alternative facilities to supply all or part of the shortfall are described in Chapter 5.

In addition to the 1.02 m.g.d. projected shortfall, there remains some question whether the San Juan WTP can produce at capacity during a dry year. 3 m.g.d. of water requires a diversion from the San Juan River of at least 4.6 c.f.s. The lowest recorded flow of the San Juan River is 9.7 c.f.s. at Pagosa Springs on October 5, 1956. The river flow at Pagosa Springs during the early fall of 2000 has dropped to 19 c.f.s. It is likely to be difficult to divert 4.6 c.f.s during very low flow conditions. In addition, no determination has been made of the legal availability of the water from the San Juan River under extreme low flow conditions.

It should be noted that the primary source of water supply during a drought is from the San Juan River. The Snowball and San Juan plants together are projected to supply 4.50 m.g.d. of the total available 5.96 m.g.d. Therefore these plants supply 75% of the total. A major state highway parallels much of the San Juan River. The pipeline that supplies water to the Snowball plant passes through an active major soil slide. If the river became contaminated as a result of a traffic accident or the pipeline should fail, the largest portion of the District's supply would be lost. To improve water supply reliability, it is apparent that water supply alternatives from alternate sources should be considered. In particular, increased raw water storage capacity should be considered for alleviation of short-term interruptions in supply caused by pipeline failures, stream contamination and extreme low flow periods.
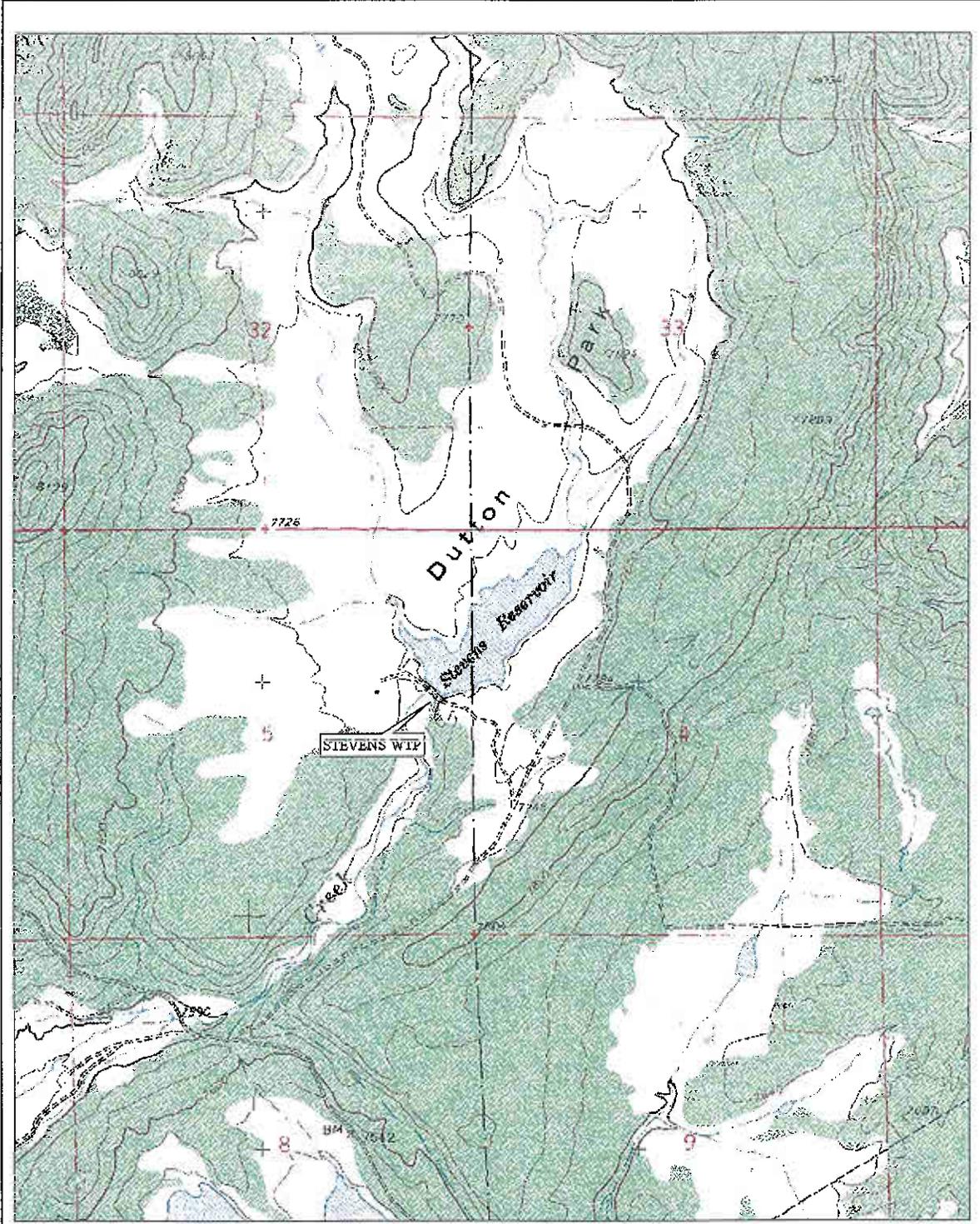
FIGURE 4-3
MAP OF STEVENS RESERVOIR
AND WATER TREATMENT PLANT
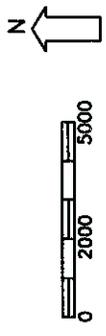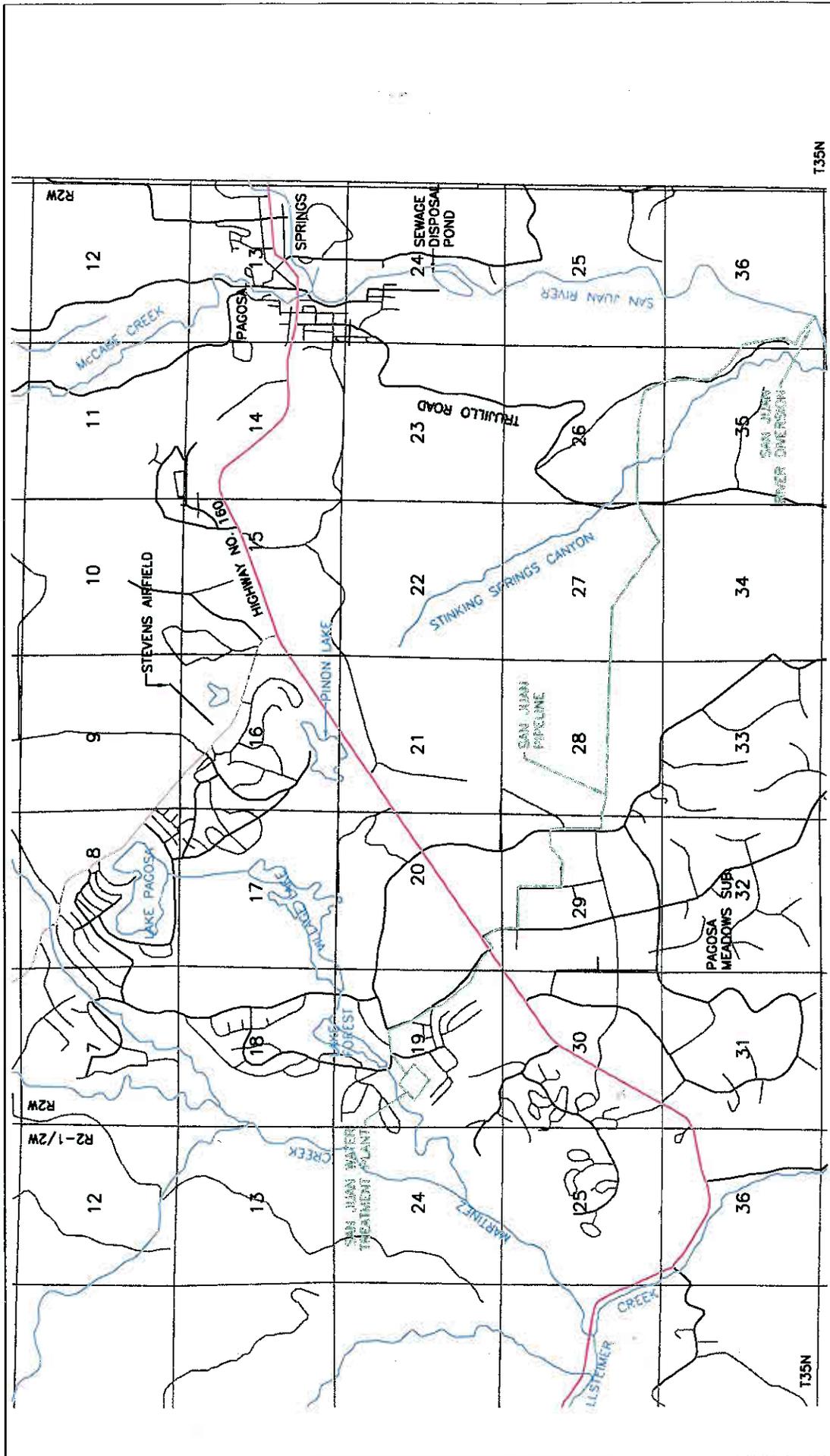
FIGURE 4—4

MAP OF SAN JUAN
WATER SUPPLY SYSTEM

5. ALTERNATE ADDITIONAL WATER SUPPLY SOURCES

5.1. GENERAL DESCRIPTION

The following three sections discuss alternate water supply sources available to PAWSD to meet all or part of the project shortfall described in Chapter 4. Although each alternative is viable, the primary concern is how to provide additional water to the District in the most cost effective manner and with minimal environmental impacts.

A list of the alternate water supply sources considered and the estimated drought water yield for each is presented in Table 5-1. More detailed descriptions of the alternatives are included in subsequent portions of this section. The water yields were derived from the CDM modified model that is described in Appendix B. The model runs are contained in Appendix A. A copy of Table 5-1 showing model runs used to derive the projected yields is also included in Appendix A.

Table 5-1
List of Alternate Water Supply Sources

Sec. No.	Alternate Description	Projected Additional Yield (a.f./yr.)
5.2.	Increase Supply and Capacity of Snowball Water Treatment Plant	1,904
5.3.	Enlarge Stevens Reservoir and Water Treatment Plant to 2 m.g.d.	682
5.4.	Construct Martinez Dam and Use of Hatcher Water Treatment Plant	325
5.5.	Improve Dutton Ditch with:	
	Existing Reservoirs with Enlarged Stevens WTP to 1 m.g.d.	717
	Existing Hatcher WTP, Enlarge Stevens Res. and WTP to 2 m.g.d.	1,172
	Construct Martinez Dam and Enlarge Hatcher WTP to 2.5 m.g.d.	730
5.6	Construct Dry Gulch Dam and Enlarge Snowball WTP to 6.5 m.g.d.	3,300

In order to compare alternatives, the annual cost of the alternative was divided by the estimated dry year raw water yield.

Due to the very low yielding wells within the District and high mineral content of the groundwater, wells were not considered as a viable alternative. The very low river flow that occurs during dry years at the diversion for the San Juan WTP eliminated from consideration the possibility of expanding this WTP.

5.2. INCREASE SUPPLY AND CAPACITY OF SNOWBALL WATER TREATMENT PLANT

5.2.1. Existing Water Supply Facilities

The existing water supply facilities at this location include a 2 m.g.d. water treatment plant, 8 million gallon raw water reservoir, 250,000 gallon treated water storage tank, and a water transmission pipeline. A more detailed description is included in Section 4.3.

5.2.2. Improvements To Increase Supply and Capacity of Water Treatment Plant

Raw Water Pipeline

To increase the water supply from this facility, the first step would be to increase the capacity of the 8 miles of raw water transmission pipeline. . The existing water right for diversion from the San Juan River is 5 c.f.s. which is equal to 3.23 m.g.d. To match the water right, the raw water pipeline capacity should be increased to approximately 3.2 m.g.d.

There are two options readily available for increasing the pipeline capacity. The options include; 1) installing a pump at the river diversion and 2) constructing a larger pipeline. A pump at the river diversion would increase the flow in the pipeline by increasing the water pressure in the pipeline. The larger pipeline would simply provide more area for the water to flow through.

To increase the flow in the pipeline to approximately 3.2 m.g.d., it is estimated that a 2,220 g.p.m. pump producing about 70 feet of head would be required. The existing raw water transmission pipeline was constructed using asbestos cement pipe with a pressure rating that only slightly exceeds existing operating pressures. Historically the pipeline has suffered numerous breaks that may have been caused by the pipe's inability to accommodate existing pressures. Therefore, installing a pump to increase the pressure and flow in the existing pipeline is impractical.

The existing raw water transmission pipeline varies in size from 18" to 14" diameter and was designed to carry 2.0 m.g.d. Preliminary design calculations indicated that it would be necessary to increase the pipe diameter to 24" to 18" to carry the desired 3.2 m.g.d. A new enlarged diversion structure at the West Fork of the San Juan River would also be required. The soil slide that the transmission pipeline presently crosses remains active. An alternate pipeline route that extends to the opposite side of the river from the soil slide and then returns to the present pipeline route below the soil slide would avoid the unstable area. This change in route would add approximately 2,000 feet to the present pipeline route.

There would be temporary disruption of wetlands associated with streams, ditches and meadows during construction of a replacement pipeline. Permanent loss of wetlands or riparian habitat should not occur as a result of the construction. However, an increase in

diversion from the river is likely to negatively impact wetlands and aquatic habitat that relies on river flow. The present maximum diversion is approximately 1.5 m.g.d. (2.3 c.f.s.). The diversion for the proposed pipeline would be 3.2 m.g.d. (5.0 c.f.s.), an increase of 2.7 c.f.s.

Water Treatment Plant

The existing 2.0 m.g.d. surface water treatment plant was retro fitted into a building without space for expansion. Therefore, replacement of the entire plant with a new 3.5 m.g.d. water treatment plant is proposed. Package water treatment plants are typically available in increments of 0.5 m.g.d. 3.5 m.g.d. is the next larger size to match the supply pipeline capacity. In order to accommodate the larger facility, acquisition of an additional 15 acres of property would be needed.

Distribution System Booster Pump

The Snowball WTP supplies water to a low-pressure portion of the distribution system. If additional water supply is produced at this location, a booster pump system will be needed on the westerly side of Pagosa Springs. The booster pump system will lift water from the lower Pagosa Springs pressure zone to the higher westerly pressure zone. A pumping capacity of about 1 m.g.d. will be needed.

5.2.3. Cost Estimates and Annual Cost Projections

The following preliminary cost estimates are based on prevailing wage, equipment and material costs as of July, 2001. Future users of these estimates should adjust them for inflation as needed. Although the cost estimates prepared as part of this report represent the best judgment of the writer herein as a design professional familiar with the construction industry, the writer does not guarantee that any proposals, bids or actual construction costs will not vary from the cost estimates prepared by him.

Table 5-2

PRELIMINARY COST ESTIMATES
FOR
IMPROVEMENTS TO INCREASE SUPPLY AND CAPACITY
OF SNOWBALL WATER TREATMENT PLANT

Item Description	Quantity	Unit	Unit Price	Total Price
Contractor Mobilization/Demobilization	1	l.s.	50,000	50,000
Transmission Pipeline:				
River diversion	1	l.s.	100,000	100,000
24" Dia. D.I.P. transmission pipeline	10,400	l.f.	60	624,000
21" Dia. D.I.P. transmission pipeline	16,690	l.f.	55	917,950
18" Dia. D.I.P. transmission pipeline	13,720	l.f.	50	686,000
River crossing	2	ea.	30,000	60,000
Highway crossing	120	l.f.	600	72,000
Air release station	8	ea.	4,000	32,000
Blow off valve	8	ea.	3,500	28,000
Water Treatment Plant:				
3.5 m.g.d. water treatment plant	1	l.s.	1,400,000	1,400,000
Sludge dewatering lagoons	1	l.s.	175,000	175,000
Building for WTP	1	l.s.	400,000	400,000
Booster Pump Between Pressure Zone:				
Pump - 700 g.p.m. @ 380 ft. T.D.H.	1	l.s.	100,000	100,000
8" Dia. D.I.P. transmission pipeline	7,700	l.f.	20	154,000
Total Estimated Construction Cost (TECC)				$4,798,950
Contingency @ 20% of TECC				959,790
Engineering & Legal @ 20% of TECC				959,790
Land Purchase - 15 acres @ $10,000/ac.				150,000
TOTAL ESTIMATED PROJECT COST				$6,868,530

The annual cost projections were prepared assuming a loan at an interest rate of 6% per year with a 20 year repayment schedule.

Table 5-3

ESTIMATE OF ANNUAL COST OF OPERATION
FOR
IMPROVEMENTS TO INCREASE SUPPLY AND CAPACITY
OF SNOWBALL WATER TREATMENT PLANT

Annual Cost of Operation:

Total Estimated Project Cost (TEPC) =		$6,688,530
Number of years of payments =	20	
Interest rate =	6.0%	

$$\text{Annual Debt Service} = \left[\frac{i}{(1+i)^n - 1} + i\right] x\,TEPC =$$

$598,830

O & M Costs per year:

Treatment of 1,904 a.f. @ $166/a.f. =	316,064
Power & chemical costs 1,904 a.f. @ $150/a.f. =	285,600
Pipeline maintenance	15,000
Booster pump power costs	59,000
	$675,664
Total Estimated Annual Cost	$1,274,494

The estimated increase in yield from the proposed improvements would be the difference between the proposed capacities of 3.2 m.g.d. and the existing transmission pipeline capacity of 1.5 m.g.d. Therefore, the yield would be 1.7 m.g.d. This yield is equivalent to 1,904 a.f./yr.

The estimated water cost would be $2.05 per 1,000 gals. Calculations are shown below.

$$\text{Water Cost} = \frac{\$1{,}274{,}494 \ / \ \text{yr.} \ x \ 1{,}000 \ \text{gals.}}{1{,}904 \ \text{a.f./yr.} \ x \ 325{,}851 \ \text{gals./a.f.}} = \$2.05 \ \text{per 1,000 gals.}$$

5.3. ENLARGE STEVENS RESERVOIR AND WATER TREATMENT PLANT

5.3.1. General Description

This alternative would involve enlarging Stevens Reservoir to 1,430 acre feet by raising the dam by ±10 feet and expanding the water treatment plant. The present storage capacity of Stevens Reservoir is 635 acre feet and the associated water treatment plant maximum capacity is 0.5 m.g.d. A sketch showing the location and major components is included as Figure 5-1.

5.3.2. Proposed Improvements
Stevens Reservoir

Stevens Reservoir dam is an existing earthfill dam built in the early 1950's and is 24 feet in height. The length of the existing dam is approximately 1,000 feet with a crest width of 20 feet. State Engineer Office's safety inspection reports indicate that the outlet conduit is corroded and the slide gate is difficult to operate. Reservoir water quality for purposes of water supply is becoming poor and cleaning is needed. To correct these deficiencies, it will be necessary to drain the reservoir in the near future. The enlarged reservoir water surface area would be about 130 acres, increased from about 80 acres presently.

It is anticipated that the proposed enlargement will raise the top of the dam by approximately 10 feet above the existing crest to an elevation of 7730 feet. This will increase the length of the dam from the existing 1,000 feet to 1,225 feet. The toe of the dam is at an elevation of 7694 feet. The proposed spillway has been located at 7723 feet and the high water line has been calculated at 7729 feet. All elevations are feet above mean sea level, 1929 datum.

Water Treatment Plant

Additional water treatment plant capacity is needed. Projected water availability during a drought is 460 a.f./yr. District personnel have indicated that the most urgent need for this water is during the months of May through September when additional water use occurs because of outside irrigation, tourist and summer residences. Dividing the total available water into five months results in 92 a.f./month. 92 a.f./month is equal to 0.98 m.g.d. To treat this quantity of water, the existing 0.5 m.g.d. plant needs to be enlarged to 1 m.g.d.

If the reservoir is enlarged, total yield is approximately doubled. Therefore, a 2 m.g.d. water treatment plant is needed if the reservoir is enlarged. The existing water treatment plant is located in a building immediately below the dam. There is no available space in the existing building, so a new building and plant are proposed.

5.3.3. Water Supply

The water supply for the proposed enlarged Stevens Reservoir and Dutton Ditch has been estimated using the CDM modified hydrologic model. The estimated additional yield from an enlarged reservoir is 682 a.f./yr. From both an enlarged reservoir and Dutton Ditch, the estimated additional yield is 1,172 a.f./yr. For both of these scenarios, the water treatment plant use is planned for only the peak water demand months of May through September.

5.3.4. Cost Estimates and Annual Cost Projections

The following preliminary cost estimates are based on prevailing wage, equipment and material costs as of July, 2001. Future users of these estimates should adjust them for inflation as needed. Although the cost estimates prepared as part of this report represent the best judgment of the writer herein as a design professional familiar with the construction industry, the writer does not guarantee that any proposals, bids or actual construction costs will not vary from the cost estimates prepared by him.

Labels visible on map:
Dutton
Park
32
31
7770
7726
7909
ADDITIONAL AREA TO INUNDATED
Stevens Reservoir
STEVENS WIP
Stevens Tank
5
4
Creek
7590

3-D TopoQuads Copyright © 1999 DeLorme Yarmouth, ME 04096   Source Data: USGS   500 ft   Scale: 1 : 17,400 Detail: 13-1 Datum: WGS84

FIGURE 5-1
MAP OF STEVENS RESERVOIR
ENLARGEMENT

Table 5-4

PRELIMINARY COST ESTIMATES
FOR
PROPOSED ENLARGEMENT OF STEVENS RESERVOIR

Item Description	Quantity	Unit	Unit Price	Total Price
Contractor Mobilization/Demobilization	1	l.s.	50,000.00	50,000
Diversion & Dewatering	1	l.s.	50,000.00	50,000
Haul road	5,000	l.f.	20.00	100,000
Excavation of Existing Dam	7,833	c.y.	2.12	16,606
Strip borrow area	4,000	c.y.	1.00	4,000
Zone 1 fill	39,094	c.y.	1.93	75,451
Zone 2 fill	39,418	c.y.	1.62	63,857
Chimney drain	2,618	c.y.	21.17	55,423
Rip rap	14,653	c.y.	40.00	586,120
Rip rap bedding	4,884	c.y.	15.00	73,260
Filter fabric	4,884	s.y.	1.52	7,424
Clear & grub	150	ac.	1,000.00	150,000
Use Existing Spillway				
Outlet Works				
Inlet structure	1	l.s.	35,000.00	35,000
Outlet structure	1	l.s.	20,000.00	20,000
Slip line 18" pipeline	150	l.f.	200.00	30,000
18" Outlet extension	100	l.f.	80.00	8,000
18" BFV	1	ea.	5,000.00	5,000
Total Estimated Construction Cost (E.C.C.)				$1,330,141
Land Acquisition 20 ac.@ $5,000/ac.				$100,000
Contingency @ 20% of E.C.C.				266,028
Engineering & Legal @ 20% of E.C.C.				266,028
TOTAL ESTIMATED PROJECT COST				$1,962,198

Table 5-5

PRELIMINARY COST ESTIMATES
FOR
PROPOSED ADDITIONAL ½ M.G.D. WATER TREATMENT PLANT
AT EXISTING STEVENS RESERVOIR

Item Description	Quantity	Unit	Unit Price	Total Price
½ m.g.d. package water treatment plant	1	l.s.	220,000.00	220,000
Metal building for WTP	1	l.s.	150,000.00	150,000
Booster pump - ½ m.g.d.	1	l.s.	20,000.00	20,000
Raw water pump - ½ m.g.d.	1	l.s.	40,000.00	40,000
Total Estimated Construction Cost (TECC)				$430,000
Contingency @ 20% of TECC				86,000
Engineering & Legal @ 20% of TECC				86,000
TOTAL ESTIMATED PROJECT COST				$602,000

Table 5-6

PRELIMINARY COST ESTIMATES
FOR
PROPOSED ADDITIONAL 1½ M.G.D. WATER TREATMENT PLANT
AT PROPOSED STEVENS RESERVOIR

Item Description	Quantity	Unit	Unit Price	Total Price
1½ m.g.d. package water treatment plant	1	l.s.	550,000.00	550,000
Metal building for WTP	1	l.s.	200,000.00	200,000
Booster pump - 1½ m.g.d.	1	l.s.	60,000.00	60,000
Raw water pump - 1½ m.g.d.	1	l.s.	120,000.00	120,000
Total Estimated Construction Cost (TECC)				$930,000
Contingency @ 20% of TECC				186,000
Engineering & Legal @ 20% of TECC				186,000
TOTAL ESTIMATED PROJECT COST				$1,302,000

The annual cost projections were prepared assuming a loan at an interest rate of 6% per year with a 20 year repayment schedule.

Table 5-7

ESTIMATE OF ANNUAL COST OF OPERATION
FOR
EXISTING STEVENS RESERVOIR AND 1 M.G.D. WTP
WITH YIELD FROM DUTTON DITCH IMPROVEMENT

Annual Cost of Operation:

Estimated Project Cost - Additional ½ m.g.d. WTP	602,000
Total Estimated Project Cost (TEPC) =	$602,000
Number of years of payments (n) =	20
Interest rate (i) =	6%

Annual Debt Service $\left[\dfrac{i}{(1+i)^n - 1} + i\right] x\,TEPC =$

$52,485

O & M Costs per year:

Treatment of 717 a.f. @ $166/a.f. =	119,022
Power & chemical costs 717 a.f. @ $150/a..f. =	107,550
Dam maintenance =	15,000
	$241,572
Total Estimated Annual Cost	$294,057

With Dutton Ditch improvement and the existing reservoir, Stevens Reservoir is projected to yield ±460 a.f./yr. The higher water demand by users during the summer months results in a projected operational need of ±92 a.f./mo. for a five month period. 92 a.f./mo. is equivalent to 0.98 m.g.d. The existing Stevens water treatment (WTP) capacity is 0.5 m.g.d. Therefore, the increased yield from enlarging the WTP is 0.48 m.g.d. for a five month period or 227 a.f./yr. Increased yield from the existing Hatcher Reservoir and water treatment plant is projected to be 490 a.f./yr. Together, the total increased yield is 717 a.f./yr. Dry year annual cost for this alternative is tabulated in Table 5-16 and the calculation deriving the cost per 1,000 gallons is shown following the table.

Table 5-8

ESTIMATE OF ANNUAL COST OF OPERATION
FOR
ENLARGED STEVENS RESERVOIR AND 2 M.G.D. WTP

Annual Cost of Operation:

Estimated Project Cost - Stevens Res.	1,962,198
Estimated Project Cost - Additional 1½ m.g.d. WTP	1,302,000
Total Estimated Project Cost (TEPC) =	$3,264,198

Number of years of payments (n) =	20
Interest rate (i) =	6%

$$\text{Annual Debt Service} = \left[\frac{i}{(1+i)^n - 1} + i\right] x\, TEPC =$$

$284,588

O & M Costs per year:

Treatment of 681 a.f. @ $166/a.f. =	113,046
Power & chemical costs 681 a.f. @ $135/a.f. =	91,935
Dam maintenance =	15,000
	$219,981
Total Estimated Annual Cost	$504,569

Water yield from the enlarged Reservoir and water treatment plant is projected to be 681 a.f./yr. without Dutton Ditch improvement. Dry year water costs would be:

Cost without Dutton Ditch improvement = $2.27/1,000 gallons

$$\text{Water Cost} = \frac{\$504,569/\ \text{yr.} \times 1,000\ \text{gals.}}{681\, \text{a.f./yr.} \times 325,851\, \text{gals./a.f.}} = \$2.27 \ \text{per}\, 1,000\ \text{gals.}$$

Table 5-9

ESTIMATE OF ANNUAL COST OF OPERATION
FOR
ENLARGED STEVENS RESERVOIR, WTP TO 2 M.G.D.
WITH ADDED YIELD FROM IMPROVED DUTTON DITCH*

Annual Cost of Operation:

Estimated Project Cost - Stevens Res.	1,962,198
Estimated Project Cost - Additional 1½ m.g.d. WTP	1,302,000
Total Estimated Project Cost (TEPC) =	$3,264,198

Number of years of payments (n) =	20
Interest rate (i) =	6%

$$\text{Annual Debt Service} = \left[\frac{i}{(1+i)^n - 1} + i \right] x\,TEPC =$$

$284,588

O & M Costs per year:

Treatment of 1,172 a.f. @ $166/a.f. =	194,552
Power & chemical costs 1,172 a.f. @ $135/a.f. =	158,220
Dam maintenance =	15,000
	$367,772
Total Estimated Annual Cost	$652,360

* Construction costs, O & M for Dutton Ditch Improvement not included.

Additional water yield from the enlarged Reservoir and treatment plant would be 1,172 a.f./yr. with Dutton Ditch improvement. Dry year annual cost for this alternative is tabulated in Table 5-16 and the calculation deriving the cost per 1,000 gallons is shown following the table.

5.4. CONSTRUCT MARTINEZ DAM AND ENLARGE HATCHER WATER TREATMENT PLANT

5.4.1. General Description

The proposed Martinez Dam would provide approximately 760 acre feet of storage which could be used at an expanded Hatcher WTP which is within approximately ½ mile of the dam site. The dam site is on Martinez Creek. In addition to inflow from the drainage basin, it has been assumed that water from an expanded Dutton Ditch would be delivered to the reservoir site. Dutton Ditch diverts from nearby Four Mile Creek. A sketch showing the location and major components is included as Figure 5-2.

5.4.2. Proposed Improvements

Martinez Dam

The proposed dam would be an earthfill dam constructed to a height of 50 feet above the existing Martinez Creek channel. A concrete chute spillway is proposed on the northerly side of the dam. The total tributary area above the dam is approximately 10.7 square miles. The normal water level in the reservoir would be below the elevation of the water level in Hatcher Reservoir. In order to convey water from the reservoir to an enlarged Hatcher water treatment plant, it will be necessary to construct a pumping system and conveyance structure to deliver the reservoir water to the water treatment plant.

Water Treatment Plant

If both Martinez Dam and the Dutton Ditch improvement were constructed, enlargement of the Hatcher water treatment plant would be required. The existing 2.0 m.g.d. surface water treatment plant would be enlarged to a capacity of 2.5 m.g.d.

5.4.3. Water Supply

The water supply for the proposed Martinez Reservoir has been estimated using the CDM modified hydrologic model developed by initially by Camp, Dresser & McKee Inc. Initially, the model was run with Hatcher Reservoir and with Hatcher and Martinez Reservoirs during drought conditions to estimate yield of the additional reservoir. The spreadsheets that calculate the two conditions are included on pages A-11 and A-8. The difference between the two model runs indicate the yield from the additional reservoir during drought conditions is 325 a.f./yr.

In addition, the model was run comparing the yield from the reservoir with improvement of the Dutton Ditch. The net increase in yield from both the addition of Martinez Dam and the improved Dutton Ditch during drought conditions was estimated to be 730 a.f./yr.

5.4.4. Cost Estimates and Annual Cost Projections

The following preliminary cost estimates are based on prevailing wage, equipment and material costs as of July, 2001. Future users of these estimates should adjust them for inflation as needed. Although the cost estimates prepared as part of this report represent the best judgment of the writer herein as a design professional familiar with the construction industry, the writer does not guarantee that any proposals, bids or actual construction costs will not vary from the cost estimates prepared by him.
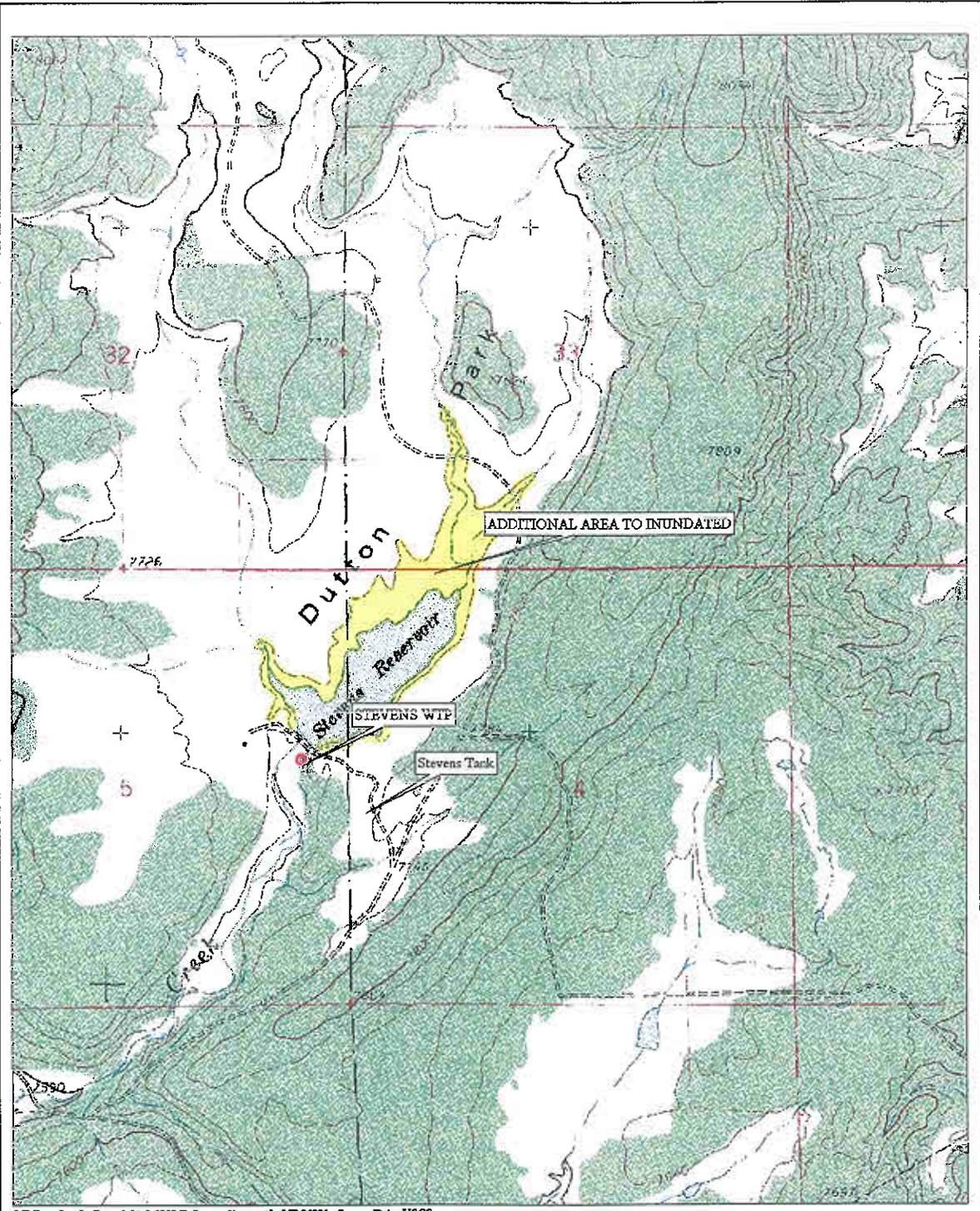
FIGURE 5-2
SKETCH OF PROPOSED MARTINEZ
DAM AND RESERVOIR
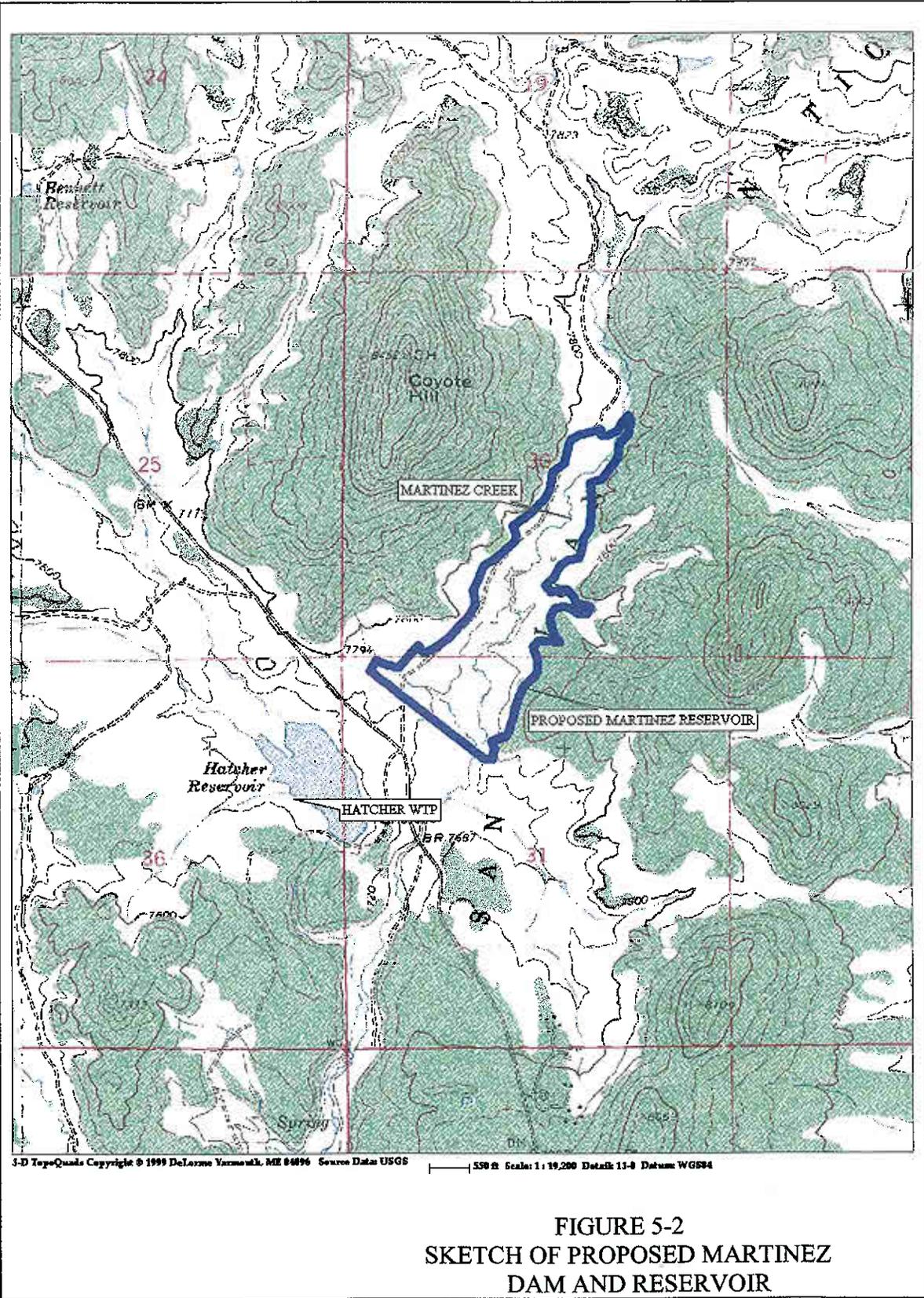
Table 5-10

PRELIMINARY COST ESTIMATES
FOR
PROPOSED MARTINEZ RESERVOIR WATER SUPPLY

Item Description	Quantity	Unit	Unit Price	Total Price
Embankment				
Clearing and Grubbing of Dam Site	22,500	c.y.	2.00	45,000
Placement of Earth Fill	328,075	c.y.	1.50	492,113
Core Trench Excavation	48,425	c.y.	5.00	242,125
Chimney & Blanket Drain	23,735	c.y.	15.00	356,025
Riprap & Bedding – Dam	10,970	c.y.	15.00	164,550
Spillway				
Excavation of Spillway	318,000	c.y.	2.00	636,000
Concrete	200	c.y.	450.00	90,000
Riprap	10,000	c.y.	15.00	150,000
Outlet Works				
Outlet Pipe, 36" dia. Concrete	500	l.f.	40.00	20,000
Concrete Cut-Off Collars	9	c.y.	500.00	4,500
Slide Gate w/operator	1	l.s.	40,000.00	40,000
Still Basin	22	c.y.	600.00	13,200
Connection of Hatcher Reservoir				
Pump station for delivery to Hatcher WTP	1	l.s.	75,000.00	75,000
Pipeline Lateral - 14" D.I.P.	1,750	l.f.	18.00	31,500
Perkins ditch construction	1,400	l.f.	25.00	35,000
Total Estimated Construction Cost (TECC)				$2,395,013
Contingency @ 20% of TECC				479,003
Engineering & Legal @ 20% of TECC				479,003
TOTAL ESTIMATED PROJECT COST				$3,353,018

Table 5-11

PRELIMINARY COST ESTIMATES
FOR
PROPOSED ADDITIONAL ½ M.G.D. WATER TREATMENT PLANT
AT HATCHER RESERVOIR

Item Description	Quantity	Unit	Unit Price	Total Price
½ m.g.d. package water treatment plant	1	l.s.	220,000.00	220,000
Metal building for WTP	1	l.s.	150,000.00	150,000
Booster pump - ½ m.g.d.	1	l.s.	20,000.00	20,000
Total Estimated Construction Cost (TECC)				$390,000
Contingency @ 20% of TECC				78,000
Engineering & Legal @ 20% of TECC				78,000
TOTAL ESTIMATED PROJECT COST				$546,000

The annual cost projections were prepared assuming a loan at an interest rate of 6% per year with a 20 year repayment schedule.

Table 5-12

ESTIMATE OF ANNUAL COST OF OPERATION
FOR
MARTINEZ RESERVOIR AND EXISTING 2 M.G.D. HATCHER WTP

Annual Cost of Operation:

Estimated Project Cost - Martinez Res.	3,353,018
Total Estimated Project Cost (TEPC) =	$3,353,018
Number of years of payments (n) =	20
Interest rate (i) =	6%

$$\text{Annual Debt Service} = \left[\frac{i}{(1+i)^n - 1} + i \right] x\, TEPC =$$

$292,331

O & M Costs per year:

Treatment of 325 a.f. @ $166/a.f. =	53,950
Power & chemical costs 325 a.f. @ $150/a.f. =	48,750
Dam maintenance =	15,000
	$117,700
Total Estimated Annual Cost	$410,031

Projected water yield from the new Martinez Reservoir would be 325 a.f./yr. without Dutton Ditch improoement. Dry year water costs would be:

Cost without Dutton Ditch improvement = $3.39/1,000 gallons

$$\text{Water Cost} = \frac{\$410,031 / \text{yr.} \times 1,000\,\text{gals.}}{325\,\text{a.f./yr.} \times 325,851\,\text{gals./a.f.}} = \$3.39 \text{ per } 1,000\,\text{gals.}$$

Table 5-13

ESTIMATE OF ANNUAL COST OF OPERATION
FOR
MARTINEZ RESERVOIR AND ENLARGED HATCHER WTP TO 2.5 M.G.D.
WITH YIELD FROM IMPROVED DUTTON DITCH

Annual Cost of Operation:

Estimated Project Cost - Martinez Res.	3,353,018
Estimated Project Cost - Additional ½ m.g.d. WTP	546,000
Total Estimated Project Cost (TEPC) =	$3,899,018

Number of years of payments (n) =	20
Interest rate (i) =	6%

$$\text{Annual Debt Service} = \left[\frac{i}{(1+i)^n - 1} + i \right] \times TEPC =$$

$339,934

O & M Costs per year:

Treatment of 730 a.f. @ $166/a.f. =	121,180
Power & chemical costs 730 a.f. @ $150/a.f. =	109,500
Dam maintenance =	15,000
	$245,680
Total Estimated Annual Cost	$585,614

Additional water yield from the new Martinez Reservoir with Dutton Ditch improvement is projected to be 730 a.f./yr. Dry year annual cost for this alternative is tabulated in Table 5-16 and the calculation deriving the cost per 1,000 gallons is shown following the table.

5.5. IMPROVE DUTTON DITCH

5.5.1 General Description

The existing Dutton Ditch diverts water from Fourmile Creek and conveys it into the Dutton Creek drainage. The largest portion of the water rights in the Ditch is used for irrigation purposes with the remainder available for domestic use. Absolute water rights in the ditch currently total 22.85 c.f.s. The rights are as follows in order of priority:

Order	Amount	Use	Owned by
1	12.85 c.f.s	Irrigation	Roger Dolese
2	8.00 c.f.s.	Domestic	PAWSD
3	2.00 c.f.s.	Irrigation	Bud Seavy

PAWSD also owns a 20 c.f.s conditional water right in the Dutton Ditch for the enlargement of the ditch capacity.

Although historically the ditch could carry substantially more, the present ditch physical capacity has declined to approximately 4 c.f.s. at the most constricted flow section. The decline in capacity is a result of accumulation of sediment in the ditch and difficulty in maintaining full capacity at two locations where it crosses unstable hillsides. The result of the above priority and the ditch capacity is that during the irrigation season (typically April 15 to October 15), only a portion of the first 12.85 c.f.s. is diverted by the ditch for irrigation purposes. For the period outside of the irrigation season, diversions up to 8.0 c.f.s. are available for PAWSD. An 8 c.f.s. pipeline was constructed during 1993 from the ditch near its discharge to Dutton Creek over the drainage divide to Hatcher Reservoir. This is called the Dutton Ditch extension pipeline.

During winter months ice forms and prevents use of the Ditch by PAWSD. Further, the varying ditch capacity limits diversion of in-priority domestic rights by PAWSD during both the non-irrigation and irrigation season.

5.5.2. Proposed Improvements

To return the availability of water from the District's Dutton Ditch right to historical levels, construction of a pipeline paralleling a large portion of the ditch is proposed. Physical improvement of the Ditch to return it to its historical capacity has also been considered, but soil instability conditions at several locations along the existing ditch make this alternative difficult and probably impractical.

The proposed pipeline will improve the ability to divert throughout the year whenever water rights are in priority. It will be particularly useful during the winter because the buried pipeline will be able to carry water during periods when water in the restricted sections of the open ditch froze and stopped flowing. Further, a water-tight pipeline will eliminate present losses to seepage from the ditch.

A preliminary feasibility study of ditch improvement alternatives was done in December, 1993 by Davis Engineering Service, Inc. In that study two pipeline alternatives were investigated. Both would carry approximately 12 c.f.s. of domestic water which the previously described CDM Model indicates would be frequently available. One of the alternatives assumes construction of a pipeline 19,000 feet long from the diversion on Fourmile Creek to a point below the unstable sections of the existing ditch and where the remaining portion of the Ditch has a capacity of approximately 25 c.f.s. Although the referenced remaining portion of the Ditch has sufficient capacity, past erosion caused by ditch flow has incised the channel to a considerable depth below the normal ground level. Further use of the ditch channel will result in some additional erosion. The other alternative assumed construction of a pipeline 28,500 feet long from Fourmile Creek to the Dutton Ditch extension pipeline. The longer pipeline would eliminate additional ditch channel erosion and improve the quality of water available to PAWSD. Due to the added benefits of the longer pipeline, only the longer pipeline was considered in this study. The 28,500 feet long pipeline improves the ability to divert water during the winter and returns the system to its historical capacity so PAWSD's 8 c.f.s. water rights can be carried without interference from other users of the ditch. A map of the Dutton Ditch and proposed pipelines is included as Figure 5-3.

5.5.3. Water Supply

The water supply for the proposed improved Dutton Ditch has been estimated using the CDM modified model. A more detailed description of the model is included in section 4.1. As described in this referenced paragraph and Appendix B, the model was used in the very dry years of 1976, 1977 and 1978 to estimate the benefits of improvements during the critical dry year periods.

To maximize yield from the pipeline, a reservoir is needed to capture the water when pipeline flow exceeds the current demand. To estimate the benefits of the improved pipeline, three alternate reservoir and WTP combinations have been considered. Following is a summary of the alternatives considered and the resulting yield:

Table 5-14
List of Alternatives Considered
With Improvement of Dutton Ditch

Description of Alternative	Additional Yield (a.f./yr.)
Existing Reservoirs and Enlarged Stevens WTP to 1 m.g.d.	717
Enlarge Stevens Reservoir and WTP to 2 m.g.d.	1,172
Construct Martinez Dam and Enlarge Hatcher WTP To 2.5 m.g.d.	730

FIGURE 5-3
MAP OF DUTTON DITCH AND
PROPOSED PIPELINE

Scale: 1"= ±2,800'
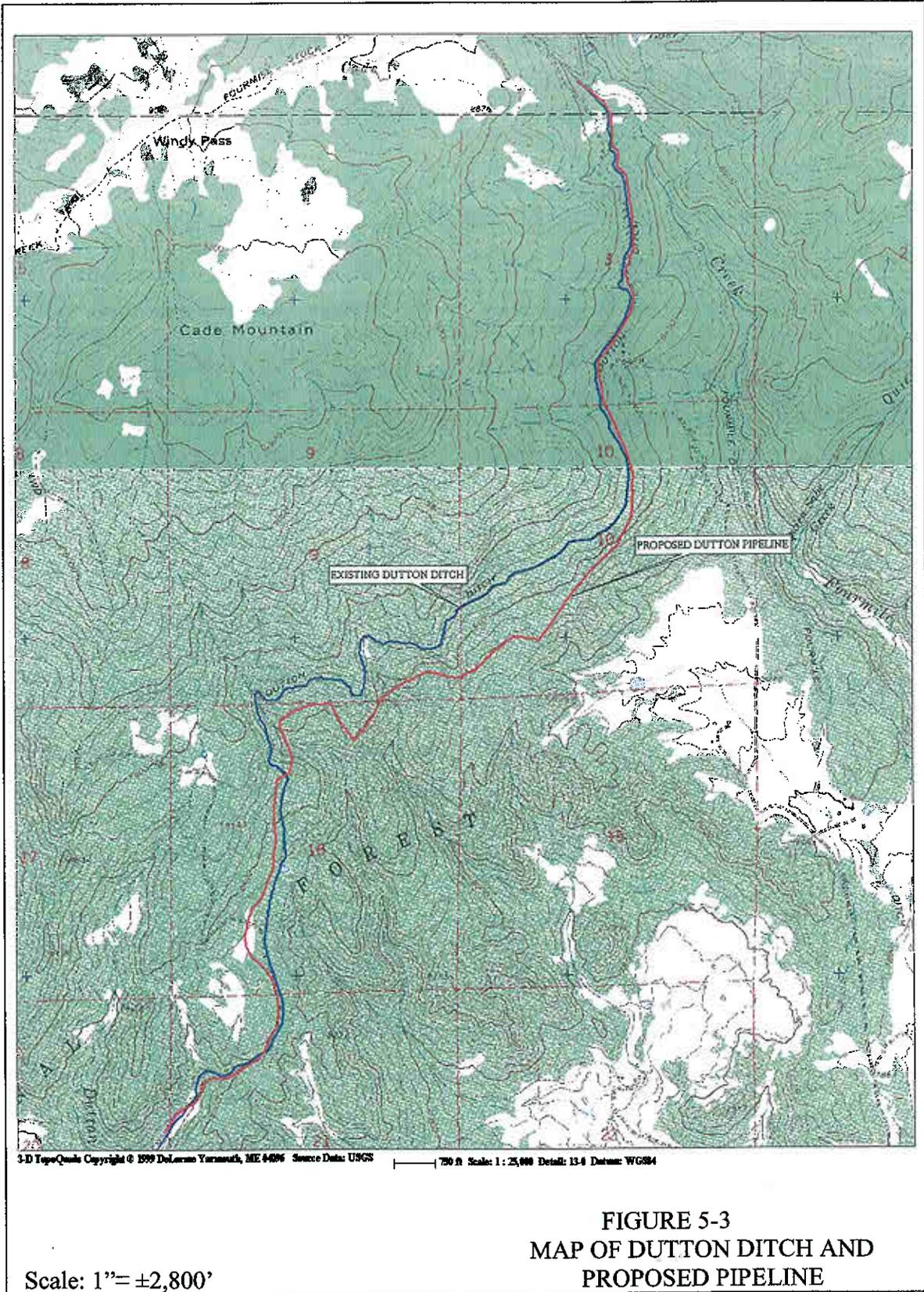
Dutton Ditch diverts from Fourmile Creek, which is a tributary of the San Juan River. Therefore the proposed improvement of the Dutton Ditch would result in a reduction in flow in Fourmile Creek and the San Juan River similar to more historical levels. However, the additional diversion to return to historical levels would occur largely during the winter months rather than during the critical low flow months of July, August and September and thus have limited impact to the District's other San Juan River water rights. Storage of resulting additional flows in an enlarged or new reservoir may permit a reduction in reliance on diversions from the river by San Juan and Snowball water treatment plants during summer low flow periods. Construction of an improved Dutton Ditch may incidentally benefit aquatic habitat and wetlands along the San Juan River.

5.5.4. Cost Estimates and Annual Cost Projections

The following preliminary cost estimates are based on prevailing wage, equipment and material costs as of July, 2001. Future users of these estimates should adjust them for inflation as needed. Although the cost estimates prepared as part of this report represent the best judgment of the writer herein as a design professional familiar with the construction industry, the writer does not guarantee that any proposals, bids or actual construction costs will not vary from the cost estimates prepared by him.

Table 5-15

PROJECT COST ESTIMATES
FOR
PROPOSED REPLACEMENT OF DUTTON DITCH
WITH A PIPELINE

Item Description	Quantity	Unit	Unit Price	Total
Pipe, 24" dia.	28,500	l.f.	75	2,137,500
Air/Vacuum valve w/vault	12	ea.	4,500	54,000
Blowoff valve	12	ea.	1,800	21,600
Diversion structure	1	l.s.	18,000.00	18,000
Discharge structure	1	l.s.	4,000.00	4,000
Isolation valve	28	ea.	5,500.00	154,000
Total Estimated Construction Cost (E.C.C.)				$2,389,100
Contingency @ 20% of E.C.C.				477,820
Engineering & Legal @ 20% of E.C.C.				477,820
TOTAL ESTIMATED PROJECT COST				$3,344,740

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ESTIMATE OF ANNUAL COST OF OPERATION
FOR
REPLACEMENT OF DUTTON DITCH
WITH A PIPELINE

Annual Cost of Operation:

Number of years of payments =   20

Interest rate =   6%

Annual Debt Service = $291,610

O & M Costs per year:

	Unit Cost	No.	Total
Ditch maintenance	10,000	1	10,000

Total Estimated Annual Cost $10,000

Total Estimated Annual Cost $301,610

To compare the alternative, the total annual cost for the WTP and reservoir is added to the annual cost for Dutton Ditch improvement. A tabulation of those estimated annual costs are included in Table 5-16.

Table 5-16
Tabulation of Annual Cost
For
Dutton Ditch Improvement Alternatives

Alternative	Existing Hatcher & Stevens Res. with enlarged WTP @ Stevens	Improved Dutton Ditch	Total
Additional Estimated Annual Cost	$294,057	$301,610	$595,667

Alternative	Enlarge Stevens Reservoir & WTP	Improved Dutton Ditch	Total
Additional Estimated Annual Cost	$652,360	$301,610	$953,970

Alternative	Construct Martinez Dam & Enlarge Hatcher WTP	Improved Dutton Ditch	Total
Additional Estimated Annual Cost	$585,614	$301,610	$887,224

Dry year water costs for Dutton Ditch improvement alternatives would be:

Cost with existing reservoirs and enlarged Stevens WTP = $2.55/1,000 gallons

$$\text{Water Cost} = \frac{\$595,667/\text{ yr. x } 1,000 \text{ gals.}}{717 \text{ a.f./yr. x } 325,851} = \$2.55 \text{ per } 1,000 \text{ gals.}$$

Cost with enlarged Stevens Reservoir and WTP = $2.50/1,000 gallons

$$\text{Water Cost} = \frac{\$953,970 \text{ / yr. x } 1,000 \text{ gals.}}{1,172 \text{ a.f./yr. x } 325,851 \text{ gals./a.f.}} = \$2.50 \text{ per } 1,000 \text{ gals.}$$

Cost with new Martinez Reservoir and enlarged Hatcher WTP = $3.73/1,000 gallons

$$\text{Water Cost} = \frac{\$887,224/\text{y r. x } 1,000 \text{ gals.}}{730 \text{ a.f./yr. x } 325,851 \text{ gals./a.f.}} = \$3.73 \text{ per } 1,000 \text{ gals.}$$

5.6. CONSTRUCT DRY GULCH DAM AND ENLARGE SNOWBALL WATER TREATMENT PLANT

5.6.1. General Description

The proposed Dry Gulch Dam would provide 4000 acre feet of storage, 2000 acre-feet active and 2000 acre-feet inactive. Water from the reservoir would be conveyed to an expanded Snowball WTP through a pipeline and pump. The dam site is on Dry Gulch about 2 miles east of the Town of Pagosa Springs and is tributary to the San Juan River. The primary source of water for the reservoir is planned to be diversions from the San Juan River through the Park Ditch, which passes through the reservoir basin.

5.6.2. Proposed Improvements

Dry Gulch Dam

The proposed dam would be an earthfill dam constructed to a height of ±74 feet with a total capacity of 4000 acre-feet. The tributary area above the dam is approximately 3.2 square miles. The Park Ditch enters the reservoir basin at elevation 7340 feet on the east abutment and exits the basin at elevation 7290 on the west abutment. The crest of the dam is planned to be at 7314 feet so that water from the Park Ditch can be discharged into the reservoir. The top of the inactive pool is at 7290 feet so that water can be released from the reservoir into the Park Ditch. The segment of the Park Ditch in the reservoir basin would no longer be used, the Park Ditch water required downstream of the dam would pass though the reservoir.

The normal high water level in the reservoir would be 7307 feet. The crest of the dam is planned to be at 7314 feet allowing 7 feet of freeboard and flood storage. The water surface area at the normal high water is about 147 acres.

The inflow design flood is very small, allowing all of the flood to be stored in the surcharge pool. A small concrete chute spillway is proposed on the east side of the dam to drain the surcharge pool in 5 days as required by Colorado dam safety standards.

Raw Water Pipeline

An 18 inch diameter, approximately 8000 feet long pipeline, is included to convey up to 7 cfs to the Snowball WTP. The Snowball WTP is higher than the reservoir, so a pumping plant would be needed.

Water Treatment Plant

The existing Snowball 2.0 m.g.d. surface water treatment plant was retro fitted into a building without space for expansion. Therefore, replacement of the entire plant with a new 6.5 m.g.d. water treatment plant is proposed, with 2.0 m.g.d. to utilize the existing Snowball Pipeline and 4.5 m.g.d. to utilize the 7 cfs from Dry Gulch Reservoir. Package water treatment plants are typically available in increments of 0.5 m.g.d. so 6.5 m.g.d. is the selected size to match the supply pipelines capacity. In order to accommodate the larger facility, acquisition of an additional 15 acres of property would be needed.

Treated Water Pipeline

The existing treated water transmission pipeline from the Snowball WTP to Pagosa Springs has a design capacity of 4.0 m.g.d. In order to obtain full benefit from the 6.5 m.g.d. supply, enlargement of the three mile long pipeline to 18 inch diameter would be needed.

The Snowball WTP supplies water to a low-pressure portion of the distribution system. If additional water supply is produced at this location, a booster pump system will be needed on the westerly side of Pagosa Springs. The booster pump system will lift water from the lower Pagosa Springs pressure zone to the higher westerly pressure zone. A pumping capacity of 1 m.g.d. will be needed.

5.6.3. Water Supply

The water supply for the proposed Dry Gulch Reservoir would be diversions from the San Juan River under water rights held by the Southwestern Water Conservation District for the West Fork Canal and Dry Gulch Reservoir. The diversions are planned to be made through an arrangement with the Park Ditch Company to utilize the existing Park Ditch when capacity is available.

The Park Ditch has a capacity of about 40 c.f.s. and is generally operated from early May through early October with diversions in May and October less than the capacity. The operation plan is predicated upon using the Park Ditch to convey water for storage in the reservoir in April, May, October and November. Arrangements to utilize the Park Ditch have not been discussed; therefore, the availability of the Park Ditch is not known. A successful change in the point of diversion of the West Fork Canal to the headgate of the Park Ditch may also be necessary for the completion of this project.

The water supply for Dry Gulch Reservoir is based upon studies performed by Harris Water Engineering, Inc. in a 1989 study titled "Alternative Reservoir Site Evaluation". A preliminary reservoir yield analysis was performed which showed that about 3,300 acre-feet per year could be provided using the assumptions herein.

5.6.4. Cost Estimates and Annual Cost Projections

The following preliminary cost estimates are based on prevailing wage, equipment and material costs as of July, 2001. Future users of these estimates should adjust them for inflation as needed. Although the cost estimates prepared as part of this report represent the best judgment of the writer herein as a design professional familiar with the construction industry, the writer does not guarantee that any proposals, bids or actual construction costs will not vary from the cost estimates prepared by him.

FIGURE 5-4
SKETCH OF PROPOSED DRY GULCH
DAM AND RESERVOIR

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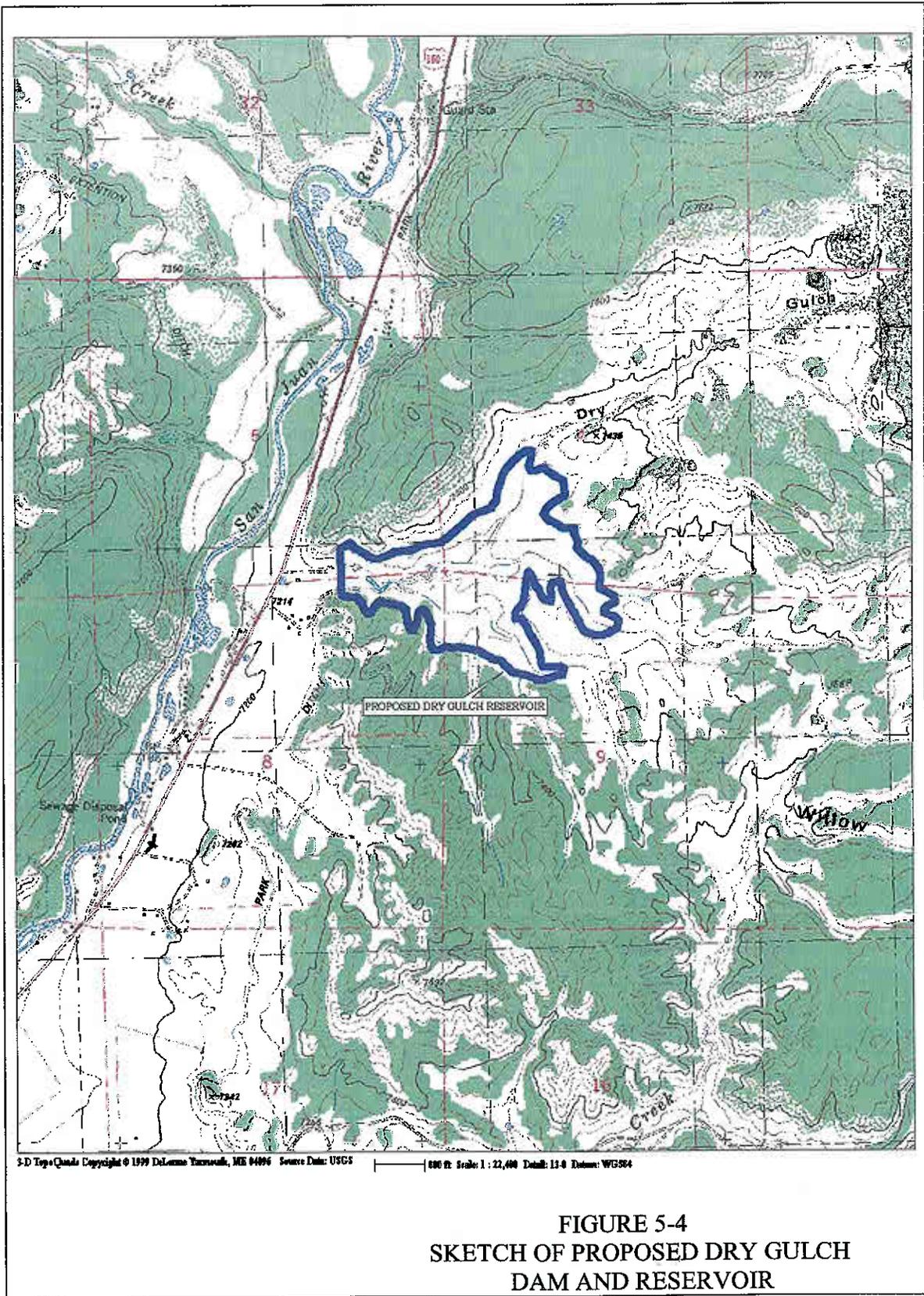
Table 5-17

PRELIMINARY COST ESTIMATES
FOR
PROPOSED DRY GULCH RESERVOIR WATER SUPPLY

Item Description	Quantity	Unit	Unit Price	Total Price
Embankment				
Clearing and Grubbing of Dam Site				150,000
Placement of Earth Fill	409,000	c.y.	7.00	2,863,000
Toe Drain	400	l.f.	30.00	12,000
Riprap & Bedding	2,800	c.y.	30.00	112,000
Spillway				
54" Overflow Pipe	350	l.f.	500.00	175,000
Outlet Works				
Outlet Pipe, 42" dia. Concrete	435	l.f.	300.00	131,000
Concrete Cut-Off Collars	9	c.y.	500.00	4,500
Slide Gate w/operator	1	l.s.	40,000.00	40,000
Still Basin	22	c.y.	600.00	13,200
Unlisted Items				400,000
Park Ditch Upgrades				
Upgrade ditch and river diversion headgate				300,000
Pipeline to Snowball Pagosa Springs WTP				
Pump station for delivery to Snowball WTP	1	l.s.	75,000.00	75,000
Pipeline Lateral - 18" D.I.P.	8,000	l.f.	50.00	400,000
Unlisted Items				50,000
Total Estimated Raw Water Construction Cost				$4,725,700
Reservoir Land Acquistion	200 ac	@	$5,000	$1,000,000
Contingency @ 20%				945,000
Engineering & Legal @ 20%				945,000
TOTAL ESTIMATED PROJECT COST				$7,615,700

Table 5-18

PRELIMINARY COST ESTIMATES
FOR
PROPOSED 6.5 M.G.D. SNOWBALL WATER TREATMENT PLANT

Item Description	Quantity	Unit	Unit Price	Total Price
6.5 m.g.d. package water treatment plant	1	l.s.	220,000.00	2,800,000
Metal building for WTP				800,000
Sludge Lagoons				400,000
Pump to Distribution System				200,000
14" D.I.P. Transmission Pipeline	7,700	l.f.	40.00	308,000
Total Estimated Construction Cost (TECC)				$4,508,000
Contingency @ 20% of TECC				901,000
Engineering & Legal @ 20% of TECC				901,000
TOTAL ESTIMATED PROJECT COST				$6,310,000

The annual cost projections were prepared assuming a loan at an interest rate of 6% per year with a 20 year repayment schedule.

Table 5-19

ESTIMATE OF ANNUAL COST OF OPERATION
FOR
DRY GULCH RESERVOIR AND SNOWBALL WTP

Annual Cost of Operation:

Raw Water Cost	7,615,700
Treated Water Cost	6,310,000
Total Estimated Project Cost (TEPC) =	$13,925,700
Number of years of payments (n) =	20
Interest rate (i) =	6%

$$\text{Annual Debt Service} = \left[\frac{i}{(1+i)^n - 1} + i \right] x\,TEPC =$$

$1,214,100

O & M Costs per year:

Treatment of 3300 a.f. @ $166/a.f. =   548,000

Power & chemical costs 3300 a.f. @ $150/a.f. =   495,000

Dam maintenance =   15,000

Total Estimated Annual Cost $2,272,100

Additional water yield from the new Dry Gulch Reservoir 3,300 a.f./yr. Dry year water costs would be:

$$\text{Water Cost} = \frac{\$2,272,100 \text{ / yr. x } 1,000 \text{ gals.}}{3300 \text{ a.f./yr. x } 325,851 \text{ gals./a.f.}} = \$2.11 \text{ per } 1,000 \text{ gals.}$$

6. EVALUATION OF ALTERNATIVES AND SELECTED PLAN

Table 6-1 contains a summary list of the alternates evaluated to provide additional water supply sources and their respective dry year estimated water yield, construction cost and annual cost per 1,000 gallons of water produced. The cost estimates are preliminary, meaning that alternatives within 10% to 15% are essentially the same cost.

Table 6-1
Comparison of Cost For Additional Alternate Water Supply Sources

	Alternate Water Supply Source	Estimated Dry-Year Yield (a.f./yr.)	Construction Cost	Annual $ per 1000 gals.
1	Increase Supply and Capacity of Snowball Water Treatment Plant	1,904	$6,868,530	$2.05
2	Improve Dutton Ditch and Stevens WTP to 1 m.g.d. With Existing Reservoirs	717	$3,946,740	$2.55
3	Improve Dutton Ditch With Enlarged Stevens Reservoir and WTP to 2 m.g.d.	1172	$6,608,938	$2.50
4	Construct Martinez Dam Without Improved Dutton Ditch	325	$3,353,018	$3.39
5	Construct Martinez Dam and Enlarge Hatcher Water Treatment Plant With Improved Dutton Ditch	730	$7,243,758	$3.73
6	Enlarge Stevens Reservoir and WTP to 2 m.g.d. Without Improved Dutton Ditch	682	$3,264,198	$2.27
7	Construct Dry Gulch Reservoir and New Snowball WTP	3,300	$12,925,700	$2.11

The alternatives to provide additional water supplies to PAWSD are separated into two cost categories. Alternatives 1, 2, 3, 6 and 7 have nearly the same annual cost per 1,000

gallons and are in the lowest cost group. Alternatives 4 and 5 are in the high cost group, about 50% greater than the low cost group.

Alternatives 4 and 5 are not recommended for consideration because of the significantly higher group cost than alternatives 1, 2, 3, 6 and 7.

Alternatives 1 and 7 are not recommended because their yield is more than double the amount needed in 2025. In the case of alternative 7, the existing rate payers are not able to finance the debt service to construct this large project and the existing water distribution system has insufficient capacity to utilize the large yield.

Alternatives 2 and 6 provide 717 and 682 acre-feet per year respectively. Individually these yields are not quite adequate for the 2025 demand of 782 acre-feet per year.

Alternative 3 provides 1,172 acre-feet per year which is enough water to serve 2025 projected population with some buffer to offset possible inaccurate estimates. The conveyance capacity of the existing Dutton Ditch has declined in the last 15 years. It is a critical supply to the water treatment plants at Hatcher and Stevens Reservoirs. Alternative 3 can provide the added benefit of improving the delivery system to both the Hatcher and Stevens WTPs.

These alternate water supply sources included in Alternative 3 have the ability to provide an emergency water supply to the town portion of the system if the Jackson Mountain soil slide disables the transmission pipeline that supplies the Snowball WTP or contamination of the river should occur. In addition, these sources will provide gravity flow of an additional water supply to the town portion of the distribution system. As these alternatives would divert during largely none irrigation season periods, reduction in river flow to critical levels would be less likely compared to direct river diversions.

Alternative 3, Improve Dutton Ditch, Stevens Reservoir and its WTP to 2 m.g.d., is the alternative that provides water at the lowest unit cost and meets the 2025 water demand. Table 6-2 provides a summary of alternative evaluations.

Table 6-2
Summary of Alternative Evaluations

	Alternate Water Supply Source	Summary of Evaluation
1	Increase Supply and Capacity of Snowball Water Treatment Plant	Provides more water than is needed
2	Improve Dutton Ditch and Stevens WTP to 1 m.g.d. With Existing Reservoirs	Does not provide an adequate amount of water to meet 2025 demand

3	Improve Dutton Ditch With Enlarged Stevens Reservoir and 2 m.g.d. WTP	Recommended Plan – Lowest unit water cost that adequately matches 2025 demand
4	Construct Martinez Dam Without Improved Dutton Ditch	Highest unit water cost and does not supply sufficient water to meet 2025 demand
5	Construct Martinez Dam and Enlarge Hatcher Water Treatment Plant With Improved Dutton Ditch	The unit water cost is nearly the highest and does not supply sufficient water to meet 2025 demand
6	Enlarge Stevens Reservoir and WTP to 2 m.g.d. Without Improved Dutton Ditch	Higher unit water cost than selected plan and does not supply sufficient water to meet 2025 demand
7	Construct Dry Gulch Reservoir and New Snowball WTP	Provides far more water than is needed and is beyond PAWSD ability to finance

7. SELECTED PLAN

7.1. Description of the Selected Plan

The selected plan is the improvement of the existing Dutton Ditch, enlargement of Stevens Reservoir and the associated water treatment plant to 2 m.g.d. capacity.

<u>Dutton Ditch</u>

The Dutton Ditch derives its water supply from Fourmile Creek at a diversion approximately nine miles northerly of the Town of Pagosa Springs. The ditch then conveys water into the Dutton Creek drainage that is tributary to Stevens Reservoir. A pipeline is available to carry a portion of the Dutton Creek flow to Hatcher Reservoir. The capacity of the open ditch has declined from ±12 c.f.s. to ±4 c.f.s. within the last 15 years due to accumulation of sediment and difficulty in stabilizing the ditch at two locations where it crosses unstable hillsides. This portion of the selected plan would involve construction of a pipeline largely along Forest Service access roads to a connection with the existing pipeline extension delivering water to Hatcher Reservoir. The pipeline would carry at least PAWSD's water rights in the ditch. The pipeline would be ±28,500 feet long and would be designed to carry ±12 c.f.s.

The pipeline returns the ability to divert water during the winter and increases the capacity of the system so PAWSD's water right can be carried regardless of other priorities in the ditch.

<u>Stevens Reservoir</u>

Stevens Reservoir is located approximately 4.5 miles northwest of the Town of Pagosa Springs on Dutton Creek, a tributary of Stollsteimer Creek which is a tributary of the Piedra River. Stevens Reservoir has an existing capacity of 635 acre-feet. The selected plan would enlarge the reservoir by 795 acre-feet to a total of 1,430 acre-feet. The reservoir is at an elevation of 7700 feet.

The inactive capacity of the enlarged reservoir will total 150 acre-feet, resulting in an active capacity of 1,280 acre-feet. The enlargement will involve raising the crest of the existing dam about 10 feet and increasing the crest length to 1,225 feet.

The additional yield predicted by the CDM modified model for the enlargement during the 1976 to 1978 drought period is estimated to be 682 acre-feet. Dutton Ditch and tributary water from the natural reservoir drainage basin that is presently lost because of lack of storage capacity will fill the enlarged reservoir.

The Stevens Water Treatment Plant will be enlarged to 2.0 m.g.d. to treat the additional supply. Treated water from the treatment plant will be conveyed to the PAWSD distribution system for use in a similar manner as now occurs.

The reservoir is located in Dutton Park which is a relatively flat uplands area consisting of a mixture of meadows interspersed with montane forest. Soils consist of clay and silt loams derived from underlying shales, sandstones and glacial till. These soils generally exhibit low permeability and low to high water capacity. Bedrock varies from 1 to more than 5 feet in depth depending on the slope of the soil.

7.2. Hydrology

The drainage area upstream of the reservoir is 5.8 square miles, 5.87 miles long, and has a vertical drop of 1,440 feet. The Probable Maximum Thunderstorm is 10,400 c.f.s. which is routed through the reservoir and used to size the spillway to be 100 feet wide with one foot of freeboard during the flood event. The drainage area of Fourmile Creek above the diversion for Dutton Ditch is approximately 16 square miles.

The yields of the existing PAWSD raw water sources and the additional yield from the improved Dutton Ditch and Stevens Reservoir used in deriving unit costs are based on the three-year drought conditions that occurred from 1976 to 1978. Though difficult to predict it appears that a drought year such as 1977 may occur two or three times a century.

In a year such as 1977, Stevens Reservoir would be emptied to meet demands. In years with greater runoff, the operation of Stevens Reservoir will be dependent on other factors such as capacity at other locations, outages at other treatment plants, rotation of water supplies, and flow through Stevens Reservoir to maintain water circulation. Operating

criteria is not proposed herein because there are too many unknown variables to develop a realistic operation plan. However, generally the reservoir will not be used to its full extent except in times of drought or other unusual operation requirements.

7.3. Reservoir Embankment Description

A plan view of the 10 foot increase in the dam is shown in Figure 7-1. After the enlargement, the upstream embankment slope will be 3.5 to 1.0 and the downstream embankment slope will be 3.0 to 1.0. The crest will be 20 feet wide. The spillway will be located over the original spillway on the east abutment of the dam. This location takes advantage of the natural side drainage to Dutton Creek. The spillway will be composed of riprap. No plunge pool or extended channel is anticipated because it lies in a natural drainage way which directs flow away from the downstream face of the dam.

A cross section of the dam through the outlet works is shown in Figure 7-2. The dam is composed of earthfill with a clay core using material excavated from the reservoir area. The upstream face of the dam will be covered with 18 inch diameter rip rap, 3 feet thick extended from the crest to the toe. A chimney drain is included to channel seepage to a toe drain consisting of gravel filter material.

The outlet works will be sized to discharge a peak day flow of 3.1 cfs (2.0 m.g.d.) and will consist of a single 18 inch diameter pipe. Control will be provided by an 18 inch butterfly valve operated by a stem riser contained in a vertical wet well located at the upstream toe of the dam. The valve operator will be accessed from a catwalk located at the new crest of the dam. The outlet will discharge to an existing conveyance structure which will route water to the treatment facility.

7.4. Environment Analysis

Attached is a report prepared by Aqua-Hab, Inc. titled "Wetland Delineation of Stevens Reservoir" which describes the environmental analysis for the enlargement. A similar report is attached for Dutton Ditch improvements.

7.5. Environmental Permitting

There may be different environmental impacts that result from the Dutton Ditch improvements and the Stevens Reservoir enlargement. The Dutton Ditch improvements largely include construction of a buried pipeline that can be conditioned and permitted by a U.S. Army Corps of Engineers Nationwide 12 permit. The reservoir enlargement may have broader environmental impact requiring the acquisition of an individual U.S. Army Corps of Engineers 404 permit.

7.6 Depletion Analysis

The following depletion analysis is included for the Section 7 consultation between the U.S. Corps of Engineers and the U.S. Fish and Wildlife Service regarding the endangered fish in the San Juan River.

The selected plan will allow diversion of an additional 1,172 acre-feet into the PAWSD drinking water distribution system. The water will be used for typical municipal purposes including in-house uses, commercial uses and lawn/garden irrigation. The homes served by the system are primarily served by a central sewer system with some homes using individual septic systems. Also, most homes have outside watering. Lacking the necessary data for an evaluation of the PAWSD system to determine the percentage of drinking water depleted, the standard depletion rate for municipal use of 33% is recommended. The result is an annual depletion of 388 acre-feet from the additional annual diversion of 1,172 acre-feet.

The plan includes construction of both improvement to the Dutton Ditch and enlargement of Stevens Reservoir. Of the total additional dry year annual diversion of 1,172 acre-feet as predicted by the CDM modified hydrologic model, 682 acre-feet will be derived from the enlargement of Stevens Reservoir with balance of 490 acre-feet derived from improvement of Dutton Ditch. Using the standard depletion rate of 33%, annual depletion is estimated at 225 acre-feet for enlargement of Stevens Reservoir and 163 acre-feet for improvement of Dutton Ditch.

The total annual dry year depletion to the San Juan River basin from improvement of Dutton Ditch and enlargement of Stevens Reservoir is estimated to be 388 acre-feet.
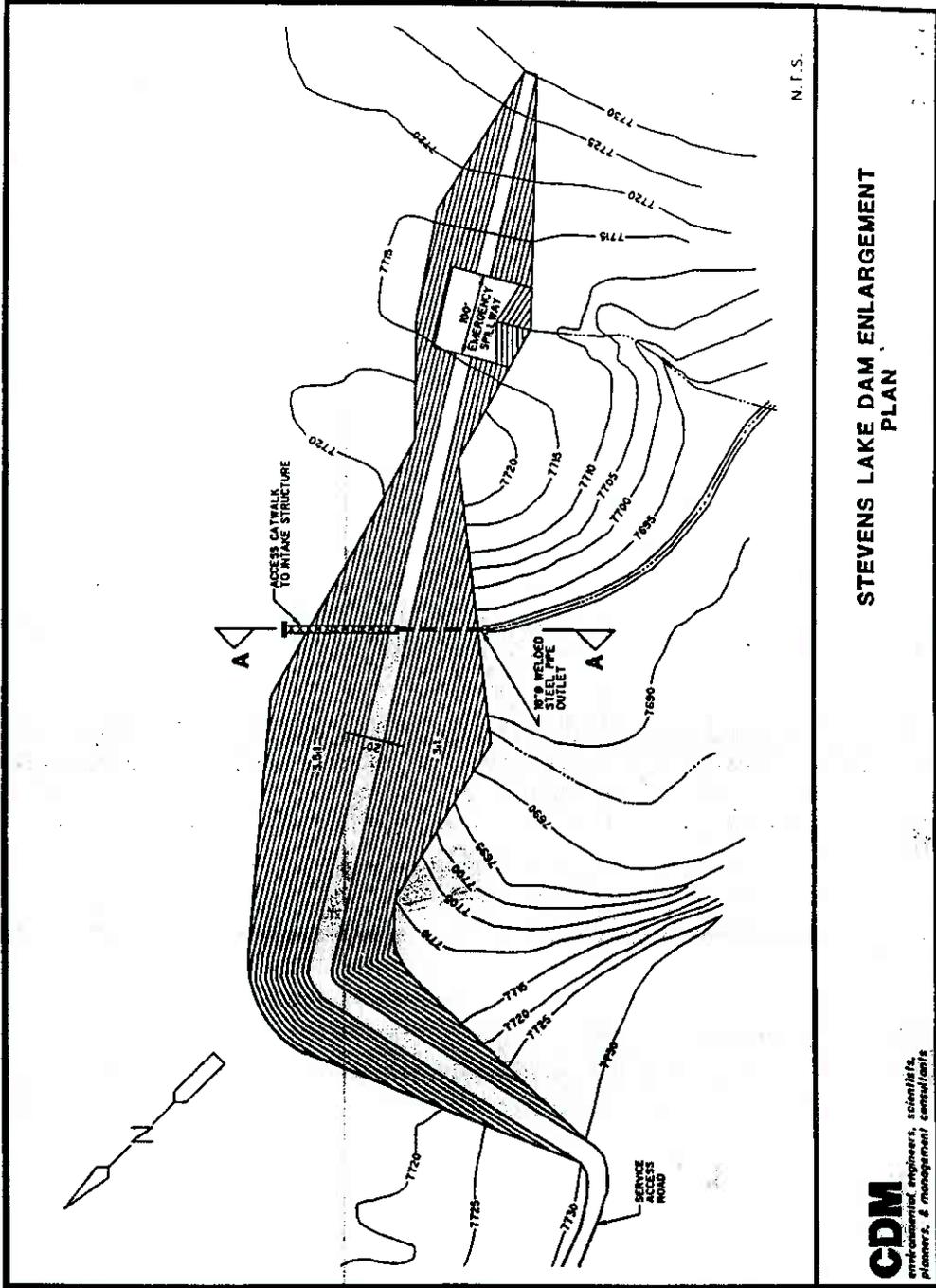
Figure 7-1
Plan View of Stevens Reservoir Enlargement
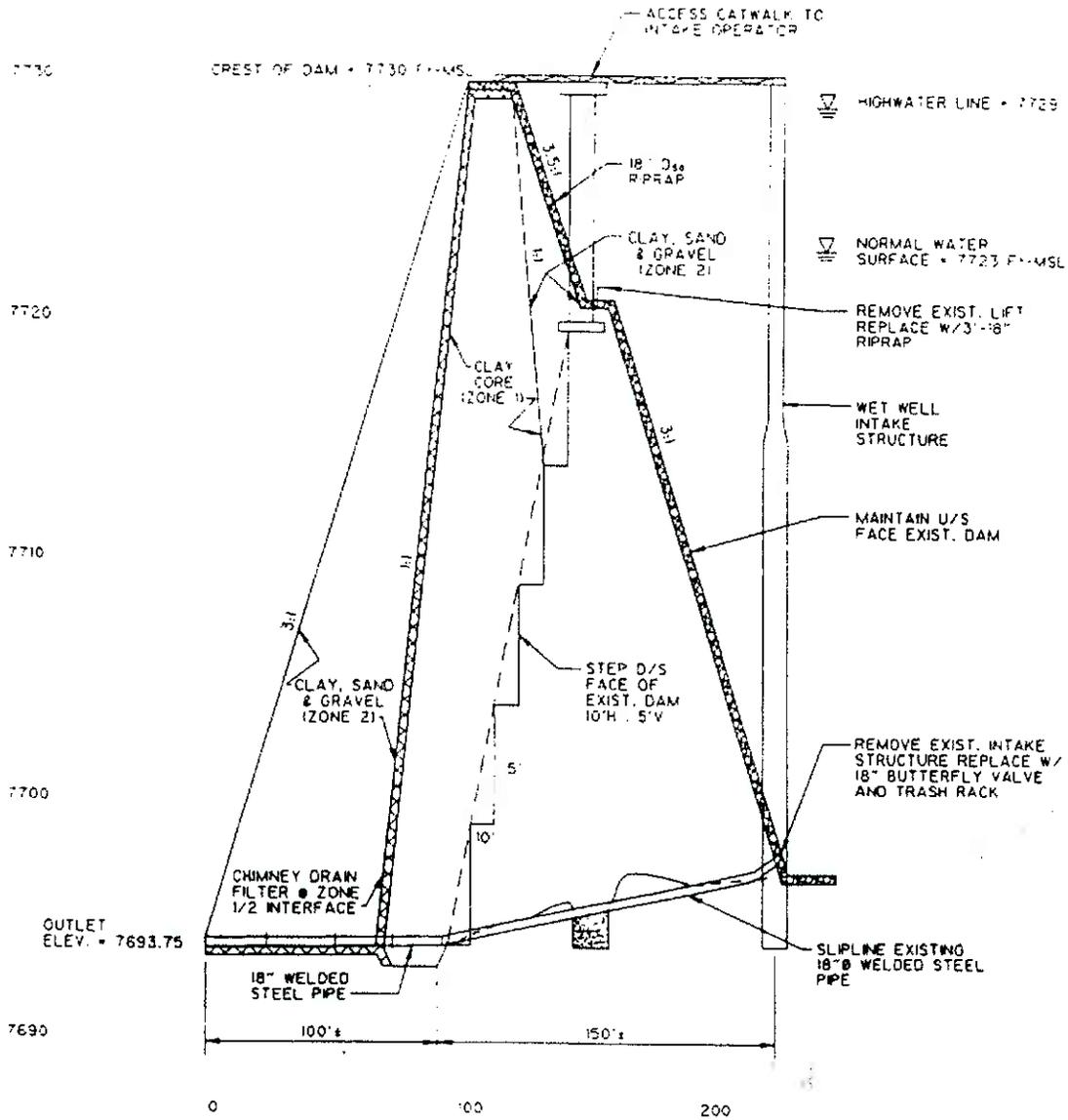
Figure 7-2
Cross Section of Stevens Reservoir Dam

APPENDIX A

ESTIMATES OF WATER YIELD

FOR

ALTERNATE WATER SUPPLY SOURCES

Hatcher Reservoir Operations
Decreed Capacity: 1729 ac-ft/yr
w/ Dutton Ditch, Steven's Res. expansion

Low Water Years, 1976, 1977, 1978
Minimum End of Month Live Storage: 850 ac-ft/yr

CASE 1

Irrigation Year (1)	Month (2)	Perkins Ditch ac-ft (3)	Hatcher Natural Inflow ac-ft (4)	Available Inflow ac-ft (5)	Storable Inflow ac-ft (6)	Cumulative Inflow Stored ac-ft (7)	Dutton Ditch Extension ac-ft (8)	Dutton Extension Available ac-ft (9)	Seepage Loss ac-ft (10)	Surface Area ac (11)	Evaporation Loss ac-ft (12)	Demand ac-ft (13)	Potential Gain/Loss ac-ft (14)	EndMonth Live Storage ac-ft (15)	Actual Gain/Loss ac-ft (16)	Net Spill/Deficit ac-ft (17)	Dutton Extension Remain ac-ft (18)	Natural Inflow Spill ac-ft (19)	Perkins Ditch Remain ac-ft (20)	Demand Deficit ac-ft (21)
entered	entered	min water rt	entered				entered 175 min													
1976	NOV	0	0	0	0	0	175	149	2	110	0	20	127	1145	127	0	0	0	0	0
	DEC	0	0	0	0	0	175	149	2	117	0	20	126	1271	126	0	0	0	0	0
	JAN	0	30	0	0	0	175	149	3	123	0	20	126	1397	126	0	0	0	0	0
	FEB	0	30	0	0	0	175	149	3	129	0	20	126	1523	126	0	0	0	0	0
	MAR	162	53	15	15	15	29	25	3	136	0	20	179	1701	179	0	0	0	0	0
	APR	755	247	209	209	15	475	404	4	147	10	20	1334	1729	28	1307	475	209	694	0
	MAY	1282	716	678	678	15	491	417	4	149	26	188	2159	1729	0	2159	491	678	1064	0
	JUN	0	0	0	0	15	0	0	4	149	43	188	-234	1495	-234	0	0	0	0	0
	JUL	0	0	0	0	15	0	0	3	135	20	188	-211	1284	-211	0	0	0	0	0
	AUG	0	0	0	0	15	0	0	3	124	6	188	-197	1087	-197	0	0	0	0	0
	SEP	0	0	0	0	15	0	0	3	114	6	188	-196	891	-196	0	0	0	0	0
	OCT	0	0	0	0	15	175	149	2	103	0	20	127	1018	127	0	0	0	0	0
	YR	2199	1076	902	902	15	1870	1590	34		111	1080	3466	1018	0	3466	966	887	1758	0
												(entry entered)								
1977	NOV	0	0	0	0	0	175	149	2	110	0	20	127	1145	127	0	0	0	0	0
	DEC	0	0	0	0	0	175	149	2	117	0	20	126	1271	126	0	0	0	0	0
	JAN	0	31	0	0	0	175	149	3	123	0	20	126	1397	126	0	0	0	0	0
	FEB	0	30	0	0	0	175	149	3	129	0	20	126	1523	126	0	0	0	0	0
	MAR	43	14	0	0	0	0	0	3	136	0	20	20	1543	20	0	0	0	0	0
	APR	208	68	30	30	11	0	0	3	137	9	20	205	1729	186	19	0	19	0	0
	MAY	162	53	15	15	26	0	0	4	149	26	188	-41	1688	-41	0	0	0	0	0
	JUN	0	0	0	0	26	0	0	4	147	42	188	-233	1455	-233	0	0	0	0	0
	JUL	0	0	0	0	26	0	0	3	132	19	188	-210	1245	-210	0	0	0	0	0
	AUG	0	0	0	0	26	0	0	3	122	6	188	-197	1048	-197	0	0	0	0	0
	SEP	0	0	0	0	26	0	0	2	112	6	188	-196	852	-196	0	0	0	0	0
	OCT	0	0	0	0	26	149	149	2	101	0	20	127	979	127	0	0	0	0	0
	YR	413	135	45	45	26	875	744	33		109	1080	-20	979	-39	19	0	19	0	0
												(entry entered)								
1978	NOV	0	0	0	0	0	267	227	2	108	0	20	205	1184	205	0	0	0	0	0
	DEC	0	0	0	0	0	266	226	2	119	0	20	204	1387	204	0	0	0	0	0
	JAN	0	31	0	0	0	202	172	3	129	0	20	149	1536	149	0	0	0	0	0
	FEB	0	30	0	0	0	214	182	3	137	0	20	159	1695	159	0	0	0	0	0
	MAR	165	54	16	16	0	67	57	4	147	0	20	215	1729	34	180	67	16	107	0
	APR	939	307	269	269	0	475	404	4	149	10	20	1577	1729	0	1577	475	269	905	0
	MAY	1282	571	533	533	0	491	417	4	149	26	188	2014	1729	0	2014	491	533	1064	0
	JUN	0	0	0	0	0	0	0	4	149	43	188	-234	1495	-234	0	0	0	0	0
	JUL	0	0	0	0	0	0	0	3	135	20	188	-211	1284	-211	0	0	0	0	0
	AUG	0	0	0	0	0	0	0	3	124	6	188	-197	1087	-197	0	0	0	0	0
	SEP	0	0	0	0	0	0	0	3	114	6	188	-196	891	-196	0	0	0	0	0
	OCT	0	0	0	0	0	175	149	2	103	0	20	127	1018	127	0	0	0	0	0
	YR	2386	993	818	818	0	2157	1833	35		111	1080	3811	1018	39	3772	1033	818	2076	0
												(entry entered)								

Steven's Lake Operations
Decreed Capacity: 1420 ac-ft/yr
w/ Dutton Ditch, Steven's Res. expansion

Low Water Years, 1976, 1977, 1978
Minimum End of Month Live Storage: 150 ac-ft

CASE 1

(1) Irrigation Year	(2) Month	(3) Steven's Natural Inflow ac-ft	(4) Available Inflow ac-ft	(5) Storable Inflow ac-ft	(6) Cumulative Inflow Stored ac-ft	(7) Dutton Ditch Extension	(8) Dutton Extension Available	(9) Seepage Loss	(10) Surface Area ac	(11) Evaporation Loss	(12) Demand	(13) Potential Gain/ Loss	(14) End of Mon Live Storage	(15) Actual Gain/ Loss	(16) Net Spill/ Deficit	(17) Dutton Extension Remain	(18) Natural Inflow Spill	(19) Demand Deficit
entered	entered	entered				from Hatcher												
1976	NOV	0	0	0	0	0	0	2	99	0	0	-2	829	-2	0	0	0	0
	DEC	0	0	0	0	0	0	2	99	0	0	-2	827	-2	0	0	0	0
	JAN	0	0	0	0	0	0	2	99	0	0	-2	826	-2	0	0	0	0
	FEB	0	0	0	0	0	0	2	99	0	0	-2	824	-2	0	0	0	0
	MAR	83	53	53	53	29	25	2	99	0	0	76	900	76	0	0	0	0
	APR	389	359	359	412	475	404	2	103	7	0	754	1420	520	234	275	0	0
	MAY	1125	1095	1008	621	491	417	3	131	23	183	1216	1420	0	1216	491	799	0
	JUN	919	889	799	844	0	0	3	131	37	183	576	1420	0	576	0	576	0
	JUL	0	0	0	844	0	0	3	131	19	183	-205	1215	-205	0	0	0	0
	AUG	0	0	0	844	0	0	3	120	6	183	-192	1023	-192	0	0	0	0
	SEP	0	0	0	844	0	0	2	110	6	183	-191	833	-191	0	0	0	0
	OCT	0	0	0	844	0	0	2	99	0	0	-2	831	-2	0	0	0	0
	YR	2516	2396	2219	844	995	846	26		98	915 (entry entered)	2026	831	0	2026	766	1375	0
1977	NOV	0	0	0	0	0	0	2	99	0	0	-2	829	-2	0	0	0	0
	DEC	0	0	0	0	0	0	2	99	0	0	-2	827	-2	0	0	0	0
	JAN	0	0	0	0	0	0	2	99	0	0	-2	826	-2	0	0	0	0
	FEB	0	0	0	0	0	0	2	99	0	0	-2	824	-2	0	0	0	0
	MAR	22	0	0	0	0	0	2	99	0	0	-2	822	-2	0	0	0	0
	APR	107	77	77	77	0	0	2	99	7	0	69	891	69	0	0	0	0
	MAY	83	53	53	130	0	0	2	103	18	183	-150	741	-150	0	0	0	0
	JUN	229	199	199	329	0	0	2	93	27	183	-12	729	-12	0	0	0	0
	JUL	0	0	0	329	0	0	2	92	13	183	-198	531	-198	0	0	0	0
	AUG	0	0	0	329	0	0	1	76	4	183	-188	343	-188	0	0	0	0
	SEP	0	0	0	329	0	0	1	57	3	183	-187	156	-187	0	0	0	0
	OCT	0	0	0	329	0	0	0	32	0	0	0	156	0	0	0	0	0
	YR	441	329	329	329	0	0	17		72	915 (entry entered)	-675	156	-675	0	0	0	0
1978	NOV	0	0	0	0	0	0	0	32	0	0	0	156	0	0	0	0	0
	DEC	0	0	0	0	0	0	0	32	0	0	0	155	0	0	0	0	0
	JAN	0	0	0	0	0	0	0	32	0	0	0	155	0	0	0	0	0
	FEB	0	0	0	0	0	0	0	32	0	0	0	155	0	0	0	0	0
	MAR	85	55	55	55	67	57	0	31	0	0	112	266	112	0	0	0	0
	APR	482	452	452	507	475	404	1	47	3	0	852	1118	852	0	0	0	0
	MAY	898	868	868	1014	491	417	2	115	20	183	1080	1420	302	778	491	361	0
	JUN	1175	1145	406	1237	0	0	3	131	37	183	183	1420	0	183	0	183	0
	JUL	0	0	0	1237	0	0	3	131	19	183	-205	1215	-205	0	0	0	0
	AUG	0	0	0	1237	0	0	3	120	6	183	-192	1023	-192	0	0	0	0
	SEP	0	0	0	1237	0	0	2	110	6	183	-191	833	-191	0	0	0	0
	OCT	0	0	0	1237	0	0	2	99	0	0	-2	831	-2	0	0	0	0
	YR	2640	2520	1781	1237	1033	878	16		92	915 (entry entered)	1636	831	675	961	491	543	0

A-3

Hatcher Reservoir Operations
Decreed Capacity: 1729 ac-ft/yr
Low Water Years, 1976, 1977, 1978
Minimum End of Month Live Storage: 850 ac-ft
w/ Dutton Ditch expansion, w/o Steven's Res expansion
CASE 2

Irrigation Year (1)	Month (2)	Perkins Ditch ac-ft (3)	Hatcher Natural Inflow ac-ft (4)	Available Inflow ac-ft (5)	Storable Inflow ac-ft (6)	Cumulative Inflow Stored ac-ft (7)	Dutton Ditch Extension ac-ft (8)	Dutton Extension Available ac-ft (9)	Seepage Loss ac-ft (10)	Surface Area ac (11)	Evaporation Loss ac-ft (12)	Demand ac-ft (13)	Potential Gain/Loss ac-ft (14)	EndMonth Live Storage ac-ft (15)	Actual Gain/Loss ac-ft (16)	Net Spill/Deficit ac-ft (17)	Dutton Extension Remain ac-ft (18)	Natural Inflow Spill ac-ft (19)	Perkins Ditch Remain ac-ft (20)	Demand Deficit ac-ft (21)
1976	NOV	0	0	0	0	0	175	149	3	135	0	20	126	1632	126	0	0	0	0	0
	DEC	0	0	0	0	0	175	149	3	143	0	20	125	1729	97	28	33	0	0	0
	JAN	0	30	0	0	0	175	149	4	149	0	20	125	1729	0	125	147	0	0	0
	FEB	0	30	0	0	0	175	149	4	149	0	20	125	1729	0	125	147	0	0	0
	MAR	162	53	15	15	0	29	25	4	149	0	20	178	1729	0	178	29	15	138	0
	APR	755	247	209	209	0	475	404	4	149	10	20	1334	1729	0	1334	475	209	721	0
	MAY	1282	716	678	678	0	491	417	4	149	26	188	2159	1729	0	2159	491	678	1064	0
	JUN	0	0	0	0	0	0	0	3	149	43	188	-234	1495	-234	0	0	0	0	0
	JUL	0	0	0	0	0	0	0	3	135	20	188	-211	1284	-211	0	0	0	0	0
	AUG	0	0	0	0	0	0	0	3	124	6	188	-197	1087	-197	0	0	0	0	0
	SEP	0	0	0	0	0	0	0	2	114	6	188	-196	891	-196	0	0	0	0	0
	OCT	0	0	0	0	0	175	149	2	103	0	20	127	1018	127	0	0	0	0	0
	YR	2199	1076	902	902	0	1870	1590	38		111	1080 (entry entered)	3462	1018	-488	3950	1322	902	1924	0
1977	NOV	0	0	0	0	0	175	149	2	110	0	20	127	1145	127	0	0	0	0	0
	DEC	0	0	0	0	0	175	149	2	117	0	20	126	1271	126	0	0	0	0	0
	JAN	0	8	0	0	0	175	149	3	123	0	20	126	1397	126	0	0	0	0	0
	FEB	0	8	0	0	0	175	149	3	129	0	20	126	1523	126	0	0	0	0	0
	MAR	43	14	0	0	11	0	0	3	136	0	20	20	1542	20	0	0	0	0	0
	APR	208	68	30	30	26	0	0	3	137	9	20	205	1729	187	19	0	19	0	0
	MAY	162	53	15	15	26	0	0	4	149	26	188	-41	1688	-41	0	0	0	0	0
	JUN	0	0	0	0	26	0	0	4	147	42	188	-233	1455	-233	0	0	0	0	0
	JUL	0	0	0	0	26	0	0	3	132	19	188	-210	1245	-210	0	0	0	0	0
	AUG	0	0	0	0	26	0	0	3	122	6	188	-197	1048	-197	0	0	0	0	0
	SEP	0	0	0	0	26	0	0	2	112	6	188	-196	852	-196	0	0	0	0	0
	OCT	0	0	0	0	26	175	149	2	101	0	20	127	979	127	0	0	0	0	0
	YR	413	151	45	45	26	875	744	33		109	1080 (entry entered)	-20	979	-39	19	0	19	0	0
1978	NOV	0	0	0	0	0	267	227	2	108	0	20	205	1184	205	0	0	0	0	0
	DEC	0	0	0	0	0	266	226	2	119	0	20	204	1387	204	0	0	0	0	0
	JAN	0	31	0	0	0	202	172	3	129	0	20	149	1536	149	0	0	0	0	0
	FEB	0	30	0	0	0	214	182	3	137	0	20	159	1695	159	0	0	0	0	0
	MAR	165	54	16	16	0	67	57	4	147	0	20	215	1729	34	180	67	16	107	0
	APR	939	307	269	269	0	475	404	4	149	10	20	1577	1729	0	1577	475	269	905	0
	MAY	1282	571	533	533	0	491	417	4	149	26	188	2014	1729	0	2014	491	533	1064	0
	JUN	0	0	0	0	0	0	0	4	149	43	188	-234	1495	-234	0	0	0	0	0
	JUL	0	0	0	0	0	0	0	3	135	20	188	-211	1284	-211	0	0	0	0	0
	AUG	0	0	0	0	0	0	0	3	124	6	188	-197	1087	-197	0	0	0	0	0
	SEP	0	0	0	0	0	0	0	2	114	6	188	-196	891	-196	0	0	0	0	0
	OCT	0	0	0	0	0	175	149	2	103	0	20	127	1018	127	0	0	0	0	0
	YR	2386	993	818	818	0	2157	1833	35		111	1080 (entry entered)	3811	1018	39	3772	1033	818	2076	0

A-4

Steven's Lake Operations

Decreed Capacity: 635 ac-ft/yr
w/ Dutton Ditch expansion, w/o Steven's Res expansion

CASE 2
Low Water Years, 1976, 1977, 1978
Minumum End of Month Live Storage: 150 ac-ft

Irrigation Year (1)	Month (2)	Steven's Natural Inflow ac-ft (3)	Available Inflow ac-ft (4)	Storable Inflow ac-ft (5)	Cumulative Inflow Stored ac-ft (6)	Dutton Ditch Extension (7)	Dutton Extension Available (8)	Seepage Loss (9)	Surface Area ac (10)	Evaporation Loss (11)	Demand (12)	Potential Gain/Loss (13)	End of Mon Live Storage (14)	Actual Gain/Loss (15)	Net Spill/Deficit (16)	Dutton Extension Remain (17)	Natural Inflow Spill (18)	Demand Deficit (19)
entered	entered	entered				from Hatcher												
1976	NOV	0	0	0	0	0	0	1	56	0	0	-1	335	-1	0	0	0	0
	DEC	0	0	0	0	145	123	1	56	0	0	122	457	122	0	0	0	0
	JAN	0	0	0	0	147	125	1	69	0	0	124	581	124	0	0	0	0
	FEB	0	0	0	0	147	125	1	81	0	0	124	635	54	70	83	0	0
	MAR	83	53	53	1	29	25	1	85	6	0	76	635	0	76	29	52	0
	APR	389	359	359	8	475	404	1	85	15	0	756	635	0	756	475	352	0
	MAY	1125	1095	627	117	491	417	1	85	24	92	936	635	0	936	491	518	0
	JUN	919	889	518	234	0	0	1	85	12	92	401	635	0	401	0	401	0
	JUL	0	0	0	234	0	0	1	85	12	92	-106	529	-106	0	0	0	0
	AUG	0	0	0	234	0	0	1	76	4	92	-97	432	-97	0	0	0	0
	SEP	0	0	0	234	0	0	1	67	3	92	-96	336	-96	0	0	0	0
	OCT	0	0	0	234	0	0	1	56	0	0	-1	335	-1	0	0	0	0
	YR	2516	2396	1557	234	1434	1219	13		65	460 (entry entered)	2238	335	0	2238	1078	1322	0
1977	NOV	0	0	0	0	0	0	1	56	0	0	-1	335	-1	0	0	0	0
	DEC	0	0	0	0	0	0	1	56	0	0	-1	334	-1	0	0	0	0
	JAN	0	0	0	0	0	0	1	56	0	0	-1	333	-1	0	0	0	0
	FEB	0	0	0	0	0	0	1	56	0	0	-1	332	-1	0	0	0	0
	MAR	22	0	0	0	0	0	1	55	0	0	-1	332	-1	0	0	0	0
	APR	107	77	77	77	0	0	1	55	4	0	73	404	73	0	0	0	0
	MAY	83	53	53	130	0	0	1	64	11	92	-51	353	-51	0	0	0	0
	JUN	229	199	199	329	0	0	1	58	16	92	90	443	90	0	0	0	0
	JUL	0	0	0	329	0	0	1	68	10	92	-103	340	-103	0	0	0	0
	AUG	0	0	0	329	0	0	1	56	3	92	-96	245	-96	0	0	0	0
	SEP	0	0	0	329	0	0	1	44	2	92	-95	150	-95	0	0	0	0
	OCT	0	0	0	329	0	0	0	31	0	0	0	150	0	0	0	0	0
	YR	441	329	329	329	0	0	8		46	460 (entry entered)	-186	150	-186	0	0	0	0
1978	NOV	0	0	0	0	0	0	0	31	0	0	0	150	0	0	0	0	0
	DEC	0	0	0	0	0	0	0	31	0	0	0	149	0	0	0	0	0
	JAN	0	0	0	0	41	35	0	31	0	0	34	184	34	0	0	0	0
	FEB	0	0	0	0	186	158	0	36	0	0	158	342	158	0	0	0	0
	MAR	85	55	55	55	67	57	1	57	5	0	111	453	111	0	0	0	0
	APR	482	452	452	243	475	404	1	69	15	0	850	635	182	668	475	264	0
	MAY	898	868	392	351	491	417	1	85	24	92	701	635	0	701	491	284	0
	JUN	1175	1145	284	469	0	0	1	85	12	92	166	635	0	166	0	166	0
	JUL	0	0	0	469	0	0	1	85	12	92	-106	529	-106	0	0	0	0
	AUG	0	0	0	469	0	0	1	76	4	92	-97	432	-97	0	0	0	0
	SEP	0	0	0	469	0	0	1	67	3	92	-96	336	-96	0	0	0	0
	OCT	0	0	0	469	0	0	1	56	0	0	-1	335	-1	0	0	0	0
	YR	2640	2520	1183	469	1260	1071	9		64	460 (entry entered)	1721	335	186	1536	966	714	0

Hatcher Reservoir Operations
Decreed Capacity: 1729 ac-ft/yr
w/o Dutton Ditch expansion, w/ Steven's Res. Exp.
CASE 3

Low Water Years, 1976, 1977, 1978
Minimum End of Month Live Storage: 850 ac-ft
No Dutton Ditch Extension taken during months of Apr. through Sept.

Irrigation Year	Month	Perkins Ditch ac-ft	Hatcher Natural Inflow ac-ft	Available Inflow ac-ft	Storable Inflow ac-ft	Cumulative Inflow Stored ac-ft	Dutton Ditch Extension ac-ft	Dutton Extension Available ac-ft	Seepage Loss ac-ft	Surface Area ac	Evaporation Loss ac-ft	Demand ac-ft	Potential Gain/ Loss ac-ft	EndMonth Live Storage ac-ft	Actual Gain/ Loss ac-ft	Net Spill/ Deficit ac-ft	Dutton Extension Remain ac-ft	Natural Inflow Spill ac-ft	Perkins Ditch Remain ac-ft	Demand Deficit ac-ft
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
entered	entered	entered	entered				entered, 175 min													
1976	NOV	0	0	0	0	0	175	149	3	130	0	20	126	1532	126	0	0	0	0	0
	DEC	0	0	0	0	0	0	0	3	137	0	20	-23	1508	-23	0	0	0	0	0
	JAN	0	30	0	0	0	0	0	3	135	0	20	-23	1485	-23	0	0	0	0	0
	FEB	0	30	0	0	0	0	0	3	134	0	20	-23	1462	-23	0	0	0	0	0
	MAR	162	53	15	15	15	29	25	3	133	0	20	179	1641	179	0	0	0	0	0
	APR	755	247	209	209	15	0	0	3	143	10	20	931	1729	88	843	0	209	634	0
	MAY	1282	716	678	678	15	0	0	4	149	26	90	1840	1729	0	1840	0	678	1162	0
	JUN	0	0	0	0	15	0	0	4	149	43	90	-136	1593	-136	0	0	0	0	0
	JUL	0	0	0	0	15	0	0	3	140	20	90	-114	1479	-114	0	0	0	0	0
	AUG	0	0	0	0	15	0	0	3	134	7	90	-100	1379	-100	0	0	0	0	0
	SEP	0	0	0	0	15	0	0	3	128	7	90	-100	1280	-100	0	0	0	0	0
	OCT	0	0	0	0	15	175	149	3	123	0	20	126	1406	126	0	0	0	0	0
	YR	2199	1076	902	902	15	379	322	38		113	590 (entry entered)	2683	1406	0	2683	0	887	1796	0
1977	NOV	0	0	0	0	0	175	149	3	130	0	20	126	1532	126	0	0	0	0	0
	DEC	0	0	0	0	0	0	0	3	137	0	20	-23	1508	-23	0	0	0	0	0
	JAN	0	0	0	0	0	0	0	3	135	0	20	-23	1485	-23	0	0	0	0	0
	FEB	0	0	0	0	0	0	0	3	134	0	20	-23	1462	-23	0	0	0	0	0
	MAR	0	0	0	0	0	0	0	3	133	0	20	-23	1439	-23	0	0	0	0	0
	APR	0	0	0	0	0	0	0	3	132	9	20	-32	1407	-32	0	0	0	0	0
	MAY	0	0	0	0	0	0	0	3	130	23	90	-116	1291	-116	0	0	0	0	0
	JUN	0	0	0	0	0	0	0	3	124	35	90	-128	1163	-128	0	0	0	0	0
	JUL	0	0	0	0	0	0	0	2	118	17	90	-109	1054	-109	0	0	0	0	0
	AUG	0	0	0	0	0	0	0	2	112	6	90	-98	956	-98	0	0	0	0	0
	SEP	0	0	0	0	0	0	0	2	107	6	90	-98	858	-98	0	0	0	0	0
	OCT	0	0	0	0	0	175	149	2	101	0	20	127	985	127	0	0	0	0	0
	YR	0	0	0	0	0	350	298	32		95	590 (entry entered)	-420	985	-420	0	0	0	0	0
1978	NOV	0	0	0	0	0	267	227	2	108	0	20	205	1190	205	0	0	0	0	0
	DEC	0	0	0	0	0	0	0	2	119	0	20	-22	1168	-22	0	0	0	0	0
	JAN	0	31	0	0	0	0	0	2	118	0	20	-22	1145	-22	0	0	0	0	0
	FEB	0	30	0	0	0	0	0	2	117	0	20	-22	1123	-22	0	0	0	0	0
	MAR	165	54	16	16	16	67	57	3	116	0	20	216	1339	216	0	0	0	0	0
	APR	939	307	269	269	16	0	0	3	126	9	20	1176	1729	390	786	0	269	517	0
	MAY	1282	571	533	533	16	0	0	4	149	26	90	1695	1729	0	1695	0	533	1162	0
	JUN	0	0	0	0	16	0	0	4	149	43	90	-136	1593	-136	0	0	0	0	0
	JUL	0	0	0	0	16	0	0	3	140	20	90	-114	1479	-114	0	0	0	0	0
	AUG	0	0	0	0	16	0	0	3	134	7	90	-100	1379	-100	0	0	0	0	0
	SEP	0	0	0	0	16	0	0	3	128	7	90	-100	1280	-100	0	0	0	0	0
	OCT	0	0	0	0	16	175	149	3	123	0	20	126	1406	126	0	0	0	0	0
	YR	2386	993	818	818	16	509	433	34		111	590 (entry entered)	2901	1406	420	2481	0	802	1679	0

Steven's Lake Operations
Decreed Capacity: 1420 ac-ft/yr
w/o Dutton Ditch expansion, w/ Steven's Res. Exp.

CASE 3

Low Water Years, 1976, 1977, 1978
Minimum End of Month Live Storage: 150 ac-ft
No Dutton Ditch Extension taken during months of Apr. through Sept. (irrigation) or Dec. through Feb. (ice)

(1) Irrigation Year	(2) Month	(3) Steven's Natural Inflow ac-ft	(4) Available Inflow ac-ft	(5) Storable Inflow ac-ft	(6) Cumulative Inflow Stored ac-ft	(7) Dutton Ditch Extension (from Hatcher)	(8) Dutton Extension Available	(9) Seepage Loss	(10) Surface Area ac	(11) Evaporation Loss	(12) Demand	(13) Potential Gain/Loss	(14) End of Mo Live Storage	(15) Actual Gain/Loss	(16) Net Spill/Deficit	(17) Dutton Extension Remain	(18) Natural Inflow Spill	(19) Demand Deficit
(entered)	(entered)	(entered)																
1976	NOV	0	0	0	0	0	0	2	99	0	0	-2	829	-2	0	0	0	0
	DEC	0	0	0	0	0	0	2	99	0	0	-2	827	-2	0	0	0	0
	JAN	0	0	0	0	0	0	2	99	0	0	-2	826	-2	0	0	0	0
	FEB	0	0	0	0	0	0	2	99	0	0	-2	824	-2	0	0	0	0
	MAR	83	53	53	53	0	0	2	99	0	0	51	875	51	0	0	0	0
	APR	389	359	359	412	0	0	2	102	7	0	350	1225	350	0	0	0	0
	MAY	1125	1095	1008	813	0	0	3	121	21	183	801	1420	195	607	0	607	0
	JUN	919	889	607	1037	0	0	3	131	37	183	383	1420	0	383	0	383	0
	JUL	0	0	0	1037	0	0	3	131	19	183	-205	1215	-205	0	0	0	0
	AUG	0	0	0	1037	0	0	3	120	6	183	-192	1023	-192	0	0	0	0
	SEP	0	0	0	1037	0	0	2	110	6	183	-191	833	-191	0	0	0	0
	OCT	0	0	0	1037	0	0	2	99	0	0	-2	831	-2	0	0	0	0
	YR	2516	2396	2027	1037	0	0	25		96	915 (entry entered)	990	831	0	990	0	990	0
1977	NOV	0	0	0	0	0	0	2	99	0	0	-2	829	-2	0	0	0	0
	DEC	0	0	0	0	0	0	2	99	0	0	-2	827	-2	0	0	0	0
	JAN	0	0	0	0	0	0	2	99	0	0	-2	826	-2	0	0	0	0
	FEB	0	0	0	0	0	0	2	99	0	0	-2	824	-2	0	0	0	0
	MAR	22	0	0	0	0	0	2	99	0	0	-2	822	-2	0	0	0	0
	APR	107	77	77	77	0	0	2	99	7	0	69	891	69	0	0	0	0
	MAY	83	53	53	130	0	0	2	103	18	183	-150	741	-150	0	0	0	0
	JUN	229	199	199	329	0	0	2	93	27	183	-12	729	-12	0	0	0	0
	JUL	0	0	0	329	0	0	2	92	13	183	-198	531	-198	0	0	0	0
	AUG	0	0	0	329	0	0	1	76	4	183	-188	343	-188	0	0	0	0
	SEP	0	0	0	329	0	0	1	57	3	183	-187	156	-187	0	0	0	0
	OCT	0	0	0	329	0	0	0	32	0	0	0	156	0	0	0	0	0
	YR	441	329	329	329	0	0	17		72	915 (entry entered)	-675	156	-675	0	0	0	0
1978	NOV	0	0	0	0	0	0	0	32	0	0	0	156	0	0	0	0	0
	DEC	0	0	0	0	0	0	0	32	0	0	0	155	0	0	0	0	0
	JAN	0	0	0	0	0	0	0	32	0	0	0	155	0	0	0	0	0
	FEB	48	18	18	18	0	0	0	32	0	0	18	173	18	0	0	0	0
	MAR	85	55	55	73	0	0	0	34	0	0	55	227	55	0	0	0	0
	APR	482	452	452	525	0	0	0	42	3	0	449	676	449	0	0	0	0
	MAY	898	868	868	1393	0	0	1	88	16	183	668	1344	668	0	0	0	0
	JUN	1175	1145	27	1420	0	0	3	127	36	183	-195	1149	-195	0	0	0	0
	JUL	0	0	0	1420	0	0	2	117	17	183	-202	947	-202	0	0	0	0
	AUG	0	0	0	1420	0	0	2	106	5	183	-190	756	-190	0	0	0	0
	SEP	0	0	0	1420	0	0	2	94	5	183	-189	567	-189	0	0	0	0
	OCT	0	0	0	1420	0	0	1	80	0	0	-1	566	-1	0	0	0	0
	YR	2688	2538	1420	1420	0	0	13		82	915 (entry entered)	410	566	410	0	0	0	0

A-7

Hatcher Reservoir Operations
Decreed Capacity: 1729 ac-ft/yr
w/o Dutton Ditch, Steven's Res expansion
CASE 4

Low Water Years, 1976, 1977, 1978
Minimum End of Month Live Storage: 850 ac-ft
No Dutton Ditch Extension taken during months of Apr. through Sept. (irrigation) or Dec. through Feb. (ice)

Irrigation Year	Month	Perkins Ditch ac-ft	Hatcher Natural Inflow ac-ft	Available Inflow ac-ft	Storable Inflow ac-ft	Cumulative Inflow Stored ac-ft	Dutton Ditch Extension ac-ft	Dutton Extension Available ac-ft	Seepage Loss ac-ft	Surface Area ac	vaporation Loss ac-ft	Demand ac-ft	Potential Gain/ Loss ac-ft	EndMonth Live Storage ac-ft	Actual Gain/ Loss ac-ft	Net Spill/ Deficit ac-ft	Dutton Extension Remain ac-ft	Natural Inflow Spill ac-ft	Perkins Ditch Remain ac-ft	Demand Deficit ac-ft
(1) entered	(2) entered	(3) entered	(4) entered	(5)	(6)	(7)	(8) entered, 175 min	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
1976	NOV	0	0	0	0	0	175	149	3	130	0	20	126	1532	126	0	0	0	0	0
	DEC	0	0	0	0	0	0	0	3	137	0	20	-23	1508	-23	0	0	0	0	0
	JAN	30	30	0	0	0	0	0	3	135	0	20	-23	1485	-23	0	0	0	0	0
	FEB	0	30	0	0	0	0	0	3	134	0	20	-23	1462	-23	0	0	0	0	0
	MAR	162	53	15	15	15	29	25	3	133	0	20	179	1641	179	0	0	0	0	0
	APR	755	247	209	209	15	0	0	3	143	10	20	931	1729	88	843	0	209	634	0
	MAY	1282	716	678	678	15	0	0	4	149	26	90	1840	1729	0	1840	0	678	1162	0
	JUN	0	0	0	0	15	0	0	4	149	43	90	-136	1593	-136	0	0	0	0	0
	JUL	0	0	0	0	15	0	0	3	140	20	90	-114	1479	-114	0	0	0	0	0
	AUG	0	0	0	0	15	0	0	3	134	7	90	-100	1379	-100	0	0	0	0	0
	SEP	0	0	0	0	15	0	0	3	128	7	90	-100	1280	-100	0	0	0	0	0
	OCT	0	0	0	0	15	175	149	3	123	0	20	126	1406	126	0	0	0	0	0
	YR	2199	1076	902	902	15	379	322	38		113	590 (entry entered)	2683	1406	0	2683	0	887	1796	0
1977	NOV	0	0	0	0	0	175	149	3	130	0	20	126	1532	126	0	0	0	0	0
	DEC	0	0	0	0	0	0	0	3	137	0	20	-23	1508	-23	0	0	0	0	0
	JAN	0	0	0	0	0	0	0	3	135	0	20	-23	1485	-23	0	0	0	0	0
	FEB	0	0	0	0	0	0	0	3	134	0	20	-23	1462	-23	0	0	0	0	0
	MAR	0	0	0	0	0	0	0	3	133	0	20	-23	1439	-23	0	0	0	0	0
	APR	0	0	0	0	0	0	0	3	132	9	20	-32	1407	-32	0	0	0	0	0
	MAY	0	0	0	0	0	0	0	3	130	23	90	-116	1291	-116	0	0	0	0	0
	JUN	0	0	0	0	0	0	0	3	124	35	90	-128	1163	-128	0	0	0	0	0
	JUL	0	0	0	0	0	0	0	2	118	17	90	-109	1054	-109	0	0	0	0	0
	AUG	0	0	0	0	0	0	0	2	112	6	90	-98	956	-98	0	0	0	0	0
	SEP	0	0	0	0	0	0	0	2	107	6	90	-98	858	-98	0	0	0	0	0
	OCT	0	0	0	0	0	175	149	2	101	0	20	127	985	127	0	0	0	0	0
	YR	0	0	0	0	0	350	298	32		95	590 (entry entered)	-420	985	-420	0	0	0	0	0
1978	NOV	0	0	0	0	0	267	227	2	108	0	20	205	1190	205	0	0	0	0	0
	DEC	0	0	0	0	0	0	0	2	119	0	20	-22	1168	-22	0	0	0	0	0
	JAN	0	31	0	0	0	0	0	2	118	0	20	-22	1145	-22	0	0	0	0	0
	FEB	0	30	0	0	0	0	0	2	117	0	20	-22	1123	-22	0	0	0	0	0
	MAR	165	54	16	16	16	67	57	3	116	0	20	216	1339	216	0	0	0	0	0
	APR	939	307	269	269	16	0	0	4	126	9	20	1176	1729	390	786	0	269	517	0
	MAY	1282	571	533	533	16	0	0	4	149	26	90	1695	1729	0	1695	0	533	1162	0
	JUN	0	0	0	0	16	0	0	4	149	43	90	-136	1593	-136	0	0	0	0	0
	JUL	0	0	0	0	16	0	0	3	140	20	90	-114	1479	-114	0	0	0	0	0
	AUG	0	0	0	0	16	0	0	3	134	7	90	-100	1379	-100	0	0	0	0	0
	SEP	0	0	0	0	16	0	0	3	128	7	90	-100	1280	-100	0	0	0	0	0
	OCT	0	0	0	0	16	175	149	3	123	0	20	126	1406	126	0	0	0	0	0
	YR	2386	993	818	818	16	509	433	34		111	590 (entry entered)	2901	1406	420	2481	0	802	1679	0

Steven's Lake Operations
Decreed Capacity: 635 ac-ft/yr
w/o Dutton Ditch, Steven's Res expansion

Low Water Years, 1976, 1977, 1978
Minimum End of Month Live Storage: 150 ac-ft/yr
No Dutton Ditch Extension taken during months of Apr. through Sept. (irrigation) or Dec. through Feb. (ice)

CASE 4

Irrigation Year	Month	Steven's Natural Inflow ac-ft	Available Inflow ac-ft	Storable Inflow ac-ft	Cumulative Inflow Stored ac-ft	Dutton Ditch Extension	Dutton Extension Available	Seepage Loss	Surface Area ac	Evaporation Loss	Demand	Potential Gain/Loss	End of Mo Live Storage	Actual Gain/Loss	Net Spill/Deficit	Dutton Extension Remain	Natural Inflow Spill	Demand Deficit
(1) entered	(2) entered	(3) entered	(4)	(5)	(6)	(7) from Hatcher	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
1976	NOV	0	0	0	0	0	0	1	56	0	0	-1	335	-1	0	0	0	0
	DEC	0	0	0	0	0	0	1	56	0	0	-1	334	-1	0	0	0	0
	JAN	0	0	0	0	0	0	1	56	0	0	-1	333	-1	0	0	0	0
	FEB	0	0	0	0	0	0	1	56	0	0	-1	332	-1	0	0	0	0
	MAR	83	53	53	53	0	0	1	55	0	0	52	385	52	0	0	0	0
	APR	389	359	359	308	0	0	1	61	4	0	354	635	250	104	0	104	0
	MAY	1125	1095	327	417	0	0	1	85	15	92	218	635	0	218	0	218	0
	JUN	919	889	218	534	0	0	1	85	24	92	101	635	0	101	0	101	0
	JUL	0	0	0	534	0	0	1	85	12	92	-106	529	-106	0	0	0	0
	AUG	0	0	0	534	0	0	1	76	4	92	-97	432	-97	0	0	0	0
	SEP	0	0	0	534	0	0	1	67	3	92	-96	336	-96	0	0	0	0
	OCT	0	0	0	534	0	0	1	56	0	0	-1	335	-1	0	0	0	0
	YR	2516	2396	957	534	0	0	11		63	460 (entry entered)	423	335	0	423	0	423	0
1977	NOV	0	0	0	0	0	0	1	56	0	0	-1	335	-1	0	0	0	0
	DEC	0	0	0	0	0	0	1	56	0	0	-1	334	-1	0	0	0	0
	JAN	0	0	0	0	0	0	1	56	0	0	-1	333	-1	0	0	0	0
	FEB	0	0	0	0	0	0	1	56	0	0	-1	332	-1	0	0	0	0
	MAR	22	77	77	77	0	0	1	55	4	0	73	404	73	0	0	0	0
	APR	107	53	53	130	0	0	1	64	11	92	-51	353	-51	0	0	0	0
	MAY	83	199	199	329	0	0	1	58	16	92	90	443	90	0	0	0	0
	JUN	229	0	0	329	0	0	1	68	10	92	-103	340	-103	0	0	0	0
	JUL	0	0	0	329	0	0	1	56	3	92	-96	245	-96	0	0	0	0
	AUG	0	0	0	329	0	0	1	44	2	92	-95	150	-95	0	0	0	0
	SEP	0	0	0	329	0	0	0	31	0	0	0	150	0	0	0	0	0
	OCT	0	0	0	329	0	0	0	31	0	0	0	150	0	0	0	0	0
	YR	441	329	329	329	0	0	8		46	460 (entry entered)	-186	150	-186	0	0	0	0
1978	NOV	0	0	0	0	0	0	0	31	0	0	0	150	0	0	0	0	0
	DEC	0	0	0	0	0	0	0	31	0	0	0	149	0	0	0	0	0
	JAN	0	0	0	0	0	0	0	31	0	0	0	149	0	0	0	0	0
	FEB	0	0	0	0	0	0	0	31	0	0	0	149	0	0	0	0	0
	MAR	85	55	55	55	0	0	0	39	3	0	55	203	55	0	0	0	0
	APR	482	452	452	490	0	0	1	85	15	0	449	635	432	17	0	17	0
	MAY	898	868	145	598	0	0	1	85	24	92	37	635	0	37	0	37	0
	JUN	1175	1145	37	635	0	0	1	78	11	92	-81	554	-81	0	0	0	0
	JUL	0	0	0	635	0	0	1	68	4	92	-105	450	-105	0	0	0	0
	AUG	0	0	0	635	0	0	1	58	3	92	-96	353	-96	0	0	0	0
	SEP	0	0	0	635	0	0	1	58	3	92	-96	258	-96	0	0	0	0
	OCT	0	0	0	635	0	0	1	46	0	0	-1	257	-1	0	0	0	0
	YR	2640	2520	689	635	0	0	8		60	460 (entry entered)	162	257	107	54	0	54	0

Hatcher/Martinez Reservoir Operations
Decreed Capacity: 2489 ac-ft/yr   1729   760 Low Water Years, 1976, 1977, 1978
w/ Dutton Ditch expansion
CASE 5   Minimum End of Month Live Storage, total: 1000 ac-ft/yr

Irrigation Year (1) entered	Month (2) entered	Perkins Ditch ac-ft (3) entered	Hatcher Natural Inflow ac-ft (4) entered	Martinez Natural Inflow ac-ft (4*) entered	Available Inflow ac-ft (5)	Storable Inflow ac-ft (6)	Cumulative Inflow Stored ac-ft (7)	Dutton Ditch Extension ac-ft (8) entered, 175 min	Dutton Extension Available ac-ft (9)	Hatcher Seepage Loss ac-ft (10)	Martinez Seepage Loss ac-ft (10*)	Hatcher Surface Area ac (11)	Martinez Surface Area ac (11*)	Hatcher Evaporation Loss ac-ft (12)	Martinez Evaporation Loss ac-ft (12*)	Demand ac-ft (13)	Potential Gain/Loss ac-ft (14)	EndMonth Live Storage ac-ft (15)	Actual Gain/Loss ac-ft (16)	Net Spill/Deficit ac-ft (17)	Dutton Extension Remain ac-ft (18)	Natural Inflow Spill ac-ft (19)	Perkins Ditch Remain ac-ft (20)	Demand Deficit ac-ft (21)
1976	NOV	0	0	0	0	0	0	175	149	2	1	96	21	0	0	20	125	1686	125	0	0	0	0	0
	DEC	0	0	0	0	0	0	175	149	2	1	102	22	0	0	20	125	1811	125	0	0	0	0	0
	JAN	0	30	92	84	84	84	175	149	3	1	108	23	0	0	20	209	2020	209	0	0	0	0	0
	FEB	0	30	92	84	84	187	175	149	3	1	121	25	0	0	20	208	2228	208	0	0	0	0	0
	MAR	0	53	162	177	177	344	29	25	3	2	139	26	11	2	20	177	2405	177	0	0	0	0	0
	APR	0	247	755	964	964	486	475	404	4	2	158	27	30	5	20	1330	2489	84	1246	475	843	0	0
	MAY	0	716	2189	2887	2023	742	491	417	4	2	169	28	48	8	236	2165	2489	0	2165	491	1747	0	0
	JUN	0	0	0	0	0	742	0	0	3	1	169	28	20	4	236	-297	2192	-297	0	0	0	0	0
	JUL	0	0	0	0	0	742	0	0	3	1	138	26	8	1	236	-284	1928	-284	0	0	0	0	0
	AUG	0	0	0	0	0	742	0	0	2	1	115	24	5	1	236	-247	1681	-247	0	0	0	0	0
	SEP	0	0	0	0	0	742	0	0	2	1	101	22	0	0	236	-246	1435	-246	0	0	0	0	0
	OCT	0	0	0	0	0	742	175	149	2	1	91	20	0	0	20	128	1560	125	0	0	0	0	0
	YR	0	1076		4175	3332	742	1870	1500	35				119		1320 (entry entered)	3411	1560	0	3411	966	2590	0	0
1977	NOV	0	0	0	0	0	0	175	149	2	1	96	21	0	0	20	125	1686	125	0	0	0	0	0
	DEC	0	0	0	0	0	0	175	149	2	1	102	22	0	0	20	125	1811	125	0	0	0	0	0
	JAN	0	0	24	0	0	0	175	149	3	1	108	23	0	0	20	125	1936	125	0	0	0	0	0
	FEB	0	0	24	5	0	0	175	149	3	1	116	24	0	0	20	125	2061	125	0	0	0	0	0
	MAR	0	0	43	5	5	5	0	0	3	1	125	25	0	0	20	-19	2042	-19	0	0	0	0	0
	APR	0	0	208	170	170	175	0	0	3	1	123	25	8	2	20	136	2177	138	0	0	0	0	0
	MAY	0	0	182	124	124	299	0	0	3	1	134	28	24	5	236	-145	2033	-145	0	0	0	0	0
	JUN	0	0	0	0	0	299	0	0	3	1	122	25	35	7	236	-282	1750	-282	0	0	0	0	0
	JUL	0	0	0	0	0	299	0	0	2	1	105	23	15	3	236	-258	1492	-258	0	0	0	0	0
	AUG	0	0	0	0	0	299	0	0	2	1	93	21	5	1	236	-245	1247	-245	0	0	0	0	0
	SEP	0	0	0	0	0	299	0	0	2	1	85	19	4	1	236	-244	1003	-244	0	0	0	0	0
	OCT	0	0	0	0	0	299	175	149	1	1	76	18	0	0	20	127	1130	127	0	0	0	0	0
	YR	0	0		299	299	299	875	744	30				91		1320 (entry entered)	-430	1130	-430	0	0	0	0	0
1978	NOV	0	0	0	0	0	0	267	227	2	1	80	17	0	0	20	205	1335	205	0	0	0	0	0
	DEC	0	0	0	0	0	0	266	226	2	1	88	19	0	0	20	203	1538	203	0	0	0	0	0
	JAN	0	31	95	88	88	88	202	172	2	1	95	21	0	0	20	236	1774	236	0	0	0	0	0
	FEB	0	30	92	84	84	171	214	182	3	1	108	23	0	0	20	242	2016	242	0	0	0	0	0
	MAR	0	54	185	181	181	353	67	57	3	1	121	25	0	0	20	214	2230	214	0	0	0	0	0
	APR	0	307	839	1208	1208	848	475	404	4	2	139	26	10	2	20	1575	2489	259	1316	475	913	0	0
	MAY	0	571	1746	2279	1841	923	491	417	4	2	169	28	30	5	236	1983	2489	0	1983	491	1566	0	0
	JUN	0	0	0	0	0	923	48	41	4	2	169	28	48	8	236	107	2489	0	107	125	0	0	0
	JUL	0	0	0	0	0	923	0	0	4	2	142	26	24	4	236	-229	2260	-229	0	0	0	0	0
	AUG	0	0	0	0	0	923	0	0	3	1	121	25	7	1	236	-240	2011	-249	0	0	0	0	0
	SEP	0	0	0	0	0	923	175	149	3	1	121	25	6	1	236	-99	1912	-99	0	0	0	0	0
	OCT	0	0	0	0	0	923	175	149	3	1	114	24	0	0	20	125	2037	125	0	0	0	0	0
	YR	0	993		3839	3402	923	2855	2427	34				125		1320 (entry entered)	4312	2037	907	3406	1091	2478	0	0

A-10

Hatcher/Martinez Reservoir Operations
Decreed Capacity: 2489 ac-ft/yr
w/o Dutton Ditch expansion
CASE 6

760 Low Water Years, 1976, 1977, 1978
Minimum End of Month Live Storage, total: 1000 ac-ft/yr
No Dutton Ditch Extension taken during months of Apr. through Sept.

Irrigation Year (1)	Month (2)	Perkins Ditch ac-ft (3)	Hatcher Natural Inflow ac-ft (4)	Martinez Natural Inflow ac-ft (4)	Available Inflow ac-ft (5)	Storable Inflow ac-ft (6)	Cumulativ Inflow Stored ac-ft (7)	Dutton Ditch Extension ac-ft (8)	Dutton Extension Available ac-ft (9)	Hatcher Seepage Loss ac-ft (10)	Martinez Seepage Loss ac-ft (10)	Hatcher Surface Area ac (11)	Martinez Surface Area ac (11')	Hatcher vaporation Loss ac-ft (12)	Martinez vaporation Loss ac-ft (12)	Demand ac-ft (13)	Potential Gain/Loss ac-ft (14)	EndMonth Live Storage ac-ft (15)	Actual Gain/Loss ac-ft (16)	Net Spill/Deficit ac-ft (17)	Dutton Extension Remain ac-ft (18)	Natural Inflow Spill ac-ft (19)	Perkins Ditch Remain ac-ft (20)	Demand Deficit ac-ft (21)
		entered	entered	1729	4175	3205		entered	322	37		112	24	121		915	2418		0	2418		2418		
1976	NOV	0	0	0	0	0	0	175	149	3	1	112	24	0	0	20	125	2005	125	0	0	0	0	0
	DEC	0	0	0	0	0	0	0	0	3	1	120	25	0	0	20	-24	1981	-24	0	0	0	0	0
	JAN	0	30	92	84	84	84	0	0	3	1	119	24	0	0	20	60	2040	60	0	0	0	0	0
	FEB	0	30	92	84	84	167	0	0	3	1	123	25	0	0	20	59	2100	59	0	0	0	0	0
	MAR	0	53	162	177	177	344	29	25	3	1	128	25	0	0	20	177	2277	177	0	0	0	0	0
	APR	0	247	755	964	964	593	0	0	3	2	144	26	10	2	20	928	2489	212	716	0	716	0	0
	MAY	0	716	2189	2867	1896	787	0	0	4	2	169	28	30	5	155	1702	2489	0	1702	0	1702	0	0
	JUN	0	0	0	0	0	787	0	0	4	2	169	28	48	8	155	-216	2273	-216	0	0	0	0	0
	JUL	0	0	0	0	0	787	0	0	4	1	143	26	21	4	155	-184	2088	-184	0	0	0	0	0
	AUG	0	0	0	0	0	787	0	0	3	1	127	25	7	1	155	-167	1921	-167	0	0	0	0	0
	SEP	0	0	0	0	0	787	0	0	3	1	115	24	6	1	155	-166	1755	-166	0	0	0	0	0
	OCT	0	0	0	0	0	787	175	149	3	1	105	23	0	0	20	125	1880	125	0	0	0	0	0
	YR	0	1076		4175	3205	787	379	322	37				121		915 (entry entered)	2418	1880	0	2418	0	2418	0	0
1977	NOV	0	0	0	0	0	0	175	149	3	1	112	24	0	0	20	125	2005	125	0	0	0	0	0
	DEC	0	0	0	0	0	0	0	0	3	1	120	25	0	0	20	-24	1981	-24	0	0	0	0	0
	JAN	0	0	0	0	0	0	0	0	3	1	119	24	0	0	20	-24	1957	-24	0	0	0	0	0
	FEB	0	0	0	0	0	0	0	0	3	1	117	24	0	0	20	-24	1933	-24	0	0	0	0	0
	MAR	0	0	0	0	0	0	0	0	3	1	115	24	0	0	20	-24	1909	-24	0	0	0	0	0
	APR	0	0	0	0	0	0	0	0	3	1	114	24	8	2	20	-33	1875	-33	0	0	0	0	0
	MAY	0	0	0	0	0	0	0	0	3	1	112	24	20	4	155	-183	1692	-183	0	0	0	0	0
	JUN	0	0	0	0	0	0	0	0	2	1	102	22	29	6	155	-194	1499	-194	0	0	0	0	0
	JUL	0	0	0	0	0	0	0	0	2	1	94	21	14	3	155	-175	1324	-175	0	0	0	0	0
	AUG	0	0	0	0	0	0	0	0	2	1	87	19	5	1	155	-163	1161	-163	0	0	0	0	0
	SEP	0	0	0	0	0	0	0	0	2	1	82	18	4	1	155	-163	998	-163	0	0	0	0	0
	OCT	0	0	0	0	0	0	175	149	1	1	76	16	1	0	20	127	1125	127	0	0	0	0	0
	YR	0	0		0	0	0	350	298	29				79		915 (entry entered)	-755	1125	-755	0	0	0	0	0
1978	NOV	0	0	0	0	0	0	267	227	2	1	80	17	0	0	20	205	1329	205	0	0	0	0	0
	DEC	0	0	0	0	0	0	0	0	2	1	87	19	0	0	20	-23	1307	-23	0	0	0	0	0
	JAN	0	31	95	88	88	88	0	0	2	1	87	19	0	0	20	65	1372	65	0	0	0	0	0
	FEB	0	30	92	84	84	171	0	0	2	1	89	20	0	0	20	61	1432	61	0	0	0	0	0
	MAR	0	54	165	181	181	353	67	57	2	1	91	20	0	0	20	215	1648	215	0	0	0	0	0
	APR	0	307	939	1208	1208	1226	0	0	2	2	100	22	7	1	20	1176	2489	841	334	0	334	0	0
	MAY	0	571	1746	2279	1263	1421	0	0	4	2	169	28	30	5	155	1068	2489	0	1068	0	1068	0	0
	JUN	0	0	0	0	0	1421	0	0	4	2	143	28	48	8	155	-216	2273	-216	0	0	0	0	0
	JUL	0	0	0	0	0	1421	0	0	3	1	143	26	21	4	155	-184	2088	-184	0	0	0	0	0
	AUG	0	0	0	0	0	1421	0	0	3	1	127	25	7	1	155	-167	1921	-167	0	0	0	0	0
	SEP	0	0	0	0	0	1421	0	0	3	1	115	24	6	1	155	-166	1755	-166	0	0	0	0	0
	OCT	0	0	0	0	0	1421	175	149	3	1	105	23	0	0	20	125	1880	125	0	0	0	0	0
	YR	0	993		3839	2823	1421	509	433	31				118		915 (entry entered)	2158	1880	755	1403	0	1403	0	0

Table 5-1
List of Alternate Water Supply Sources

A	B	C	D	E
Sec. No.	Alternate Description	Yield From Model Runs (a.f./yr.)		Additional Yield (a.f./yr.) Column C-D
5.2.	Increase Supply and Capacity of Snowball Water Treatment Plant	None	None	1,904
5.3.	Enlarge Stevens Reservoir and Water Treatment Plant *Comparison of model runs of "Stevens Res. w/o Dutton Ditch expansion, w/Stevens Res. expansion" (Pg. A-7) WITH "Stevens Res. w/o Dutton Ditch expansion, w/o Stevens Res. expansion." (Pg. A-9)**	915	233*	682
5.4.	Construct Martinez Dam and Use of Hatcher Water Treatment Plant *Comparison of model runs of "Hatcher/Martinez Res. w/o Dutton Ditch expansion" (Pg. A-11) WITH "Hatcher Res. w/o Dutton Ditch expansion w/o Stevens Res. Expansion". (Pg. A-8)*	915	590	325
5.5.	Improve Dutton Ditch with:			
	Existing WTPs at Hatcher and Stevens Reservoirs *Comparison of model runs of "Hatcher Res. w/Dutton Ditch, w/o Stevens Res. expansion" (Pg. A-4) and "Stevens Res. w/Dutton Ditch, w/o Stevens Res. expansion" (Pg. A-5) WITH "Hatcher Res. w/o Dutton Ditch expansion, w/o Stevens Res. expansion" (Pg. A-8) and "Stevens Res. w/o Dutton Ditch expansion, w/o Stevens Res. expansion." (Pg. A-9)*	1080 460	590 233*	490 +227 717
	Enlarge Stevens Res. and WTP *Comparison of model runs of "Hatcher Res. w/Dutton Ditch, w/Stevens Res. expansion" (Pg. A-2) and "Stevens Res. w/Dutton Ditch, w/Stevens Res. expansion" (Pg. A-3) WITH "Hatcher Res. w/o Dutton Ditch expansion, w/Stevens Res. expansion" (Pg. A-6) and "Stevens Res. w/oDutton Ditch expansion, w/o Stevens Res. expansion." (Pg. A-9)*	1080 915	590 233*	490 +682 1172
	Construct Martinez Dam and Enlarge Hatcher WTP *Comparison of model runs of "Hatcher/Martinez Res. w/o Dutton Ditch" (Pg. A-11) and "Hatcher/Martinez Res. w/Dutton Ditch expansion" (Pg. A-10) WITH "Hatcher Res. w/o Dutton Ditch expansion w/o Stevens Res. Exp." (Pg. A-8) and "Hatcher/Martinez Res. w/o Dutton Ditch" (Pg. A-11)*	915 1320	590 915	325 405 730

* Projected yield was reduced from 460 a.f./yr. to 233 a.f./yr. because existing 0.5 m.g.d. water treatment plant will produce only 233 a.f./yr. when operated five months per year. Operation of the water treatment plant for five months per year was assumed for scenarios including Stevens Reservoir.

APPENDIX B

EXPLANATIONS OF SPREADSHEETS

Hatcher Reservoir Operations (Page numbers referenced are from the CDM report.)
Decreed Capacity: 1729 ac-ft/yr

(1), (2) Irrigation Year/Month

$$\begin{pmatrix} Irrigation \\ Year \end{pmatrix} = entered \qquad \begin{pmatrix} Irrigation \\ Month \end{pmatrix} = entered$$

(3)   Perkins Ditch, ac-ft

During the months of March through May when Perkins Ditch is flowing, it was assumed
the District's water right of 21.25 cfs (1282.02 ac-ft/mo) could be taken whenever
it was available. The available flow in Perkins Ditch was taken as the natural
inflow in the Martinez drainage. This was determined using the drainage area
method described in the CDM report. The drainage area of Martinez Reservoir is
10.7 sq. mi.

$$If \begin{pmatrix} Martinez \\ Natural \\ Inflow \\ ac-ft \end{pmatrix} < 1282.02 \_\_\_\_ then \begin{pmatrix} Perkins \\ Ditch \\ ac-ft \end{pmatrix} = \begin{pmatrix} Martinez \\ Natural \\ Inflow \\ ac-ft \end{pmatrix} \_\_\_\_ otherwise \begin{pmatrix} Perkins \\ Ditch \\ ac-ft \end{pmatrix} = 1282.02$$

where

$$\begin{pmatrix} Martinez \\ Natural \\ Inflow \\ ac-ft \end{pmatrix} = \frac{10.7 acres}{3.5 acres} * \begin{pmatrix} Hatcher \\ Natural \\ Inflow \\ ac-ft \end{pmatrix}$$

(4)   Hatcher Natural Inflow, ac-ft

Natural inflow is inflow from streams into the reservoir and does not include flow
from diversions. It was estimated from flow in Four Mile Creek, based on the drainage
area. Flow in Four Mile Creek was estimated from flow in Turkey Creek. All values
were multiplied by 0.61 and in several cases further reduced by PAWSD personnel
because the flows estimated with the drainage area method seemed high. (p. 6-10 to 6-
12) For purposes of this analysis, data was entered.

$$\begin{pmatrix} Hatcher \\ Natural \\ Inflow \\ ac-ft \end{pmatrix} = entered$$

(5)   Available Inflow, ac-ft

A minimum bypass requirement was determined based on the senior water rights
located downstream of each reservoir. The average bypass requirement for Hatcher was
38 ac-ft/month. (p. 6-33) The remainder of the inflow was available.

$$If \begin{pmatrix} Natural \\ Inflow \\ ac-ft \end{pmatrix} - 38 > 0 \_\_\_\_ then \begin{pmatrix} Available \\ Inflow \\ ac-ft \end{pmatrix} = \begin{pmatrix} Natural \\ Inflow \\ ac-ft \end{pmatrix} - 38 \_\_\_\_ otherwise \begin{pmatrix} Available \\ Inflow \\ ac-ft \end{pmatrix} = 0$$

(6)   Storable Inflow, ac-ft

The volume of water that could be stored in a reservoir was limited to the decreed
capacity, 1729 ac-ft/yr for Hatcher. If the cumulative inflow stored at the beginning of
the month plus the available inflow exceeded the decreed amount, the exceedance was

not included as storable inflow. Otherwise, the storable inflow equaled the available inflow.

$$
If \left(\begin{matrix} Cumulative \\ Inflow \\ Stored \\ ac-ft \end{matrix} \right)_{n-1} + \left(\begin{matrix} Available \\ Inflow \\ ac-ft \end{matrix} \right)_{n} > 1729 ac-ft
$$

$$
then \left(\begin{matrix} Storable \\ Inflow \\ ac-ft \end{matrix} \right) = \left(\begin{matrix} Available \\ Inflow \\ ac-ft \end{matrix} \right)_{n} - \left[\left(\begin{matrix} Cumulative \\ Inflow \\ Stored \\ ac-ft \end{matrix} \right)_{n-1} + \left(\begin{matrix} Available \\ Inflow \\ ac-ft \end{matrix} \right)_{n} - 1729 ac-ft \right] \underline{\quad} otherwise \left(\begin{matrix} Storable \\ Inflow \\ ac-ft \end{matrix} \right) = \left(\begin{matrix} Available \\ Inflow \\ ac-ft \end{matrix} \right)_{n}
$$

(7) Cumulative Inflow Stored, ac-ft

This is a tally of the storable inflow accumulated for the year. If any natural inflow spills occurred, the cumulative inflow was reduced by that amount. The tally was reset to zero at the beginning of each irrigation year in November.

$$
\left(\begin{matrix} Cumulative \\ Inflow \\ Stored \\ ac-ft \end{matrix} \right)_{n} = \left(\begin{matrix} Cumulative \\ Inflow \\ Stored \\ ac-ft \end{matrix} \right)_{n-1} + \left(\begin{matrix} Storable \\ Inflow \\ ac-ft \end{matrix} \right)_{n} - \left(\begin{matrix} Natural \\ Inflow \\ Spill \\ ac-ft \end{matrix} \right)_{n}
$$

(8) Dutton Ditch Extension, ac-ft

Derivation of this amount is found in Table 6-7 (p. 6-20 to 6-28). It represents the flow available to Dutton Ditch from Four Mile Creek after other diversions were taken historically. When the actual diversion exceeded the decreed capacity for the water right listed, only the decreed amount was considered when determining flows available to Dutton Ditch.

For the Cases where Dutton Ditch enlargement was considered, the capacity was increased by 8 cfs so it will carry the water available. For the Cases where Dutton Ditch enlargement was not considered, no water was taken during the irrigation months. During the months of November through February and in September and October, the minimum flow was taken as 175 ac-ft/mo. For purposes of this analysis, data was entered from Table 6-11 and as noted.

$$
\left(\begin{matrix} Dutton \\ Ditch \\ Extension \\ ac-ft \end{matrix} \right) = entered
$$

(9) Dutton Extension Available, ac-ft

Conveyance losses for carrying water to Hatcher over 5.25 miles were estimated to be 15% of the water used for diversions. The available water is 85% of the ditch diversion amount. (p. 6-31)

$$
\left(\begin{matrix} Dutton \\ Extension \\ Available \\ ac-ft \end{matrix} \right) = 0.85 * \left(\begin{matrix} Dutton \\ Ditch \\ Extension \\ ac-ft \end{matrix} \right)
$$

(10)   Seepage Loss, ac-ft

An annual seepage rate for water in the reservoir of 2.5 % was selected. The monthly loss was estimated by multiplying the rate by the beginning of month live storage and dividing that by the number of months in a year. (p. 6-31)

$$\begin{pmatrix} Seepage \\ Loss \\ ac-ft \end{pmatrix}_n = \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_{n-1} * \frac{.025}{12}$$

(11)   Surface Area, ac

Surface area of the reservoir was needed to estimate evaporation losses. An area-capacity curve was developed for Stevens Reservoir (p. 6-35) and a best-fit equation was fitted to the data. Data was not available for Hatcher Reservoir, so the equation for Stevens was used. (p. 6-33) The equation was not supplied in the report, so points were taken from the curve and a best-fit equation found. The surface area used for evaporation losses was based on beginning of month live storage.

$$\begin{pmatrix} Surface \\ Area \\ ac \end{pmatrix}_n = 5.8340959 + 0.18175979 * \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_{n-1} - 0.00010785922 * \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_{n-1}^2 + 2.935741E-08 * \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_{n-1}^3$$

(12)   Evaporation loss, ac-ft

A net evaporation value in inches was developed for each month. (Table 6-8, p. 6-32). That value was multiplied by the surface area and then divided by 12 to get ac-ft.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	0.82	2.11	3.42	1.74	0.62	0.62	0	0	0

$$\begin{pmatrix} Evaporation \\ Loss \\ ac-ft \end{pmatrix} = \begin{pmatrix} Surface \\ Area \\ ac \end{pmatrix} * NetEvaporationRate_{mon}(in) * \frac{ft}{12in}$$

(13)   Demand, ac-ft

Demand changed based on the different reservoir conditions considered, but was a constant for a specific scenario. Reservoirs were allowed to fill with water only to their decreed capacity, but no reservoir was allowed to drop below 150 ac-ft. In each case considered, the demand, or the amount of water the District could expect to use, was adjusted under the specific scenario such that in the reservoir operations, the live storage never dropped below 150 ac-ft. The demand, then, became the maximum yield expected under the specific scenario.

$$\begin{pmatrix} Demand \\ ac-ft \end{pmatrix} = entered, based\_on\_minimum\_reservoir\_storage$$

(14)   Potential Gain/Loss, ac-ft

To derive the potential gain or loss, all the inputs to the reservoir were added and all the losses were subtracted. Inputs included Perkins Ditch, Storable Inflow, and

Dutton Extension Available. Losses included Seepage Loss, Evaporation Loss, and Demand.

$$\begin{pmatrix} Potential \\ Gain/ \\ Loss \\ ac-ft \end{pmatrix} = \begin{pmatrix} Perkins \\ Ditch \\ ac-ft \end{pmatrix} + \begin{pmatrix} Storable \\ Inflow \\ ac-ft \end{pmatrix} + \begin{pmatrix} Dutton \\ Extension \\ Available \\ ac-ft \end{pmatrix} - \begin{pmatrix} Seepage \\ Loss \\ ac-ft \end{pmatrix} - \begin{pmatrix} Evaporation \\ Loss \\ ac-ft \end{pmatrix} - \begin{pmatrix} Demand \\ ac-ft \end{pmatrix}$$

(15)   End of Month Live Storage, ac-ft

The live storage in the reservoir was limited to the decreed capacity, 1729 ac-ft/yr for Hatcher. The potential gain/loss was added to the beginning of month live storage to get the end of month live storage. If it exceeded the decreed capacity, the end of month live storage defaulted to the decreed capacity.

$$If \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_{n-1} + \begin{pmatrix} Potential \\ Gain/ \\ Loss \\ ac-ft \end{pmatrix}_n > 1729ac-ft \underline{\quad} then \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_n = 1729ac-ft$$

$$otherwise \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_n = \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_{n-1} + \begin{pmatrix} Potential \\ Gain/ \\ Loss \\ ac-ft \end{pmatrix}_n$$

(16)   Actual Gain/Loss, ac-ft

The actual gain/loss was found by subtracting the end of month live storage from the beginning of month live storage.

$$\begin{pmatrix} Actual \\ Gain/ \\ Loss \\ ac-ft \end{pmatrix}_n = \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_n - \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_{n-1}$$

(17)   Net Spill/Deficit, ac-ft

The net spill/deficit was found by subtracting the actual gain/loss from the potential gain/loss. (p. 6-40)

$$\begin{pmatrix} Net \\ Spill/ \\ Deficit \\ ac-ft \end{pmatrix} = \begin{pmatrix} Potential \\ Gain/ \\ Loss \\ ac-ft \end{pmatrix} - \begin{pmatrix} Actual \\ Gain/ \\ Loss \\ ac-ft \end{pmatrix}$$

(18)   Dutton Extension Remain, ac-ft

When spill conditions existed, it was assumed first Dutton Ditch water would not be taken and therefore made available to Stevens Lake, limited to the amount of Dutton Ditch available. To get the amount remaining in the ditch, the available water was adjusted for the conveyance losses. (p. 6-40)

$$If \begin{pmatrix} Net \\ Spill/ \\ Deficit \\ ac-ft \end{pmatrix} > \begin{pmatrix} Dutton \\ Extension \\ Available \\ ac-ft \end{pmatrix} \underline{\quad then} \begin{pmatrix} Dutton \\ Extension \\ Remain \\ ac-ft \end{pmatrix} = \begin{pmatrix} Dutton \\ Extension \\ Available \\ ac-ft \end{pmatrix} * \frac{1}{0.85}$$

otherwise

$$If \begin{pmatrix} Net \\ Spill/ \\ Deficit \\ ac-ft \end{pmatrix} > 0 \underline{\quad then} \begin{pmatrix} Dutton \\ Extension \\ Remain \\ ac-ft \end{pmatrix} = \begin{pmatrix} Net \\ Spill/ \\ Deficit \\ ac-ft \end{pmatrix} * \frac{1}{0.85} \underline{\quad otherwise} \begin{pmatrix} Dutton \\ Extension \\ Remain \\ ac-ft \end{pmatrix} = 0$$

(19) Natural Inflow Spill, ac-ft

If spill conditions still existed, natural flows would then be spilled, limited to the amount of storable inflow. (p. 6-48)

$$If \begin{pmatrix} Net \\ Spill/ \\ Deficit \\ ac-ft \end{pmatrix} - \begin{pmatrix} Dutton \\ Extension \\ Available \\ ac-ft \end{pmatrix} > \begin{pmatrix} Storable \\ Inflow \\ ac-ft \end{pmatrix} \underline{\quad then} \begin{pmatrix} Natural \\ Inflow \\ Spill \\ ac-ft \end{pmatrix} = \begin{pmatrix} Storable \\ Inflow \\ ac-ft \end{pmatrix}$$

otherwise

$$If \begin{pmatrix} Net \\ Spill/ \\ Deficit \\ ac-ft \end{pmatrix} - \begin{pmatrix} Dutton \\ Extension \\ Available \\ ac-ft \end{pmatrix} > 0 \underline{\quad then} \begin{pmatrix} Natural \\ Inflow \\ Spill \\ ac-ft \end{pmatrix} = \begin{pmatrix} Net \\ Spill/ \\ Deficit \\ ac-ft \end{pmatrix} - \begin{pmatrix} Dutton \\ Extension \\ Available \\ ac-ft \end{pmatrix} \underline{\quad otherwise} \begin{pmatrix} Natural \\ Inflow \\ Spill \\ ac-ft \end{pmatrix} = 0$$

(20) Perkins Ditch Remain, ac-ft

If spill conditions still existed, Perkins Ditch water would be left at the headgate, limited to the amount diverted for Perkins Ditch. (p. 6-48)

$$If \begin{pmatrix} Net \\ Spill/ \\ Deficit \\ ac-ft \end{pmatrix} - \begin{pmatrix} Dutton \\ Extension \\ Available \\ ac-ft \end{pmatrix} - \begin{pmatrix} Storable \\ Inflow \\ ac-ft \end{pmatrix} > \begin{pmatrix} Perkins \\ Ditch \\ ac-ft \end{pmatrix} \underline{\quad then} \begin{pmatrix} Perkins \\ Ditch \\ Remain \\ ac-ft \end{pmatrix} = \begin{pmatrix} Perkins \\ Ditch \\ ac-ft \end{pmatrix}$$

otherwise

$$If \begin{pmatrix} Net \\ Spill/ \\ Deficit \\ ac-ft \end{pmatrix} - \begin{pmatrix} Dutton \\ Extension \\ Available \\ ac-ft \end{pmatrix} - \begin{pmatrix} Storable \\ Inflow \\ ac-ft \end{pmatrix} > 0 \underline{\quad then} \begin{pmatrix} Perkins \\ Ditch \\ Remain \\ ac-ft \end{pmatrix} = \begin{pmatrix} Net \\ Spill/ \\ Deficit \\ ac-ft \end{pmatrix} - \begin{pmatrix} Dutton \\ Extension \\ Available \\ ac-ft \end{pmatrix} - \begin{pmatrix} Storable \\ Inflow \\ ac-ft \end{pmatrix} \underline{\quad otherwise} \begin{pmatrix} Perkins \\ Ditch \\ Remain \\ ac-ft \end{pmatrix} = 0$$

(21) Demand Deficit, ac-ft

If the reservoir empties, the actual gain/loss becomes a deficit and demand is not met. (p. 6-40)

$$If \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix} < 0 \underline{\quad then} \begin{pmatrix} Demand \\ Deficit \\ ac-ft \end{pmatrix} = \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix} \underline{\quad otherwise} \begin{pmatrix} Demand \\ Deficit \\ ac-ft \end{pmatrix} = 0$$

Stevens Lake Operations
Decreed Capacity: 1420 ac-ft/yr

(1), (2) Irrigation Year/Month

$$\binom{Irrigation}{Year} = entered \qquad \binom{Irrigation}{Month} = entered$$

(3) Stevens Natural Inflow, ac-ft

Natural inflow is inflow from streams into the reservoir and does not include flow from diversions. It was estimated from flow in Four Mile Creek, based on the drainage area of approximately 16 sq.mi. above the Dutton Ditch diversion. Flow in Four Mile Creek was estimated from flow in Turkey Creek. All values were multiplied by 0.61 and in several cases further reduced by PAWSD personnel because the flows estimated with the drainage area method seemed high. (p. 6-10 to 6-12) For purposes of this analysis, data in this table was entered.

$$\begin{pmatrix} Stevens \\ Natural \\ Inflow \\ ac-ft \end{pmatrix} = entered$$

(4) Available Inflow, ac-ft

A minimum bypass requirement was determined based on the senior water rights located downstream of each reservoir. The average bypass requirement for Stevens was 30 ac-ft/month. (p. 6-33) The remainder of the inflow was available.

$$If \begin{pmatrix} Natural \\ Inflow \\ ac-ft \end{pmatrix} - 30 > 0 \underline{\quad} then \begin{pmatrix} Available \\ Inflow \\ ac-ft \end{pmatrix} = \begin{pmatrix} Natural \\ Inflow \\ ac-ft \end{pmatrix} - 30 \underline{\quad} otherwise \begin{pmatrix} Available \\ Inflow \\ ac-ft \end{pmatrix} = 0$$

(5) Storable Inflow, ac-ft

The volume of water that could be stored in a reservoir was limited to the decreed capacity, 1420 ac-ft/yr for Stevens. If Stevens Lake is not enlarged, the capacity is 635 ac-ft. If the cumulative inflow stored at the beginning of the month plus the available inflow exceeded the decreed amount, the exceedance was not included as storable inflow. Otherwise, the storable inflow equaled the available inflow.

$$If \begin{pmatrix} Cumulative \\ Inflow \\ Stored \\ ac-ft \end{pmatrix}_{n-1} + \begin{pmatrix} Available \\ Inflow \\ ac-ft \end{pmatrix}_n > 1420 ac-ft$$

$$then \begin{pmatrix} Storable \\ Inflow \\ ac-ft \end{pmatrix} = \begin{pmatrix} Available \\ Inflow \\ ac-ft \end{pmatrix}_n - \left[\begin{pmatrix} Cumulative \\ Inflow \\ Stored \\ ac-ft \end{pmatrix}_{n-1} + \begin{pmatrix} Available \\ Inflow \\ ac-ft \end{pmatrix}_n - 1420 ac-ft \right]$$

$$otherwise \begin{pmatrix} Storable \\ Inflow \\ ac-ft \end{pmatrix} = \begin{pmatrix} Available \\ Inflow \\ ac-ft \end{pmatrix}_n$$

(6)   Cumulative Inflow Stored, ac-ft

This is a tally of the storable inflow accumulated for the year. If any natural inflow spills occurred, the cumulative inflow was reduced by that amount. The tally was reset to zero at the beginning of each irrigation year in November.

$$\begin{pmatrix} Cumulative \\ Inflow \\ Stored \\ ac-ft \end{pmatrix}_n = \begin{pmatrix} Cumulative \\ Inflow \\ Stored \\ ac-ft \end{pmatrix}_{n-1} + \begin{pmatrix} Storable \\ Inflow \\ ac-ft \end{pmatrix}_n - \begin{pmatrix} Natural \\ Inflow \\ Spill \\ ac-ft \end{pmatrix}_n$$

(7)   Dutton Ditch Extension, ac-ft

Data for this column is forwarded from worksheet Hatcher Reservoir Operations, entry "Dutton Extension Remain". It represents flow from Dutton Ditch that was not taken at Hatcher because the flows into Hatcher exceeded its decreed capacity. It was assumed Hatcher would take all flow it was capable of before passing any Dutton Ditch water for Stevens. (p. 6-40) During all scenarios irrigation water rights in Dutton Ditch were assumed to have priority.

$$\begin{pmatrix} Dutton \\ Ditch \\ Extension \\ ac-ft \end{pmatrix} = fowarded\_from\_Hatcher$$

(8)   Dutton Extension Available, ac-ft

Conveyance losses for carrying water to Stevens over 5.0 miles were estimated to be 15% of the water used for diversions. The available water is 85% of the ditch diversion amount. (p. 6-31) There was consideration given to increasing losses, but gains to the ditch from side drainage flows were assumed to offset some losses due to ditch seepage.

$$\begin{pmatrix} Dutton \\ Extension \\ Available \\ ac-ft \end{pmatrix} = 0.85 * \begin{pmatrix} Dutton \\ Ditch \\ Extension \\ ac-ft \end{pmatrix}$$

(9)   Seepage Loss, ac-ft

An annual seepage rate for water in the reservoir of 2.5 % was selected. The monthly loss was estimated by multiplying the rate by the beginning of month live storage and dividing that by the number of months in a year. (p. 6-31)

$$\begin{pmatrix} Seepage \\ Loss \\ ac-ft \end{pmatrix}_n = \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_{n-1} * \frac{.025}{12}$$

(10)   Surface Area, ac
        Surface area of the reservoir was needed to estimate evaporation losses. An area-capacity curve was developed for Stevens Reservoir (p. 6-35) and a best-fit equation was fitted to the data. The equation was not supplied in the report, so points were taken from the curve and a best-fit equation found. The surface area used for evaporation losses was based on beginning of month live storage.

$$\begin{pmatrix} Surface \\ Area \\ ac \end{pmatrix}_n = 5.8340959 + 0.18175979 * \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_{n-1} - 0.00010785922 * \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_{n-1}^{2} + 2.935741E-08 * \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_{n-1}^{3}$$

(11)   Evaporation loss, ac-ft
        A net evaporation value in inches was developed for each month. (Table 6-8, p. 6-32). That value was multiplied by the surface area and then divided by 12 to get ac-ft.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	0.82	2.11	3.42	1.74	0.62	0.62	0	0	0

$$\begin{pmatrix} Evaporation \\ Loss \\ ac-ft \end{pmatrix} = \begin{pmatrix} Surface \\ Area \\ ac \end{pmatrix} * NetEvaporationRate_{mon}(in) * \frac{ft}{12in}$$

(12)   Demand, ac-ft
        Demand changed based on the different reservoir conditions considered, but was a constant for a specific scenario. Reservoirs were allowed to fill with water only to their decreed capacity, but no reservoir was allowed to drop below 150 ac-ft. In each case considered, the demand, or the amount of water the District could expect to use, was adjusted under the specific scenario such that in the reservoir operations, the live storage never dropped below 150 ac-ft. The demand, then, became the maximum yield expected under the specific scenario.

$$\begin{pmatrix} Demand \\ ac-ft \end{pmatrix} = entered, based\_on\_minimum\_reservoir\_storage$$

(13)   Potential Gain/Loss, ac-ft
        To derive the potential gain or loss, all the inputs to the reservoir were added and all the losses were subtracted. Inputs included Storable Inflow and Dutton Extension Available. Losses included Seepage Loss, Evaporation Loss, and Demand.

$$\begin{pmatrix} Potential \\ Gain/ \\ Loss \\ ac-ft \end{pmatrix} = \begin{pmatrix} Storable \\ Inflow \\ ac-ft \end{pmatrix} + \begin{pmatrix} Dutton \\ Extension \\ Available \\ ac-ft \end{pmatrix} - \begin{pmatrix} Seepage \\ Loss \\ ac-ft \end{pmatrix} - \begin{pmatrix} Evaporation \\ Loss \\ ac-ft \end{pmatrix} - \begin{pmatrix} Demand \\ ac-ft \end{pmatrix}$$

(14)   End of Month Live Storage, ac-ft
        The live storage in the reservoir was limited to the decreed capacity, 1420 ac-ft/yr or 635 ac-ft/yr for Stevens. The potential gain/loss was added to the beginning of month live storage to get the end of month live storage. If it exceeded the decreed capacity, the end of month live storage defaulted to the decreed capacity.

$$If \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_{n-1} + \begin{pmatrix} Potential \\ Gain/ \\ Loss \\ ac-ft \end{pmatrix}_n > 1420ac-ft \underline{\quad} then \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_n = 1420ac-ft$$

$$otherwise \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_n = \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_{n-1} + \begin{pmatrix} Potential \\ Gain/ \\ Loss \\ ac-ft \end{pmatrix}_n$$

(15)   Actual Gain/Loss, ac-ft

The actual gain/loss was found by subtracting the end of month live storage from the beginning of month live storage.

$$\begin{pmatrix} Actual \\ Gain/ \\ Loss \\ ac-ft \end{pmatrix}_n = \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_n - \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_{n-1}$$

(16)   Net Spill/Deficit, ac-ft

The net spill/deficit was found by subtracting the actual gain/loss from the potential gain/loss. (p. 6-40)

$$\begin{pmatrix} Net \\ Spill/ \\ Deficit \\ ac-ft \end{pmatrix} = \begin{pmatrix} Potential \\ Gain/ \\ Loss \\ ac-ft \end{pmatrix} - \begin{pmatrix} Actual \\ Gain/ \\ Loss \\ ac-ft \end{pmatrix}$$

(17)   Dutton Extension Remain, ac-ft

When spill conditions existed, it was assumed first Dutton Ditch water would not be taken and therefore made available downstream, limited to the amount of Dutton Ditch available. To get the amount remaining in the ditch, the available water was adjusted for the conveyance losses. (p. 6-48)

$$If \begin{pmatrix} Net \\ Spill/ \\ Deficit \\ ac-ft \end{pmatrix} > \begin{pmatrix} Dutton \\ Extension \\ Available \\ ac-ft \end{pmatrix} \underline{\quad} then \begin{pmatrix} Dutton \\ Extension \\ Remain \\ ac-ft \end{pmatrix} = \begin{pmatrix} Dutton \\ Extension \\ Available \\ ac-ft \end{pmatrix} * \frac{1}{0.85}$$

otherwise

$$If \begin{pmatrix} Net \\ Spill/ \\ Deficit \\ ac-ft \end{pmatrix} > 0 \underline{\quad} then \begin{pmatrix} Dutton \\ Extension \\ Remain \\ ac-ft \end{pmatrix} = \begin{pmatrix} Net \\ Spill/ \\ Deficit \\ ac-ft \end{pmatrix} * \frac{1}{0.85} \underline{\quad} otherwise \begin{pmatrix} Dutton \\ Extension \\ Remain \\ ac-ft \end{pmatrix} = 0$$

(18)   Natural Inflow Spill, ac-ft

If spill conditions still existed, natural flows would then be spilled, limited to the amount of storable inflow. (p. 6-48)

$$\text{If} \begin{pmatrix} Net \\ Spill / \\ Deficit \\ ac-ft \end{pmatrix} - \begin{pmatrix} Dutton \\ Extension \\ Available \\ ac-ft \end{pmatrix} > \begin{pmatrix} Storable \\ Inflow \\ ac-ft \end{pmatrix} \underline{\quad} then \begin{pmatrix} Natural \\ Inflow \\ Spill \\ ac-ft \end{pmatrix} = \begin{pmatrix} Storable \\ Inflow \\ ac-ft \end{pmatrix}$$

otherwise

$$\text{If} \begin{pmatrix} Net \\ Spill / \\ Deficit \\ ac-ft \end{pmatrix} - \begin{pmatrix} Dutton \\ Extension \\ Available \\ ac-ft \end{pmatrix} > 0 \underline{\quad} then \begin{pmatrix} Natural \\ Inflow \\ Spill \\ ac-ft \end{pmatrix} = \begin{pmatrix} Net \\ Spill / \\ Deficit \\ ac-ft \end{pmatrix} - \begin{pmatrix} Dutton \\ Extension \\ Available \\ ac-ft \end{pmatrix} \underline{\quad} otherwise \begin{pmatrix} Natural \\ Inflow \\ Spill \\ ac-ft \end{pmatrix} = 0$$

(19)   Demand Deficit, ac-ft

If the reservoir empties, the actual gain/loss becomes a deficit and demand is not met. (p. 6-48)

$$\text{If} \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix} < 0 \underline{\quad} then \begin{pmatrix} Demand \\ Deficit \\ ac-ft \end{pmatrix} = \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix} \underline{\quad} otherwise \begin{pmatrix} Demand \\ Deficit \\ ac-ft \end{pmatrix} = 0$$

B-11

Hatcher/Martinez Reservoir Operations (Only the entries that are different from Hatcher Operations are included here.)
Decreed Capacity: 1729 + 760 ac-ft/yr = 2489 ac-ft/yr

(3)   Perkins Ditch, ac-ft
No Perkins Ditch flow was taken, as the ditch would be under the waters of the proposed
        Martinez Reservoir.

$$\begin{pmatrix} Perkins \\ Ditch \\ ac-ft \end{pmatrix} = 0$$

(4')   Martinez Natural Inflow, ac-ft
        Natural inflow is inflow from streams into the reservoir and does not include flow
from diversions. For purposes of this analysis, the Martinez inflow was estimated from
Hatcher natural inflow using the drainage area method described in the CDM report. The
drainage area for Martinez is 10.7 acres and for Hatcher is 3.5 acres.

$$\begin{pmatrix} Martinez \\ Natural \\ Inflow \\ ac-ft \end{pmatrix} = \frac{10.7 acres}{3.5 acres} * \begin{pmatrix} Hatcher \\ Natural \\ Inflow \\ ac-ft \end{pmatrix}$$

(5)   Available Inflow, ac-ft
        A minimum bypass requirement was determined based on the senior water rights
located downstream of each reservoir. The average bypass requirement for Hatcher and
Martinez was 38 ac-ft/month, as they are in the same drainage. (p. 6-33) The remainder
of the inflow was available.

$$If \begin{pmatrix} Natural \\ Inflow \\ ac-ft \end{pmatrix} - 38 > 0 \underline{\quad} then \begin{pmatrix} Available \\ Inflow \\ ac-ft \end{pmatrix} = \begin{pmatrix} Natural \\ Inflow \\ ac-ft \end{pmatrix} - 38 \underline{\quad} otherwise \begin{pmatrix} Available \\ Inflow \\ ac-ft \end{pmatrix} = 0$$

(6)   Storable Inflow, ac-ft
        The volume of water that could be stored in a reservoir was limited to the decreed
capacity, 2489 ac-ft/yr for Hatcher and Martinez together. If the cumulative inflow
stored at the beginning of the month plus the available inflow exceeded the decreed
amount, the exceedance was not included as storable inflow. Otherwise, the storable
inflow equaled the available inflow.

$$If \begin{pmatrix} Cumulative \\ Inflow \\ Stored \\ ac-ft \end{pmatrix}_{n-1} + \begin{pmatrix} Available \\ Inflow \\ ac-ft \end{pmatrix}_{n} > 2489 ac-ft$$

$$then \begin{pmatrix} Storable \\ Inflow \\ ac-ft \end{pmatrix} = \begin{pmatrix} Available \\ Inflow \\ ac-ft \end{pmatrix}_{n} - \left[\begin{pmatrix} Cumulative \\ Inflow \\ Stored \\ ac-ft \end{pmatrix}_{n-1} + \begin{pmatrix} Available \\ Inflow \\ ac-ft \end{pmatrix}_{n} - 2489 ac-ft \right] \underline{\quad} otherwise \begin{pmatrix} Storable \\ Inflow \\ ac-ft \end{pmatrix} = \begin{pmatrix} Available \\ Inflow \\ ac-ft \end{pmatrix}_{n}$$

(10), (10')   Seepage Loss, ac-ft

An annual seepage rate for water in the reservoir of 2.5 % was selected. The monthly loss was estimated by multiplying the rate by the beginning of month live storage and dividing that by the number of months in a year. (p. 6-31) Since two reservoirs have been combined in this spreadsheet, the total live storage in any month was divided between the two in the same ratio as their capacities. Hatcher has a capacity of 1729 ac-ft/yr and Martinez has a capacity of 760 ac-ft/yr.

$$
\begin{pmatrix} Hatcher \\ Seepage \\ Loss \\ ac-ft \end{pmatrix}_n = \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_{n-1} * \frac{.025}{12} * \frac{1729}{2489}
\qquad
\begin{pmatrix} Martinez \\ Seepage \\ Loss \\ ac-ft \end{pmatrix}_n = \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_{n-1} * \frac{.025}{12} * \frac{760}{2489}
$$

(11), (11')   Surface Area, ac

Surface area of the reservoir was needed to estimate evaporation losses. An area-capacity curve was developed for Stevens Reservoir (p. 6-35) and a best-fit equation was fitted to the data. Data was not available for Hatcher Reservoir, so the equation for Stevens was used. (p. 6-33) The equation was not supplied in the report, so points were taken from the curve and a best-fit equation found. An area-capacity curve was developed for Martinez Reservoir from a separate report and a best-fit equation was fitted to the data.

The surface area used for evaporation losses was based on beginning of month live storage. Since two reservoirs have been combined in this spreadsheet, the total live storage in any month was divided between the two in the same ratio as their capacities. Hatcher has a capacity of 1729 ac-ft/yr and Martinez has a capacity of 760 ac-ft/yr.

$$
\begin{pmatrix} Hatcher \\ Surface \\ Area \\ ac \end{pmatrix}_n = \left(5.8340959 + 0.18175979 * \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_{n-1} - 0.00010785922 * \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_{n-1}^2 + 2.935741E-08 * \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_{n-1}^3 \right) * \frac{1729}{2489}
$$

$$
\begin{pmatrix} Martinez \\ Surface \\ Area \\ ac \end{pmatrix}_n = \left(\frac{0.41499129 * (-2.1517762E+10) - (1.8559701E+10) * \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_{n-1}^{0.59581452}}{-(2.1517762E+10) + \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_{n-1}^{0.59581452}} \right) * \frac{760}{2489}
$$

(13)   Demand, ac-ft

Demand changed based on the different reservoir conditions considered, but was a constant for a specific scenario. Reservoirs were allowed to fill with water only to their decreed capacity, but no reservoir was allowed to drop below 150 ac-ft. Since two reservoirs were combined in this spreadsheet, the total minimum capacity was taken as 300 ac-ft. In each case considered, the demand, or the amount of water the District could expect to use, was adjusted under the specific scenario such that in the reservoir operations, the live storage never dropped below 300 ac-ft. The demand, then, became the maximum yield expected under the specific scenario.

$$\left(\frac{Demand}{ac-ft}\right) = entered, based\_on\_minimum\_reservoir\_storage$$

(14) Potential Gain/Loss, ac-ft

To derive the potential gain or loss, all the inputs to the reservoir were added and all the losses were subtracted. Inputs included Perkins Ditch, Storable Inflow, and Dutton Extension Available. Losses included Seepage Loss, Evaporation Loss, and Demand.

$$\begin{pmatrix} Potential \\ Gain/ \\ Loss \\ ac-ft \end{pmatrix} = \begin{pmatrix} Perkins \\ Ditch \\ ac-ft \end{pmatrix} + \begin{pmatrix} Storable \\ Inflow \\ ac-ft \end{pmatrix} + \begin{pmatrix} Dutton \\ Extension \\ Available \\ ac-ft \end{pmatrix} - \begin{pmatrix} Hatcher \\ Seepage \\ Loss \\ ac-ft \end{pmatrix} - \begin{pmatrix} Martinez \\ Seepage \\ Loss \\ ac-ft \end{pmatrix} - \begin{pmatrix} Hatcher \\ Evap. \\ Loss \\ ac-ft \end{pmatrix} - \begin{pmatrix} Martinez \\ Evap. \\ Loss \\ ac-ft \end{pmatrix} - \begin{pmatrix} Demand \\ ac-ft \end{pmatrix}$$

(15) End of Month Live Storage, ac-ft

The live storage in the reservoir was limited to the decreed capacity, 2489 ac-ft/yr for Hatcher and Martinez together. The potential gain/loss was added to the beginning of month live storage to get the end of month live storage. If it exceeded the decreed capacity, the end of month live storage defaulted to the decreed capacity.

$$If \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_{n-1} + \begin{pmatrix} Potential \\ Gain/ \\ Loss \\ ac-ft \end{pmatrix}_{n} > 2489ac-ft \_\_\_\_ then \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_{n} = 2489ac-ft$$

$$otherwise \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_{n} = \begin{pmatrix} EndMonth \\ Live \\ Storage \\ ac-ft \end{pmatrix}_{n-1} + \begin{pmatrix} Potential \\ Gain/ \\ Loss \\ ac-ft \end{pmatrix}_{n}$$